REVIEW OF CURRENT ESTIMATING CAPABILITIES OF THE 3D BUILDING INFORMATION MODEL SOFTWARE TO SUPPORT DESIGN FOR PRODUCTION/CONSTRUCTION

By

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A thesis submitted to the faculty
of the Worcester Polytechnic
Institute in partial fulfillment of the
requirements for the degree of

Master of Science

July 2005

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ABSTRACT

The fragmented environment in the construction industry has a big influence on production. The multi-disciplinary nature of the project development process imposes the need for clear communications and team effort coordination. Information Technology (IT) has been playing a tremendous role in facilitating this process. The most recent contribution of IT in this regard is the Building Information Model (BIM).

It is clear that BIM technology improves the design drawings productivity; drawings are automatically coordinated in all views from plans, to sections, to elevations, to details and to perspectives. It also provides an innovative way of scheduling through by allowing a 3D visualization of the construction progress. But, there are still many technical issues that still need to be addressed before this technology is fully adopted by the industry. For example, what are the files formats that BIM supports? What is the needed knowledge for best use of BIM? How does BIM integrate with the estimating discipline? Where does BIM store the building data? What are the codes that are shown in the automatically generated "quantity take-offs" schedules? This research attempts to provide answers to these questions and explores possible ways to link different coding systems within the BIM platform itself.

After reviewing the basic design concepts from the conceptual to the construction stages and how it is related to the different project delivery ways, this work illustrates the role of different work breakdown structures (WBS) in the life cycle of estimating discipline from the preliminary to the detailed stage. The research reviewed the different database designs and structures, the database management systems (DBMS), as well as the database organization systems. This review draws a picture on how information

system (IS) and its tools support the different needs of the multiple players involved in a construction project. The focus was on the object oriented database and building information model (BIM) software, and how it integrates with other estimating and project planning software.

The findings seem promising, but before BIM technology can reshape the construction industry, it is still necessary to conduct additional experimental work as the software continues to evolve and becomes mature.

ACKNOWLEDGMENTS

The author wishes to thank God, his mentor and all family, friends and colleagues whose continuous supports have made his goal come true.

This research would not have been possible save for the encouragement, guidance and brilliance of Professor Guillermo F. Salazar and for the support of Mr. Ken Stowe (AutoDesk Revit). It would not have been written had Professor Roberto Pietroforte not awakened the author's interest in a better contribution from the "architect" side in the construction management practice, and had Mr. Frederick Mulligan and Mr. David Dutton (Cutler Associates) not tremendously enriched his knowledge in the estimating discipline.

Every attempt has been made to give credit to quoted sources. While many contributed in ways large and small to the development of this report, the errors in content are the author's responsibility. In spite of everyone's best efforts, he is sure that he has left many opportunities for improvements.

Finally, the author would like to dedicate this work to his parents, whom love, devotion and prayers have been inspiring him for a continuous strive in life and for intellectual achievements.

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In popular terms it has been commonly known for long time that "Time is Money". In the industrial world and construction industry in particular, Time, Money and Quality form a triangular relationship (See Figure1). In the majority of decision making occasions, management has to compromise in one area in order to get the best result in the other two. Mainly, "Money" and "Quality" are always fighting for "Time".

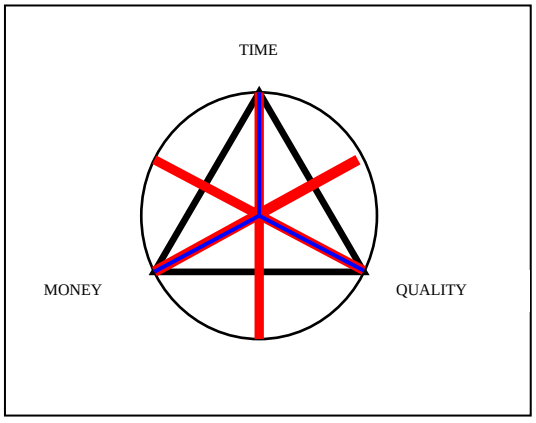


Figure1. Triangular relationship

"I'd like to see the architect become the master builder again" - said well known and controversial architect Frank O. Gehry (ENR 02/28/00 p. 76-83). He had directed CAD-enabled construction and had relied on computer integrated technology to transform Frank O. Gehry & Associates (FOGA) design of Experience Music Project into a reality. Architect Frank Gehry knew that the construction industry is very fragmented, and in order to successfully build an exceptional geometry, he had to build a construction team that is appropriate for his project. He had to provide the steel fabricator, the general

contractor and the structural engineer with electronic design that could be used by their systems and could be implemented in their firms, in order to execute the project on time. CATIA software was used by FOGA to generate the drawings, other corresponding robotics software were used in the manufacturing process of the structural shell, and Pro Engineer structural software was totally integrated with CATIA and had automatically both calculated and described the metallic sheets and frames of the building's exterior shell.

1.1 Big Picture

In the present time, the "Architect/Master Builder" concept has been rarely employed in the construction industry. The construction project has a life cycle that starts when an owner identifies an opportunity and that ends when an organization operates and maintains the building. In commercial buildings, productivity and timely construction rely on the team members: owner-architect-engineer-contractor-builder and on their inter-relationships. Since every player has different interest in the project, the concept of partnership among all involved parties becomes critical, in order to improve the production of a building (from a time and cost point of view).Their reliance on computer software to improve the efficiency of planning, building and managing a project have been tremendously growing in the last few years.

It's in the earliest stages of a project, particularly during the programming, schematic and preliminary stages that crucial design decisions are made that largely dictate the economics of the project. The industry has been adopting Information Technology tools like "Building Information Model" that provide both the owner and the

management organization with detailed specific information about the building, (http://www.enr.com/news/informationtech/archives/050121.asp). The object oriented database of BIM stores the detailed parameters and descriptions of the building components that could be used for construction as well as for maintenance purposes. If this database were well developed and were filled with cost data, BIM tools would enable the architect to forecast the total building cost at the earliest stages of its design where the cost saving potential is the greatest. BIM tools drive the cost of pre-construction services down and reduce the time needed for quantity take-offs, estimating, breakdown coding and scheduling only if compatible software were used by all players. BIM tools enhance the collaboration between the architect, builder and subcontractor and also change the delivery's way of design from manual (x, y, z, 1, 2, 3) alpha-numerical data (used in tables, take-off schedules and spreadsheets) and from (2D, 3D drawings) graphical data, to a 4D module in which the library (the components of project's module) provides breakdown coding (items and assemblies) and automatic quantity take-offs.

Using the same BIM by all involved parties of a project drives the inter-communication problems to be automatically reduced, if not completely solved. The design modifications resulting in change orders problems are instantaneously measured in terms of cost, tender, and planning schedules. All this would result in an ease to control the project, only if appropriate and well developed databases were have been used by the architect.

1.2 Building Information Model (BIM) Tools

Currently, there are three major software providers of BIM in the construction industry; AutoDesk, Bentley Systems and Graphisoft. However, the BIM answers the nature of planning and control functions that are made more challenging by the simultaneous nature of the design and construction, the current BIM software aren't totally compatible with the needs of traditional estimating practice like cost/item, labor and production rates. BIM software like ArchiCAD and Revit, allocate the cost by coded construction elements and assemblies (i.e. wall, column, beam, floor, roof, window, door, etc.), and not by coded individual materials that form the assembled components. This limitation affects the role that the architect could play in managing the construction process, and opposes to the "Architect/Master Builder" concept; the two previous BIM software do not integrate with any structural analysis software which conclude in reducing the role of the structural elements in the model to strictly illustrative. This inadequacy limits also the efficiency in calculating the quantity take-offs of wall, floor and roof components such as wood/steel studs, CMU/brick blocks, blue boards, tiles, paintings, carpeting, hardwood, shingles, etc. The new Uniformat II (ASTM Standard E-1557) and Means Assembly Cost Data Manual provide Work Breakdown Structure (WBS) that is suitable for both schematic design and elemental estimate. Further explanation and comparison between the different coding systems and their uses can be found in Chapter 5: Database Organization, Formats and Coding Systems.

1.3 Specific Objectives and Scope

This work's main purpose is to identify both the advantages and limitations that BIM technology brings to the Architect/Master Builder concept. The main focus is the support of BIM technology to the estimating practices and techniques. A secondary focus is the revolutionary approach that BIM introduces in terms of project planning and construction scheduling. It evaluates two BIM software in terms of ease of use, cost per element and different parameters within the central object database, different database organizations, rendering features and element ID record within the project-model, take-offs reports and schedules, interface with other CAD software (Import, Export), integration with estimating software (like Timberline through ODBC) and project planning (like Primavera P3 and Microsoft Project). It didn't explore any integration with Structural Analysis Engineering software nor with Cost Control and Document Management software.

1.4 Methodology

Currently, there are many computer aided design software that use 2D&3D platform. The most dominant software in the construction industry is AutoDesk's product-the famous "AutoCAD". At different design stages, the contractor uses different corresponding techniques and tools, as well as suitable software in which the cost data resides. In other words, the design documents are reviewed separately from the design platform. The efficiency of this process depends immensely on the intercommunication among the involved parties. Some technology limitations affect the interoperability such as electronic file exchange, scope definition and different database organization

(Uniformat vs. Master Format). The new BIM technology presents more advantages in that regards than the traditional CAD software. This thesis experimental research part consists of:

- Building a warehouse project using two BIM tools; AutoDesk Revit and Graphisoft ArchiCAD.
- Comparison between the two BIM; their features, ease of use and databases structures.
- Working with CSI-Master Format and Uniformat II coding systems using the two BIM tools.
- Exploring the two BIM tools' possibilities of integration and interface with other software used by estimating discipline.

1.5 Results

BIM is promising to reshape the way construction industry is functioning today. The use of BIM Technology by the architect is going to result in “fewer” design documents, and in better communication environment. However, a new education for “the architect” is required, and investments of time and money are essentials. The implementation of advanced technology in the designing firms will provide an improved end product in the programming stage of a project, with “no loss” of design professional as an independent advisor and agent, and with “no reduction” in design quality and creativity. BIM generated documents are the end products of an attempt to provide other players involved in the project with a “Design for Production”. The contribution of BIM technology to the design is discussed in Chapter 2: Architectural design process.

Architecture by definition is “the art or science of building; especially, the art of building houses, churches, bridges, and other structures for the purposes of civil life” (Webster’s 1913 Dictionary). It is “the discipline dealing with principles of design and construction and ornamentation of fine buildings; architecture and eloquence are mixed arts whose end is sometimes beauty and sometimes use” (WordNet Dictionary). In other words, architecture deals with all aspects of life and intersects almost all fields of human endeavor. The size of projects and construction organizations has increased as well as the technological complexity level. This increase has resulted in more complex interdependencies and variations in the relationships among its organizations and institutions, and proliferating regulations and demands from government.

2.1 Construction Delivery Systems

Construction by definition is “in a more general sense, frame or structure, workmanship” (Webster’s 1913 Dictionary). Construction approach and project nature have a strong effect on the design process and it delivery way during the project life cycle. There are four major construction approaches: Traditional (Design-Bid-Build), Turnkey (Design-Build, Design-Manage), Owner-Builder (Develop; Design-Build-Manage), and Professional Construction Management (GC, CM). The three following figures (Figures2, 3, 4) are borrowed from the book “Professional Construction Management” by Donald S. Barrie and Boyd C. Paulson (page 27). The

"Architect/Master Builder" concept is in between two approaches; Owner-Builder and Turnkey.

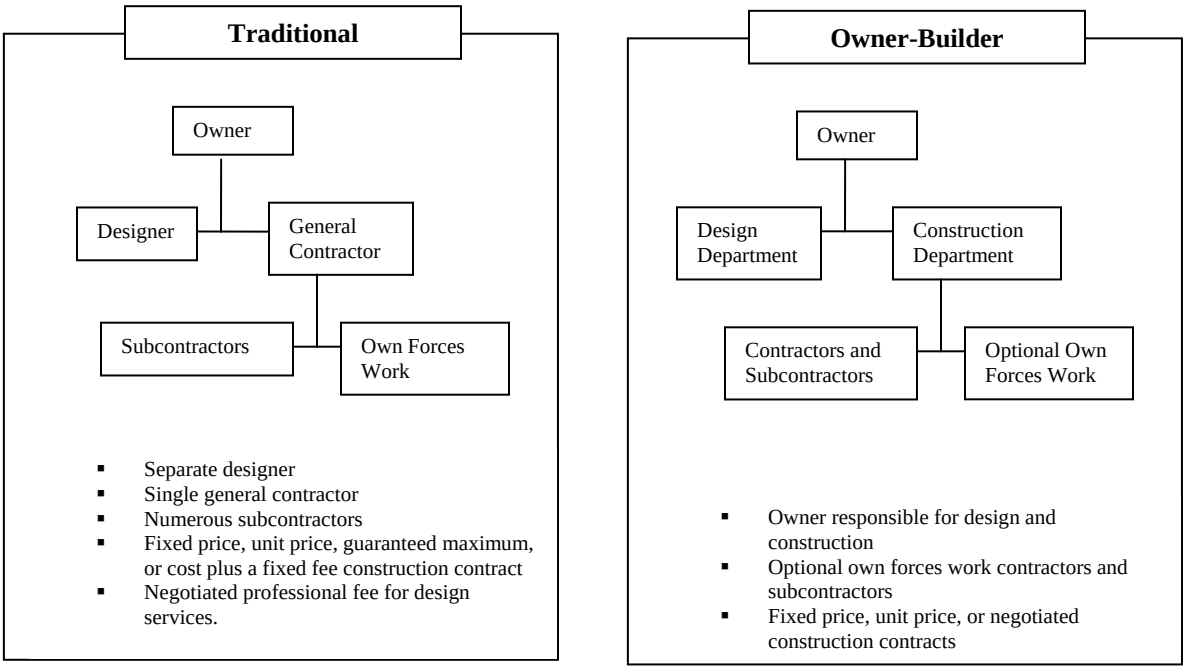


Figure2. Traditional Contractual approaches

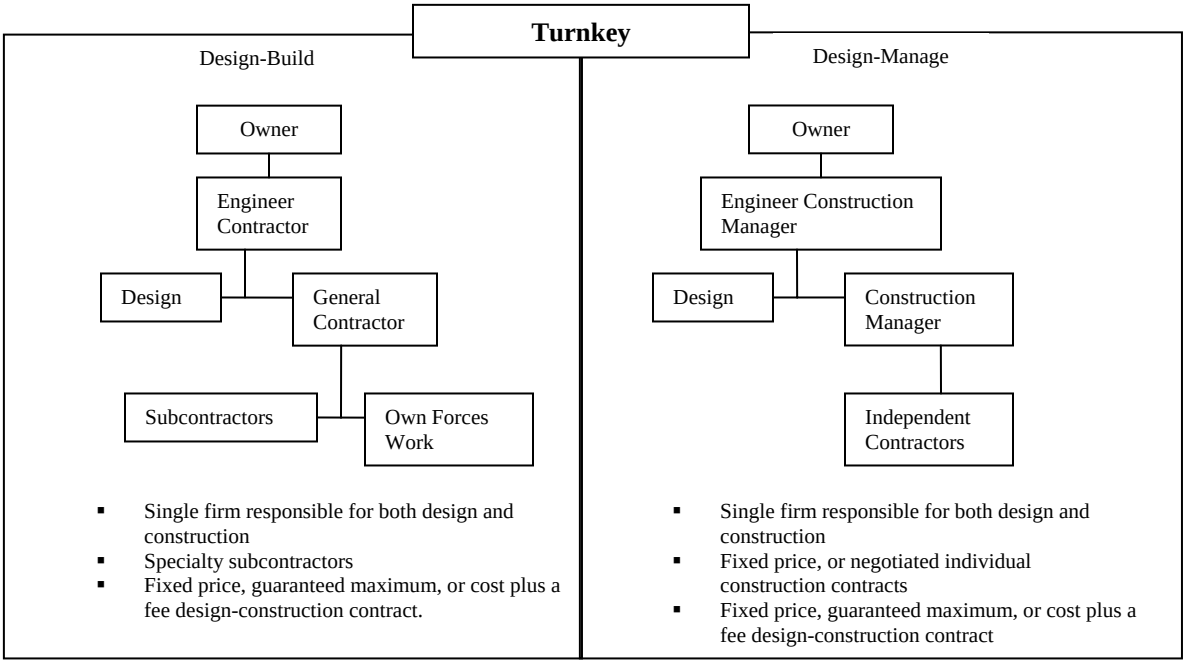


Figure3. Turnkey contractual approaches

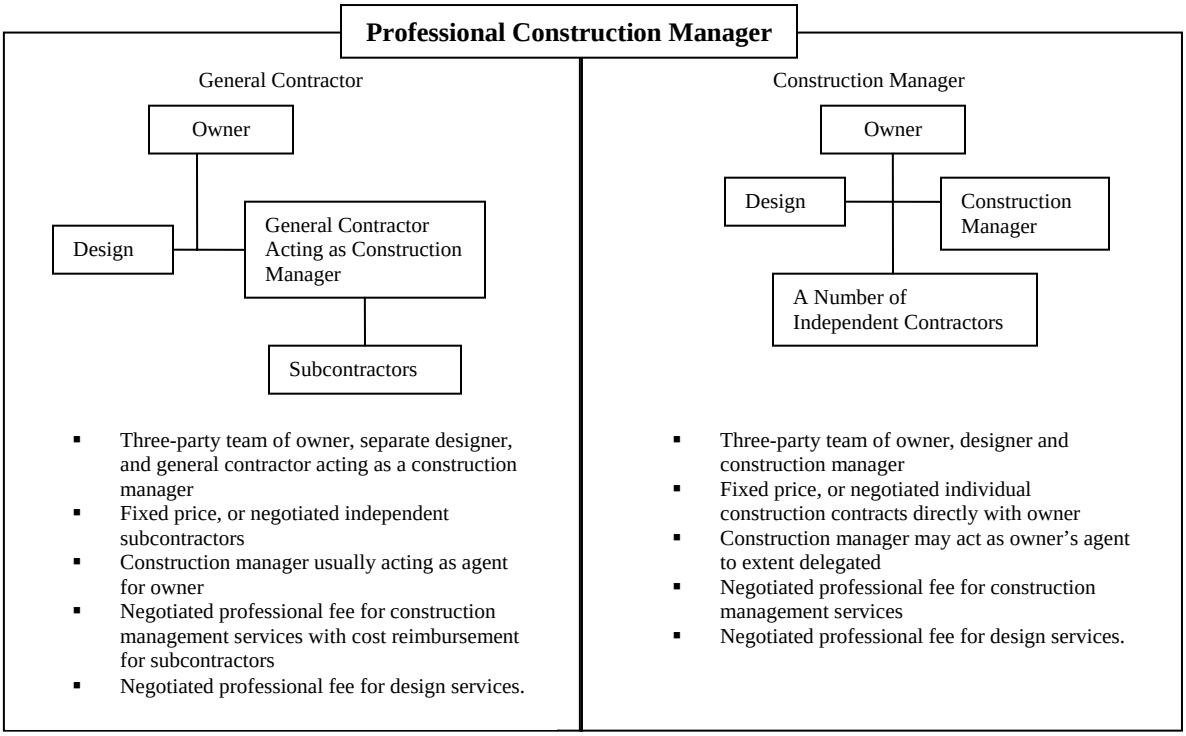


Figure4. Alternate contractual approaches

2.2 Design Stages, BIM Technology and Cost Estimate

In general, the design process has five stages; conceptual, preliminary design, final design, tender preparation, and construction administration.

- The Concept stage defines the scope of the project. It consists of all initial work on a project, from the identification of requirements to satisfy some perceived need, to selection of the most feasible alternative solution that meets those requirements, and to the decision to commit engineering and technical resources to the project design. BIM technology provides a quick visualization for alternatives. BIM has easy and simple features that

support building materials changes and different structural choices that range from wooden to concrete and steel.

- The Preliminary Design phase involves preparation of outline drawings, choosing the desired construction materials, and performing other preliminary operations required to “freeze” the design. BIM technology makes design faster through the concept of automatic correlation; any change or design in one view is automatically updated in all sections, elevations, perspectives and even in the animated presentations of the project. BIM also facilitates design/build budgetary decisions based on preliminary or conceptual information.

- At the end of the Final design stage, working drawings, technical specifications, and contract drawings are complete, and the project is ready to go to tender. BIM technology enhances the productivity of final design drawings and documentations because of the various objects parameters recorded in the model database. Actually, the design generated by BIM becomes the documents which quality differs from software to another. Documents quality depends on the amount of details and specific descriptions associated with the elements that form the parametric model generated by BIM tools.

- At the Tender Preparation stage, the project is in the hands of the contractors and the detailed, comprehensive “pricing” of the project is under way. BIM technology supports “System Estimate”, which is very helpful to develop accurate SF cost estimates and to verify “Unit Price Estimates”. A discussion about estimate practice is presented in Chapter3: Overview of cost estimating process.

- During Construction, the contractor’s estimate is used as the standard to measure progress payments due; it can also be instrumental in the pricing of changes to the work. The designer is still present to respond to all Requests for Information coming from the job site as well as to make sure that the contractor is building what has been designed.

Although the degree of responsibilities of all the people involved in the project differs between the four approaches of construction, each method has its advantages and disadvantages for a particular application, and it has developed certain degrees of flexibility so that many of the alternatives overlap one another. However, a very good interrelationship between all members and excellent communications, leadership & human relations skills remain critical in order to meet quality, cost, and time objectives.

Chapter 3. Overview of the cost estimating process

Estimate by definition is “an approximate calculation of quantity or degree or worth; i.e. an estimate of what it would cost, a rough idea how long it would take” Synonym: appraisal, approximation, forecast, gauge, and guess (WordNet Dictionary). It is “to form an opinion of, as to amount, number, etc., from imperfect data, comparison, or experience; to make an estimate of; to calculate roughly; to rate; as to estimate the cost of a trip, the number of feet in a piece of land” (Webster’s 1913 Dictionary). Project cost estimates have a tremendous role and a crucial effect during the life cycle of a project from conceptual to operational stage; it deals with costs in function of time, productivity, available resources and many other factors. Project management depends on the estimating techniques for best project control measures at each project phase till it is being constructed and it has been commissioned. Relative estimating techniques are used for feasibility analysis, financial requirements and approvals, budgeting, bidding and awards, warranty, maintenance and operation costs.

3.1 Estimating Techniques

Project phases, estimating techniques, and control measures taken by project management are all linked in order to achieve the cost objectives. As mentioned in Chapter 2, five stages are considered: conceptual design, preliminary design, detailed design, tender preparation, project implementation and commissioning. Estimating techniques are categorized as: preliminary, unit price, elemental cost analysis, detailed

estimating, and updates (ref: “Estimating: from concept to completion”). A definite pattern of relationship exists between the project phases and estimating techniques. Figure5 illustrates the role of estimates in the project management environment (ref: “Estimating: from concept to completion, p.4). In addition, project control measures such as project approval, budgeting and cash-flow forecasting, and cost control and corrective action have a distinct relationship with different estimating techniques.

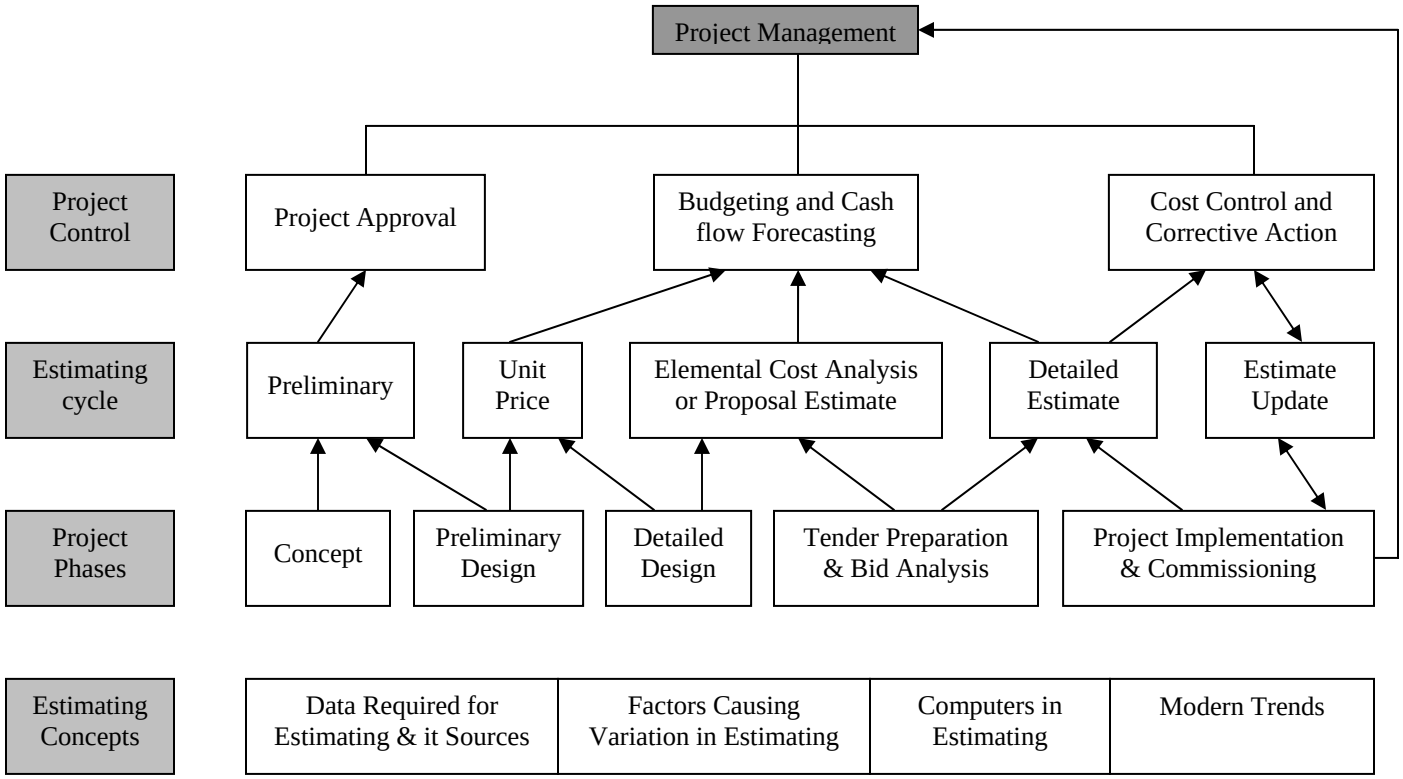


Figure5. Role of estimates in the Project Management Environment

Most cost estimating techniques are developed by different construction team member on different cost estimating concepts, such as capacity at the conceptual design stage, functional analysis at the preliminary design stage, quantity takeoff at the detailed design stage, and method study at the tender preparation and construction stage. There

are four major types of cost estimating that are used in the construction industry. Every technique has a different level of precision in forecasting the cost during the estimating cycle. Preliminary estimate has ±25% accuracy, elemental analysis estimate has ±15% accuracy, unit price estimate has ±10% accuracy and detailed estimate has ±5% accuracy. The precision of an estimate is directly related to four factors:

1. The available data.
2. The time spent preparing the estimate.
3. The estimating technique used.
4. The skill and experience of the estimator.

Most estimates are based on historical data and on the experience of the estimators. Ten factors have to be considered every time before the implementation of historical or published data into a new project. These factors are: time, location, size and shape, capacity, number, quality, soil conditions, weather, competition, and local regulations (ref: “Estimating: from concept to completion). The scope of the estimate indicates the amount and source of data used as the basis, that is, estimating guide used, previous project data, firm quotation, actual production labor hours, and so on.

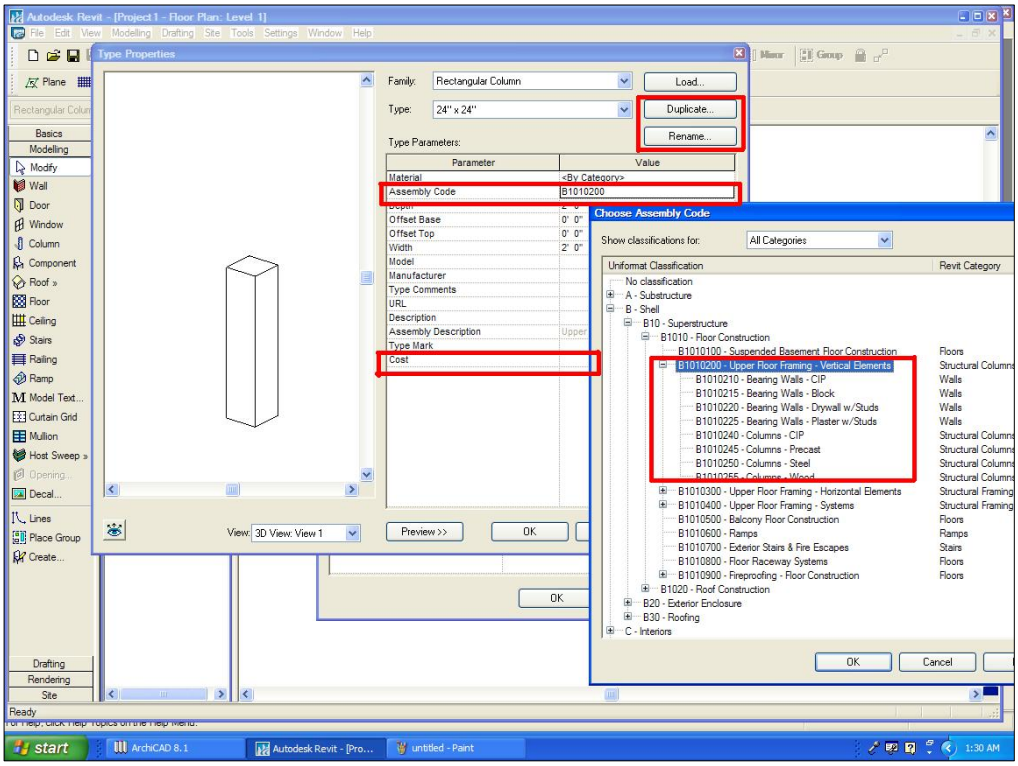
As each phase of a project requires a different type of estimate, so each estimate requires different types of information and data. The precision of the estimate varies with the degree and quality of design/construction information that is available for use during its preparation. As the design progresses through each phase, more detailed information becomes available, and the estimate is increasingly reliable.

3.2 Role of Software to Support Cost Estimates Generated by the Architect

Architect's first responsibility is to meet the client's expectations in design quality as well as in budget. Widely used by architectural firms, 2D - 3D CAD software like AutoCAD, doesn't support any cost data storage on their platform. In order to generate the estimate, Architect/Engineer has to rely on other software. It could vary from a MS Excel spreadsheet or Lotus notes to a powerful Timberline spreadsheet. BIM technology presents a revolutionary approach in that regards. Both Graphisoft ArchiCAD and AutoDesk Revit have the cost feature allocated with the building elements (Figure6). However, the database structure is not the same in both software. The real challenge is to develop that "library-database" that contains both materials and labor costs and productivity information. Another challenge is the choice between the different work breakdown structures (WBS) and their different coding systems. CSI's formats are trade based while Uniformat formats are building based which makes it more suitable for BIM concepts. Chapter 5 will explicitly discuss WBS and the various coding systems.

