DESIGN-BUILD INTEROPERABILITY AND CONCEPTUAL DESIGN AND DEVELOPMENT OF A DESIGN-BUILD MANAGEMENT CONTROL SYSTEM

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By

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DESIGN-BUILD INTEROPERABILITY AND CONCEPTUAL DESIGN AND DEVELOPMENT OF A DESIGN-BUILD MANAGEMENT CONTROL SYSTEM

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Special thanks to Robert Charette of Uniformat II. I had printed Robert's article titled "Uniformat II Elemental Classifications for Building Specifications, Cost Estimating, and Cost Analysis" document while doing research during my first class at Georgia Tech but never completely understood the document during my early course work. I had decided on attempting to design a management control system as a thesis topic and was having a lot of difficulty attempting to get my thoughts around how best to pursue the challenge. I then recalled Robert's article on the theoretical building system combining Uniformat with MasterFormat that would be useful in life cycle analysis. I contacted Robert several times during this thesis work; he was always very helpful and informative of my use and implementation of many of his ideas.

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SUMMARY

The design-build construction industry has recognized the advantages of a collaborative contracting method; however it has yet to create information systems that can truly support the industry. Many software applications have been created to assist the Design-Builder; however no software provider has created an application that can completely manage the design-build process from beginning to end. Although some software providers have attempted to integrate data between various project management activity modules (estimating, scheduling, accounting, etc), no software provider has resolved the need to integrate data between both project management activity modules and the various phases of the design-build life cycle. The advancements of the design-build industry method of contracting will never be fully achieved until an information system is designed to specifically support the industry. This paper details the conceptual development of a management control system designed to not only integrate data among various project management activities modules but also to integrate data between all phases of the design-build project life cycle.

Chapter 1

INTRODUCTION

1.1 Background

Design-Build is a construction project methodology in which a single entity, the Design-Builder, forms a single contract with an Owner to provide both architectural and construction services. The Design-Build Institute of America also refers to this project delivery as design/construct and/or single source responsibility. Design-Build is in contrast with the "traditional" design-bid-build approach in which the Owner commissions the architect or engineer to prepare drawings and specifications via one contract; then separately contracts with a Constructor via a competitive bidding process or negotiations to build a facility under a separate contract.

The traditional method of contracting (design-bid-build) is still the most often used delivery method. However, the Design-Build Institute of America predicts that by 2010 design-build will surpass design-bid-build as the most often used delivery system for Non-Residential construction. Currently design-build makes up approximately 45% of all non-residential construction projects[1].

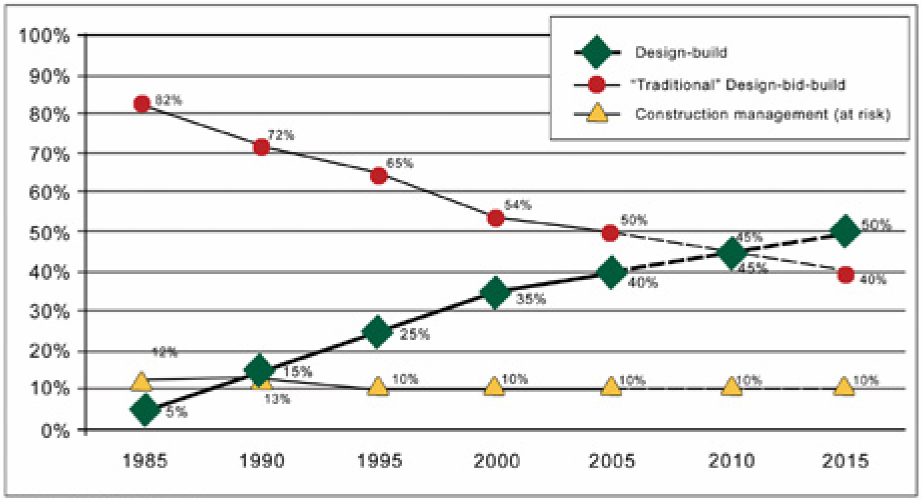

Figure 1
Design-Build Contract Percentage Diagram
Non-Residential Design and Construction Contract Percentage in the United States

Design-Build has grown in popularity due mostly to the several key advantages (later describe in detail) over the traditional methods. Design-Build is quickly becoming known in the construction industry as the contracting methodology that can reduce cost, save time, improve quality, and lower project risk.

1.2 The Research Problem

Despite the growth of design-build construction methodology and the recognition of the advantages in using a collaborative contracting method; the industry has yet to create an information system that is designed specifically to support the business processes and the business characteristics that are unique to the design-build industry. Design-Build is presently functioning using legacy application designed to support the more traditional process of design-bid-build or is using applications that were designed as stand alone solutions to any industry – such as accounting and scheduling software.

Additionally, the use of disparate applications on design-build projects has increased the issue of non-interoperability that the predecessor / traditional project methodology faced.

The National Institute of Standards and Technology (NIST) defines "interoperability[2]" as:

> Interoperability is defined as the ability to manage and communicate electronic product and project data between collaborating firms' and within individual companies' design, construction, maintenance, and business process systems. Interoperability problems in the capital facilities industry stem from the highly fragmented nature of the industry…

Industry research has documented some of the issues associated with the current use of these tools and the net cost of not having achieved interoperability. This interoperability cost is exponentially increased when applied to design-build. The construction industry is moving forward with new and better contract methodologies using information technology tools that remained insufficient to the traditional construction methodologies – the result is an exponential increase in the cost of interoperability.

1.3 Formulation of the Research Problem

Although there are numerous amounts of literary research available that defines the information technology problem facing the design-build industry, there is limited literary references on how best to solve the problem. Additionally, many of the industry people I interviewed during this research have a preconceived notion that a problem does not exist and that the information technology solutions currently available were being adequately applied to the industry.