CATIA was totally integrated with Pro-Engineer for structure analysis and calculations in FOGA's design of Experience Music Project (ENR 02/28/00 p. 76-83). The author of this work didn't explore the feasibility of BIM integration with other software used by structure engineers, and he is not aware of such feature. If such integration existed and the load calculation is automatically determined, the creation of a detailed elements database based on Uniformat II would be considered a very good investment of time and resources. BIM's duplication feature of library elements will

make the mission easy and feasible (Figure6). Why Uniformat II and not CSI? Because of “Assemblies Cost Data”, the publication of RS Means that provides building assembly and component costs that is suitable by both BIM’s concept and by architectural practice. Then, BIM technology would be used to generate accurate estimating square foot costs, to compare building systems and to verify unit price estimates.



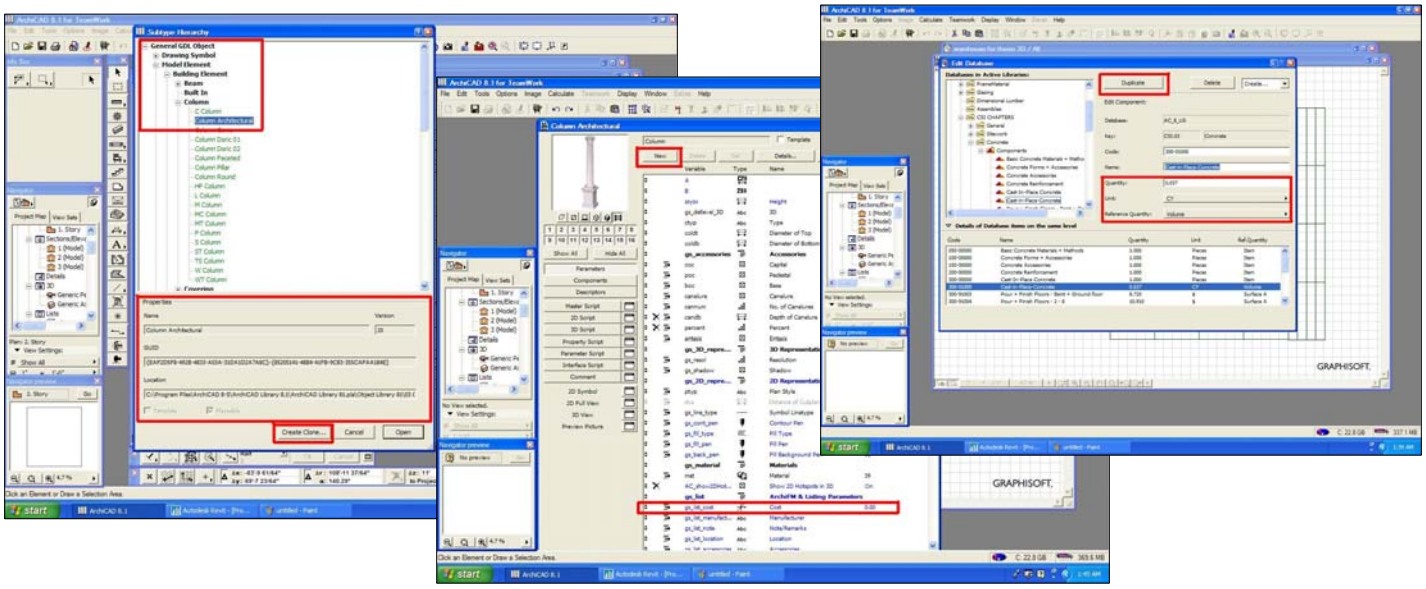


Figure6. Library-Database in Revit (upper) and in ArchiCAD (lower)

With Object Oriented database and BIM approach, automatic quantity take-offs are instantly generated at any design stage. What does that means in terms of estimating techniques? How does this affect the project management's environment in general, and the estimating cycle in particular? How does BIM interface with estimating categories?

3.3 BIM, Estimating Categories and Project Management

Estimates are divided into four categories based upon different given information, different purpose of usage, and different motivation and level of expertise. The four categories are order of magnitude, system estimate, detailed estimate and appraisals.

3.3.1 Order of magnitude (O/M) estimate

a. Factor estimate
b. Elemental estimate
c. Parametric estimate

O/M estimates are used by owners to know: measures of revenue and cost/unit of revenue. The concept of O/M is to compare similar projects in different locations and time. The base is a historical data which could be statistical (Square Foot Cost Data, RSMeans), scientific (time study), and prototypical function data (experience). Actually, AutoDesk Revit has a limited feature in producing O/M estimates (Figure7). However, in the case of prototypical projects, BIM technology will save lots of time and effort through "copy, cut, and paste" features. Modifications and adjustments to previous

similar projects could be relatively easier than designing from scratch. BIM advantage is the model itself at that early stage of the project. Even though, detailed quantity take-offs would be available at that time, they have no relevance importance in terms of project budgeting. Newer versions of Revit (6.1 and above) do not longer support SF cost estimates that are based on R.S.Means Preliminary Cost estimates.

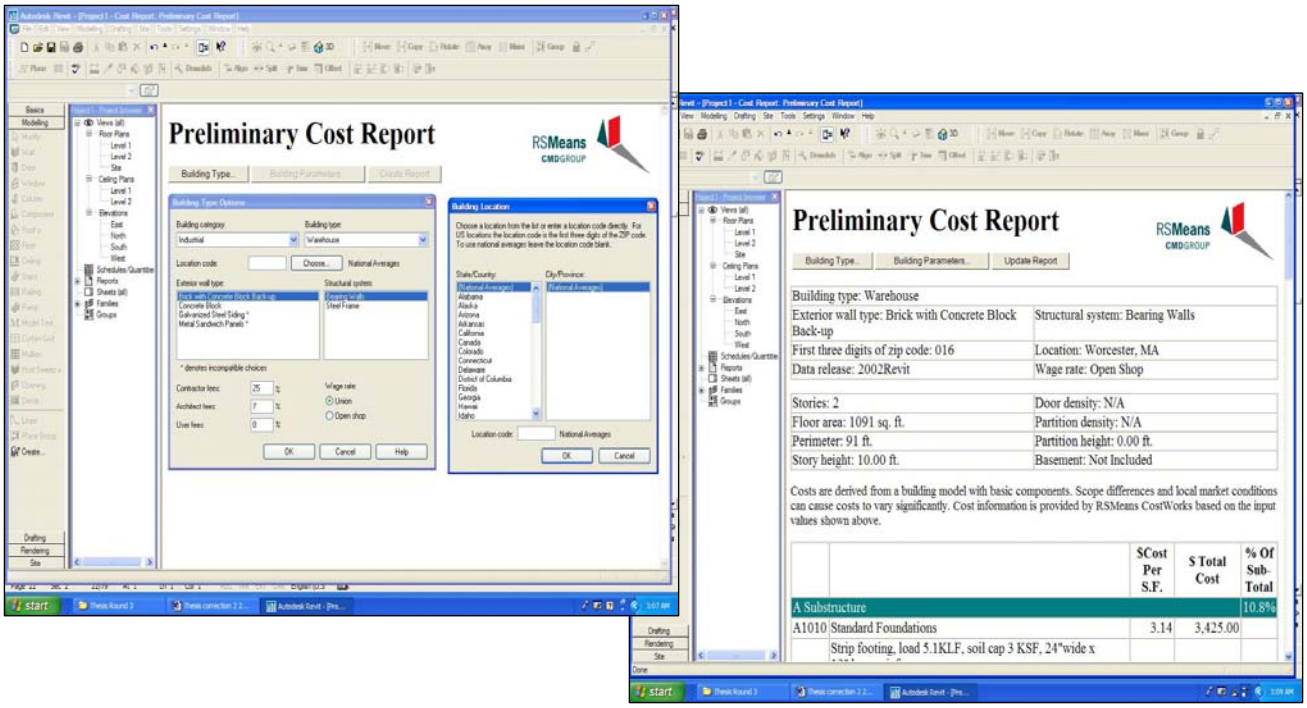


Figure7. AutoDesk Revit feature of generating O/M estimate

3.3.2 Conceptual estimates or systems estimates

a. Elemental analysis (to learn which element drives the cost up)
b. Parametric estimating (the parameters of the building are used to produce an estimate for the project)
c. Based on CSI (master format = trades-based building) or on Uniformat (system-based building)

d. Range estimate: mean value of the total estimates is equal to the sum of mean values (1). The variance is equal to the square root of precisions (2). To be able to reduce the range, we have to go back to our deviations and try to improve the level of precisions. Range estimates (statistical) are like Monte Carlo simulation of probability; they are used to produce the level of uncertainty and to defeat the cost overrun.

Systems estimates are mainly produced for value engineering practice. They are also used to help budgetary decisions and to prepare the documents for bids and contracts in Turnkey construction delivery's way. BIM technology is promising to reshape the construction industry in that regards through the schedule and cost report features. This would become a reality only if an accurate detailed database were well developed in BIM platform. Chapter4 would address database types and management.

3.3.3 Detailed estimate

They are based on the working drawings to produce a GMP contract or a hard Bid in a very competitive environment. Three formats are used: CSI format, Uniformat and Specs format. The major difference between the formats is the coding systems, and in consequences the costs allocation. An example of this difference would be concrete. In a Unit Price estimate, all the concrete items on a job would be priced in the "Concrete" section of the estimate; CSI Division 3. In a system estimate, concrete is found in a number of locations. For instance, concrete is used in all of these systems: Division A10, Foundations; Division A20, Basement Construction; Division B10, Superstructure, and

Division B20, Exterior Closure. A detailed description and comparison between the different formats would be found in chapter5 – Database Organization, Formats and Coding Systems.

Is it possible to link different WBS formats using only BIM platform? In one hand, AutoDesk Revit does not support multi-database concept. On the other hand, ArchiCAD supports multi-database concept. However, in order to be able to successfully link the different WBS formats, database should contain lots of details in their system assemblies. To summarize, BIM technology is not yet mature enough to support detailed estimates needs in a hard bid environment.

3.3.4 Appraisals

There are three methods to produce an appraisal: comparables (especially for houses), NPV of cash flow (for commercial properties), and replacement cost. Appraisals are used by funding organizations to know the cash flow and the value of the existing assets. BIM technology and architectural practice have nothing to do with this type of estimate, unless the cost of project element is recorded in a relevant and detailed way –material cost, labor and installation costs. The recorded costs could be used as a reference for future replacement in a facility management environment.

The database by definition is “a set of related files that is created and managed by a database management system (DBMS). Today, DBMSs can manage any form of data including text, images, sound and video. Database and file structures are always determined by the software. As far as the hardware is concerned, it is all bits and bytes” (http://www.answers.com/database&r=67) . (Figure8) is an illustration of the database.

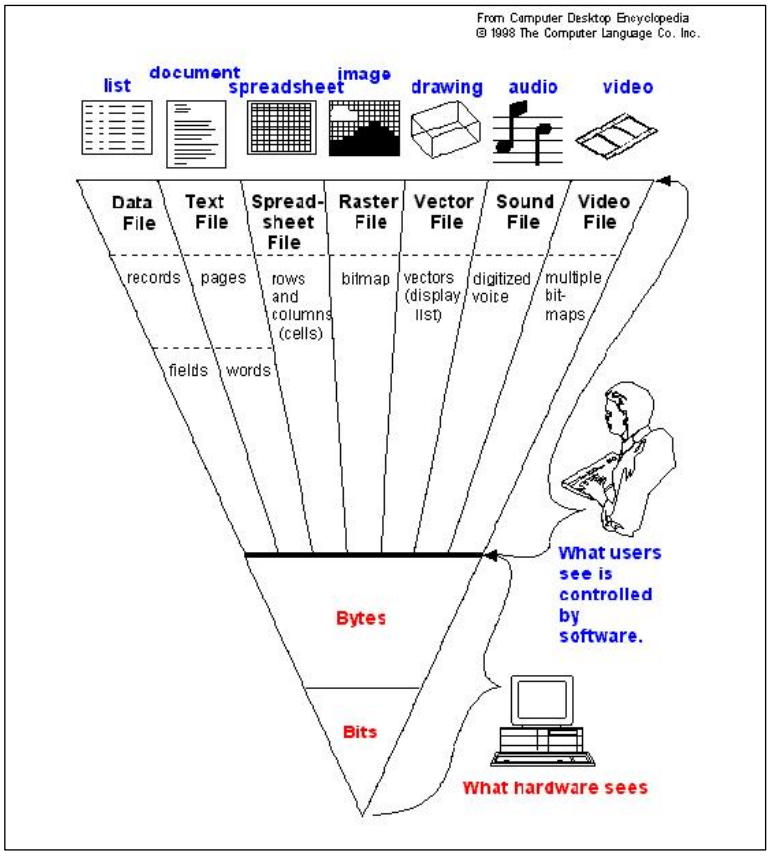


Figure8. The Database

Database is an organized collection of data, often created or manipulated with the help of a DMS. These data may be organized in several ways, but data structures that use relational tables have become the most common method for organizing and manipulating attribute data. Selections or queries are among the most common methods used to frequently identify and extract data that supports analyses conducted on attribute data. Relational tables are often placed in normal forms to improve correctness and consistency, to remove redundancy, and to ease updates.

A database typically contains complex structures, primarily to provide data security, stability, and to allow multiple users or programs to access the same data simultaneously. Database users often demand shared access, that is, multiple users or programs may be allowed to open, view, or modify a data set simultaneously. However if each program or user has direct file access, then multiple copies of a database may be open for modification at the same time. The database management system may act as an intermediary between the files and the application programs or user. The database management system may prevent errors due to simultaneous access.

4.1 Database Designs

Two database designs are currently finding significant application. First, network database where each entity may be a node in the network and is connected as appropriate to other entities in the network. Network designs may be powerful and flexible. However, designing and implementing the network structure can be quite complex and

network databases are often difficult to modify. A great deal of information is stored in the complex network relationships, and updates require modifications of these linkages. Significant amounts of time, money, and expertise are usually required.

Object oriented database models are a second area that has received significant commercial interest in recent times. Object orientation has the ability to define classes of objects with values that are both private (restricted access) and public, and defines procedures or functions with the same name and general outcome, but which differ for each class of objects. Sub-classes may be derived from super-classes, and inherit some or all of the properties of the super-class. Object oriented designs have been described as more flexible and more easily understood and maintained, although there are relatively few successful examples of object-oriented spatial database management systems.

4.2 Database Management System (DBMS)

The approach of database management system -that best suits the construction industry- should be the one that allows interfacing and integration between adopted software with minimum required human manipulation. In the market today, there is a wide variety of software that deals separately with design, cost estimate and subs, scheduling and planning, cost control and management, documents control and storage, and properties management. But very few are well integrated, either through open database connectivity ODBC, or directly between each other with few manipulations. However, many software providers have developed application software that is called a

"package" to deal digitally with some aspects of the industry's needs. Some packages overlap some areas, but still have to face the challenge of how to interface with the computer aided design systems. Information technology has succeeded to certain extent to link the cost estimating with scheduling, cost and document control. For more detail about this topic, please review Chapter6 - Overview of some available tools (Timberline, Revit, and ArchiCAD).

4.3 Object Oriented DBMS and Architectural Practice

What does object oriented DBMS can do for an architect? Would it be possible to use old vector files like CAD drawings in BIM? What are the options to export from BIM to CAD software? Does BIM support the level of details required for shop drawings production? "You own the data – but will you always be able to access it?" is the title of an article published by CAD Digest about Intellectual Property Rights in May 2003 (http://www.caddigest.com/subjects/autocad/select/croser_dwg.htm) . This article addressed architectural firms' rights from a legal point of view that BIM developers have to take into consideration. At the same time of that year, an online debate between Bentley and AutoDesk took place on MSM. It was called "The building Information modeling Debate – Do You Develop on What You Already have or Do You Start Over?" (http://www.msmonline.com/commentary/default.cfm?objectid=8EA3DC8D-475A-40F2-B...). This debate addressed the integration and interface issue from a technical point of view. For more detail about this topic, please review Chapter6. What is sure about BIM technology today is that it supports multi-users environment through the "team" or "team work" feature. It allows multiple users to coordinate their design

instantaneously. Through multiple security access settings, design confusions and coordination problems are eliminated.

4.4 Current Estimating Practice

What does BIM bring to the estimator's plate? How does it interface with the contractor's database? Does BIM support the contractor's database life cycle? Before to answer these questions, let's have an overview of what is going on in current estimating practice. (Figure9) illustrates the database life cycle as it is utilized for best practice in the industry at the tendering and construction stages.

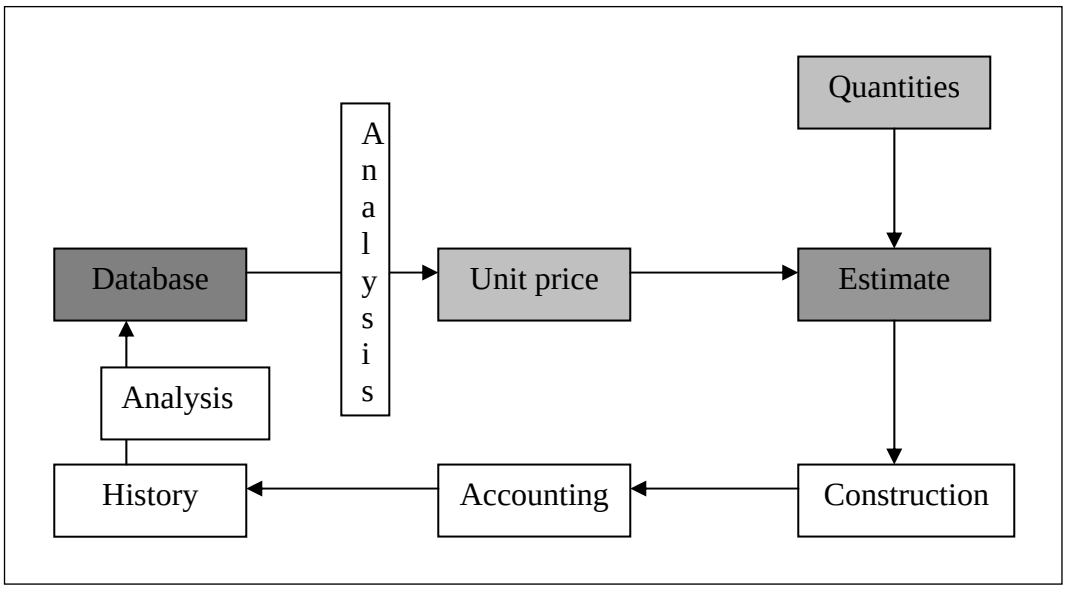


Figure9. Contractor's Database Life Cycle

"Eric Lamb, executive vice president of DPR Construction Inc., Redwood City, Calif., estimates the industry's 40,000 construction cost estimators spend 25% of their time, for an estimated 20 million hours per year, doing quantity take-offs. He estimates 75% to 80% of that labor could be avoided altogether if construction documents were circulated as 3D models built with industry-standard objects, instead of as plans and 2D views." This is a quote from an article published by ENR about Estimating and titled: "Finding the bottom line gets a gradual life from technology" (ENR/August12, 2002 /p.26-30)

4.4.1 Spreadsheets vs. Commercial Software Packages

Some GC estimators use a generic spreadsheet -30% use Excel of Microsoft, others use specialized estimating software -25% use Precision Collection of Timberline- (CFMA's 2002 Information Technology Survey for the Construction Industry, published by the Construction Financial Management Association, Princeton, NJ. The complete survey is available at www.cfma.org). In general, the more conceptual an estimate is and the more complex the job, the more likely it is that an estimator will turn to the flexibility of customized spreadsheet that support the limited scope definition available at that stage (Square Footage estimates based on O/M techniques). The closer a job estimate gets to the final "hard bid" and the more standardized the work, the more likely it is that an estimator may opt for a commercial software package that supports the hard bid environment and last minute quotes from Subs. Many estimators still insist that you can't beat the classic spreadsheet-primarily Excel and Lotus 1-2-3- for flexibility, updating databases, report creation and customizing estimates to meet individual client needs. Spreadsheets can deal with uncertainties in the very early design stages when the

estimator is working from vague drawings and has to figure out what the designer has left out of the drawing. On the other hand, commercial packages serve a purpose, but people should realize that they will have to spend three to six months with one to four people to customize the data in these software packages. Commercial packages don't use parallel databases, but you can do that with spreadsheets. (ENR/August12, 2002 /p.26-30)

Packaged estimating application software users think that the package they use makes them more efficient for "quick bid", and it is perfectly tailored to their needs. The estimating product gives a standard for everyone, is extremely efficient and accurate, and it produces "very good reports" that are useful for estimating and for communication with the field. Another important feature is that multiple users could work on an estimate simultaneously. The estimators concerns about software products are that they want them to integrate with project management and scheduling, and they want the ability to change the assumptions, such as work crew breakdowns and productivity rates, that govern calculations. Does BIM support that?

4.5 BIM and Database Management & Costs Updates

Quantities take-off process could be automated by the available BIM technology, and this technology could improve industry efficiency significantly. Each take-off element has attribute data that includes dimensions, location, CSI or Uniformat codes, total cost estimate and descriptions (Figure6). However, as stated earlier in Chapter3, BIM does not support all the needs of estimators such as automatic update of the main cost database, the breakdown of work into tasks and packages, and the assignment of packages to individuals and organizations. In another word, current BIM technology

does not support in it platform the database life cycle, especially in terms of cost maintenance. It is designed more for architectural practice. What about BIM's interface feature with other estimating software?

4.6 BIM's Interface with Estimating Software

The export feature from BIM to estimating software application is limited at this time, and it varies between different tools. While Revit has the option to interface through ODBC (Chapter 6), and the ability to generate customized templates spreadsheets in excel and text formats, ArchiCAD take-offs reports are in text format and excel only. Therefore, ArchiCAD feature that supports multi-database concept seams to be fruitless in terms of integration with other software used by different disciplines in the complex management environment of construction industry. More on that could be found in Chapter6 – Overview of some available tools. What does BIM technology bring to the scheduling discipline?

4.7 BIM's Interface with Scheduling Software

In terms of schedule, current BIM lacks the feature to interface directly with scheduling software -such as Primavera Planner P3 and Microsoft Project- which deals with tasks, not elements. However, BIM has a phasing feature which can be used to graphically illustrate the schedule, and to show the owner the schedule as a progressive model that enables simulation of the construction process. BIM does not support Critical Path Method network as produced by most scheduling software. However, Kathleen Liston –a 4D consultant who helped Walt Disney Imagineering develop InviznOne

software- says “schedule data can also be imported from various platforms such as Primavera Project Planner and Microsoft Project, as well as generic text files. Each activity in the schedule can be linked with one or more corresponding objects in the 3D model, enabling the construction sequence to play out like a movie” (ENR/February 25, 2002 /p.29-31). The article title is “Building Digitally Provides Schedule, Cost Efficiencies”. In this article, there are many stories about how efficient BIM’s phasing feature is in terms of reducing the number of potentially costly change orders. Chapter5 – Database Organization, Formats and Coding Systems will address the role of work breakdown in the project’s life cycle, the different formats and the importance of codes as glue that ties together the different disciplines of the construction industry.

Chapter 5. Database Organization, Formats and Coding Systems

A construction project may be any undertaking, large, medium, small, or mega sized. Too many difficulties are depicted during construction and the risk of cost overrun is always present due to many factors (Michael Putzer wrote a feature article titled "So, the Budget Ran Over…Because?" that was published by Cost Engineering Vol.37/No.7 – July 1995). Project management discipline has introduced five systems as tools for solving problems and controlling work and cash flow during pre-construction and construction stages of a project. These systems are: Project Definition System (for scope & budget development), Work Breakdown System (for task & budget development), Organization Breakdown System (for package & cost development), Project Budget and Cost Control System (for scope and budget control), and Project Planning and Schedule Control System (for time control). Computer Systems and tools have a tremendous role to play in the project, but every system has it application. The key role for the project manager is to coordinate these systems in order to improve communication and to make them a tool to serve the production-construction.

The database organization has to well respond to the life cycle of the project. Therefore, coding or numbering systems are the "invisible" glue between data. There are three major formats used by the building construction industry that assign alpha- numeric codes to categories and numeric codes for items and quantity take-offs. These formats are: Construction Specifications Institute (CSI-Master Format, 16 divisions) -Appendix

A, Uniformat 1 (12 divisions) -Appendix C- and Uniformat 2 (8 divisions) -Appendix D. A new outline of Master Format 04 was furnished for information purpose only by CSI on March 25, 2004. It contains 50 divisions -Appendix B. This outline is not to be considered a final draft or official publication of the Construction Specifications Institute.

5.1 Database Organization and Coding Systems

An alpha- numeric coded list of organizations (information and person of contact) is supported neither by AutoDesk Revit nor by Graphisoft ArchiCAD platforms. It is created in outside platform as a separate file, and has the ability to be tracked by some other compatible software. The same thing is for the resources costs and crews productivity data. A coded cost data could be created and divided under five categories:

1. labor cost/each (not supported by BIM)
2. labor cost/crew (not supported by BIM)
3. material cost/each (questionable support by BIM)
4. material cost/assembly (supported by BIM)
5. subcontractor cost/lump sum (not supported by BIM)

5.1.1 Database and Construction Systems

The project planning and scheduling system is not a stand-alone system. A scheduling activity derives from the other systems. An effective schedule is a combination of activities, events, milestones, and timeline targets. Each activity has a project definition code, a functional organization code, a cost number, and single time

duration. The activities are developed through the project WBS of typical project phases. The cost number assigned to each activity comes from the cost estimate -the discipline responsible for cost accuracy. Cost estimating and budgeting is driven by definitions of functions and elements, by the breakdown of work into tasks and packages, and by the assignment of packages to individuals and organizations. The process leads to more accurate cost pictures at each transition point. Project Cost and Expenditure Control System requires that the project scope be maintained throughout each stage and must be able to relate to all interested project participants. This is achieved through breakdowns and codes that capture cost at its source and deliver the information to the corporate financial manager as well as to the project manager responsible. (Figure10) illustrates the role of codes as glue between all data used in construction project systems from estimating, to scheduling, to construction management.

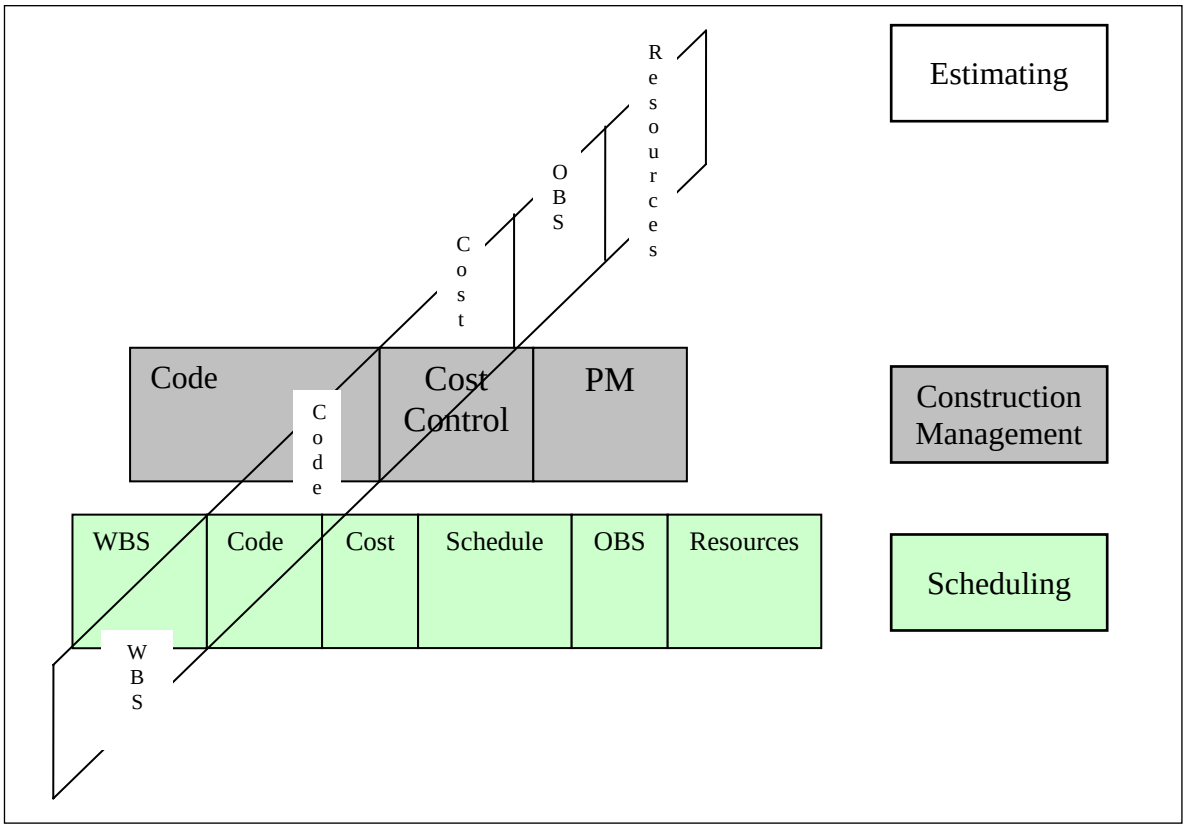


Figure10. Code-Glue used by different management systems

At the tender stage, detailed estimating files are created. Since the estimate could contain elements and assemblies of elements, their codes could fall under many formats (CSI and Uniformat). Than the interface takes place with scheduling. Since the schedule contains both hard tasks that have direct cost and soft tasks that have indirect cost, it becomes necessary to group different tasks into group tasks that have their own codes. Than the interface takes place with construction management and document control. Since the bid packages contain several group tasks, these packages have their own codes, too. The resources assignment are easily linked and identified from the organization breakdown structure (OBS) codes. All kind of reports to track the resources productivity, to control their project cost and to communicate between all participants in the project, could be easily generated with the usage of the appropriate software without the need for another database. The project functional organization alpha-numerical code is used as a cost code. (Figure11) illustrates the project code structure based on functional organization as a cost code (George Suhanic – Computer-Aided Project Management, page 135).

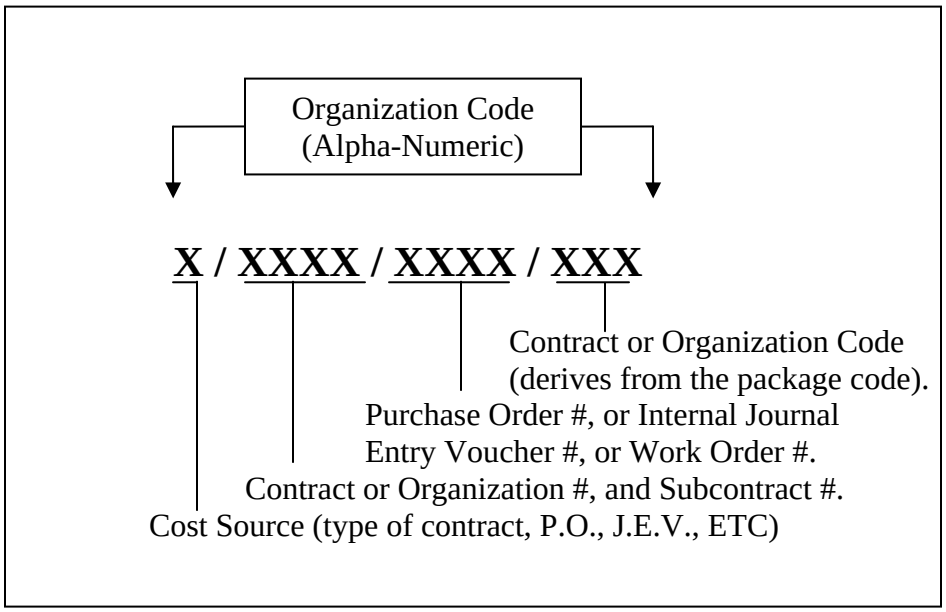


Figure11. Project cost code structure based on functional organization

5.1.2 Database Formats and Published Cost Data

As stated earlier in Chapter3, The major difference between database formats is the number of divisions, the components code or numbering systems, and in consequences the cost per component or per measurement unit. Actually, this difference is coming from different ways to interpret a building. In one hand, Construction Specifications Institute (CSI) has produced a Master Format that consists of 16 divisions for the work breakdown. It is trade based format that suits the construction process. It gains a big importance for the reason of it familiarity within the contractors and the manufacturing industry. A new Master format 04 has been developed and the CSI-"16 divisions" has been expanded to become "50 Divisions".

On the other hand, the General Services Administration (GSA) and the American Institute of Architects (AIA) had jointly developed the original Uniformat 1 that consists of 12 divisions in 1972. It is building based format that suits the building system. It is mainly used by the architects for estimating and design cost analysis. The new Uniformat 2, first issued by ASTM in 1993, is an enhanced version developed by a task group that included amongst others CSI, GSA, American Association of Cost Engineers (AACE), The Tri-Services, R.S. Means and Canadian Institute of Quantity Surveyors (CIQS). It is more comprehensive than the original, particularly with respect to the mechanical and site work (http://www.constructioneducation.com). It consists of 8 divisions and the group of associations who had worked on developing it believes that it

suits better the project's life cycle from early stages, and in which the elemental design estimates will be consistent from phase to phase.

5.2 Quick comparison between database formats

The coding or numbering systems range from numeric to alpha numeric and the code structure grows as long as we move between the five data levels –from divisions, to sub-divisions, to group elements, to sub-groups, to elements. For example, a sub-division's code under (CSI-16) will look like this: 14200 – Elevators in which the first two digits indicate that it is in division 14– Conveying Systems. The new CSI's Master format code consists of six digits instead of five, and it will look like this: 142000 – Elevators. This sub-division code will be different under Uniformat 1, and it will look like this: A7.1 – Elevators in which the letter "A" stands for assemblies and the number 7 for conveying systems division. Under the new Uniformat 2's numbering system, it will look like this: D1010 – Elevators and Lifts as a group elements, in which the letter D is designated for "Services" division and the combination D10 is designated for the "Conveying" sub-division. (Figure12) represents level 1 numbering systems in CSI-Master format, Uniformat 1 and 2. Appendixes A, B, C, and D at the end provide levels 1, 2 & 3 numbering systems of a full construction's database. In the published Cost Data books, cost is generally recorded at level 5 – the element level – but in Square Foot Cost Data where the cost is recorded at level 3 of Uniformat 1 & 2 only. During the project's stages, cost data is used in all formats in order to meet the needs of everyone involved in the project. The real challenge for BIM technology is either to provide the ability to link different formats' numbering systems, or to stick to the new Uniformat 2's numbering systems as AutoDesk did with REVIT. Another challenge is whether or not, it is feasible

to provide the ability to record all cost categories - labor, materials, and equipments - in BIM's platform itself with object oriented database where "import" feature is very limited to CAD files.

Master Format **(CSI-16 divisions)**	**Uniformat 1** **(12 divisions)**	**Uniformat 2** **(8 divisions)**
00 – Conditions and Requirements.	- Project Description.	- Project Description.
01 – General Requirements. 02 – Site Construction. 03 – Concrete. 04 – Masonry. 05 – Metals. 06 – Woods and Plastics. 07 – Thermal and Moisture Protection. 08 – Doors and Windows. 09 – Finishes. 10 – Specialties. 11 – Equipment. 12 – Furnishings. 13 – Special Construction. 14 – Conveying Systems. 15 – Mechanical. 16 – Electrical.	A1.0 – Foundations. A2.0 – Slab on Grade. A3.0 – Superstructure. A4.0 – Exterior Closure. A5.0 – Roofing. A6.0 – Interior Construction. A7.0 – Conveying. A8.0 – Mechanical System. A9.0 – Electrical. A10.0 – General Conditions. A11.0 – Special Construction. A12.0 – Site Work. A13.0 – Miscellaneous	A – Substructure. B – Shell. C – Interiors. D – Services. E – Equipments and Equipments. F – Special Construction and Demolition. G – Building Site Work. Z – General.

Figure12. Level 1 numbering systems of Database's components

5.2.1 CSI – Master Format and RS Means Building Construction Cost Data

Many Cost Data publishers have used the Master format numbering system in their books. One is the book called "Building Construction Cost Data (BCCD)" published by RS Means. It is "the most used, most quoted, most respected unit price guide available to the construction industry. It is the professional estimator's first choice for reliable unit costs." (RS Means, BCCD 2003). It is widely used in construction cost information for general construction. Installation costs are broken down into labor and equipments costs and are recorded at level 5 – element level - with 12 digits referential numbering system. It provides access to thousands of materials and labor prices. All costs records are based on a National Average Cost. BCCD supports crew-based, hourly and unit-cost methods of pricing. (Figure13) is an illustration of the combined CSI-Master format and Means numbering systems used in BCCD to provide unit price. Appendix E is a page from BCCD-RS Means (http://www.rsmeans.com)

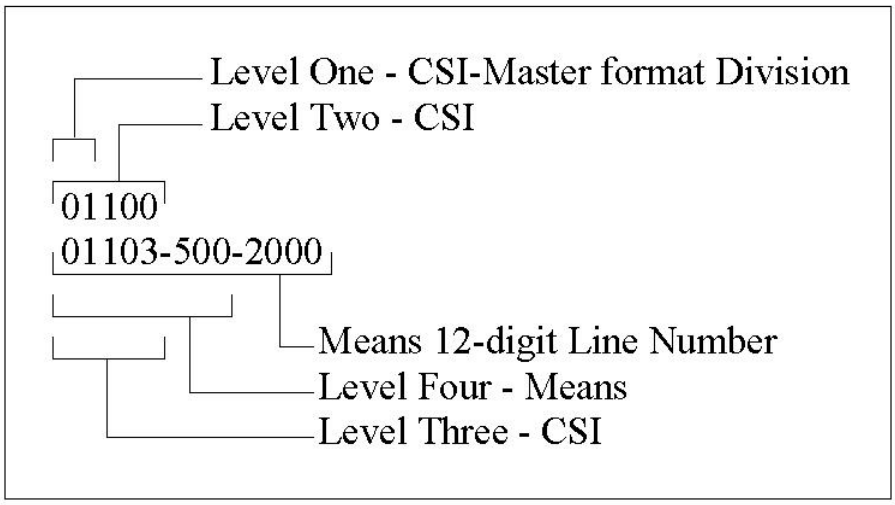


Figure13. Levels 1 to 5 numbering systems for unit price line item

5.2.2 Uniformat 1 & 2 and RS Means Square Foot Cost Data

"Square Foot Costs (SFC)" is the name of the book published by RS Means that used Uniformat 1 numbering system of 12 divisions. Besides the cost per SF, It includes nearly 6,000 assemblies driven by unit quantities, from concrete footings to mechanical and electrical systems. After the release of Uniformat 2, new updated versions of SFC books are published using the new numbering system. Appendix F illustrates a sample page of the new SFC release in which all BCCD items are included. A new book was born in RS Means family; "Square Foot & Assemblies Estimating Methods" (SF&AEM). It provides RS Means labor and equipment costs, and formulas at the item level that allow for automatic calculation of quantities. It supports three pricing methods: unit cost, hourly, and crew. "It is an essential reference for anyone who creates conceptual, construction, or appraisal estimates. The updated edition explains how to develop accurate and verifiable estimates with a minimal investment of time". (http://www.rsmeans.com)

5.2.3 Uniformat 2 and RS Means Assemblies Cost Data

"Assemblies Cost Data" (ACD) book is another member of RS Means' family. "It is used by construction professionals for quickly and accurately estimating square foot costs and verifying unit price estimates." (RS Means, ACD 2004). It provides thousands of building assembly and component costs. It is used by A/E/C for a quick system estimate and for easy comparison between alternative solutions and prices. It is also used for a quick check of a unit price estimate or subcontractor proposal. ACD has accompanying drawings, explanations, component breakdowns based on Uniformat 2 numbering system, and reference tables that are illustrated in Appendix G. Tables of unit prices allow costing out virtually any combination of building components or assemblies – in the logical sequence of how the building is built. (Figure14) is an illustration of the combined Uniformat 2 and Means numbering systems used in ACD to provide unit price. Appendix H is sample pages that illustrate how Uniformat 2 links schematic phase elemental preliminary project descriptions and design estimates, in an effort to prove that Uniformat 2 facilitates design/build budgetary and value engineering decisions based on preliminary or conceptual information (http://www.rsmeans.com).

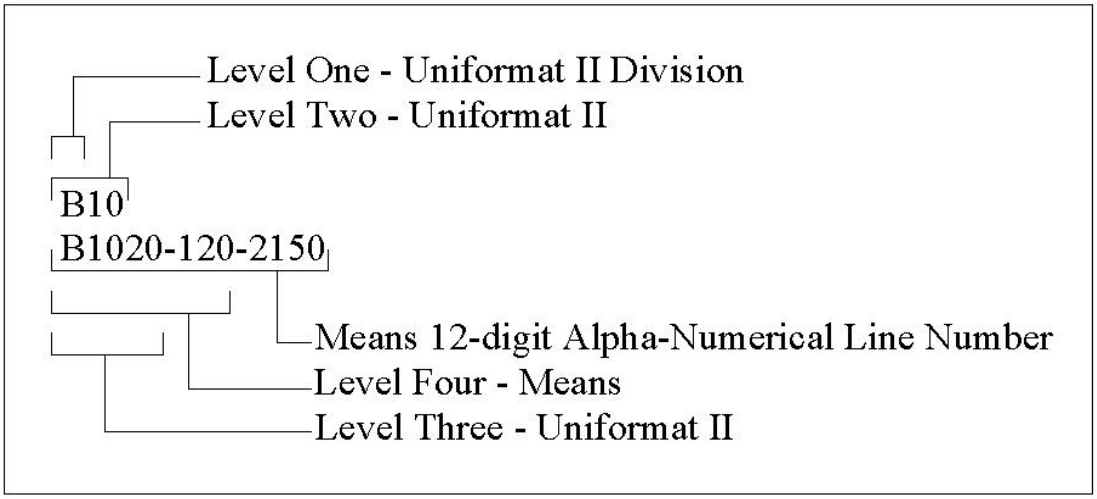


Figure14. Levels 1 to 5 numbering systems for assembly price line item

Chapter 6. Overview of some available tools

(Timberline, Revit, and ArchiCAD)

Information Technology has been improving the construction industry for many years. Emails substitute fax, FedEx expedite delivery of documents, and laptops are used with remote connectivity. Day after day, the contractors are getting away from paper and going into electronic communication. Too many benefits and promises are resulting from the implementation of IT, such as having instant updated information instead of periodic updated information. By definition, "Information Technology (IT) or Information and Communication Technology (ICT) are the technology required for information processing. In particular, the use of electronic computers and computer software to convert, store, protect, process, transmit, and retrieve information from anywhere, anytime"(Wikipedia-web dictionary).

"The process of selection the proper software isn't simple or easy, if the objective is to implement integrated information systems within the organization. Training sessions are essential and key for a successful implementation of new software. The ROI (return of investment) study is substituted by the principle of "making the same margin of profit" after adopting the new system. Not everyone is capable to be on the leading edge, because it requires lot of investments and researches. Therefore when mistakes occur, this organization may suffer financial problems and ends on the bleeding edge. Electronic documents and electronic data are vulnerable. Software liability is only limited to the cost of the license. Litigation issue is present when the software is wrong,

which results in loss of time and money at the court. The life span of software is five years. The average spending on IT is between $2500 and $ 3500 per employee."(David Dutton's lecture @WPI on April 15, 2003 – course CE584; Advanced Cost Estimating)

6.1 Information Systems (IS)

Since "IT is the development, installation, and implementation of computer systems and applications"(http://www.answers.com), Information System (IS) is "a business application of the computer. It is made up of the database, application programs, manual and machine procedures and encompasses the computer systems that do the processing" (computer desktop encyclopedia). The department of defense (DOD) define IS as "the entire infrastructure, organization, personnel, and components that collect, process, store, transmit, display, disseminate, and act on information." (Figure15) illustrates the relationship between the systems.

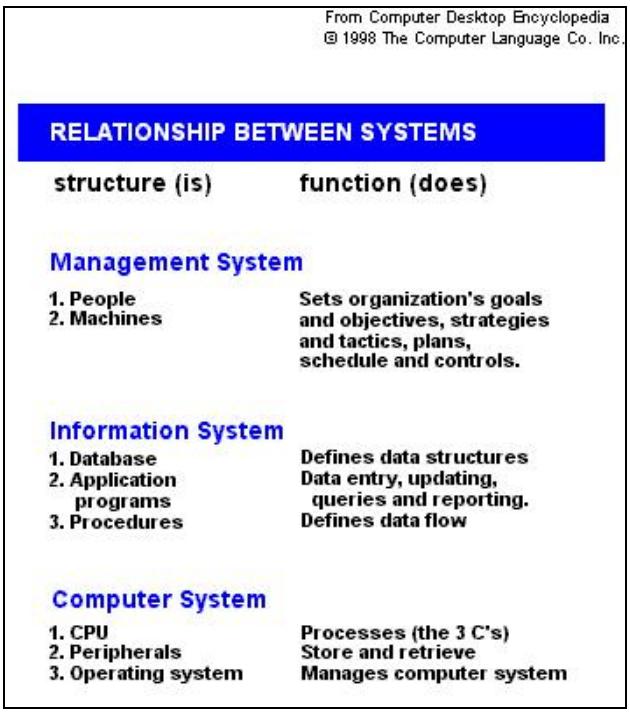


Figure15. Relationship Between Systems

6.1.1 Management System in the Construction Industry

To resolve the project delivery difficulties, the Construction Industry has developed five project management systems that suit the life cycle process by which projects are conceptualized and eventually started up. In his book - Computer-Aided Project Management - George Suhanic defines the systems as the following:

- Project Definition Structure (PDS) is a systematic means to establish project scope and quality parameters of elements as deliverables…it is the basis for the project code system. The earliest cost estimates and budgets are tied to it.(page 9)

- Project Work Breakdown Structure (WBS) identifies project activities or tasks that create the PDS deliverables…WBS activities take on code numbers based on the structure, and become the code of accounts for estimates and budgets. The WBS budget is compared to the PDS as the first measure of project cost control.(page 9)

- Organizational Breakdown Structure (OBS) aims to define and code the organizations and their project human resources…every element of project work ultimately has three code numbers, one for each of PDS, WBS, and OBS.(page 10)

- Project Budget and Cost Control. Project budgets are based on estimates. Estimates are derived from scope and quality information set by

progressive developments in the PDS, WBS, and OBS exercises…through the use of codes, the final cost for an element may be referred to the initial budget for the same element. Constant comparisons of cost to budget provide the means for cost control.(page11)

- Project Schedule and Progress Control. Time is of the essence in project work…computer programs were written to process the results of Critical Path Methods (CPM) networks and convert the information to schedules…progress control is achieved by ensuring that activities are carried out within the timeline.(page11)

The five systems aim to integrate project information into a common database to facilitate project control. The systems identify who does what, when, and for how much without the imposition of a rigid, hierarchical organization structure.

6.1.2 Information System in the Construction Industry

Information System (IS) in the construction industry means a Computer-Aided Project Management. IS uses a database of accurate information to define a project in language the customer can understand and the project team can use to deliver the finished job. IS ties in and integrates the five project management systems for scope, quality, cost, and schedule control, throughout the corporate functions. IS uses the project cost coding as a means to track the project scope from the time the project is known only by a ballpark estimate to when it becomes a definitive estimate, which forms the basis for project cost control.

6.1.3 Project Control System in the Construction Industry

A project control system is dependent on a range of management, corporate, and engineering systems and subsystems. (Figure16) illustrates the statement that a project control system is not a stand alone system. Other corporate systems are shown tying into project control, and project control feeds other corporate information needs (George Suhanic, CAPM, p. 246).

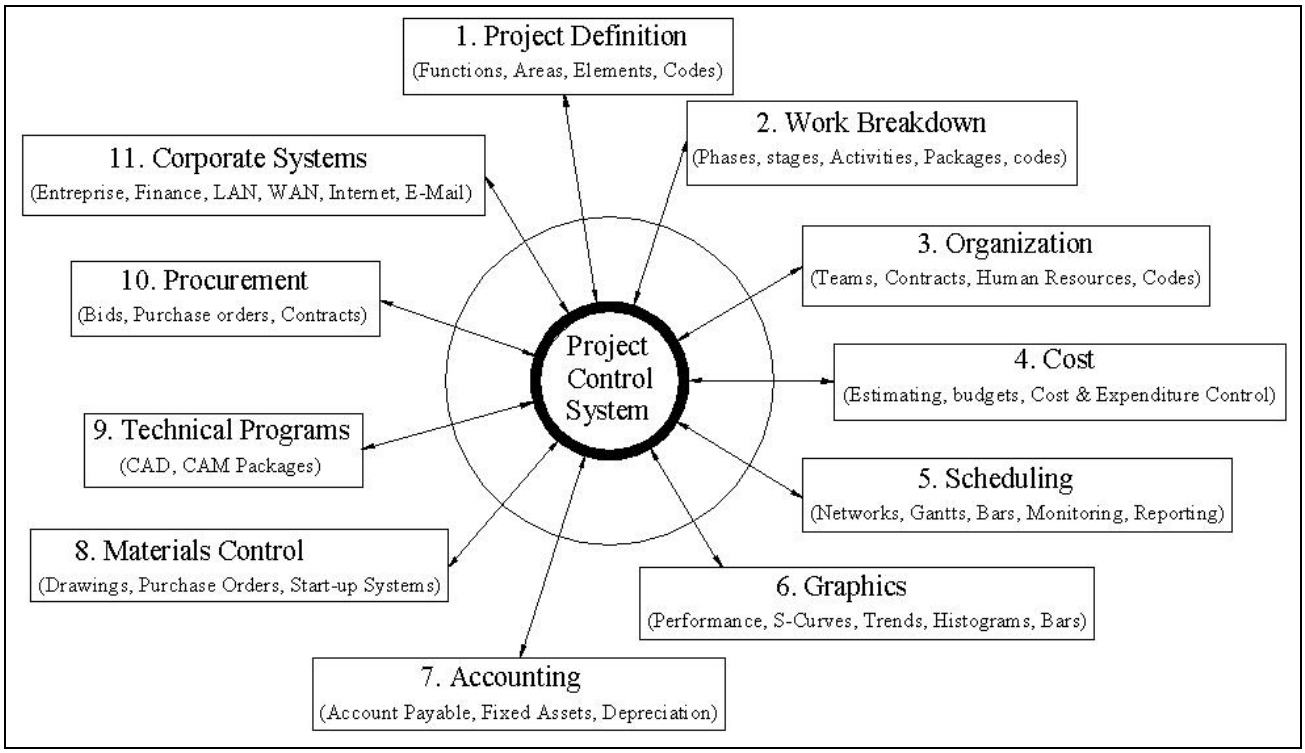


Figure16. Project Control System

6.2 Some available tools

Information Industry has developed different tools for different applications in order to meet the construction industry needs. The real challenge for people around the globe is the "integrated IT approach" that suits the life of a project. For example, the 3D-

CAD is heading in developing new software which supports the standardization and the interface with estimating and scheduling. IAI, the international alliance for interoperability, and similar organizations are supporting the International Foundation Classes (IFC) files and Extensible Markup Language (XML) files which can be read by the majority of the software used in the A/E/C industry. Also, assemblies, models, check lists and online take-offs are all available tools for estimating at this time. Some companies, like Plan Well Enterprise, utilize the internet in the construction. They build project websites, display the drawings on the web before to bid them, order print out of the drawings, and submit your bid electronically. Other companies are working very hard to invent security software and tools like ID and password, digital thumb finger print, and so on, in an attempt to defeat hackers and to avoid their troubles.

Since database structures are diversified, and sometimes are not compatible with each other, integration and interface features between different systems were never easy or simple. Some companies have developed what is known as electronic "office" in order to solve integration issues in certain area of concentration. For example, Timberline office provides a platform that is compatible with both estimating and project control practices, and it also interfaces with scheduling software through export feature, and it supports ODBC concept. Another example, AutoDesk office provides a platform that is compatible with BIM, 2D-3D drawings and rendering. It also provides secure electronic communication where the project participants can share and store their documents. Maybe the simplest way to explain "office" concept is by using MS Office example; copy/paste feature is applicable in all Microsoft family members.

6.2.1 Timberline Office – Estimating (http://timberline.com/software/default.aspx)

Timberline Office estimating is a package database type. It is powerful software for Cost estimating using preset databases. These databases contain standard cost items used for takeoff, including item productivity factors, formulas and prices. Thus there is no need to type the same information again and again, as any information entered into a database can be easily retrieved. New items could be created, as well as new databases considering the particular needs and requirements of an organization, the zone or the location factor, or a particular type of a project. The estimates are presented in the form of Spreadsheets. These can be modified to show varying amounts of detail for presenting the estimates at various levels such as Corporate, Owner, and Project Manager. It enables to save all kinds of time, curb risk, and maximize profits by automating estimating and bid management processes. The core estimating application gets extra muscle from a full range of thorough databases packed with thousands of standard industry items that can be customized and used right away - or be enhanced with unique items, formulas, and factors. It is fully integrated with RSMeans databases and pricing services. Assemblies and modules in Timberline are formed from existing elements in the database, and their costs derive from the detailed prices of the components that form the assembly or module. Therefore the cost of assemblies generated in Timberline is more precise and relevant than the published cost assemblies' data.

In the last couple of years, a new feature has been developed to add CAD integrator which enables Timberline to do fast takeoffs directly from CAD drawing files.

With the Timberline Office CAD Integrator, there is no longer need for a custom interface to transfer information from CAD drawings into a Timberline estimate since Timberline draws on the common information format of Industry Foundation Classes (IFCs), used to standardize CAD objects such as doors, windows, walls or HVAC ductwork. Estimates are generated directly from any IFC - compliant CAD software in a matter of minutes. Eliminating manual and digitizer takeoff means increased speed and improved productivity.

The following image has been taken from Timberline website and it shows the process of CAD integrating with IFC file.

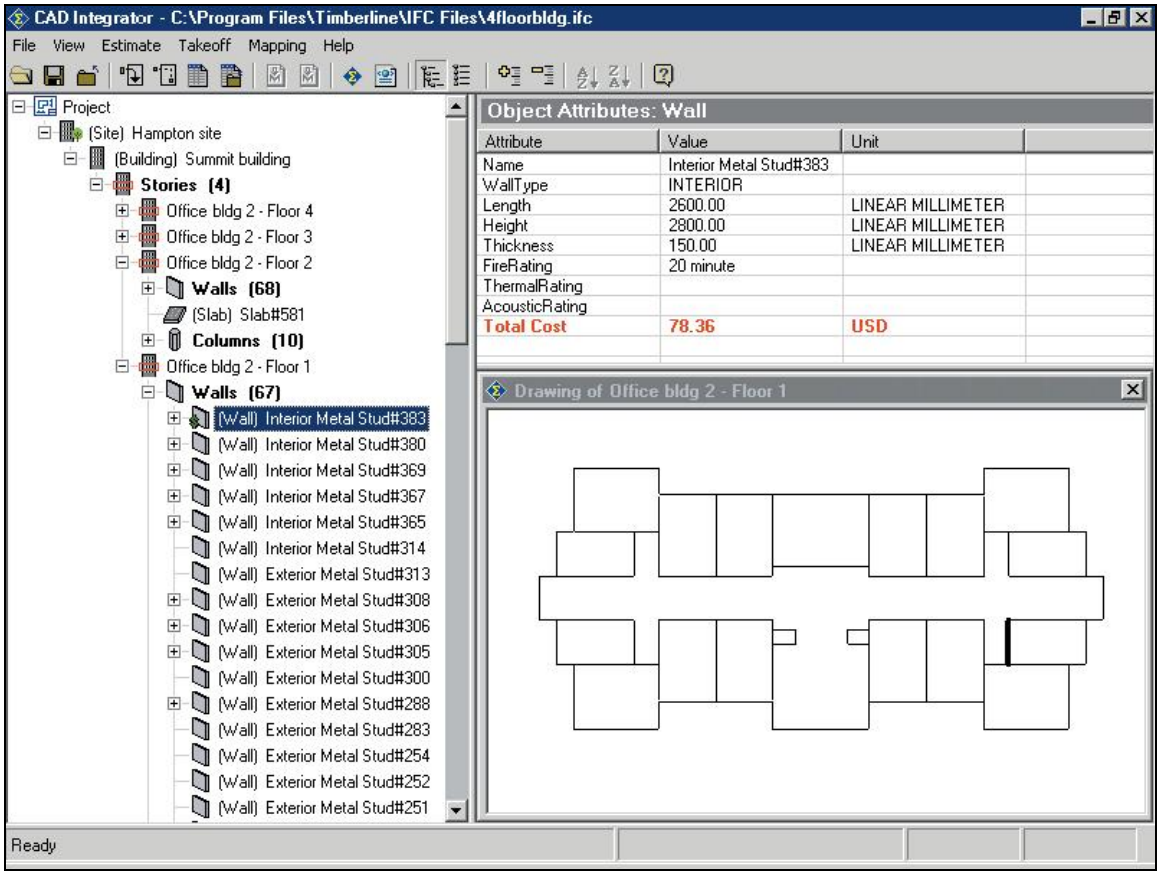
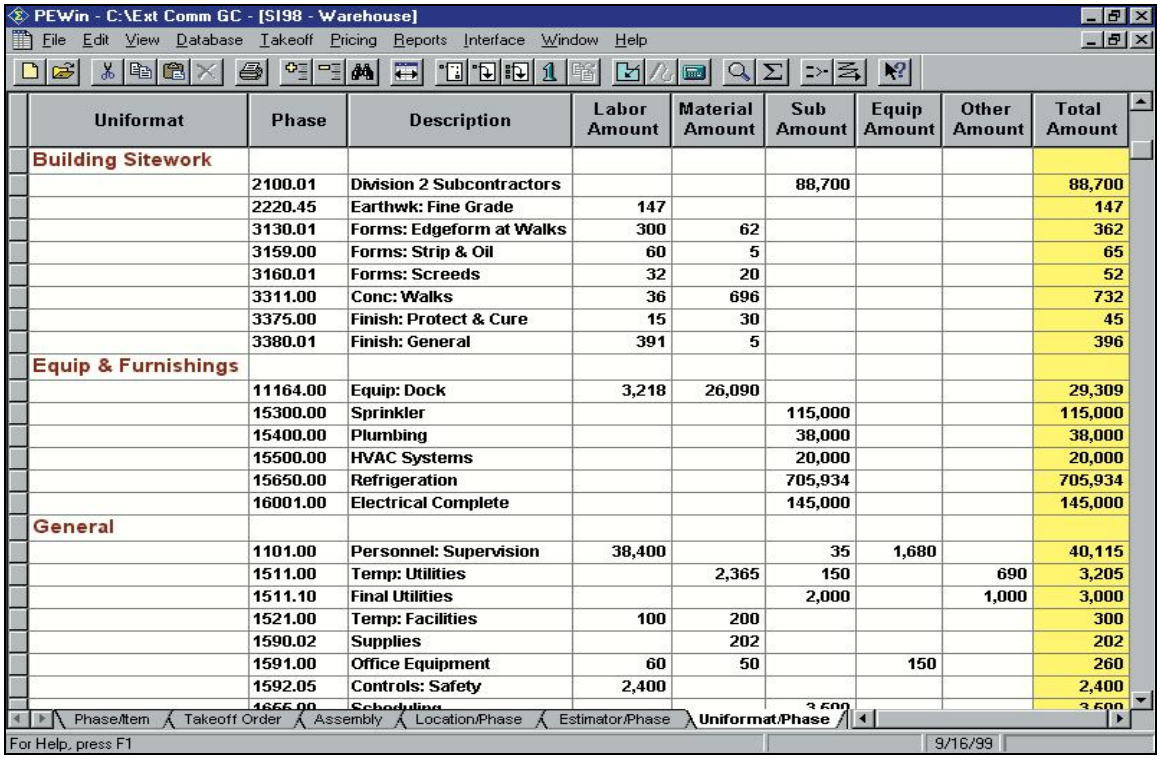


Figure17. Timberline – CAD integrator with IFC file

Also Timberline Implements the use of WBS and OBS. However a PDS can not be created using Timberline, due to the quality and poor level of information available at early stages of the project. The Master format (CSI-16 divisions) is used to create estimates. The tasks are thus assigned WBS codes. The items can also be assigned to different geographical locations in a project. WBS codes allow organizing the estimate in a variety of ways - by project phase, drawing detail, or location. Timberline allows attaching up to 12 WBS codes to each item, which makes the analysis and reporting possibilities endless. Although, Timberline database is based on Master format, it provides a way to bind Uniformat and Master format together in one estimate using the phasing tool. It is very general sorting feature that links the coded "level 5 items" of CSI-Timberline to the not coded "level 1 groups" of Uniformat I or II. The following image has been taken from Timberline website and it shows the report that link Uniformat I to Master format.



Uniformat	Phase	Description	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Amount
Building Sitework								
	2100.01	Division 2 Subcontractors			88,700			88,700
	2220.45	Earthwk: Fine Grade	147					147
	3130.01	Forms: Edgeform at Walks	300	62				362
	3159.00	Forms: Strip & Oil	60	5				65
	3160.01	Forms: Screeds	32	20				52
	3311.00	Conc: Walks	36	696				732
	3375.00	Finish: Protect & Cure	15	30				45
	3380.01	Finish: General	391	5				396
Equip & Furnishings								
	11164.00	Equip: Dock	3,218	26,090				29,309
	15300.00	Sprinkler			115,000			115,000
	15400.00	Plumbing			38,000			38,000
	15500.00	HVAC Systems			20,000			20,000
	15650.00	Refrigeration			705,934			705,934
	16001.00	Electrical Complete			145,000			145,000
General								
	1101.00	Personnel: Supervision	38,400		35	1,680		40,115
	1511.00	Temp: Utilities		2,365	150		690	3,205
	1511.10	Final Utilities			2,000		1,000	3,000
	1521.00	Temp: Facilities	100	200				300
	1590.02	Supplies		202				202
	1591.00	Office Equipment	60	50		150		260
	1592.05	Controls: Safety	2,400					2,400

Figure18. Timberline – Uniformat I/Master Format phasing feature

Timberline also allows the assigning of various organizations or people to various different tasks. These can be used as the OBS, to show the responsibility for the various tasks. Timberline can create a wide range of reports - Standard Estimates, Field reports, comparison reports, Variance reports, bill of materials, who's doing what reports, crew reports, and many other reports related with the cost and the resources for the project.

Timberline has also developed an interface tool with TRA-SER. This software automates item pricing, giving the ability to import and update Timberline database with item pricing from the i2 Technologies solution - pricing service software for electrical, plumbing and HVACR components. The following image has been taken from Timberline website and it shows the interface with TRA-SER Pro.

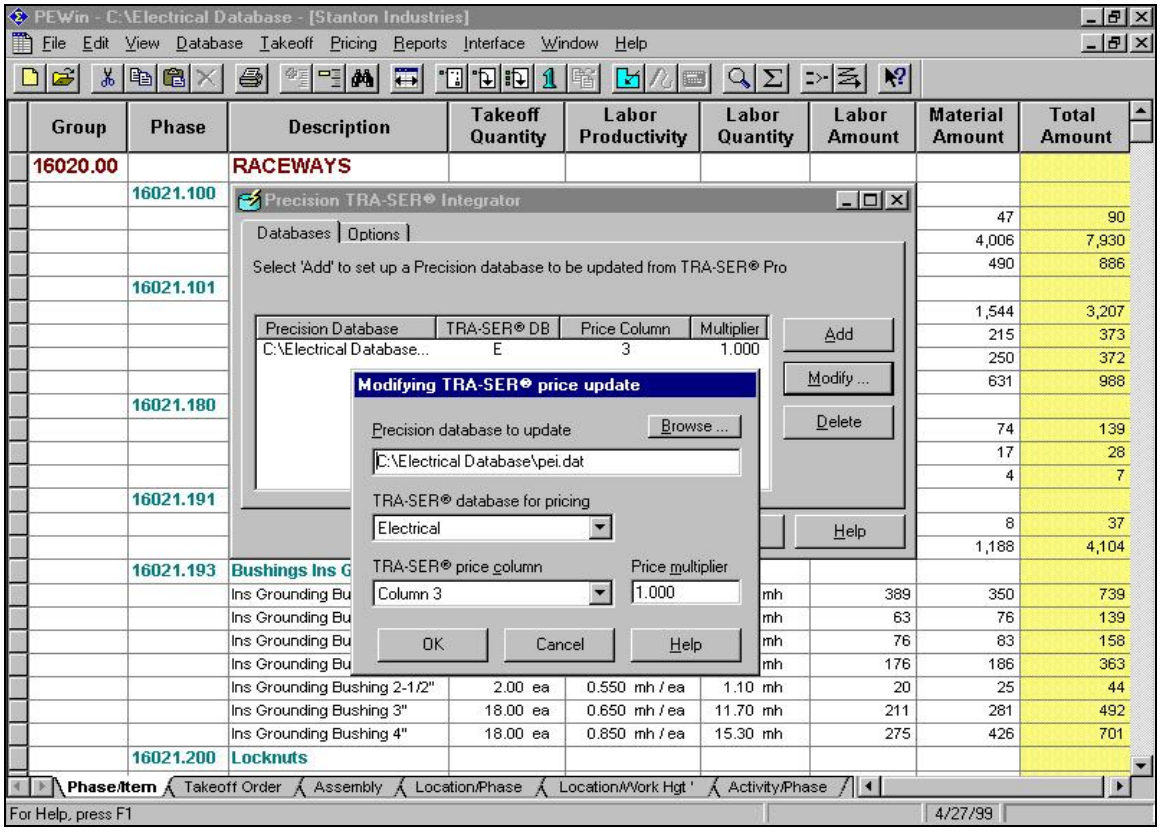


Figure19. Timberline/TRA-SER Pro interface

Timberline has the ability to interface with industry-standard scheduling software such as Primavera - Project Planner P3 or Sure Track Project Manager - Microsoft Project for Windows. Scheduling Integrator provides instant access to labor and equipment details, material items, productivity factors, and estimator notes. The items from the estimate when exported to Primavera are assigned the WBS codes from Timberline as their Activity IDs. The WBS codes from Timberline can not be used for a WBS in Primavera unless a compliant WBS dictionary is preset in Primavera. Otherwise, new WBS codes and descriptions have to be created. The cost data and the resources for a particular activity are correctly transferred to Primavera. The following image has been taken from Timberline website and it shows the interface with Sure Track.

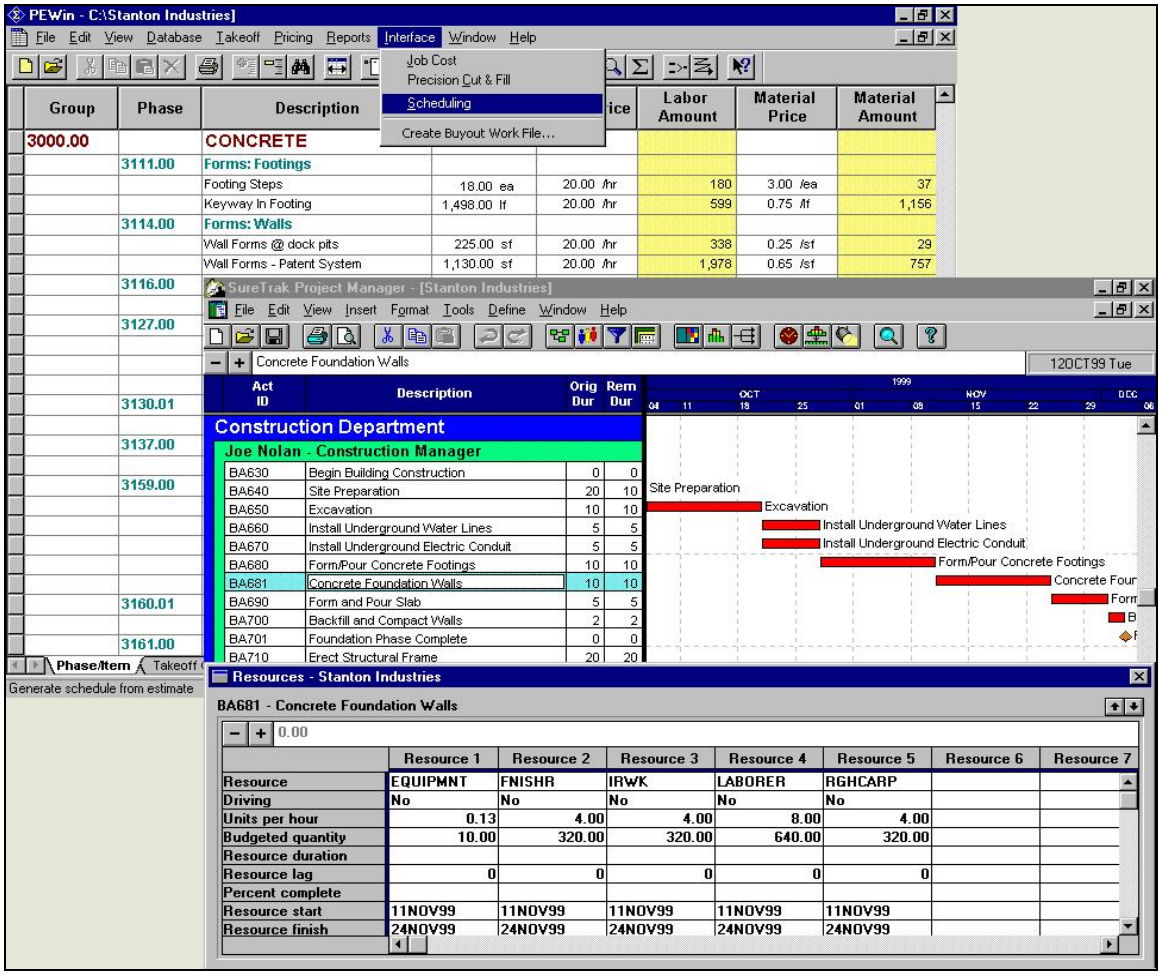


Figure20. Timberline/Sure Track interface

Timberline has developed an Open Database Connectivity (ODBC) feature that serves as a translator between different database file structures and other application software. The ODBC driver allows certain front-end applications to collect data from back-end applications. Because of ODBC, Access databases, Word processors and Excel Spreadsheets are able to communicate with Timberline.

In order to achieve a successful use of ODBC, one must first set up a Data Source Name (DSN) for each Timberline database to serve as a link with other applications. However, some steps are required to go from Timberline to Word passing by Access and Excel.

Step 1: Create an estimate in Timberline.

Step 2: Extract the file from Timberline into Access.

Step 3: Manipulate the file in Access.

Step 4: Export the file from Access to Excel.

Step 5: Export the Excel spreadsheet to a text file.

The communication between Timberline and Access is very strong; any change occurs in one file, the same change occurs in the other file in the second software. The level of communication between Timberline and Excel is reduced to one way; the change in Timberline affects the Excel file, but the reverse isn't necessarily true.

Timberline's ODBC driver is limited in terms of importing. It only allows importing of some Invoices from Access into Accounts Payable. Records that are rejected by Import Invoices are copied to a separate rejected records text file. The Import Invoices journal lists any warnings and errors that occur during the import process. This information is used to edit erroneous information in the rejected records file. The rejected records file can be edited using any text editor that does not convert the file from the comma-delimited text format to a different format. After reviewing the errors on the Import Invoices journal and correcting the rejected records file, the file can then be used as the source import file when reprocessing rejected records. Each invoice that gets imported must have an invoice line APIF and a distribution line APDF. Just like entering an invoice manually, one first enters the invoice and then enters the invoice distribution information. The Access database has to be set up in a way required by Timberline needs. Two separate tables-one for APIF, and for APDF- have to be created in Access. They have to be exported through ODBC into a text file that Timberline can read. These two fields will be assigned WBS code and OBS code in Timberline.

6.2.2 AutoDesk Revit (http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=331041)

The AutoDesk Revit platform for building information modeling is a complete architectural design - as well as - documentation system supporting almost all phases of design and all the architectural drawings and schedules required for a building project. It is an object oriented database application that has a very easy way to obtain different building sections and elevations. Its library is full of standards items used for windows,

doors, furniture and utilities. Once a symbol is being inserted in any view - for example a plan view, it automatically appears in all other views of the project such as sections, elevations and 3D views. From massing and conceptual studies through the most detailed construction drawings and schedules, Revit helps provide better coordination and quality, and can contribute to higher profitability for architects and the rest of the building team. AutoDesk Revit has an export feature to AutoDesk AutoCAD, for the purpose of generating detailed workshop drawings. The communication between Revit and AutoCAD isn't strong; any change occurs in one file after the export is done, the same change doesn't occur in the other file in the second software. The import feature in Revit is limited to read AutoCAD generated files as reference drawing files only. This issue raised a debate between AutoDesk and Bentley systems in early 2003. I quote the following paragraph from a white paper published by Bentley Systems titled: "Does the Building Industry Really Need to Start Over?"

"*We believe that "starting over" with a new, incompatible platform (as AutoDesk suggest with Revit) in order to achieve these goals is dangerous, wrong and wholly unnecessary. This path has never been an option for our users – there is simply too much investment and value in today's tools, data and workflows to throw it all away. Users with large investments and lots to lose from technology discontinuities demand and deserve a predictable and evolutionary path. Bentley has been and remains committed to providing an evolutionary path to our users." (Paragraph #6, page 3, "does the building industry really need to start over" white paper, Bentley Systems, January 2003 http://www2.bentley.com/industry_groups/default.cfm?objectid=7DC81D9D-2CBD-43..)*

In the Revit parametric building module, every drawing sheet, every 2D and 3D view, and every schedule is a direct presentation of information from the same underlying building database that uses Uniformat II coding system (8 divisions). However Revit original database supports only the first three divisions. Revit provides the room and the tools to create new elements and families within the local database. Also, a wide web library is available for Revit users. The Revit parametric change engine automatically coordinates changes made anywhere. AutoDesk Revit supports some phases of the building process, preserving all information from beginning to end. The same model that is rendered in design generates quantities exported to an estimating database after construction documents are prepared. Revit stores the project data in one single central database in an attempt to provide "one single design tool and database".

IAI and similar organizations are addressing the standardization issues by supporting the IFC and XML files which can be read by the majority of the software used in the A/E/C industry. However, Revit does not seem willing to address issues concerning interoperability in order to support these types of files. AutoDesk's major concern is to extend Revit's market, to reach competitor's level of development and to have mechanical packages included in their program. Maybe Revit's team feels that this can be overcome because other software in the A/E/C industry, like Timberline and Primavera, support IFC. Through the ODBC and CAD Integrator features, they can benefit from Timberline's research and results. However, the effective usage of Revit requires not only the knowledge of "form and materials" of the building, but also the knowledge of construction process.

Revit 6.0 has a clean and easy interface to pick up. As with most of the Windows based programs you have the usual File, Edit and Help pull down menu, and a second menu toolbar for Cut, Copy, Zoom and 3D etc. The remainder of the interface is then divided into two areas (Figure21):

- Design Bar with rollout functions covering Modelling (for most of the typical AEC and project based functions), Massing (for those feasibility studies), Documentation (schedules, text and drawing set-up), Detailing, and Edit.

- The Project Browser is similar in essence to an explorer type tree structure, allowing you to display all of the current, views, schedules, sheets and families active in the current project.

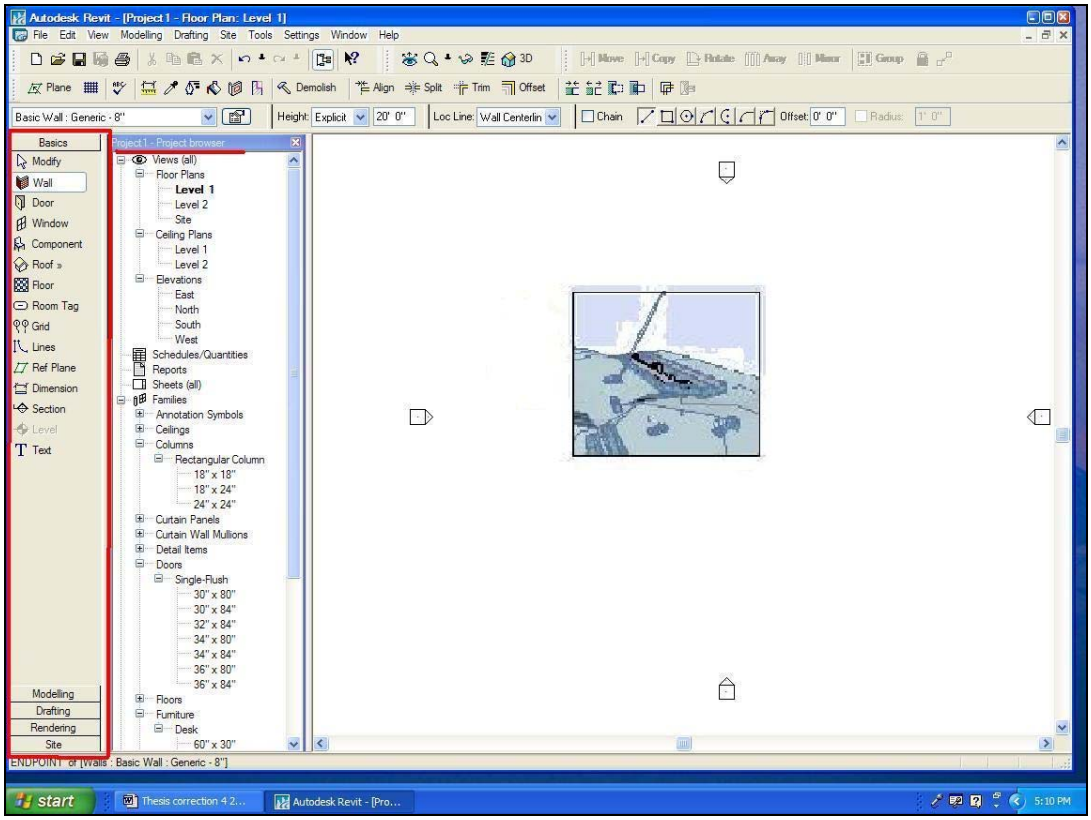


Figure21. Revit – Design Bar and Project Browser

Revit has many advantages over other CAD software and that includes rendering; once you apply the type of material used during the design process, colors and landscape can be easily modified. Revit is very promising in order to achieve the aim of implementation of Computer Integrated Building Design. Revit provides a graphical/alpha-numeric data understandable by the all participants in the project life cycle. Appendix I (AutoDesk Revit 6 – Features and Benefits) at the end provides information about Revit as integrated project model, and describes Revit's features in terms of building design and components, powerful intuitive editing tools, site and landscape design, drafting and documentation, multi-user work environment, presentation and visualization, and reporting and data sharing.

Collaborative design can be achieved in Revit through its Project Sharing feature. There is a significant amount of pre-work that must be done in order for this feature to work among multiple project participants. Initially, until the project reaches a reasonable point of design, only one person can be responsible for the design development using Revit. Once design is at a point determined to be "reasonable" by Revit, Worksets must be created in order for the various components of the building to be sectioned off for multiple users in order for independent, simultaneous contributions to the design advancement to occur. These worksets allow for the controlling of the various stages of a projects development. A project manager can control who is working on what by only releasing worksets at particular times.

A major issue that needs to be addressed in the initial project planning stages, especially in a design-build environment or one in which involves multiple locations responsible for design, is the computer networking among the participants. In order for Revit's Project sharing to work, the 'central file', which coordinates and propagates the multiple changes by all users, must be centrally located and accessible by all who will be involved in the project. This becomes an especially daunting task when you can have multiple offices or multiple designers designing the various systems of any one project.

In terms of schedule, Revit -as all available BIM tools- lacks the feature to interface directly with scheduling software - such as Primavera Planner P3 - which deals with tasks, not elements. However, Revit has the 4D model feature which can be used to graphically illustrate the schedule. The phasing feature is an innovative way to show the owner the schedule as a progressive model that enables simulation of the construction process, instead of bar charts and CPM network as produced by most scheduling software.

6.2.3 Graphisoft ArchiCAD (http://www.graphisoft.com//products/archicad/)

Graphisoft develops software solutions for the design, marketing and maintenance of buildings. At the foundation of all Graphisoft products is the Virtual Building TM, a 3D digital database that tracks all elements that make up a building. The virtual building model makes it possible to administer and manage a building throughout its entire life

cycle. Graphisoft products range from Architecture design tools to rendering and facility management tools. The virtual building environment of Graphisoft supports open communication, modifications and enhancements to the design. Because file format compatibility is crucial, ArchiCAD provides the functionality to ensure that no data or time is lost in the conversion process. The DXF/DWG translator of ArchiCAD supports up to AutoCAD 2004 and accurately maps layers, pen colors, fonts and blocks. ArchiCAD can write out DXF/DWG data. ArchiCAD intelligent handling of AutoCAD Xrefs, at input and output, not only preserves the link but allows Xref administration (including linking, unlinking and binding) within ArchiCAD. In addition, ArchiCAD imports and exports AutoCAD's vectorial DWF file format and Micro Station's DGN file format. ArchiCAD supports all major data exchange formats in use in the CAD industry and it supports International object standard, IFC 1.5.1, 2.0 and 2x (Phase 1 Certification) format.

Since 1996, Graphisoft has been a member of the International Alliance for Interoperability (IAI) that developed Industry Foundation Classes (IFC). The IFC concept is based on the idea of objects (or elements in ArchiCAD terms) brought together in an integrated model (ArchiCAD Virtual Building). IFC offers a higher-level "common language" for the sharing of intelligent objects between disciplines across the building lifecycle. IFCs object description protocol preserves the full geometric description in 3D, knows its locations and relationships, as well as all the properties (or parameters) of each object, such as finish, serial number and material description. The Geometry Description

Language (GDL) object browser technology of Graphisoft allows information to be saved and transmitted in IFC format.

ArchiCAD provides complete plans, sections and elevations, architectural and construction details, renderings, animations and virtual reality scenes. It is fully integrated and provides quick and easy sun studies, fly-through and movies (Figure22). ArchiCAD automatically handles the documentation. It generates files that describe the design like bills of material and window/door/finish schedules. It records surface area and volume, thermal properties, room descriptions, price, and specific product information.

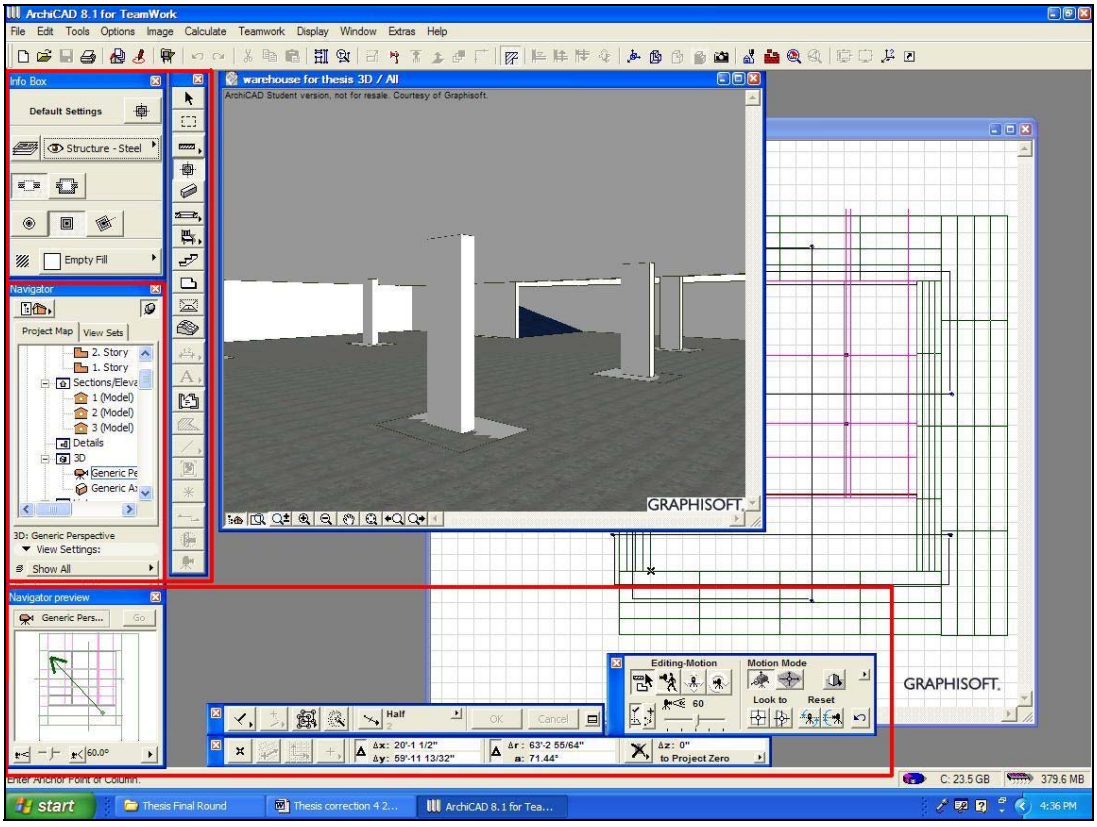


Figure22. ArchiCAD – Design and Animation Tools

ArchiCAD supports team work environment through it collaboration functionality. Team work feature provides seamless communication for all the design development team using one platform. Individual security access with password system is available under “team work” feature. Also, ArchiCAD strongly supports the interoperability concept because it can read other CAD files and not stick to one solution only. The project resources can choose the combination of techniques those best suits both the specific task in hand and the available skills. ArchiCAD Internet enabled work flow management functionality provides a mean for electronic communication and design coordination.

In ArchiCAD, the parametric Virtual Building change engine automatically coordinates changes made anywhere. ArchiCAD has a central intelligent objects database as well as GDL objects library, and it supports multiple federated database concepts. The central object database (Figure23) is the core of the digital model; every element of the database has associated geometry, position per project, layer, pen color and architectural schedule code of three digits. The GDL objects library (Figure24) has more associated parameters and descriptors to its elements such as cost and material type and serial manufacturing numbers. The library manager engine supports the creation of multiple federated databases. ArchiCAD originally comes with CSI-Master format database (Figure25); the database supports three levels of components coding system. It also supports level four element coding under the descriptors field. Even though it supports multiple measurements units per database, only one unit could be assigned to one component – one to one relationship. The cost is considered as a measurement unit.

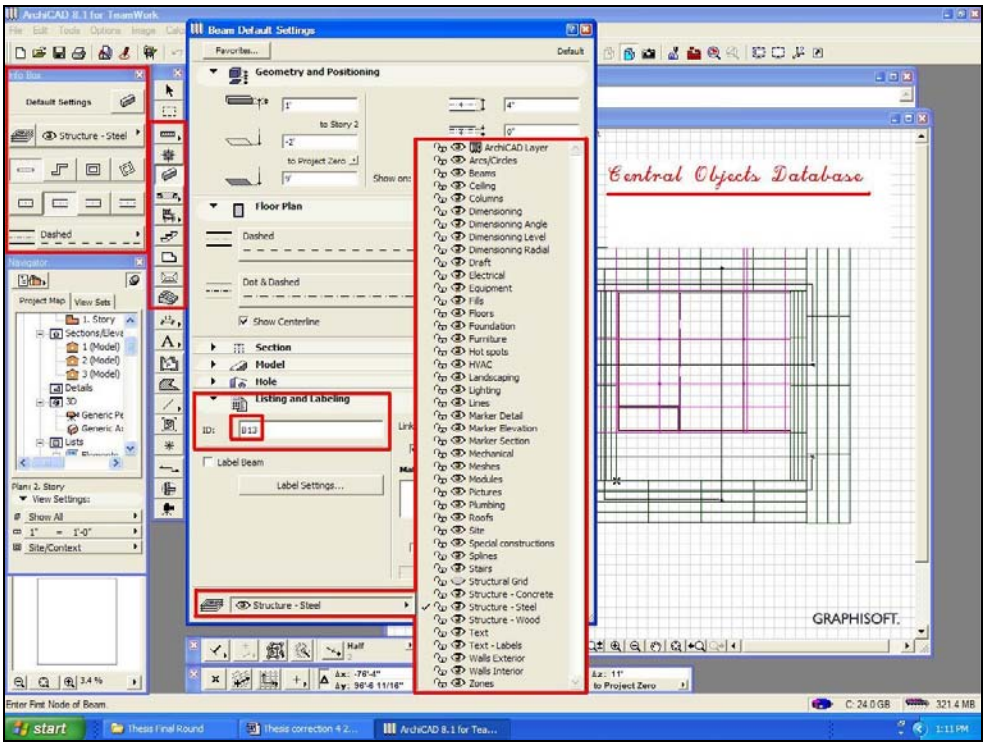


Figure23. ArchiCAD – Central Objects Database

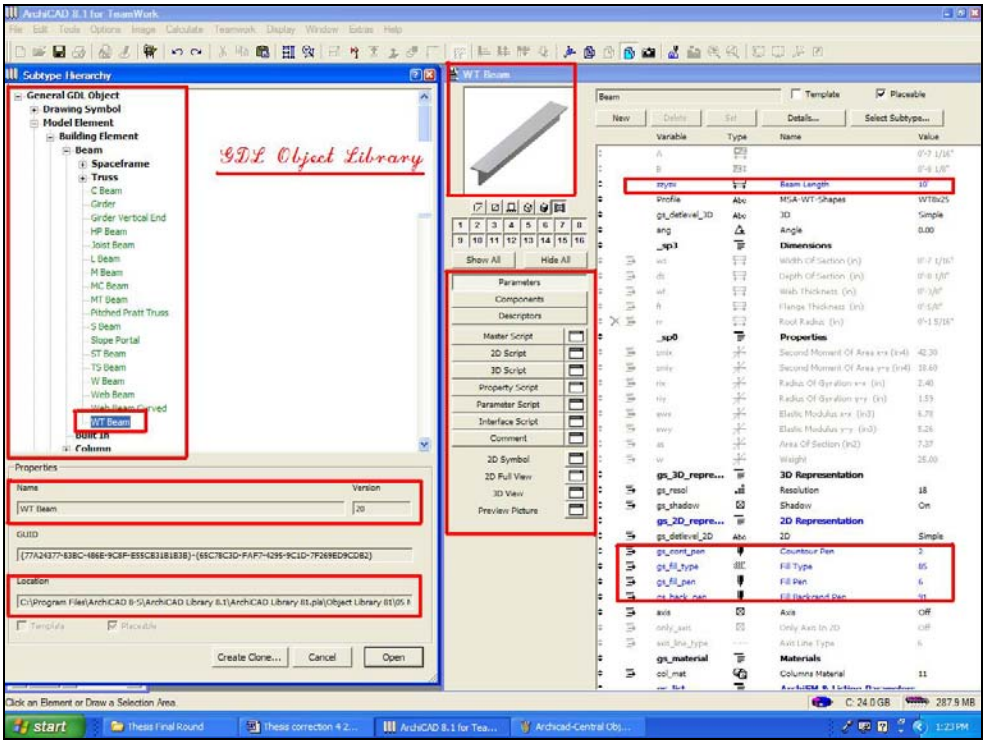


Figure24. ArchiCAD – GDL Object Library

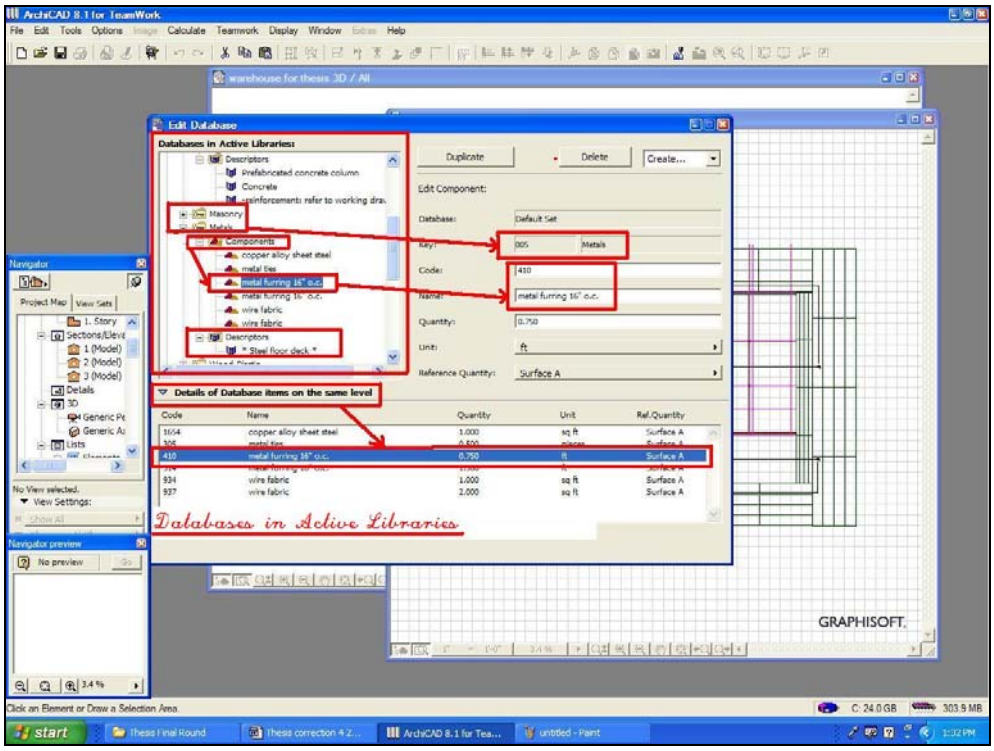


Figure25. ArchiCAD – Databases in Active Libraries

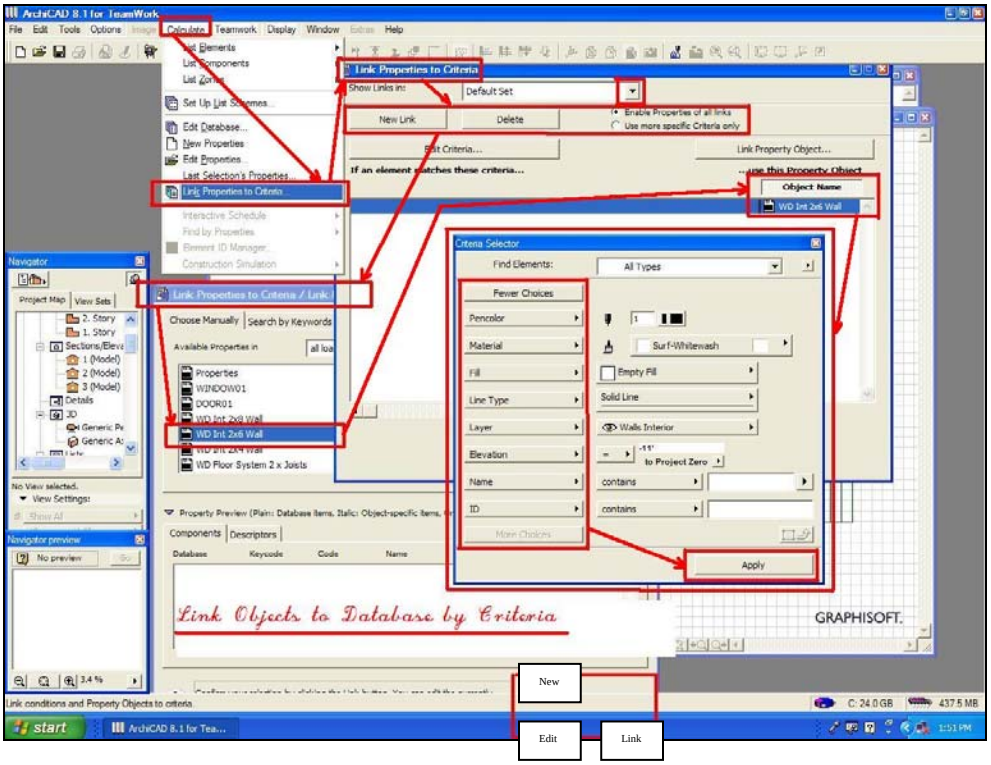


Figure26. ArchiCAD – Link Central Objects to Active Database By Criteria

The link feature between the central objects library and the federated libraries is located under “calculate” tool of ArchiCAD (Figure26); it links object properties of the first to the component criteria of the second – one by one. The same model that is rendered in design generates quantities exported as text and/or excel document after construction documents are prepared.

In terms of schedule, ArchiCAD also lacks the feature to interface directly with scheduling software - such as Primavera Planner P3 - which deals with tasks, not elements. Like Revit, ArchiCAD has the 4D model feature which can be used to graphically illustrate the schedule and electronically simulate the construction process.

The Construction industry has been adopting Information Technology tools and has been regulating the use of "Building Information Model" in the public sector. BIM provides both the owner and the management organization with detailed specific information about the building, but how effective and useful is this information? Could BIM really reshape the construction industry? How valid is the claim of BIM developers about enabling the architect to forecast the total building cost at the earliest stages of its design? What are the contributions of BIM in estimating field? This case study aimed to find some answers using two different BIM tools - Revit and ArchiCAD, as well as to unfold the capabilities of interface and integration features among different software and systems.

7.1 Methodology

This case study is based on the use of two BIM tools - AutoDesk Revit and Graphisoft ArchiCAD - and all the steps taken to manipulate the database within BIM platform. It also encounters the integration with estimating and scheduling software.

The following steps were taken in AutoDesk Revit, Timberline and Primavera Planner:

- Building a warehouse project using AutoDesk Revit for ease of use assessment and proficiency evaluation purposes.

- Working with object parameters and creating new fields for estimating purposes.
- Using a model built by AutoDesk and it customized spreadsheets for analysis purposes.
- Creating an ODBC file for integration purposes.
- Using ODBC feature in Timberline for estimating purposes.
- Interface between Timberline and Primavera for scheduling purposes.
- Using Critical Path information in Revit for construction simulation purposes.

The following steps were taken In Graphisoft ArchiCAD, MS Excel and MS Project:

- Building a warehouse project using Graphisoft ArchiCAD for ease of use assessment and proficiency evaluation purposes.
- Creating Uniformat I and II databases in ArchiCAD Libraries for estimating purposes.
- Linking elements parameters from the central objects database to the components of the federated databases for estimating purposes.
- Creating an Excel file format of the take-offs schedules.
- Interface between MS Excel and MS Project for scheduling purposes.
- Using Critical Path information in ArchiCAD for construction simulation purposes.

One thing to note is that this research didn’t explore any cost control neither any structural engineering software.

7.1.1 First Scenario: AutoDesk Revit

Many and different steps took place within Revit platform. The major focus was to manipulate the parameters of the elements that form the warehouse project. The goal was to improve the detail level of cost per element. The research attempted to find a way that supports the interoperability concept needs. The following list describes the actions performed by the researcher and records some particular steps in detail.

1. While using Revit to build the warehouse project, the researcher customized the line style, line weight and line properties (Figure27) – Setting Pull down List. This customization of color line and style played a tremendous role in terms of visually illustrating different objects in 2D and 3D views, and in terms of easing the selection process of different elements for phasing and construction simulation purposes (Figure27).

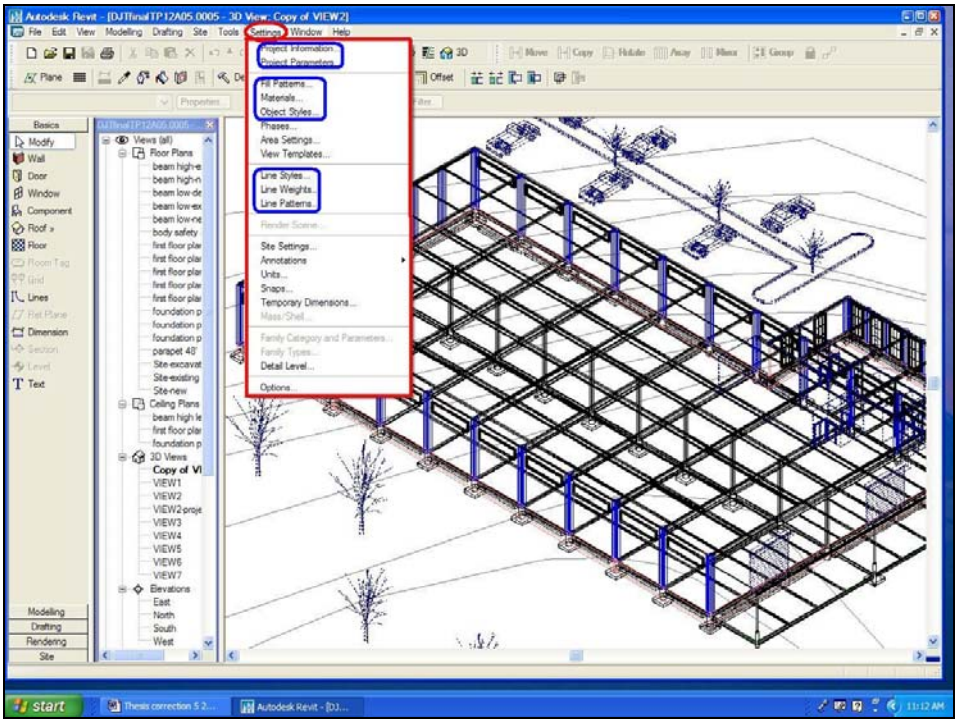


Figure27. Revit – Settings Pull Down List

2. When the digital model was done, the focus had shifted on working with object parameters and creating new fields for estimating purposes. Revit database is structured on Uniformat II coding systems. The database provides a cost field per element as a "type parameter" (Figure28) – Element Properties. New "shared parameters" were created and saved in separate files as a text documents. The new groups of parameters were given names like "CSI master format Group". New parameters were created under every group (Figure29) – Project Parameters.

   Since Revit allows the user to add parameters to the database categories per project, two new groups of parameters were added to all categories. The parameters values were stored as "type parameters" and not as "instance parameters" (Figure29).

   Uniformat II "Assembly Codes" were selected correspondingly from the pull down list (Figure28), and the "Assembly descriptions" were automatically assigned to the elements as "type parameters".

   The new field parameters from the shared parameters groups were filled manually. Since Revit elements are assemblies, and in order to dissect the assembly into its components, couple selected elements - wall and column - were provided by two sets of new codes that included "costs 1&2" fields. However, all the cost fields were not filled because they won't have relevant reflection to all the cost categories required by the estimating discipline.

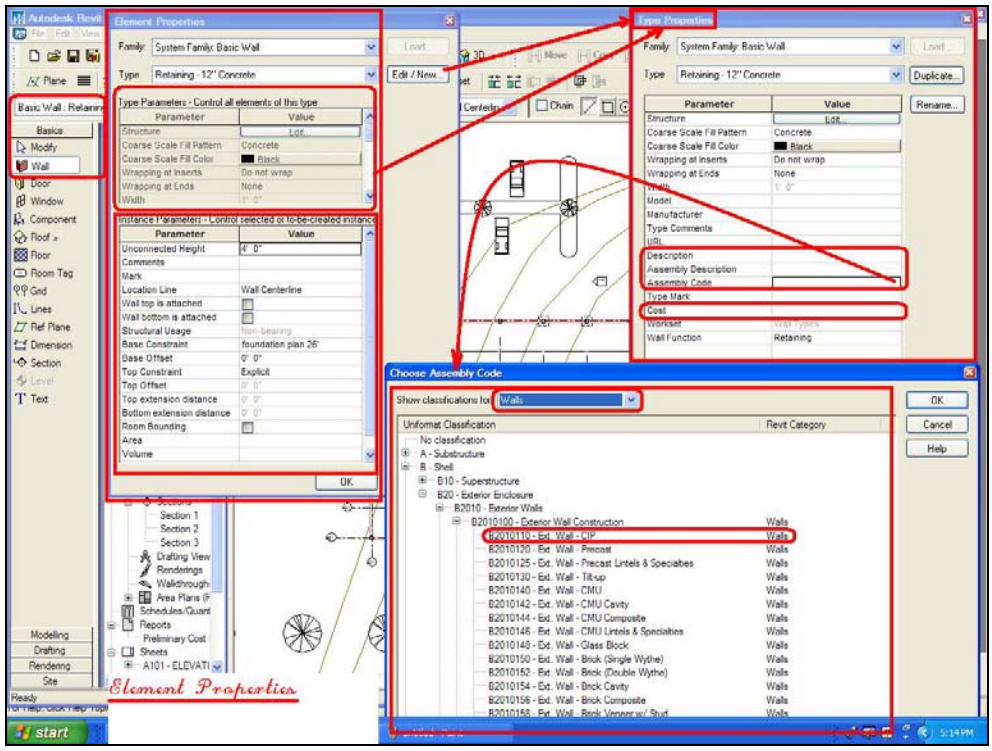


Figure28. Revit – Element Properties

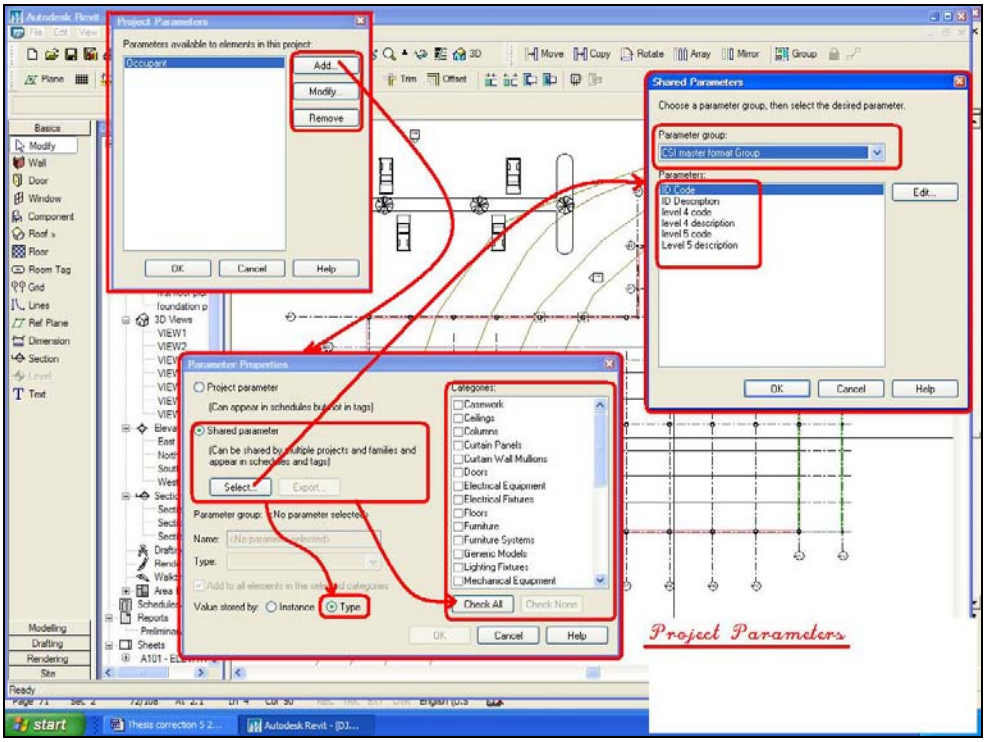


Figure29. Revit – Project Parameters

3. AutoDesk Revit team has developed template reports to serve estimating and value engineering practices. The team has exported these templates into MS Excel and manipulated the information in the spreadsheets. Mr. Ken Stowe from AutoDesk has passed the work to the researcher who did a thorough examination of the displayed info in the spreadsheet. The first finding was that there was no tag to identify each element of the project. Apparently the assembly code alone is not enough to serve identification purposes. The same assembly code was used as a reference to each element of the same category - i.e. B2010156 = Exterior, Brick CMU - (Figure30).

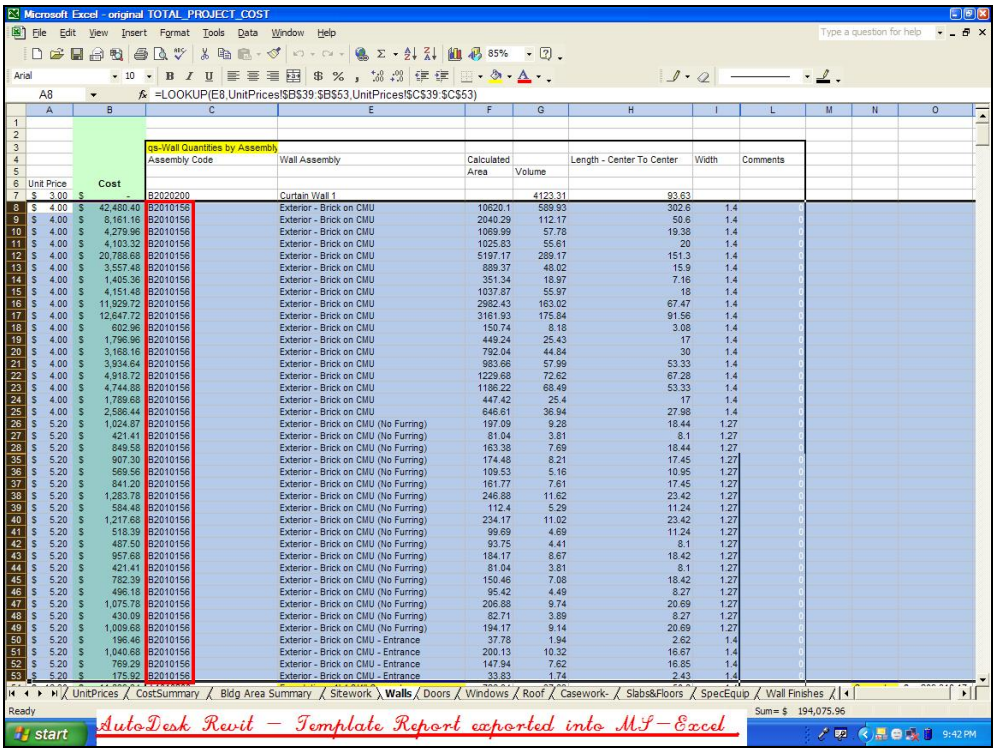


Figure30. Revit – Template Report exported into MS Excel

4. After some of the parameters fields - type and instance - were filled, ODBC driver in Revit was used to create data readable by Timberline. Data Source Name (DSN) was assigned to the new data. The researcher didn't expand his work to include the use of ODBC driver in Timberline. However, he did present this feature previously while giving an overview of Timberline software (page 55 of this report).

5. Timberline could open DSN file, but the information was similar to the one in the "template report"; no tag to identify the elements of the project. It was kind of impossible to benefit from the volume and area calculations generated by Revit since only "type parameters" were transferred by ODBC (Figure31).

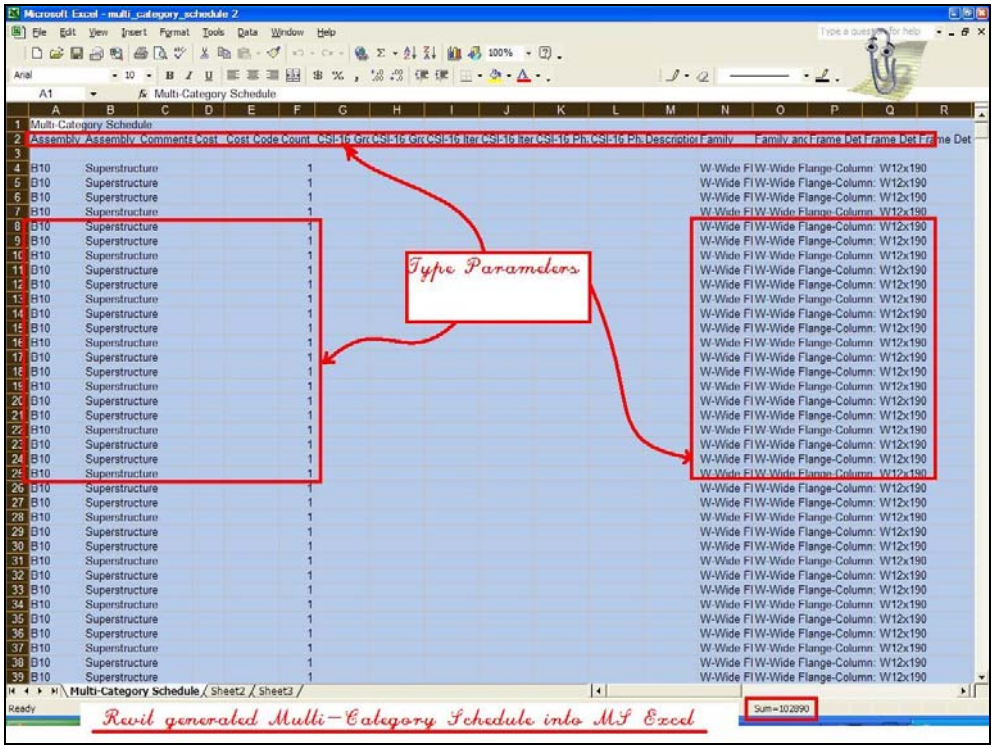


Figure31. Revit – Multi category Schedule into MS Excel

6. In a separate research path, an estimate was created in Timberline. An interface with Primavera Planner was run to generate a work schedule and to assign work packages to sub-contractors.

The Activity ID's in the schedule were a direct correlation to the Timberline estimate. The Activity ID's were based on the appropriate division and phase of the CSI 16 divisions of Timberline. A 5 day work week calendar with holidays loaded was created. A basic WBS breakdown was created to create 5 subsections of the warehouse. Common types of work were grouped within the same WBS section. Each subsection was then broken down further in order to visibly reflect the work flow of the project (Figure32). A section preceding the subsections was created to track the goals and milestones of the project.

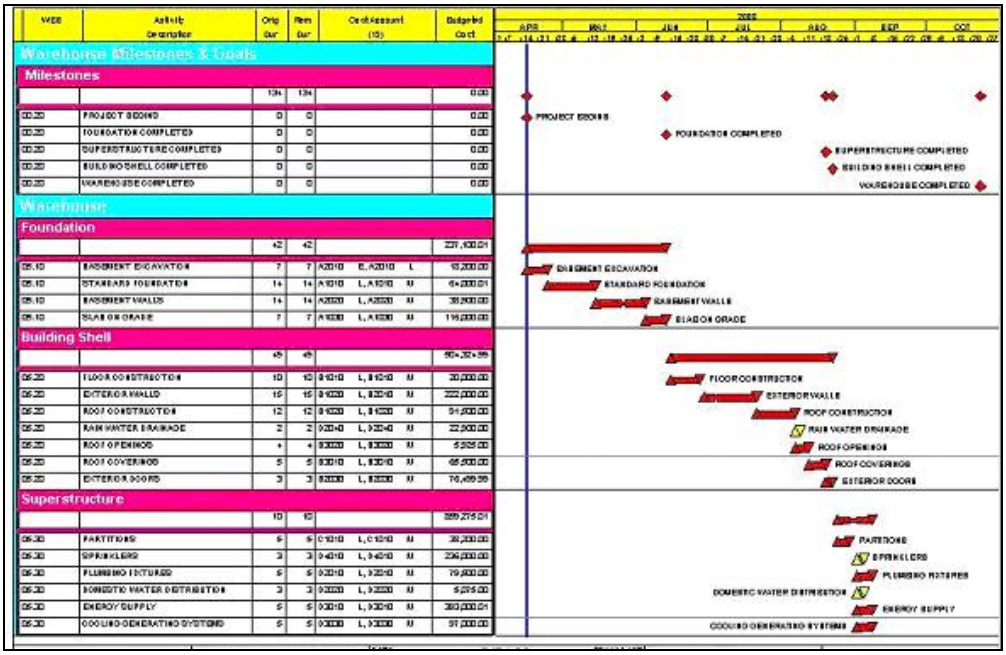


Figure32. Primavera Planner generated work schedule

Cost accounts were then created in Primavera, based on the CSI -Master format codes, to provide a correlated tie-back and reference to the Timberline estimate. Resources were then assigned as determined by the estimate for labor, material and equipment.

7. The Critical Path of construction was determined by Primavera. This information was used as a base for the visual construction simulation in Revit. Creating the 4D model -"time" is the fourth dimension- was a straightforward task as repeating the same steps multiple times at each level of the project in Revit. The same plan has three phases: existing, work in progress (demolition) and new construction.

7.1.2 Second Scenario: Graphisoft ArchiCAD

Many and different steps took place within ArchiCAD platform, too. The second scenario had the same major focus and primary goal as the first scenario. The following list describes the actions performed by the researcher and records some particular steps in detail.

8. While using ArchiCAD to build the warehouse project, the researcher wants to record that his use of layers combinations of color, style, weight, and material in the different plans views (Figure33) was mainly for visual display purposes. However, the "layer setting" is kind of neat; it duplicates the plan drawings in a fraction of a second with the flexibility to hide or add elements from or to the project respectively. Every element has many parameters that range from "geometry and positioning" to "labels and listings" (Figure34).

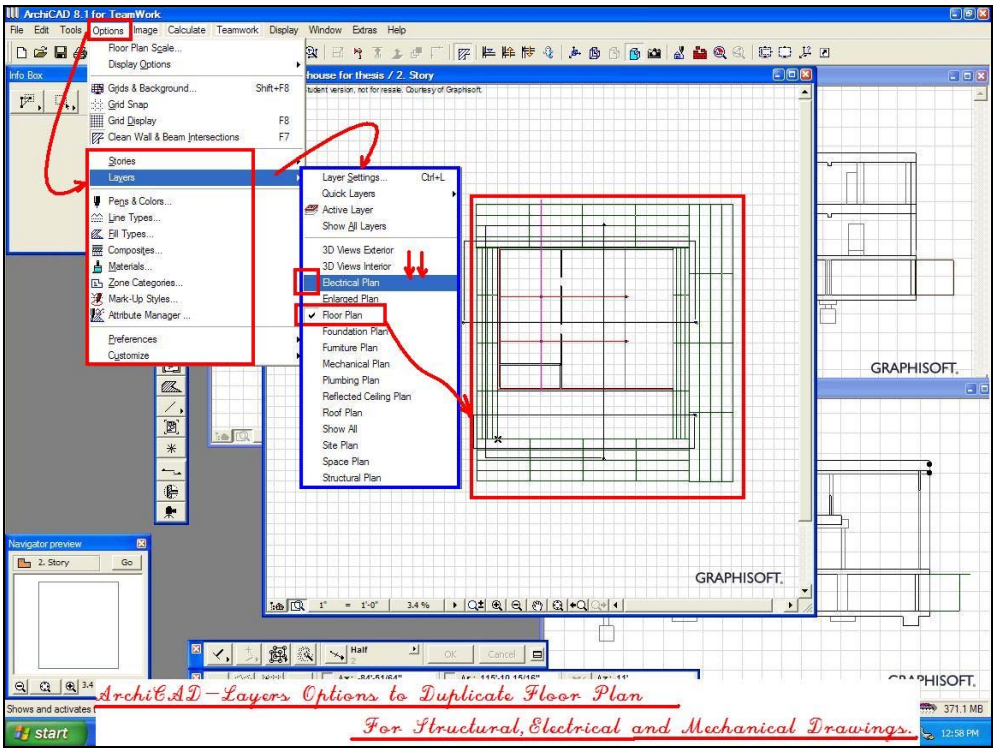


Figure33. ArchiCad – Layers Settings and Combinations

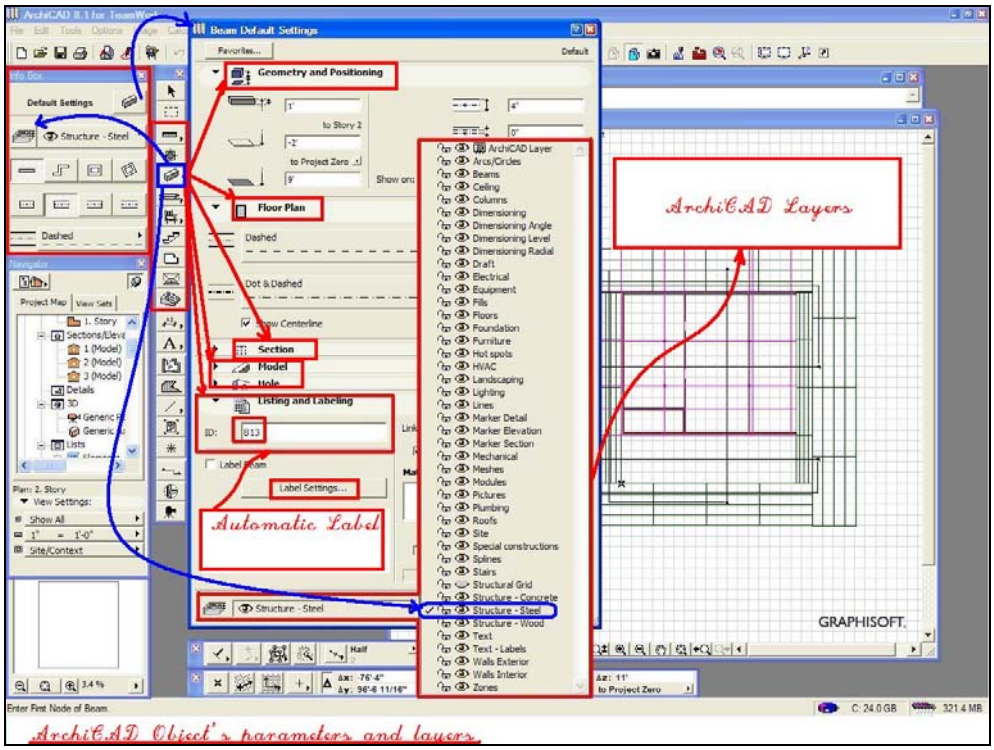


Figure34. ArchiCad – Object's parameters and layers

9. When the digital model was built and after the struggle with the "positioning feature" of ArchiCAD, the focus had shifted on creating two federated databases - Uniformat I and II - in ArchiCAD Library (Figure35). To create a database, click on the "calculate" tab and choose "edit database". ArchiCAD has originally two databases; one is called "default" and the other one is called "AC 8 US". They are both based on CSI's Master format coding system. The database has a tree structure that provides two levels -keys and components- that is combined with descriptors level for components.

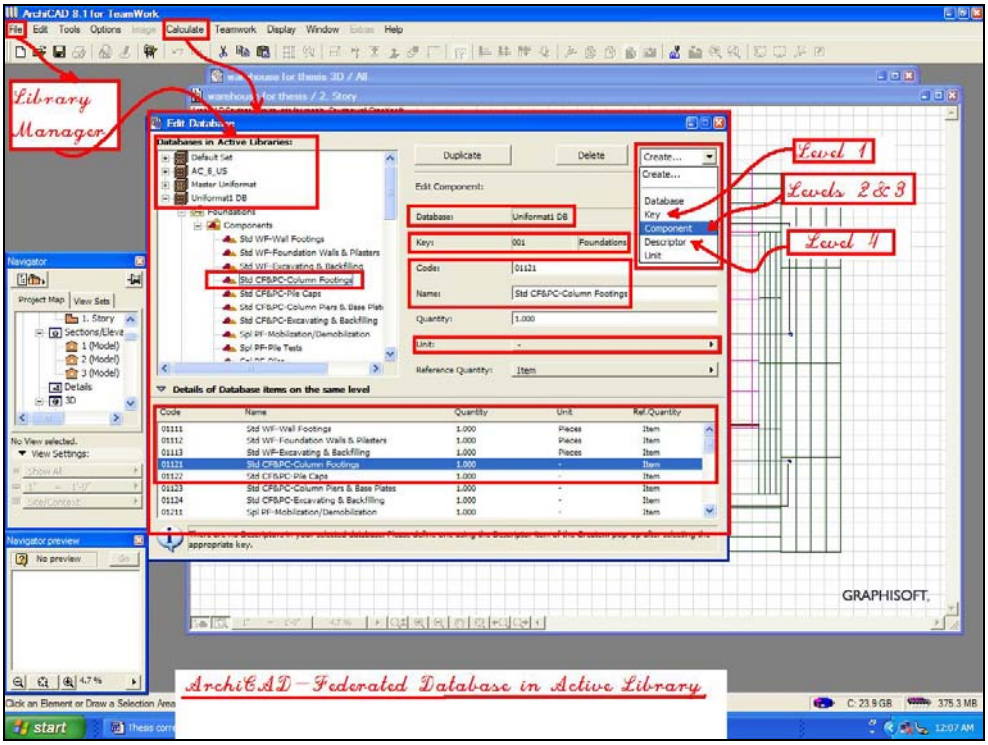


Figure35. ArchiCad – Federated databases in active libraries

The researcher has assigned level 1 coding to the “keys” and level 3 coding to the “components” in the databases. Level 4 coding was assigned to the descriptors. Also, he has created a list of units (Figure35).

In order to make the new databases active in the library, he used the “library manager” feature from the “file” pull down list. He selected them and imported them into the project (Figure35).

ArchiCAD provides the user with the power to customize the lists or schedules of elements, components and zones of the project through the “setting” tool. It has also default settings for all the lists. (Figure36) illustrates two text formatted ArchiCAD schedules which are relative to the selected database from the libraries of the project.

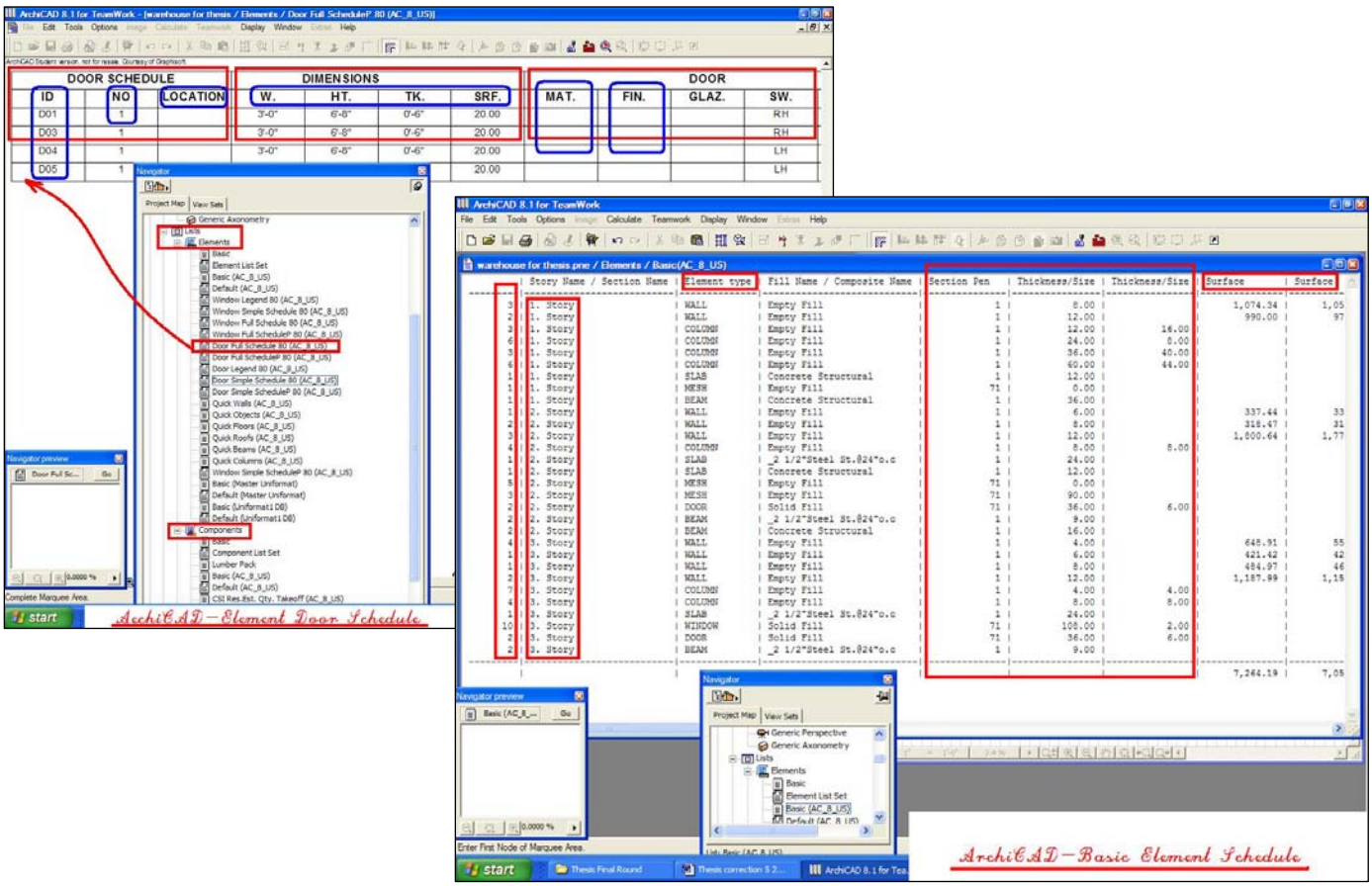


Figure36. ArchiCad – Full Door Schedule (upper) and Basic Element Schedule (lower)

10. After the completion of the digital model, the researcher has explored ArchiCAD feature “Project Publisher” (Figure37). The user could publish a part of or the entire project to a public folder within the company’s network provided by the option of choosing the display format of the documents.

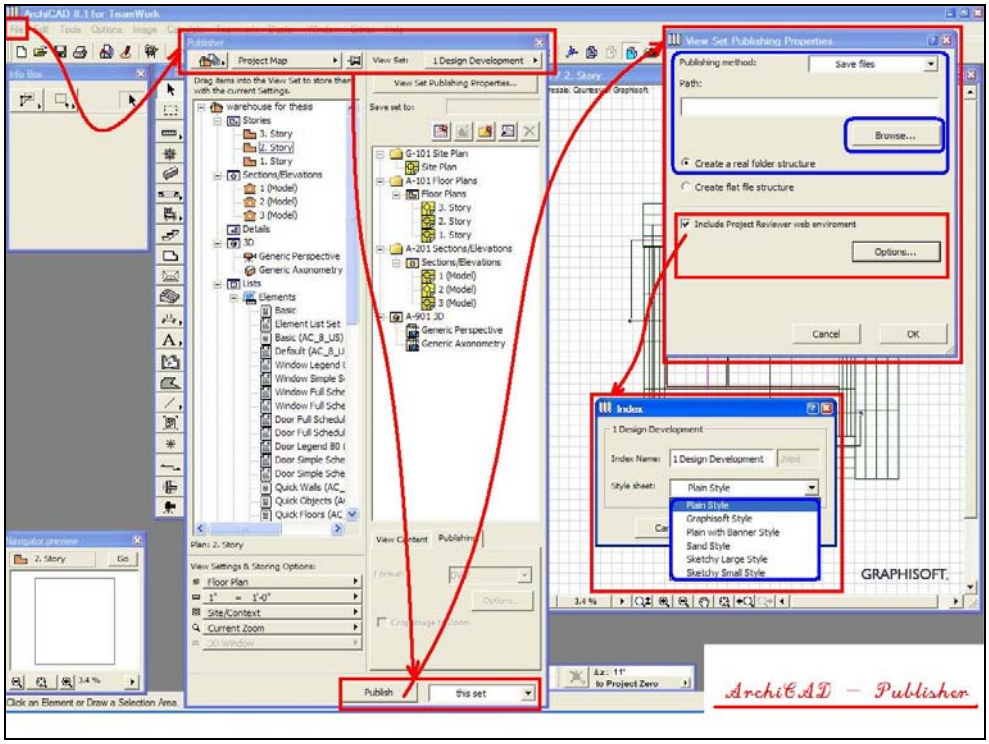


Figure37. ArchiCad – Project Publisher

11. After linking elements parameters from the central objects database to the components of the federated databases (Figure26), couple schedules were successfully exported into MS Excel.

12. Since estimating software that could import Excel spreadsheets -like Quest- has not been available for the researcher, no work in the estimating field has been done after this point under the second scenario. However, since all Microsoft products are compatible with each other, selected fields from the exported Excel spreadsheet were copied and pasted into MS Project in order to generate the project work schedule.

13. The Critical Path of construction was determined by MS Project. This information was used as a base for the visual construction simulation in ArchiCAD.

Chapter 8. Results (Accomplishments, Testing and Limitations)

The case study has - to some extend - touched the role of BIM technology in all stages of the project's life cycle passing by collaborative design to scheduling and documents control. However, the area of concentration was the contribution of BIM to the estimating discipline and practice.

8.1 Accomplishments

In terms of design, there is no doubt that BIM auto correlation engine enhances the productivity of construction documents. Still, the production of detailed drawings solutions vary between Revit and ArchiCAD.

In terms of estimating, the two BIM tools differ between each other. The following is a separate presentation of accomplishments in Revit 6.0 and ArchiCAD 8.1.

8.1.1 First Scenario: AutoDesk Revit 6.0 and estimating

Few accomplishments in estimating have been made using Revit 6.0; adding parameters to the project as "type and instance" was beneficial but not totally successful when transferred through ODBC engine; ODBC could transfer only the "type parameters" of the project.

Since the particular object information like ID tags, surface and volume are stored under “instance parameters” in Revit 6.0; ODBC feature was kind of useless, and the promise to integrate with Timberline -estimating software- has faded.

New fields were created under “instance parameters” like ID tags and costs. The cost fields were filled manually based on “RSMeans Assemblies Cost Data book” and on lots of assumptions made by the researcher on construction materials. Since Revit 6.0 stores the rendering information in different place than “instance parameters”, these assumptions were not maintained every time a change in construction material has occurred during the rendering process, because the rendering feature in Revit 6.0 is not linked to the object instance parameters.

In addition, Revit 6.0 supports only the level 3 in Uniformat II coding system, while the cost of materials is recorded under level 5 in the cost data books in order to provide enough fields of different cost categories such as labor, material and installation costs.

Finally, the template reports generated by Revit 6.0 team could benefit the total cost of material for a given project, but they are not relevant to the specific needs of estimators when a change order occurs during the construction stage of that project.

8.1.2 Second Scenario: Graphisoft ArchiCAD 8.1 and estimating

Some accomplishments in estimating area have been made using ArchiCAD 8.1; creating 2 federated databases for Uniformat I and II was successful in ArchiCAD 8.1

platform. The “Codes and Descriptions” data were entered manually in the system as well as the list of units and were stored under its own database separately.

The newly created databases were successfully imported to the warehouse project of the case study. The warehouse project’s elements parameters, which are stored in the central object database, were linked to the components -the second level of the federated database’s tree structure.

During the process of building the warehouse model, detail construction materials were selected separately and were related to the specific element of the building model. This information was automatically assigned an ID and was the basis for the automated rendering.

When the elements schedules were generated, the rendering information like ID and finishing materials fields were generated side by side to the location, number, dimensions, quantity, and surface fields.

Two types of “elements” schedules were generated; full door schedule and basic element schedule. Also, three “components” schedules were generated; one based on CSI’s master format, the other two based on Uniformat I and II respectively. No “zones” schedule was generated.

P.S. “Elements, Components and Zones schedules” represent the terminology used in ArchiCAD 8.1.

The schedules generated by ArchiCAD 8.1 are in “rich text” format. Their quality doesn’t support the need of powerful estimating software like Timberline. However, they were successfully exported into MS Excel. Since other estimating software that could import Excel spreadsheets -like Quest estimator that is distributed by RS Means- has not been available for the researcher, no further work in the estimating field has been done by him.

8.2 Testing and Limitations

The project final cost in estimating discipline is the final outcome of a function with multiple factors and some assumptions. The project size and shape have an effect on the bottom line as well as the location, time and quality of construction materials. Also, production and labor rates vary between crews as well as the equipments costs. In a competitive environment like bidding a job, cost is neither a simple element’s parameter nor a single measurement unit. The following is a recording of some BIM limitations in that regards.

8.2.1 First Scenario: AutoDesk Revit 6.0

When the new cost fields were created manually in Revit 6.0, they were treated as elements parameters. Revit 6.0 doesn’t support a tree structure in its fields which results in no support for multiple categories that contribute to that particular element cost such as labor, material and equipment costs.

When Revit's team created their templates reports as a way around the issue, the reports didn't connect to the actual model when a change in the design occurred. The templates were not secured and were acting independently like customized spreadsheets; the change in the reports didn't result in a change in the model. Also, in order to update the data in the reports after a change in the design, new schedules have to be generated and be manipulated again.

The fact that Revit 6.0 doesn't support a tree structure in its parameters database, but it only provides multiple "one line" as parameters, has a tremendous effect on the codes needed by estimating discipline beyond the automatic level three Uniformat II code that is automatically assigned to the model's elements. As previously presented, all factors of element's cost are recorded at level 5.

Not only the cost factors are not supported by Revit 6.0, but also the detailed components of the walls, ceilings and structures are not either. Revit 6.0 doesn't generate the number of studs in the interior walls, nor the number of panels, or concrete masonry units (CMU blocks), or bricks. It deals with the finishing materials only as a rendering feature and as a presentation tool.

Moreover, Revit 6.0 doesn't carry the type of reinforcing steel for concrete structures. The researcher finds that if we can not extract that information in a way or another from the model, it means we can not use it for estimating purposes where reinforced concrete structures are used in a project. Furthermore, BIM technology becomes no much different from the first generation of CAD in regards to estimating.

8.2.2 Second Scenario: Graphisoft ArchiCAD 8.1

Graphisoft ArchiCAD 8.1 went a step further than AutoDesk Revit 6.0 by supporting level four in the coding system within their database platform. Nevertheless ArchiCAD 8.1 supports multiple measurement units per database; only one unit could be assigned to one component-one to one relationship. The cost is considered as a measurement unit in ArchiCAD 8.1. If the cost value was assigned to level four and not to level five in the database, this value is insufficient for cost estimate discipline.

If ArchiCAD 8.1 could support the very detailed level of design (like AutoCAD and SOFTPLAN) within its central database platform, than the matter of supporting level five in the federated database would not have been an item on the "issues list".

Like Revit 6.0, ArchiCAD 8.1 doesn't support the cost factors or the very detailed level of construction components like the walls, ceilings and structures. ArchiCAD 8.1 doesn't generate the number of studs in the interior walls, nor the number of panels, or concrete masonry units (CMU blocks), or bricks.

Moreover, like Revit 6.0, ArchiCAD 8.1 doesn't carry the type of reinforcing steel for concrete structures. The researcher finds that if we can not extract that information in a way or another from the model, it means we can not use it for estimating purposes where reinforced concrete structures are used in a project.

8.3 Conclusion

The researcher concludes that the current stage of the two BIM tools on which he based his work benefits most architects, facility managers and to some extend the construction managers. Since the needs of estimators and structural engineers are not completely supported, BIM technology developers have been competing to move the construction practice forward and to reshape the industry in the future. The author of this work is looking forward to that day when the “Design for Construction” is supported by BIM, and when total team collaboration for “Production” becomes reality in the digital century and Information Technology age!

The construction people's reliance on computer software has been tremendously growing in order to improve the efficiency of planning, building and managing a project. In the wooden framed residential construction industry, interoperability issue seems to be less complicated than in commercial and institutional.

Some CAD software like "SOFTPLAN-Architectural Design Software" provide the architect-designer with automatic wooden structure and wall frames generated from the plan views, as well as the exterior and interior perspectives, exterior elevations, and sections. It also supports the generation of detailed drawings for completed construction documents - Reference (www.softplan.com). Even though SOFTPLAN is not considered as BIM technology since it doesn't store the building information in a separate database, SOFTPLAN generates schedules of material in form of spreadsheets that could be used in excel as well as in "HomeTech ADVANTAGE" software which supports unit cost estimating system (www.HomeTechOnline.com).

Since MS Project is compatible with Excel and HomeTech ADVANTAGE spreadsheets, it would represent a good IT option to use in order to generate the critical path of the project work schedule. Many document control software are compatible with MS Project during the project life cycle which resumes in maintaining the needs of database life cycle maintenance of the architectural/construction firms.

9.1 Recommendations

The “Architect/Master Builder” concept could be successfully supported by the current IT for wood framed residential industry. Nevertheless, commercial projects have different level of details and different construction materials such as concrete and steel structure and CMU blocks, construction IT major providers are still working hard to develop a solution that supports the commercial buildings’ life cycle needs. Graphisoft has announced the birth of new member in its family; the new software supports the critical path method in scheduling and integrates with ArchiCAD and ArchiFM. Bentley System has developed Bentley Structure (Micro Station Triforma) that complements Bentley Architecture. For future research in the BIM technology areas, the author of this work recommends exploring the following areas:

- Review Bentley systems products like Bentley architecture and Bentley structure.
- Explore the possibility of linking the rendering features -of Bentley and AutoDesk products- to the project database.
- Explore the possibility of either interface or integrate between Revit and ArchiCAD with any structural software.
- Explore Graphisoft newly released software for Critical Path Method Scheduling.
- Extend the work done in estimating using the schedules generated by Graphisoft ArchiCAD; i.e. “Quest” estimating software could import excel spreadsheets.

- Explore some Oracle database document control and management systems that reject the need for a coded functional organization structure.

Finally, some computer programming skills might be necessary to walk around and solve some obstacles that might encounter the future researcher/s in the way.

Good Luck!

(http://www.bdcorr.ca.gov/cppd/construction%20grant/2001_construction_audit_guide/htm_files/csi_divisions.htm)

(http://tacoma.wpi.edu/masterbuilder/breakdown)

Breakdown Structure	
0 - Conditions & Requirements **1 - General Requirements** **2 - Site work** **3 - Concrete** **4 - Masonry** **5 - Metals** **6 - Wood and Plastics** **7 - Thermal and Moisture Protection** **8 - Doors and Windows**	**9 - Finishes** **10 - Specialties** **11 - Equipment** **12 - Furnishings** **13 - Special Construction** **14 - Conveying Devices** **15 - Mechanical** **16 - Electrical**
Categories	
01010 - Summary of Work 01020 - Allowances 01025 - Measurement and Payment 01030 - Alternates / Alternatives 01035 - Modification Procedures 01040 - Coordination 01050 - Field Engineering 01060 - Regulatory Requirements 01080 - Identification Systems 01090 - References 01100 - Special Project Procedures 01200 - Project Meetings 01300 - Submittals 01400 - Quality Control 01500 - Construction Facilities and Temporary Controls 01600 - Material and Equipment 01650 - Facility Startup Commissioning 01700 - Contract Closeout 01800 - Maintenance	02010 - Subsurface Investigation 02050 - Demolition 02100 - Site Preparation 02140 - Dewatering 02150 - Shoring and Underpinning 02160 - Excavation Support Systems 02170 - Cofferdams 02200 - Earthwork 02300 - Tunneling 02350 - Piles and Caissons 02450 - Railroad Work 02480 - Marine Work 02500 - Paving and Surfacing 02600 - Utility Materials 02660 - Water Distribution 02680 - Fuel and Steam Distribution 02700 - Sewerage and Drainage 02760 - Restoration of Underground Pipe 02770 - Ponds and Reservoirs 02780 - Power and Communications 02800 - Site Improvements 02900 - Landscaping

- 03050 - Concrete Materials
- 03100 - Concrete Formwork
- 03200 - Concrete Reinforcement
- 03250 - Concrete Accessories
- 03300 - Cast-in-Place Concrete
- 03370 - Concrete Curing
- 03400 - Pre-cast Concrete
- 03500 - Cementations Decks and Toppings
- 03600 - Grout
- 03700 - Concrete Restoration and Cleaning
- 03800 - Mass Concrete

- 04100 - Mortar and Masonry Grout
- 04150 - Masonry Accessories
- 04200 - Unit Masonry
- 04400 - Stone
- 04500 - Restoration and Cleaning
- 04550 - Refractory
- 04600 - Corrosion Resistant Masonry
- 04700 - Simulated Masonry

- 05010 - Metal Materials
- 05030 - Metal Coatings
- 05050 - Metal Fastenings
- 05100 - Structural Metal Framing
- 05200 - Metal Joists
- 05300 - Metal Decking
- 05400 - Cold Formed Metal Framing
- 05500 - Metal Fabrications
- 05580 - Sheet Metal Fabrications
- 05700 - Ornamental Metal
- 05800 - Expansion Control
- 05900 - Hydraulic Structures

- 06050 - Fasteners and Adhesives
- 06100 - Rough Carpentry
- 06130 - Heavy Timber Construction
- 06150 - Wood and Metal Systems
- 06170 - Prefabricated Structural Wood
- 06200 - Finish Carpentry
- 06300 - Wood Treatment
- 06400 - Architectural Woodwork
- 06500 - Structural Plastics
- 06600 - Plastic Fabrications
- 06650 - Solid Polymer Fabrications

- 07100 - Waterproofing
- 07150 - Damp proofing
- 07180 - Water repellents
- 07190 - Vapor Retarders
- 07195 - Air Barriers
- 07200 - Insulation
- 07240 - Exterior Insulation and Finish Systems
- 07250 - Sprayed Fireproofing
- 07270 - Fire stopping
- 07300 - Shingles and Roofing Tiles
- 07400 - Roofing and Siding Panels
- 07480 - Exterior Wall Assemblies
- 07500 - Membrane Roofing
- 07570 - Traffic Coatings
- 07600 - Flashing and Sheet Metal
- 07700 - Roof Specialties & Accessories
- 07800 - Skylights
- 07900 - Joint Sealers

- 08100 - Metal Doors and Frames
- 08200 - Wood and Plastic Doors
- 08250 - Door Opening Assemblies
- 08300 - Specialty Doors
- 08400 - Entrances and Storefronts
- 08500 - Metal Windows
- 08600 - Wood and Plastic Windows
- 08650 - Special Windows
- 08700 - Hardware
- 08800 - Glazing
- 08900 - Glazed Curtain Walls

- 09100 - Metal Support Systems
- 09200 - Plaster & Gypsum Board
- 09250 - Gypsum Board
- 09270 - Gypsum Board Accessories
- 09300 - Tile
- 09400 - Terrazzo
- 09450 - Stone Facing

- 10100 - Visual Display Boards
- 10150 - Compartments and Cubicles
- 10200 - Louvers and Vents
- 10240 - Grilles and Screens
- 10250 - Services Wall Systems
- 10260 - Wall and Corner Guards
- 10270 - Access Flooring

- 09500 - Acoustical Treatment
- 09510 - Acoustical Ceilings
- 09540 - Special Wall Surfaces
- 09550 - Wood Flooring
- 09600 - Stone Flooring
- 09630 - Unit Masonry Flooring
- 09650 - Resilient Flooring
- 09680 - Carpet
- 09700 - Special Flooring
- 09780 - Floor Treatment
- 09800 - Special Coatings
- 09900 - Painting
- 09950 - Wall Coverings

- 10290 - Pest Control
- 10300 - Fireplaces and Stoves
- 10340 - Manufactured Exterior Specialties
- 10350 - Flagpoles
- 10400 - Indentifying Devices
- 10450 - Pedestrian Control Devices
- 10500 - Lockers
- 10520 - Fire Protection Specialties
- 10530 - Protective Covers
- 10550 - Postal Specialties
- 10600 - Partitions
- 10650 - Operable Partitions
- 10670 - Storage Shelving
- 10700 - Exterior Protection Devices for Openings
- 10750 - Telephone Specialties
- 10800 - Toilet and Bath Accessories
- 10880 - Scales
- 10900 - Wardrobe and Closet Specialties

- 11010 - Maintenance Equipment
- 11020 - Security and Vaul Equipment
- 11030 - Teller and Service Equipment
- 11040 - Ecclesiastical Equipment
- 11050 - Library Equipment
- 11060 - Theater and Stage Equipment
- 11070 - Instrumental Equipment
- 11080 - Registration Equipment
- 11090 - Check Room Equipment
- 11100 - Mercantile Equipment
- 11110 - Commercial Laundry and Dry Cleaning Equipments
- 11120 - Vending Equipment
- 11130 - Audio-Visual Equipment
- 11140 - Vehicle Service Equipment
- 11150 - Parking Control Equipment
- 11160 - Loading Dock Equipment
- 11170 - Solid Waste Handling Equipment
- 11190 - Detention Equipment
- 11200 - Water Supply and Treatment Equipment
- 11280 - Hydraulic Gates and Valves
- 11300 - Fluid Waste Treatment and Disposal Equipment
- 11400 - Food Service Equipment
- 11450 - Appliances/Residential Equipment
- 11460 - Unit Kitchen
- 11470 - Darkroom Equipment
- 11480 - Athletic, Recreational, and Therapeutic Equipment
- 11500 - Industrial and Process Equipment
- 11600 - Laboratory Equipment
- 11650 - Planetarium Equipment
- 11680 - Office Equipment

- 12050 - Fabrics
- 12100 - Artwork
- 12300 - Manufactured Casework
- 12500 - Window Treatment
- 12600 - Furniture and Accessories
- 12670 - Rugs and Mats
- 12700 - Multiple Seating
- 12800 - Interior Plants and Planters

11700 - Medical Equipment 11780 - Mortuary Equipment 11850 - Navigation Equipment 11870 - Agricultural Equipment	
13010 - Air Supported Structures 13020 - Integrated Assemblies 13030 - Special Purpose Rooms 13080 - Sound, Vibration, Seismic Control 13090 - Radiation Protection 13100 - Nuclear Reactors 13120 - Pre-Engineered Structures 13150 - Aquatic Facilities 13175 - Ice Rinks 13180 - Site Constructed Incinerators 13200 - Storage Tanks 13220 - Filter Underdrains and Media 13230 - Digester Covers and Appurtenances 13240 - Oxygenation Systems 13260 - Sludge Conditioning Systems 13330 - Utility Control System 13400 - Industrial and Process Control Systems 13500 - Recording Instrumentation 13550 - Transportation Control Instrumentation 13600 - Solar & Wind Energy Systems 13700 - Wind Energy Systems 13750 - Cogeneration Systems 13800 - Building Automation and Control 13900 - Fire Suppression and Supervisory Systems 13950 - Special Security Construction	14100 - Dumbwaiters 14200 - Elevators 14300 - Escalators and Moving Walks 14400 - Lifts 14500 - Material Handling System 14600 - Hoists and Cranes 14700 - Turntables 14800 - Scaffolding 14900 - Transportation Systems
15050 - Basic Mechanical Materials and Methods 15250 - Mechanical Insulation 15300 - Fire Protection 15400 - Plumbing 15500 - Heating, Ventilating, Air Condition 15550 - Heat Generator 15750 - Heat Transfer 15850 - Air Handling 15880 - Air Distribution 15950 - Controls 15990 - Testing, Adjusting, and Balancing	16050 - Basic Electrical Materials and Methods 16200 - Power Generation-Build-up Systems 16300 - Medium Voltage Distribution 16400 - Service and Distribution 16500 - Lighting 16600 - Special Systems 16700 - Commonications 16850 - Electrical Resistance Heating 16900 - Controls

Breakdown Structure

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 for future expansion
Division 16 – Reserved for future expansion
Division 17 – Reserved for future expansion
Division 18 – Reserved for future expansion
Division 19 – Reserved for future expansion

Facility Services Subgroup:
Division 20 – Reserved for future expansion
Division 21 – Fire Suppression
Division 22 – Plumbing
Division 23 – Heating Ventilating and Air Conditioning
Division 24 – Reserved for future expansion
Division 25 – Integrated Automation
Division 26 – Electrical
Division 27 – Communications
Division 28 – Electronic Safety and Security
Division 29 – Reserved for future expansion

Site and Infrastructure Subgroup:
Division 30 – Reserved for future expansion
Division 31 – Earthwork
Division 32 – Exterior Improvements
Division 33 – Utilities
Division 34 – Transportation
Division 35 – Waterway and Marine
Division 36 – Reserved for future expansion
Division 37 – Reserved for future expansion
Division 38 – Reserved for future expansion
Division 39 – Reserved for future expansion

Process Equipment Subgroup:
Division 40 – Reserved for future expansion
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 for future expansion
Division 47 – Reserved for future expansion
Division 48 – Electrical Power Generation
Division 49 – Reserved for future expansion

Breakdown Structure

01 Foundations

011 Standard Foundations

0011 Wall Foundations
01111 Wall Footings
01112 Foundation Walls & Pilasters
01113 Excavating & Backfilling

0112 Column Foundations & Pile Caps
01121 Column Footings
01122 Pile Caps
01123 Column Piers & Base Plates
01124 Excavating & Backfilling

012 Special Foundation Conditions

0121 Pile Foundations
01211 Mobilization/Demobilization
01212 Pile Tests
01213 Piles

0122 Caissons
01221 Open Caissons
01222 Caisson Accessories
01223 Special Caissons

0123 Underpinning
01231 Temporary Shoring to Structure
01232 Excavating
01233 Sheeting & Shoring to Excavation
01234 Backfilling
01235 Concreting
01236 Formwork
01237 Steel Bar Reinforcing
01238 Cutoff Projecting Footings
01239 Grouting & Dry Packing

0124 Dewatering
01241 Pumping
01242 Well-Point
01243 Gravity Drainage

0125 Raft Foundations
01251 Slab Construction
01252 Base Courses
01253 Moisture Protection

0126 Other Special Foundation Conditions
01261 Removal of Old Foundations
01262 Rock Grouting
01263 Tunneling
01264 Shoring Existing Buildings

02 Substructure

021 Slab on Grade

0211 Standard Slab on Grade
02111 Slab Construction
02112 Base Courses
02113 Moisture Protection

0212 Structural Slab on Grade
02121 Slab Construction
02122 Grade Beams
02123 Base Courses
02124 Moisture Protection

0213 Inclined Slab on Grade
02131 Ramps
02132 Inclined Floor Slabs
02133 Stepped Slabs on Grade
02134 Steps

0214 Trenches, Pits, & Bases
02141 Trenches & Depression in Slabs
02142 Pits
02143 Equipment & Machine Bases

0215 Foundation Drainage
02151 Perimeter Drains
02152 Under Slab Drains

022 Basement Excavation

0221 Excavation for Basements
02211 Excavating
02212 Waste Material Disposal

0222 Structure Backfill & Compaction
02221 Structure Backfill with Excavated Material
02222 Borrow Backfill

0223 Shoring
02231 Sheeting and Shoring
02232 Tiebacks & Anchors
02233 Slurry Walls

023 Basement Walls

0231 Basement Wall Construction
02311 Basement Walls
02312 Pilasters
02313 Expansion & Construction Joints

0232 Moisture Protection
02321 Damp proofing
02322 Waterproofing

0233 Basement Wall Insulation

03 Superstructure

031 Floor Construction

0311 Suspended Basement Floor Construction
03111 Structural Frame
03112 Interior Structural Walls
03113 Floor Slabs & Decks
03114 Inclined & Stepped Floors
03115 Expansion & Contraction Joints

0312 Upper Floors Construction
03121 Structural Frame
03122 Interior Structural Walls
03123 Floor Slabs & Decks
03124 Inclined & Stepped Floors
03125 Expansion & Contraction Joints

0313 Balcony Construction
03131 Supported Balconies
03132 Cantilevered Balconies

0314 Ramps
03141 Pedestrian Ramps
03142 Vehicle Ramps

0315 Special Floor Construction

03151 Catwalks
03152 Space Frames
03153 Cable-Supported Floor Systems

032 Roof Construction

0321 Flat Roof Construction
03211 Structural Frame
03212 Interior Structural Walls
03213 Roof Slabs & Decks
03214 Expansion & Contraction Joints

0322 Pitched Roof Construction
03221 Frame & Trusses
03222 Roof Decking & Sheathing

0323 Canopies
03231 Supported Canopies
03232 Cantilevered Canopies

0324 Special Roof Systems
03241 Concrete Shells & Domes
03242 Hyperbolic Parabolic Roofs
03243 Space Frames
03244 Barrel Vault Roofs
03245 Saw Tooth Roofs
03246 Cable-Supported Roofs
03247 Air-Supported Structures

033 Stair Construction

0331 Stair Structure
03311 Regular Stairs
03312 Curved Stairs
03313 Spiral Stairs
03314 Exterior Fire Escape Stairs
03315 Steps in Suspended Slabs

04 Exterior Closure

041 Exterior Walls

0411 Exterior Wall Construction
04111 Exterior Skin
04112 Insulation & Vapor Barriers
04113 Interior Skin
04114 Parapets
04115 Damp proof Courses
04116 Finish to Exposed Structure
04117 Expansion Joints
04118 Cornerstones

0412 Exterior Louvers & Screens
04121 Exterior Louvers
04122 Decorative Grilles & Screens
04123 Exterior Vents

0413 Sun Control Devices (Exterior)
04131 Projecting Sun Screens
04132 Awnings
04133 Exterior Shutters & Blinds

0414 Balcony Walls & Handrails
04141 Balcony Walls
04142 Balcony Railings
04143 Balcony Handrails
04144 Balcony Dividing Walls

0415 Exterior Soffits
04151 Building Soffits
04152 Balcony Soffits
04153 Canopy Soffits

042 Exterior Doors & Windows

0421 Windows
04211 Window Units & Hardware
04212 Glazing
04213 Wall Opening Elements
04214 Protective Window Elements
04215 Exterior Window Painting & Staining

0422 Curtain Walls
04221 Curtain Walls-Grid Systems
04222 Curtain Walls-Panel Systems

0423 Exterior Doors
04231 Glazed Doors & Entrances
04232 Solid Exterior Doors
04233 Revolving Doors
04234 Overhead Doors
04235 Special Doors & Entrances

0424 Storefronts
04241 Framing
04242 Panels & Bulkheads
04243 Doors & Hardware
04244 Glazing
04245 Rolling Grilles & Folding Closures
04246 Storefront Awnings
04247 Caulking

05 Roofing

No Level 3

0501 Roof Coverings
05011 Membrane Roofing
05012 Shingles & Roofing Tile
05013 Preformed Roofing
05014 Sheet Metal Roofing
05015 Expansion Joints & Covers

0502 Traffic Toppings & Paving Membrane
05021 Traffic Toppings
05022 Waterproof Membranes Below Paving
05023 Slatted Roof Decks & Walkways

0503 Roof Insulation & Fill
05031 Roof Vapor Barriers
05032 Roof & Deck Insulation
05033 Roof Fill

0504 Flashings & Trim
05041 Flashings
05042 Gravel Stops
05043 Fascia & Eaves
05044 Gutters & Downspouts
05045 Miscellaneous Roofing Specialties

0505 Roof Openings
05051 Glazed Roof Openings
05052 Hatches
05053 Gravity Roof Ventilators

06 Interior Construction

061 Partitions

0611 Fixed Partitions
06111 Solid Partitions
06112 Glazed Partitions
06113 Mesh Partitions

0612 Demountable Partitions
06121 Full Height Demountable Partitions
06122 Bank Height Demountable Partitions

0613 Retractable Partitions
06131 Accordion Folding Partitions
06132 Folding Leaf Partitions
06133 Coiling Partitions

0614 Compartments & Cubicles
06141 Toilet Partitions
06142 Shower & Dressing Compartments
06143 Hospital Cubicles

0615 Interior Balustrades & Screens
06151 Stair Balustrades
06152 Balustrades At Floor Openings
06153 Interior Grilles & Decorative Screens

0616 Interior Doors & Frames
06161 Interior Doors
06162 Interior Door Frames
06163 Interior Door Hardware
06164 Interior Door Wall Opening Element
06165 Interior Door Sidelights & Transoms
06166 Interior Door Painting & Staining
06167 Hatches & Access Doors

0617 Interior Storefronts
06171 Framing
06172 Panels & Bulkheads
06173 Doors & Hardware
06174 Glazing
06175 Rolling Grilles & Folding Closures

062 Interior Finishes

0621 Wall Finishes
06211 Wall Finishes to Inside Exterior Wall
06212 Wall Finishes to Interior Walls
06213 Column Finishes

0622 Flooring

06221 Screens & Toppings
06222 Floor Finishes
06223 Bases, Curbs & Trim
06224 Stair Finish
06225 Access Flooring (Pedestal Floors)

0623 Ceiling Finishes
06231 Ceiling Finishes Applied to Structure
06232 Suspended Ceilings
06233 Special Ceilings
06234 Stair Soffits
06235 Expansion Joint Covers

063 Specialties

0631 General Specialties

	06311 Chalk & Tack boards 06312 Identifying Devices 06313 Lockers 06314 Toilet & Bath Accessories 06315 Storage Shelving 06316 Miscellaneous Metalwork 06317 Miscellaneous Specialties **0632 Built-in Fittings** 06321 Counters & Vanities 06322 Kitchen Cabinets 06323 Closets 06324 Miscellaneous Built-in Cabinetwork
07 Conveying Systems No Level 3 **0701 Elevators** 07011 Passenger Elevators 07012 Freight Elevators **0702 Moving Stairs & Walks** 07021 Escalators 07022 Moving Walks **0703 Dumbwaiters** 07031 Hand-Operated Dumbwaiters 07032 Electric-Operated Dumbwaiters **0704 Pneumatic Tube Systems** 07041 Pneumatic Message Tube Systems 07042 Pneumatic Trash Tube Systems 07043 Pneumatic Linen Tube Systems **0705 Other Conveying Systems** 07051 Lifts 07052 Hoists & Cranes 07053 Conveyors 07054 Chutes 07055 Turntables **0706 General Construction Items** 07061 Hoist way Beams 07062 Hydraulic Elevator Shaft Drilling 07063 Miscellaneous Metals 07064 Lintels to Openings 07065 Concrete Work 07066 Masonry Work 07067 Painting	**08 Mechanical** 081 Plumbing **0811 Domestic Water Supply System** 08111 Cold Water Service 08112 Hot Water Service 08113 Domestic Water Supply Equipment **0812 Sanitary Waste & Vent System** 08121 Waste Piping & Fittings 08122 Vent Piping & Fittings 08123 Floor Drains 08124 Sanitary Waste Equipment 08125 Thermal Pipe Insulation **0813 Rainwater Drainage System** 08131 Pipe & Fittings 08132 Roof Drains 08133 Rainwater Drainage Equipment 08134 Thermal Pipe Insulation **0814 Plumbing Fixtures** 08141 Bath Tubs 08142 Bidets 08143 Kitchen Sinks 08144 Laundry Sinks & Trays 08145 Lavatories 08146 Mop Sinks 08147 Service Sinks 08148 Showers 08149 Urinals 081410 Water Closets 081411 Wash Fountains 081412 Drinking Fountains & Coolers 082 HVAC **0821 Energy Supply** 08211 Oil Supply System 08212 Gas Supply System 08213 Coal Supply System 08214 Steam Supply System 08215 Solar Energy Supply System 08216 Wind Energy Supply System **0822 Heat Generating System** 08221 Steam Boilers 08222 Hot Water Boilers 08223 Furnaces 08224 Boiler Room Piping & Specialties 08225 Auxiliary Equipment 08226 Equipment Thermal Insulation

0823 Cooling Generating Systems
08231 Chilled Water Systems
08232 Direct Expansion Systems

0824 Distribution Systems
08241 Air Distribution
08242 Exhaust Ventilation Systems
08243 Steam Distribution
08244 Hot & Chilled Water Distribution
08245 Change Over Distribution Systems
08246 Glycol Heating Distribution System

0825 Terminal& Package Units
08251 Terminal Units
08252 Packaged Units

0826 Controls & Instrumentation
08261 Air-Conditioning Systems
08262 Energy Supply System
08263 Heat-Generating System
08264 Cooling-Generating System
08265 Special Mechanical Systems
08266 Instrument Panels
08267 Instrument Air Compressor
08268 Gas Purging System

0827 Systems Testing & Balancing
08271 Water Side Testing & Balancing
08272 Air Side Testing & Balancing

083 Fire Protection

0831 Water Supply (Fire Protection)
08311 Water Connection
08312 Pipe & Fittings
08313 Valves

0832 Sprinklers
08321 Wet Sprinkler System
08322 Dry Sprinkler System

0833 Standpipe Systems
08331 Standpipe Equipment
08332 Fire Hose Equipment
08333 Pumping Equipment

0834 Fire Extinguishers
08341 Hand-Held Fire Extinguishers
08342 Wheeled Cart Fire Extinguishers
08343 Fire Extinguisher Cabinets

084 Special Mechanical Systems

0841 Special Plumbing Systems
08411 Special Piping Systems
08412 Acid Waste Systems
08413 Interceptors
08414 Pool Equipment
08415 Special Plumbing Fixtures

0842 Special Fire Protection Systems
08421 Carbon Dioxide Extinguishing Equipment
08422 Foam-Generating Equipment
08423 Halon System Equipment
08424 Hood & Duct Fire Protection

0843 Miscellaneous Special Systems & Devices
08431 Special Cooling Systems & Devices
08432 Process Heating

08433 Storage Cells & Devices
08434 Dust & Fume Collectors
08435 Deodorizing Equipment
08436 Carbon Monoxide Equipment
08437 Sound Attenuating Equipment
08438 Special Waste Treatment Devices

09 Electrical

91 Service & Distribution

0911 High Tension Service & Distribution
09111 High Tension System Monitoring
09112 High Tension System Equipment
09113 High Tension System Distribution

0912 Low Tension Service & Distribution
09121 Low Tension System Monitoring
09122 Low Tension System Equipment
09123 Low Tension System Distribution

92 Lighting and Power

0921 Branch Wiring
09211 Wiring Circuits
09212 Branch Wiring Devices

0922 Lighting Equipment
09221 Fluorescent Interior Lighting Fixtures
09222 Incandescent Interior Lighting Fixtures
09223 Other Lighting Fixtures & Equipment

093 Special Electrical Systems

0931 Communications & Alarm Systems
09311 Public Address Systems
09312 Central Music Systems
09313 Intercommunication Systems
09314 Paging Systems
09315 Utility Telephone Systems
09316 Nurses' Call System
09317 In-Out Registers
09318 Bell Systems
09319 Television Systems
093110 Clock & Program Systems
093112 Burglar Alarm Systems
093113 Other Systems

0932 Grounding Systems
09321 Lightning Protection
09322 Building Ground Systems
09323 Special Grounding Systems

0933 Emergency Light & Power
09331 Emergency Generator Systems
09332 Emergency Battery Systems
09333 Other Emergency Light & Power Systems

0934 Electric Heating

09341 Heating Equipment
09342 Control Devices
09343 Branch Wiring
09344 Other Heating Systems

0935 Floor Raceway Systems
09351 Standard Under floor Duct Systems
09352 Header (Feeder) Duct
09353 Industrial (square) Duct

10 General Conditions & Profit

1001 Mobilization & Initial Expenses
10011 Mobilization
10012 Permits & Fees
10013 Insurance & Bonds

1002 Site Overhead
10021 Site Supervisory & Emergency Staff
10022 Labor On-Costs
10023 Sales & Use Taxes
10024 Construction Equipment
10025 Site Office Operating Costs
10026 Temporary Facilities
10027 Site Protection Security
10028 Cleanup
10029 Inspection & Testing
100210 Winter Conditions
100211 Miscellaneous Site Overheads

1003 Demobilization
10031 Temporary Enclosures (Removal)
10032 Temporary Buildings (Removal)
10033 Temporary Services (Removal)
10034 Equipment Demobilization
10035 Final Clean-up
10036 Repairing Sidewalks & Streets
10037 Punch List & Warranties
10038 Maintenance Manuals & As-built Drawings
10039 Staff Relocation Costs
100310 Opening Ceremonies

1004 Main Office Expense & Profit
10041 Main Office Expense
10042 Profit

09354 Trench Duct
09355 Wiring Devices & Accessories

0936 Other Special Systems & Devices
09361 Special Lighting Systems
09362 Special Protective Systems & Devices
09363 Special Electronic Controls

0937 General Construction Items
09371 Cuffing & Patching
09372 Trenching & Backfill
09373 Painting.
09374 Equipment Installation Items

11 Equipment

111 Foxed & Movable Equipment

1111 Built-in Maintenance Equipment
11111 Window Washing Equipment
11112 Vacuum Cleaning System

1112 Checkroom Equipment
11121 Manual Checkroom Equipment
11122 Automatic Storage & Retrieval Cheek room Equipment

1113 Food Service Equipment
11131 Refrigeration Cases
11132 Insulated Rooms
11133 Storage Units
11134 Cooking Equipment
11135 Food Preparation Machines
11136 Food Serving Units
11137 Washing Units & Conveyors

1114 Vending Equipment
11141 Hot Drink Vending Unit
11142 Cold Drink Vending Unit
11143 Hot Food Vending Unit
11144 Cold Food Vending Unit
11145 Cigarette Vending Unit
11146 Condiment Unit & Counter
11147 Refuse Unit
11148 Coin Changer
11149 Microwave Oven
111410 Bases for Unit

1115 Waste Handling Equipment
11151 Waste Compactors
11152 Incinerators
11153 Waste Storage Containers
11154 Pulping Machines & Systems

1116 Loading Dock Equipment
11161 Dock Levelers
11162 Leveling Platforms
11163 Dock Bumpers
11164 Dock Seats & Shelters

1117 Parking Equipment
11171 Parking Bumpers & Guard Rails
11172 Parking Control Equipment

1118 Detention Equipment
11181 Cell & Corridor Construction
11182 Cell Accessories
11183 Courtroom Security Devices
11184 Detention Screens

12 Site Work

121 Site Preparation

1211 Clearing
12111 Clearing & Grubbing
12112 Tree Removal
12113 Selective Thinning
12114 Tree Pruning

1212 Demolition
12121 Building Demolition
12122 Site Demolition
12123 Relocations

1213 Site Earthwork
12131 Site Grading
12132 Site Excavating
12133 Borrow Fill
12134 Soil Stabilization
12135 Soil Treatment
12136 Site Dewatering
12137 Site Shoring

122 Site Improvements

1221 Parking Lots
12211 Parking Lot Paving & Surfacing
12212 Curbs, Rails & Barriers
12213 Parking Booths & Equipment

1222 Roads, Walks, & Terraces
12221 Roads
12222 Walks
12223 Terraces & Plazas

1223 Site Development
12231 Fences & Gates
12232 Walls
12233 Signs
12234 Site Furnishings
12235 Fountains, Pools & Watercourses
12236 Playing Field & Sports Facilities
12237 Flagpoles
12238 Miscellaneous Structures

1224 Landscaping
12241 Fine Grading & Soil Preparation
12242 Top Soil & Planting Beds
12243 Seeding & Sodding
12244 Planting
12245 Planters
12246 Special Landscape Feature

123 Site Utilities

1119 Postal Equipment
11191 Mail Boxes
11192 Post Office Equipment

11110 Other Specialized Equipment
111101 Darkroom Equipment
111102 Educational Equipment
111103 Athletic Equipment
111104 Laboratory Equipment
111105 Laundry Equipment
111106 Library Equipment
111107 Medical Equipment
111108 Mortuary Equipment
111109 Residential Equipment
111110 Auditorium & Stage Equipment
111111 Miscellaneous Specialized Equipment

112 Furnishings

1121 Artwork
11211 Bases & General Contract Work for Artwork & Sculpture

1122 Window Treatment
11221 Blinds
11222 Interior Shutters
11223 Roll Shades
11224 Curtains & Drapes

1123 Seating
11231 Auditorium Seating
11232 Bleachers

113 Special Construction

1131 Vaults
11311 Steel Vault Linings
11312 Vault Doors & Frames
11313 Vault Ventilation
11314 Prefabricated Vaults

1132 Interior Swimming Pools
11321 Prefabricated Swimming Pools
11322 Swimming Pool Equipment

1133 Modular Prefabricated Assemblies

1134 Special Purpose Rooms
11341 Audiometric Room
11342 Clean Room
11343 Hyper baric Room
11344 Sauna
11345 Fallout Shelters (Interior)

1135 Other Special Construction
11351 Radiation Protection
11352 Radio Frequency Shielding

1231 Water Supply & Distribution
12311 Potable Water Systems
12312 Fire Protection Systems
12313 Process Water Systems
12314 Irrigation Systems

1232 Drainage & Sewerage Systems
12321 Storm Drainage
12322 Sanitary Sewer
12323 Process & Acid Waste Systems
12324 Combined Drainage & Sewerage Systems

1233 Heating & Cooling Systems
12331 Heating System
12332 Cooling Systems

1234 Gas Distribution Systems
12341 Natural Gas Systems
12342 Other Gas Systems

1235 Electric Distribution & Lighting Systems
12351 Overhead Power Services
12352 Underground Services
12353 Exterior Yard & Road Lighting
12354 Exterior Flood Lighting
12355 Exterior Lighting Controls
12356 Exterior Sign Lighting

1236 Snow Melting Systems
12361 Piped Snow Melting Systems
12362 Electrical Snow Melting Systems

1237 Service Tunnels
12371 Excavating & Backfilling
12372 Constructed Service Tunnel
12373 Prefabricated Service Tunnels
12374 Moisture Protection
12375 Insulation
12376 Miscellaneous Items

124 Off-Site Work

1241 Railroad Work

1242 Marine Work

1243 Tunneling

1244 Other Off-Site Work

ASTM UNIFORMAT II Classification of Building Elements (E1557-97)		
Level 1 Major Group Elements	**Level 2 Group Elements**	**Level 3 Individual Elements**
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 Closure	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 Specialties
	C20 Staircases	C2010 Stair Construction C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes
D. SERVICES	D10 Conveying Systems	D1010 Elevators D1020 Escalators & Moving Walks D1030 Material Handling Systems D1090 Other Conveying Systems
	D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2050 Special Plumbing Systems
	D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems D3030 Cooling Generating Systems D3040 HVAC Distribution Systems D3050 Terminal & Package Units D3060 Controls & Instrumentation D3070 Special HVAC Systems & Equipment D3080 Systems Testing & Balancing
	D40 Fire Protection	D4010 Fire Protection Sprinkler Systems D4020 Stand-Pipe & Hose Systems D4030 Fire Protection Specialties D4040 Special Fire Protection Systems
	D50 Electrical	D5010 Electrical Service & Distribution D5020 Lighting & Branch Wiring D5030 Communication & Security Systems D5040 Special Electrical Systems
E. EQUIPMENT & FURNISHINGS	E10 Equipment	E1010 Commercial Equipment E1020 Institutional Equipment E1030 Vehicular Equipment E1040 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 & Instrumentation
	F20 Selective Building Demolition	F2010 Building Elements Demolition F2020 Hazardous Components Abatement
G. BUILDING SITEWORK	G10 Site Preparation	G1010 Site Clearing G1020 Site Demolition & Relocations 1030 Site Earthwork G1040 Hazardous Waste Remediation
	G20 Site Improvements	G2010 Roadways G2020 Parking Lots G2030 Pedestrian Paving G2040 Site Development G2050 Landscaping
	G30 Site Civil / Mechanical Utilities	G3010 Water Supply & Distribution Systems G3020 Sanitary Sewer Systems G3030 Storm Sewer Systems 3040 Heating Distribution G3050 Cooling Distribution G3060 Fuel Distribution G3070Other Civil / Mechanical Utilities
	G40 Site Electrical Utilities	G4010 Electrical Distribution G4020 Exterior Lighting G4030 Exterior Communications & Security G4040 Other Site Electrical Utilities
	G50 Other Site Construction	G5010 Service Tunnels G5020 Other Site Systems & Equipment
Z. GENERAL	Z10 General Requirements	Z1010 Administration Z1020 Quality Requirements Z1030 Temporary Facilities Z1040 Project Closeout Z1050 Permits, Insurance, And Bonds Z1060 Fee
	Z20 Contingencies	Z2010 Design Contingency Z2020 Escalation Contingency Z2030 Construction Contingency
	Z30 Inflation Allowance	
	Z90 Project Cost Estimate	Z9010 Lump Sum Z9020 Unit Prices Z9030 Alternates / Alternatives

01100 | Summary

01103 | Models & Renderings

1 GENERAL REQUIREMENTS

			CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2002 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
200	0010	**MODELS** Cardboard & paper, 1 building, minimum				Ea.	570			570	625	200
	0050	Maximum					1,300			1,300	1,425	
	0100	2 buildings, minimum					760			760	840	
	0150	Maximum					1,725			1,725	1,900	
	0200	Plexiglass and metal, basic layout				SF Flr.	.06			.06	.07	
	0210	Including equipment and personnel				"	.25			.25	.28	
	0300	Site plan layout, minimum				Ea.	1,100			1,100	1,200	
	0350	Maximum				"	1,825			1,825	2,000	
500	0010	**RENDERINGS** Color, matted, 20" x 30", eye level,										500
	0020	1 building, minimum				Ea.	1,700			1,700	1,875	
	0050	Average					2,850			2,850	3,125	
	0100	Maximum					4,000			4,000	4,400	
	1000	5 buildings, minimum					3,500			3,500	3,850	
	1100	Maximum					6,800			6,800	7,475	
	2000	Aerial perspective, color, 1 building, minimum					2,850			2,850	3,125	
	2100	Maximum					6,800			6,800	7,475	
	3000	5 buildings, minimum					3,400			3,400	3,750	
	3100	Maximum					11,400			11,400	12,500	

01107 | Professional Consultant

100	0011	**ARCHITECTURAL FEES** R01107-010										100
	0020	For new construction										
	0060	Minimum				Project					4.90%	
	0090	Maximum									16%	
	0100	For alteration work, to $500,000, add to fee									50%	
	0150	Over $500,000, add to fee									25%	
200	0010	**CONSTRUCTION MANAGEMENT FEES** $1,000,000 job, minimum				Project					4.50%	200
	0050	Maximum									7.50%	
	0300	$5,000,000 job, minimum									2.50%	
	0350	Maximum									4%	
300	0010	**ENGINEERING FEES** R01107-030										300
	0020	Educational planning consultant, minimum				Project					.50%	
	0100	Maximum				"					2.50%	
	0200	Electrical, minimum				Contrct					4.10%	
	0300	Maximum									10.10%	
	0400	Elevator & conveying systems, minimum									2.50%	
	0500	Maximum									5%	
	0600	Food service & kitchen equipment, minimum									8%	
	0700	Maximum									12%	
	0800	Landscaping & site development, minimum									2.50%	
	0900	Maximum									6%	
	1000	Mechanical (plumbing & HVAC), minimum									4.10%	
	1100	Maximum									10.10%	
	1200	Structural, minimum				Project					1%	
	1300	Maximum				"					2.50%	
700	0010	**SURVEYING** Conventional, topographical, minimum	A-7	3.30	7.273	Acre	16	236		252	385	700
	0100	Maximum	A-8	.60	53.333		48	1,700		1,748	2,675	
	0300	Lot location and lines, minimum, for large quantities	A-7	2	12		25	390		415	635	
	0320	Average	"	1.25	19.200		45	620		665	1,025	
	0400	Maximum, for small quantities	A-8	1	32		72	1,025		1,097	1,650	
	0600	Monuments, 3' long	A-7	10	2.400	Ea.	19	78		97	142	
	0800	Property lines, perimeter, cleared land	"	1,000	.024	L.F.	.03	.78		.81	1.24	
	0900	Wooded land	A-8	875	.037	"	.05	1.16		1.21	1.85	
	1100	Crew for building layout, 2 person crew	A-6	1	16	Day		540		540	845	
	1200	3 person crew	A-7	1	24			780		780	1,200	

Important: See the Reference Section for critical supporting data - Reference Nos., Crews, & City Cost Indexes

SAMPLE PAGE, Building Construction Cost Data, © R.S. Means Co., Inc

COMMERCIAL/INDUSTRIAL/INSTITUTIONAL | **M.330** | **Hospital, 2-3 Story**

Costs per square foot of floor area

Exterior Wall	S.F. Area	25000	40000	55000	70000	85000	100000	115000	130000	145000
	L.F. Perimeter	388	520	566	666	766	866	878	962	1045
Face Brick with Structural Facing Tile	Steel Frame	165.80	155.20	147.85	144.90	142.95	141.70	139.40	138.60	138.00
	R/Conc. Frame	172.95	162.40	155.00	152.10	150.10	148.85	146.60	145.75	145.15
Face Brick with Concrete Block Back-up	Steel Frame	160.35	150.70	144.25	141.60	139.80	138.65	136.75	136.05	135.45
	R/Conc. Frame	167.55	157.85	151.40	148.75	146.95	145.80	143.90	143.20	142.60
Precast Concrete Panels	Steel Frame	159.65	150.05	143.75	141.15	139.35	138.25	136.40	135.70	135.15
	R/Conc. Frame	166.85	157.25	150.90	148.30	146.55	145.40	143.55	142.85	142.30
Perimeter Adj., Add or Deduct	Per 100 L.F.	6.60	4.15	3.00	2.40	1.95	1.60	1.45	1.25	1.05
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	1.90	1.60	1.30	1.15	1.10	1.00	.95	.85	.85
***For Basement**, add $22.30 per square foot of basement area*										

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements. Reported completed project costs, for this type of structure, range from $109.25 to $275.95 per S.F.

Common additives

Description	Unit	$ Cost
Cabinet, Base, door units, metal	L.F.	194
Drawer units	L.F.	370
Tall storage cabinets, 7' high, open	L.F.	365
With doors	L.F.	450
Wall, metal 12-1/2" deep, open	L.F.	144
With doors	L.F.	256
Closed Circuit TV (Patient monitoring)		
One station camera & monitor	Each	1400
For additional camera, add	Each	760
For automatic iris for low light, add	Each	1950
Doctors In-Out Register, 200 names	Each	13,700
Comb. control & recall, 200 names	Each	17,100
Recording register	Each	6475
Transformers	Each	299
Pocket pages	Each	965
Hubbard Tank, with accessories		
Stainless steel, 125 GPM 45 psi	Each	23,800
For electric hoist, add	Each	2600
Mortuary Refrigerator, End operated		
2 capacity	Each	12,200
6 capacity	Each	22,500

Description	Unit	$ Cost
Nurses Call Station		
Single bedside call station	Each	248
Ceiling speaker station	Each	113
Emergency call station	Each	152
Pillow speaker	Each	233
Double bedside call station	Each	405
Duty station	Each	253
Standard call button	Each	121
Master control station for 20 stations	Each	4800
Sound System		
Amplifier, 250 watts	Each	1800
Speaker, ceiling or wall	Each	150
Trumpet	Each	281
Station, Dietary with ice	Each	14,500
Sterilizers		
Single door, steam	Each	143,500
Double door, steam	Each	184,500
Portable, countertop, steam	Each	3450 - 5375
Gas	Each	35,500
Automatic washer/sterilizer	Each	48,900

SAMPLE PAGE, 2003 Square Foot Costs

Model costs calculated for a 3 story building with 12′ story height and 55,000 square feet of floor area

Hospital, 2-3 Story

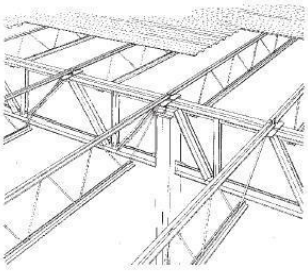
				Unit	Unit Cost	Cost Per S.F.	% Of Sub-Total
A. SUBSTRUCTURE							
1010	Standard Foundations	Poured concrete; strip and spread footings		S.F. Ground	3.87	1.29	3.0%
1030	Slab on Grade	4" reinforced concrete with vapor barrier and granular base		S.F. Slab	3.57	1.19	
2010	Basement Excavation	Site preparation for slab and trench for foundation wall and footing		S.F. Ground	.12	.04	
2020	Basement Walls	4' foundation wall		L.F. Wall	88	.92	
B. SHELL							
	B10 Superstructure						
1010	Floor Construction	Cast-in-place concrete beam and slab		S.F. Floor	16.19	10.79	13.4%
1020	Roof Construction	Cast-in-place concrete beam and slab		S.F. Roof	13.26	4.42	
	B20 Exterior Enclosure						
2010	Exterior Walls	Face brick and structural facing tile	*85% of wall*	S.F. Wall	30	9.59	9.7%
2020	Exterior Windows	Aluminum sliding	*15% of wall*	Each	516	1.25	
2030	Exterior Doors	Double aluminum and glass and sliding doors		Each	1929	.21	
	B30 Roofing						
3010	Roof Coverings	Built-up tar and gravel with flashing; perlite/EPS composite insulation		S.F. Roof	3.93	1.31	1.2%
3020	Roof Openings	Roof hatches		S.F. Roof	.03	.01	
C. INTERIORS							
1010	Partitions	Concrete block, gypsum board on metal studs	*9 S.F. Floor/L.F. Partition*	S.F. Partition	4.68	5.20	26.3%
1020	Interior Doors	Single leaf hollow metal	*90 S.F. Floor/Door*	Each	541	6.01	
1030	Fittings	Hospital curtains		S.F. Floor	.71	.71	
2010	Stair Construction	Concrete filled metal pan		Flight	4425	1.05	
3010	Wall Finishes	40% vinyl wall covering, 35% ceramic tile, 25% epoxy coating		S.F. Surface	5.55	6.17	
3020	Floor Finishes	60% vinyl tile, 20% ceramic, 20% terrazzo		S.F. Floor	7.07	7.07	
3030	Ceiling Finishes	Plaster on suspended metal lath		S.F. Ceiling	3.74	3.74	
D. SERVICES							
	D10 Conveying						
1010	Elevators & Lifts	Two hydraulic hospital elevators		Each	76,450	2.78	2.4%
1020	Escalators & Moving Walks	N/A		–	–	–	
	D20 Plumbing						
2010	Plumbing Fixtures	Kitchen, toilet and service fixtures, supply and drainage	*1 Fixture/265 S.F. Floor*	Each	3463	13.07	15.4%
2020	Domestic Water Distribution	Electric water heater		S.F. Floor	4.14	4.14	
2040	Rain Water Drainage	Roof drains		S.F. Roof	.81	.27	
	D30 HVAC						
3010	Energy Supply	Oil fired hot water, wall fin radiation		S.F. Floor	3.12	3.12	11.0%
3020	Heat Generating Systems	N/A		–	–	–	
3030	Cooling Generating Systems	Chilled water, fan coil units		S.F. Floor	9.34	9.34	
3050	Terminal & Package Units	N/A		–	–	–	
3090	Other HVAC Sys. & Equipment	N/A		–	–	–	
	D40 Fire Protection						
4010	Sprinklers	Wet pipe sprinkler system		S.F. Floor	1.62	1.62	1.4%
4020	Standpipes	N/A		–	–	–	
	D50 Electrical						
5010	Electrical Service/Distribution	1200 ampere service, panel board and feeders		S.F. Floor	1.12	1.12	11.0%
5020	Lighting & Branch Wiring	Fluorescent fixtures, receptacles, switches, A.C. and misc. power		S.F. Floor	8.68	8.68	
5030	Communications & Security	Alarm systems, communications systems, emergency lighting, emergency generator		S.F. Floor	1.73	1.73	
5090	Other Electrical Systems	Emergency generator, 125 kW		S.F. Floor	.93	.93	
E. EQUIPMENT & FURNISHINGS							
1010	Commercial Equipment	N/A		–	–	–	4.8%
1020	Institutional Equipment	Conductive flooring, oxygen piping, curtain partitions		S.F. Floor	.69	.69	
1030	Vehicular Equipment	N/A		–	–	–	
2020	Other Equipment	Patient wall systems		S.F. Floor	4.77	4.77	
F. SPECIAL CONSTRUCTION							
1020	Integrated Construction	Conductive flooring		S.F. Floor	.55	.55	0.5%
1040	Special Facilities	N/A		–	–	–	
G. BUILDING SITEWORK		**N/A**					
					Sub-Total	113.78	**100%**
	CONTRACTOR FEES (General Requirements: 10%, Overhead: 5%, Profit: 10%)				*25%*	28.42	
	ARCHITECT FEES				9%	12.80	
					Total Building Cost	**155.00**	

SAMPLE PAGE, 2003 Square Foot Costs

B10 Superstructure

B1020 Roof Construction

B SHELL



Description: Table below lists costs for a roof system supported on exterior bearing walls and interior columns. Costs include bracing, joist girders, open web steel joists and 1-1/2" galvanized metal deck.

Design and Pricing Assumptions:
Columns are 18' high.
Joists are 5'-0" O.C.
Joist girders and joists have bottom chords connected to columns. Roof deck is 1-1/2", 22 gauge galvanized steel. Costs include bridging and bracing. Deflection is limited to 1/240 of the span.

Fireproofing is not included.
Costs/S.F. are based on a building 4 bays long and 4 bays wide.
Costs for bearing walls are not included.

Column costs are not included but are listed separately per S.F. of floor.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	INST.	TOTAL
SYSTEM B1020 120 2050					
30' X 30' BAY SIZE, 20 PSF SUPERIMPOSED LOAD					
Open web joist girders, average	.475	Lb.	.22	.10	.32
Open web joists, horiz. bridging, T.L. lots, 30' to 50' span	.067	Lb.	.68	.29	.97
Cross bracing, rods, shop fabricated, 1" diameter	.062	Lb.	.05	.10	.15
Metal decking, open, galv., 1-1/2" deep, 22 ga., over 50 sq.	1.050	S.F.	.75	.43	1.18
TOTAL			1.70	.92	2.62

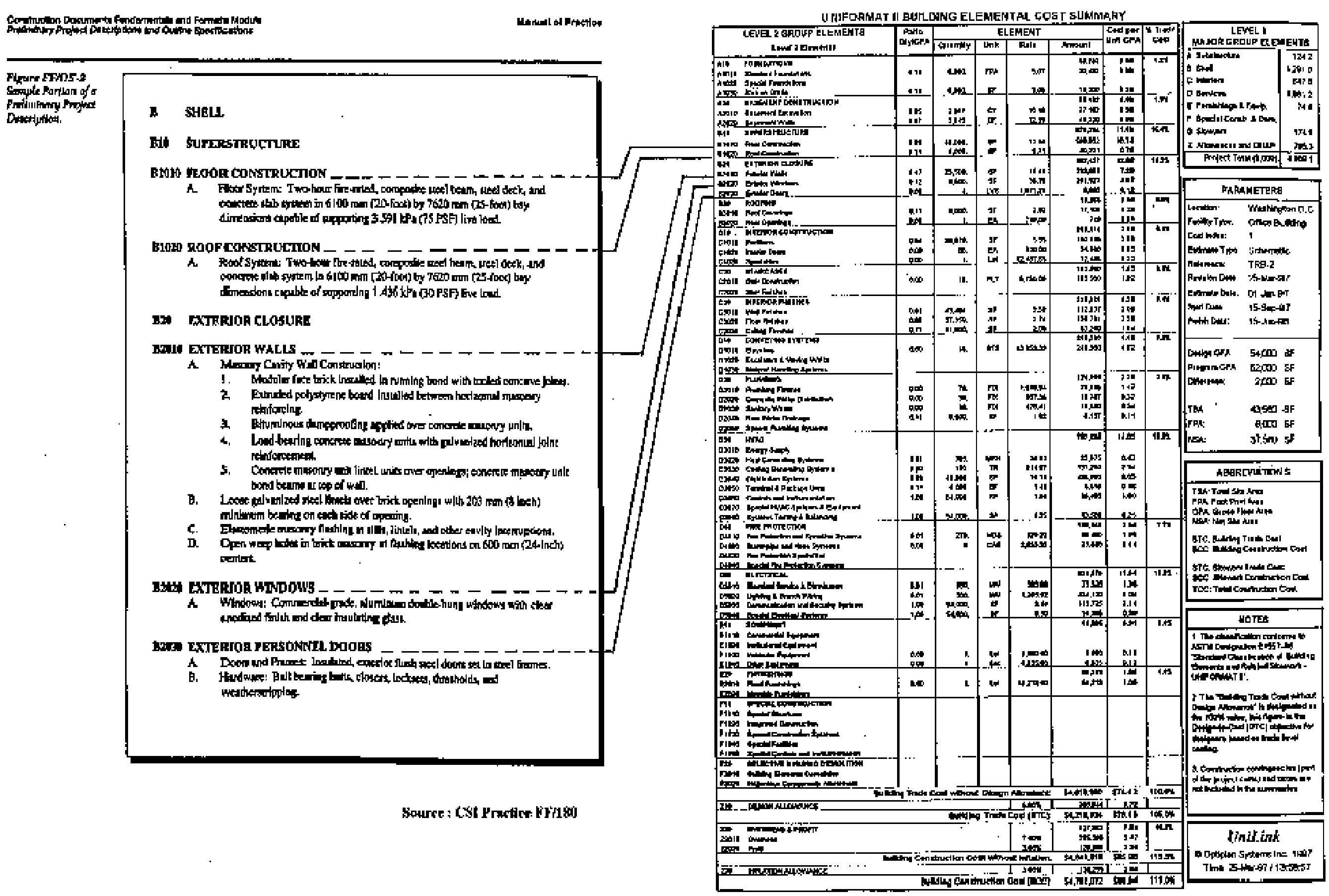
B1020 120 Steel Joists, Joist Girders & Deck on Columns & Walls

	BAY SIZE (FT.) GIRD X JOISTS	SUPERIMPOSED LOAD (P.S.F.)	DEPTH (IN.)	TOTAL LOAD (P.S.F.)	COLUMN ADD	COST PER S.F. MAT.	INST.	TOTAL
2050	30x30	20	17-1/2	40		1.70	.92	2.62
2100					columns	.20	.07	.27
2150		30	17-1/2	50		1.86	.98	2.84
2200					columns	.20	.07	.27
2250		40	21-1/2	60		1.96	1.04	3
2300					columns	.20	.07	.27
2350	30x35	20	32-1/2	40		1.96	1.04	3
2400					columns	.17	.07	.24
2450		30	36-1/2	50		2.06	1.08	3.14
2500					columns	.17	.07	.24
2550		40	36-1/2	60		2.21	1.16	3.37
2600					columns	.20	.07	.27
2650	35x30	20	36-1/2	40		1.81	.98	2.79
2700					columns	.17	.07	.24
2750		30	36-1/2	50		2.01	1.06	3.07
2800					columns	.17	.07	.24
2850		40	36-1/2	60		2.74	1.38	4.12
2900					columns	.20	.07	.27
3000	35x35	20	36-1/2	40		2.13	1.28	3.41
3050					columns	.15	.05	.20
3100		30	36-1/2	50		2.20	1.31	3.51
3150					columns	.15	.05	.20
3200		40	36-1/2	60		2.42	1.41	3.83
3250					columns	.19	.07	.26

Important: See the Reference Section for critical supporting data - Reference Numbers and City Cost Indexes

Schematic Phase Elemental
Preliminary Project Descriptions
and Design Estimates

Fig.3 Elemental Preliminary Project Description **Fig.4 UNIFORMAT II Building Elemental Cost Summary**



Source : CSI Practice FF/180

UNIFORMAT II Links Schematic Phase Elemental Preliminary Project Descriptions and Design Estimates

Autodesk Revit 6

autodesk

Features and Benefits

The Autodesk® Revit® building information modeler is a powerful design and documentation system delivering competitive advantage, improved coordination and quality, and higher profitability to architects, builders, and other building industry professionals.

In the Autodesk Revit parametric building model, every drawing sheet, every 2D and 3D view, and every schedule is a direct presentation of information from the same underlying building database. As you work in familiar drawing and schedule views, Autodesk Revit collects information about the building project and coordinates this information across all other representations of the project. The parametric change technology in Autodesk Revit automatically coordinates changes made anywhere—in model views or drawing sheets, schedules, sections, plans, renderings … you name it.

Autodesk Revit supports all phases of the building process, preserving all information from beginning to end. The same model that is rendered in design generates quantities exported to an estimating database after construction documents are prepared.

Integrated Project Model

These features deliver coordinated construction documents at all times, providing enormous time savings and quality improvements in drawing deliverables.

Feature	Benefit	New
Automatic sheet/drawing references	Ensures that no section, elevation, or callout ever references the wrong drawing or sheet.	
Bidirectional associativity	Ensures all changes to any part of the building need to be made only once. Ensures annotation decisions, such as a changed sheet scale properly resizing all annotations and graphics, need to be made only once.	
Dimension driven	Enables you to modify geometry by typing a new number, saving time during iterative design processes. In Revit 6.1, the Rotate tool creates a listening dimension for more accurate placement.	X*
Drawing coordination	Ensures all data and graphics, details, schedules, drawings, and sheets in the drawing set are current and coordinated.	
Integrated building materials	Real-world materials drive detailed plan, section, and elevation representations of building components to save documentation time. The integrated AccuRender® raytracing and radiosity engine uses the same materials, saving time and effort when producing visualizations.	
Integrated project phasing	Project phasing reduces the amount of time required to create renovation and planning documents.	

Feature	Benefit	New
Live building sections and elevations	Sections and elevations are computed on demand in a fraction of the time required to draw the sections by hand or with traditional CAD. Work in any appropriate view of the building, including sections and elevations.	
Live editing in any view or sheet	Work in any appropriate view of the building. All views are updated without user intervention, ensuring drawing coordination.	
Parametric design	Quickly make changes to refine your design, arriving at your optimum design in the shortest amount of time.	
Project browser	Project-wide browser reduces the time needed to manage and navigate the various views, families, groups, renderings, and sheets of the project. In Revit 6, reorganize the project browser's Views and Sheets sections to match your desired project organization.	X
Project templates	Creating convenient starting points for your project types saves time when making a new project.	
Relationships between parametric components	Lockable, user-defined relationships between building components in the model enable you to preserve your design intent as your design progresses.	
Scale-dependent annotation and symbols	Automatic scaling of annotation items ensures that no drawing has incorrectly sized text or annotation symbology.	
Single multiuser building database	Single, compact project database file simplifies project management and ensures drawing coordination across the project.	
Design Options	Develop and study multiple simultaneous design alternatives to make key design decisions. Present multiple schemes to your clients easily. Each option can be substituted into the model for visualization, quantification and other data analysis to inform decision making. In Revit 6.1, this feature has been enhanced to include more control options.	X*

Building Design and Components

These features are the heart of the Autodesk Revit modeling capability and deliver a robust, single building database with many valuable downstream uses.

Feature	Benefit	New
Assemblies of "nested" component families	Multiple family components can be combined into more complex assemblies, with parametric control of the individual components within the assembly. Enables building a kit of parts to speed designs that use combinations of standard components. In Revit 6.1, the visibility of solid elements and nested families can be controlled parametrically.	X*

Feature	Benefit	New
Attachable and insertable components	Components attached or inserted into built-in-place construction support complex hosting relationships; for example, doors and windows that span different wall materials.	
Butt-glazed curtain walls	This common curtain wall system, including automatically mitered horizontal mullions, is supported, reducing layout time dramatically.	
Complex roofs and joining	Multiple, simple roofs can be joined to form more complex roofs. All roofs are defined by simple 2D sketching, delivering flexible yet geometrically complex 3D roofs that can be iteratively changed by altering the sketch or slopes of sketch lines. In Revit 6.1, additional roof slope control has been added.	X*
Complex solid geometry	Expressive geometry and design are supported by real-world, constructible materials and systems.	
Compound assemblies and joins	Built-in-place (host) items (wall, floor, roof, and so forth) support complex assemblies of multiple materials and material functions. Join information between host components speeds section and detail creation.	
Curtain walls	Flexible, intuitive curtain wall tools make designing any curtain wall easy. Panel and mullion families can be designed to produce any type of wall and can be substituted for rapid evaluation of exterior curtain wall ideas.	
Curtain wall grid patterns	Layout curtain walls quickly by defining complex grid patterns in the wall definition. Edit portions of already placed grids without disturbing the relationship of the remaining grids to the pattern.	X
Demolition and construction phasing	Make an existing condition, perform demolition, and then design the renovation. Autodesk Revit automates renovation projects by managing the different time phases assigned to components within the building.	
Edge conditions; Fascia, Gutter, Soffit	Profile-based tools for creating roof and floor edge conditions save time, representing accurate, real-world construction practices.	
Mass modeling	Updating the massing changes the building. Simple yet powerful massing interface enables exploration of building ideas while providing the ability to iterate between mass and finished shell of a proposed building.	
Nonstandard host geometry (wall, floor, roof, and so forth)	"Create-in-place" mechanism enables custom, nonstandard component creation such as sloping or spline-based curved walls.	
Parametric building component library	Thousands of imperial and metric building component families for every project type, delivered on CD, can be used as is or customized for specific designs.	

Feature	Benefit	New
Preannotated model families	Make self-annotating building components by inserting annotation families into model family components. This eliminates errors resulting from having untagged items and ensures drawing consistency because annotation always scales with the paper.	
Railings	Define railings on stairs, ramps and floors. In Revit 6, create railings with complex patterns of rails and balusters. Specify their start, end, and corner conditions.	X
Rooms and Spaces	Create and maintain a wealth of information about rooms and space. Develop area plans that aggregate spaces and use standard area reporting rules. In Revit 6, rooms understand project phases.	X
Sketch-based hosts	Built-in-place items (wall, floor, roof, and so forth) are defined by simple 2D sketching, delivering flexible but geometrically complex 3D items in the building that can be iteratively changed by altering the sketch.	
Sketch-based stair layout	Stairs, ramps and railings are defined by simple 2D sketching, delivering flexible yet geometrically complex 3D stairs that can be iteratively changed by altering the sketch.	
Sloped and complex glazing systems	Create sloped glazing representing roofs and other special curtain construction, making complex designs easy. Special tools for ruled surfaces, now more common in today's buildings, make creating and maintaining nonstandard designs simple.	
Splines and spline-based solids	Splines can be used for geometry creation by creating then them in sketches for walls, floors, roofs, site elements, and other free-form project geometry. In Revit 6.1, this includes sweep path sketches.	X*
Stairs and Ramps	Create stairs and ramps that match a wide range of forms and construction types. In Revit 6, define true monolithic stairs with control over material and form. In Revit 6.1, define curved ramps in the same manner.	X*
Stair slope calculator	Enables creation of stairs calculated by the slope method (as opposed to U.S. tread/riser) in European countries.	
Structural detailing	Library of parametric 2D structural detailing components enables you to create structural details directly in the model.	X
Structural modeling	Library of parametric 3D structural framing components enables you to create structural frames and foundations directly in the model.	X
Structural design and drafting	Structural engineers and architects use the structural tools in Revit for design and documentation. New tools in Revit 6.1 make this process even more steamlined	X*
Structural grid	Create and identify grid lines with simple intuitive tools. Use intelligent structural grid elements to control your design. Revit 6 supports curved and radial grids.	X

Feature	Benefit	New
Subscription component library	Web-based content library available directly in the system. Includes detailed component families from quality manufacturers.	
User-defined building components	Graphical parametric component editor enables component creation by simply drawing, without programming or scripting. In Revit 6.1, constrained elements are driven interactively in the Family Editor	X*
Vertically compound wall types	Designing complex wall types in section saves time by preinserting different heights of materials and surface features, such as reveals. Saves both modeling and drafting time. In Revit 6.1, enhanced wall layer wrapping gives detailed control over how individual layers of a compound structure wrap at inserts such as doors and windows.	X*

Powerful, Intuitive Editing Tools

These straightforward tools contribute to the Autodesk Revit software's widely recognized ease of use, providing a design system that is accessible to everyone.

Feature	Benefit	New
Active workplane grid	This user-displayable grid provides easier visualization of modeling and sketching operations, resulting in fewer errors.	
Align, split, trim, offset tools	These editing tools are like their CAD equivalents, but better. As you use these tools, they imply constraints between the things you pick so the model knows how to update as your design changes, saving effort and rework.	
Arrays: linear and radial	These tools are similar to their CAD equivalents, but more powerful. Arrays make constrained groups of items, saving you time when altering the layout of multiple items constrained by their endpoints or radii.	
Flexible graphic controls	Detailed graphic controls and view-specific graphics make drawings look exactly the way you want them to.	
Group tool	Groups are similar to AutoCAD® blocks, but more flexible. More than just dumb geometry, grouped items maintain join behaviors (walls, floors, and so forth), sequential annotation numbering, and constraint relationships to other items in the model, saving you time when switching layouts.	
Linework tool	Provides a parametric model line/edge override, enabling you to easily create a picture of what is needed in any specific view.	

Feature	Benefit	New
Paint tool	A simple tool for painting surfaces with different material so you can perform what-if rendering studies. Also used for making portions of objects that have different materials, such as a floor with multiple carpet colors, speeding the description of many plan and elevation material-change conditions drawings.	
Spell Checker	Improve the quality of documents. Check spelling of text entries using a dictionary containing standard architectural terms and abbreviations, standard dictionaries, or your custom dictionary.	X
Temporary thin-lines mode	This viewing mode makes drawing complicated sketches and small components in details easier, reducing errors.	
Transfer view templates	Enables moving preset view settings between projects, and eliminates duplication of effort among projects.	
View templates	Specify all the settings for a certain type of plan, section, elevation, or other view and name it as a template that can be applied to other views in the project. Ensures graphic consistency and saves setup time.	
WYSIWYG display and printing	An important usability benefit. Enables all team members (even those who don't use CAD) to look at the screen and see exactly what will print. Ensures graphic consistency, and makes Autodesk Revit accessible to everyone.	

Site and Landscape Design

These features constitute Autodesk Revit software's acclaimed site design environment and are important in the creation of construction documents, saving time and eliminating rework.

Feature	Benefit	New
Automatic contour line labels	Ensures consistency of annotation in site plans. Saves time, since contour lines self-annotate and the labels are always neatly lined up.	
Construction logistics component library	Provides clarity in construction planning. Add cranes, trailers, scaffolding, and other temporary and staging items to the project to plan the actual delivery of the building project.	X
Parametric plant library and editor	Choose from a large library of plant component families arranged by common and Latin terms, or create your own with the Autodesk Revit plant editor.	
Parametric site component library	Thousands of imperial and metric building component families for every project type, provided on CD, can be used as is or customized for specific designs.	
Parking components and schedules	No more time counting parking spaces. Autodesk Revit schedules them automatically.	

Feature	Benefit	New
Procedural plants	High performance: stores no geometry in the model. Plants are calculated at rendering time by a fractal algorithm that produces unique plants in all locations. Plants can be rendered for different seasons and growth conditions.	
Property lines	Entering bearing and distance data from deed descriptions to create your closed property boundary reduces drawing headaches and the need to switch to different drawing units.	
Site grading and pad layout	Enables architects to model buildings in context of the site.	
Site terrain surfaces	Provides site context for the building and creates all ground lines and hatch patterns in sections and elevations, saving time and eliminating tedious hatching chores.	

Drafting and Documentation

These tools help you create integrated construction documents by taking full advantage of the building model. The result drastically reduces the amount of drawing needed, saving time and ensuring document coordination and quality.

Feature	Benefit	New
Automatic sheet index	The sheet index always lists the right drawing sheets in your set. Renumbering drawings in the sheet index renumbers all the sheets themselves, ensuring consistency.	
Automatic sheet and drawing references	Automatic drawing references ensure that no section, elevation, or callout ever references the wrong drawing or sheet.	
Detail-level view control	User-defined control of what level of detail displays at different scales of drawings. Saves time in detailing.	
Detail Views	Easily create many standard detail view types and control their keying in other views to match your standards.	X
Edit Cut Profile tool	Make your own joins between walls, floors, or roofs by altering the boundaries between different materials so your drawings look exactly the way you want.	
Ellipses	Create true full and partial ellipses with a simple input interface for lines and sketches. Ellipses can be used for geometry creation, including in sweep path sketches.	X
Insulation tool	Draws parametric, variable width/length batt insulation for use in detailing, providing time savings on most detail drawings.	
Keynoting	Use keynote families to reduce the time required for creating a schedule of generic notes based on any system (CSI, and so on). Tag items in any view with keynotes.	

Feature	Benefit	New
Live schedules	Schedules are computed on demand. Dramatically reduces the time to create and edit schedules. Work in any appropriate view of the building, including schedules. Changing schedules makes the appropriate geometric changes in the model. In Revit 6.1, enhancements include associative split schedule sections, selectable design elements via schedule views, and enhancements to door schedules. You can also apply filters to schedules to show only the elements you need, and use computed fields which contain formulas calculated from values in other fields. In Revit 6.1, conditional tests for formulas are supported.	X*
Manage office standards across projects	Project standards comprise a specific list of settings that control the look and types of construction in a project. These settings can be preset in templates and transferred between projects, providing high-level control over projectwide settings. They can also be checked out to a project lead to make them read-only, providing security and change control.	
More project templates	Templates are included for residential and light commercial project types, saving time in project setup.	
Multicategory schedules	Enables more scheduling/queried reporting than typical architectural schedules. Allows scheduling all components with certain properties within the project, enabling useful data gathering, and provides valuable answers to project questions.	
Opening rough width and rough height	Doors and windows provide guaranteed fields for rough openings, eliminating errors and providing more value in schedules.	
Parametric annotations/tags/keys	Powerful, data-driven tagging enables you to link your tags to your building components and rapidly create and maintain live schedules directly in the model.	
Parametric detailing	Powerful 2D drafting and parametric detailing tools enable you to create detail drawings directly in the model that can update as the model changes.	
Plan Regions	Create regions with different view ranges in plan and RCP views. Supports standard methods for representing split levels and wall hosted elements above the standard cut plane.	X
Prints sets/saved print settings	Save batch print settings and sheet lists for different print sets, eliminating redundant tasks when reissuing drawing sets.	
Reference schedules and keys	Save project time and tracking by making schedule keys to represent a group of items for creating reference schedules such as door hardware type, room type, and finish type.	

Feature	Benefit	New
Reference sections and callouts	Referring to similar conditions that are already detailed in your project saves detailing time and ensures coordination.	
Repeating Detail components	Create and modify detail views more quickly. Draws linear arrays of detail components that add and remove items as the defining line is modified.	X
Revision cloud	Provides bubbling of revisions and tagging for display in title blocks. Speeds issuing addenda.	
Scale-based line weight control	User-defined control of what level of line weights display at different scales of drawings helps establish drawing consistency.	
Scale-dependent annotation and symbols	Automatic scaling of annotation items ensures that drawings always have correctly sized text or annotation symbology, removing this headache from the project team.	
Sheet-based view rotation	Provides toggle between portrait and landscape orientation of views to place them on sheets, saving time when laying out deliverables in differing formats.	
Sheet layout tools	Drag-and-drop sheet layout makes setting up and maintaining a set of construction drawings easy.	
Split sectional views	Enables detailed section views to be split (with breaklines) to fit on a drawing sheet. Used for enlarged sections, such as wall and stair sections.	
Spot elevations	An annotation as well as a parametric control, spot elevations enable movement of items as well as ability to report their elevations, ensuring consistency.	
Title block families	Use multiple title blocks in a project to make different sheet formats for presentation, design approval, and construction documents.	
"True North" views	View can be switched between Project North and True North orientation, saving time by eliminating the need to rotate text and symbols.	
View duplication with detailing	Copying a whole view with all its detailing components enables quick creation of similar detail conditions.	
Dimensioning	Dynamic dimensions update as your design changes, reducing rework. In Revit 6.1, walls support single-click dimensioning including dimensioning support for openings such as windows and doors.	X*
Color-Fill Regions	In Revit 6.1, color-fill regions now support transparent backgrounds.	X*

Multiuser Work Environment

Teams can simultaneously design a building while Autodesk Revit coordinates all the changes between the team members, decreasing time cycles for any design.

Feature	Benefit	New
Autodesk Buzzsaw web folder support	The ability to export drawings for consultants and post families and other Autodesk Revit files directly to your Autodesk® Buzzsaw® site using web folders simplifies collaboration for the extended design team.	
Change history audit trail	Workset change history shows which team member changed what and when, helping to maintain an audit trail for key changes on your project.	
Graphic controls for linked Revit models	Standard model-viewing mechanisms are supported for linked models. Linked models can also draw themselves based on phase- and floor-level information in the linked project, enabling a range of drawing deliverables not previously possible.	
Model linking	Link other Autodesk Revit building models directly within your project. Create multiple buildings and link them together for campus-style projects, enabling teams to do much larger projects.	
Multiuser worksets	Worksets enable multiple team members to work together on the same model, while their work is fully coordinated. In Revit 6.1, worksets have been enhanced with the removal of reference restrictions.	X*
Element Borrowing	Allows sharing of elements across worksets, reducing editing conflicts in multi user work teams.	X
On-demand database reading	Autodesk Revit reduces memory usage and increases performance on large models by computing only those things you see in your currently open views.	
Runtime shared parameters	In addition to adding external shared parameters at family creation time, you can also add them to family components in existing projects. This enables more powerful queries for many design and construction situations.	
Selective workset opening	Opening portions of a large building model increases performance and provides project-wide visibility control, speeding your interactive work.	
Shared coordinate systems	Once a model is located with respect to another model, its position is "known" by every model in the project that shares the coordinate system. This saves time and tedious effort in continually trying to match up coordinate systems between multiple projects and DWG files.	
Task-specific user interface	Customizable design bar with grouped tools for modeling, detailing, site design, structural layout, and construction planning makes it easier for design professionals to do their job.	

Feature	Benefit	New
Temporary hide/show/isolate	Something getting in your way while editing? Isolate your selection or temporarily hide it make editing easier.	

Presentation and Visualization

Integrated rendering and other tools provide on-demand presentation material as an added benefit, without additional work by the team.

Feature	Benefit	New
AccuRender rendering	Integrated AccuRender raytracing and radiosity for on-demand visualizations enable any designer to create fast, high-quality renderings for clients.	
Animated walkthroughs	Path creation produces rendered animations for stunning client presentations, enabling any designer to create fast, high-quality walkthroughs for clients.	
Area takeoff and diagramming tools	Industry-standard, built-in area analysis for producing multiple area schemes for any given floor dramatically improves the productivity of architects needing to produce area studies for their clients.	
Automatic color fill	Instant color-plan diagrams of program assignments or any other room data dramatically improves the productivity of architects needing to produce area studies for their clients. In Revit 6.1, Color schemes can be controlled by Area, or Perimeter values. Color Fills can also be derived by Value Range.	X*
Daylight sources	Include doors, windows, and skylights in rendering calculations to simulate daylight conditions.	
Decals	Apply signage and other graphics to surfaces. Enables realistic rendering and reduces modeling.	
Entourage	ArchVision® RPC™ image-based rendering for unprecedented realism.	
Integrated rendering material library	Use thousands of renderable materials, textures, and patterns, or create your own to speed the time required for anyone in the firm to create a rendering.	
Light groups	Make sets of lights that turn on and off together, for faster evaluation of lighting alternatives during rendering.	
PANTONE color support	Integrated PANTONE® Color Picker for thousands of print-coordinated color selections.	
Photo backgrounds	Superimpose photographs for rendering.	
Procedural plants	High performance: stores no geometry in the model. Plants are calculated at rendering time by a fractal algorithm that produces unique plants in all locations. Plants can be rendered for different seasons and growth conditions.	
Radiosity rendering	Provides daylighting and interior lighting study capability.	

Feature	Benefit	New
Render scenes	Creating collections of settings representing the environment for a rendering reduces tedious tasks creating several renderings.	

Reporting and Data Sharing

The robust building database in Autodesk Revit can interface with and drive many valuable downstream uses such as publishing, cost estimating, and construction planning.

Feature	Benefit	New
DWG/DXF file support	Autodesk Revit imports, exports and links your data with the industry's best DWG compatibility. Native support for DWG and DXF™ formats assures fully compatible data exchange for smooth coordination between team members, including engineering consultants. Enables some people on the team to work in Autodesk Revit while others can continue to use their favorite drafting system.	
External shared parameters	Shared parameters added to family components can be output via schedules. This enables powerful queries for many design and construction situations. In addition, Revit 6.1 additional shared parameters have been added to various families for export to ODBC databases.	X*
Image (bitmap) import	Include graphic image formats directly within your project. Reuse standard detail images in title blocks or presentations.	
Import and linking (xref)	Use data in DWG, DXF, or MicroStation® DGN file formats directly within your project. Reuse standard detail files without redrawing, enabling some people on the team to work in Autodesk Revit and others to work on their favorite drafting system.	
Integrated local layering standards	Built-in support for local layer standards, including U.S. standards (AIA/NCS), BS1192 (U.K.), ISO13567 (Europe), and CP83 (Asia) ensures layering consistency and enables error-free file transfer with other team members.	
Interface to external databases (ODBC)	Output to any ODBC-compliant database product to communicate with third-party estimating, planning, procurement, and facility management tools.	X
Interface with energy analysis (gbXML)	Output to Green Building XML (gbXML) and perform energy analysis using web service from GeoPraxis Inc.	X*
Interface to external spreadsheets	Text output from standard schedules can be used to provide data for Microsoft® Excel and other spreadsheets.	
Material take-off for detailed cost estimating	Reporting of "preferred unit of measurement" for all items exported to ODBC databases enables detailed cost estimating from construction assembly data.	
MicroStation DGN file support	Output to MicroStation DGN file format for smooth coordination between team members.	
PDF file support	Plot directly to PDF for digital collaboration and document sharing.	

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