Admittedly, I was asked by my research advisors to begin by researching what information technologies were currently available to the industry and how they were being used. This is where any good researcher would start; ensure that what you are setting out to do has not already been accomplished. This however, was intentionally avoided out of fear of being consciously (or subconsciously) guided into the directions or a resolution already taken by the current information technology industry. My fear was that if I became overly aware of what others believed to be the solution to "the problem" or as to what "the problem" was itself - then my solution may subconsciously become a variation of what is already available or merely a minor improvement on current shortcomings. I therefore intentionally avoided the current information solutions available until I had composed a conceptual design that I believed could best service the industry. I was convinced that if I remained focused on the aspects and needs of the design-build industry and intentionally removed myself from other solutions already created then I would be capable of finding "the problem".

I therefore began my research by applying my information systems background to every class, book, project, or classroom discussion that took place during my course work at Georgia Tech. Appearing in the margins of most every textbook used during my graduate courses are my own hand written notes and ideas about what would be needed in order to create the optimal information technology system for the industry that I chose to study. At first the notes and ideas in the margins of my textbooks were mostly "wonderings" about how and/or if the issue or business process being discussed were handled by the current information systems. As the course work continued I became more and more capable of asking the questions that in the end helped formulate "the problem" facing the industry. Questions such as "when fast tracking a project how does the master schedule remain up to date when alternative portions of the project are at different phases of the life cycle" or "how does a Design-Builder ensure that the specifications created early in the project are maintained as the project moves into higher detailed phases."

My thesis began without knowing if my final thoughts and ideas were already in practice. First I commenced by researching the industry and the business aspects that I felt were important to be managed by a proposed design-build information system. Subsequently, I transitioned that information into conceptual base-line design of what the information system should do and how it could be done. Only after I had solidified my conceptual ideas and beliefs into a partially functioning application did I begin to do a detailed research of the current software solutions. However, it should be noted that throughout the entire process I did confer with professors and industry leaders about my ideas and overall vision for the application design. However, it would have been impossible to pose solutions until I became aware as to what the actual problem was and how I believed it should / could be resolved. Once complete with my baseline vision and ideas I did begin detailed research of currently available solutions. This research is documented in the second section of this paper and prior to the section in which I pose solutions for the industry.

1.4 Research Objectives and Scope

The goal of this research is to create a conceptual design of a business management information system that can begin to address the issue of interoperability that faces the design-build construction industry.

The goal of this research can be divided into the following three objectives:

1. Review the business aspects and characteristics of the design-build industry and identify those characteristics that should be managed by a proposed information technology system.
2. Review the current information systems available in the industry and identify shortcomings of these systems when applied to design-build construction methodology.
3. Propose a conceptually designed design-build management information system able to overcome some of the short comings of the current systems available (specifically interoperability) and further define how this proposed system should support the management of the business characteristic unique to the industry.

The scope of this paper is limited to project management of design-build "building type" projects as oppose to the construction of bridges, roads, or other non-building projects. A building type construction project is required because the Construction Information Classification System used is limited to the description of buildings and can not be used to describe other project types.   Additionally, this paper has scoped other information technology aspects of the construction industry such as Building Information Modeling (BIM). BIM tools are rapidly changing and improving the industry. BIM systems are too important of a topic to not be discussed in this paper; however, this paper is focused mainly on the project management needs of the industry such as scheduling, accounting, contracting, etc. The following section is dedicated to brief research on the current status of BIM and conceptual ideas on how BIM could be improved or modified to work with the requirements of a design-build complete project management system.

1.5 Building Information Modeling

BIM has gained significant ground in the construction industry market, however according to recent research the industry has yet to become a commonplace solution to the industry. According to Ken Sanders (FAIA), BIM is not making more significant gains in the construction industry due to the fact that digital modeling is unable to offset the upfront cost for building projects that are always unique on a project by project basis. Building construction projects, unlike mass production of items such as airplanes and cars, are rarely if ever the same from one project to another. Even when projects are of similar nature the designer / constructor is faced with external issues that in the end differentiate the project from the other. Site conditions, conflicting local building codes and regulations, varying standards and methods of local contractors are all factors that make even the most similar two projects on paper in the end become substantially different. Non-construction type projects can better absorb the cost of digital modeling (along with the training cost required) when the digital model is used to create mass production output.

Interestingly, Sanders suggest that one of the other areas limiting BIM in construction projects is the fact that digital modeling works best when the designer and the constructor work together on a project as is the case in airplane and automotive design. Sanders suggest that design-build's integrated approach can help BIM chances by allowing constructors and designers to collaborate on the process; however, he also suggests that the manufacturers of BIM applications need to make significant progress on data transformation from the 2D early designs process to the 3D requirements[3].

From Sanders article it appears that BIM faces many of the same issues that the current project management software industry faces. BIM needs to be capable of achieving its own interoperability between design and construction phases of the design-build project life cycle.

1.6 Study Hypothesis

The overall hypothesis of this study is as follows:

An information system can be developed with an internal data storage format to overcome the issue of interoperability in the design-build industry – specifically interoperability issues between design and construction phases of building projects.

The hypothesis will be supported by the development of a representative application that is specifically designed to address the requirements of the industry and can overcome issues of interoperability.

1.7 Research Outline

The following paragraphs outline the steps taken in this study to address the research problem described in section 1.3. Figure 2 lists these steps, along with the chapter structure of this paper. It should be noted that the chapters proceed in this document in a logical format for the reader; however, the research was conducted in the alternative order shown in the data flow of Figure 2.

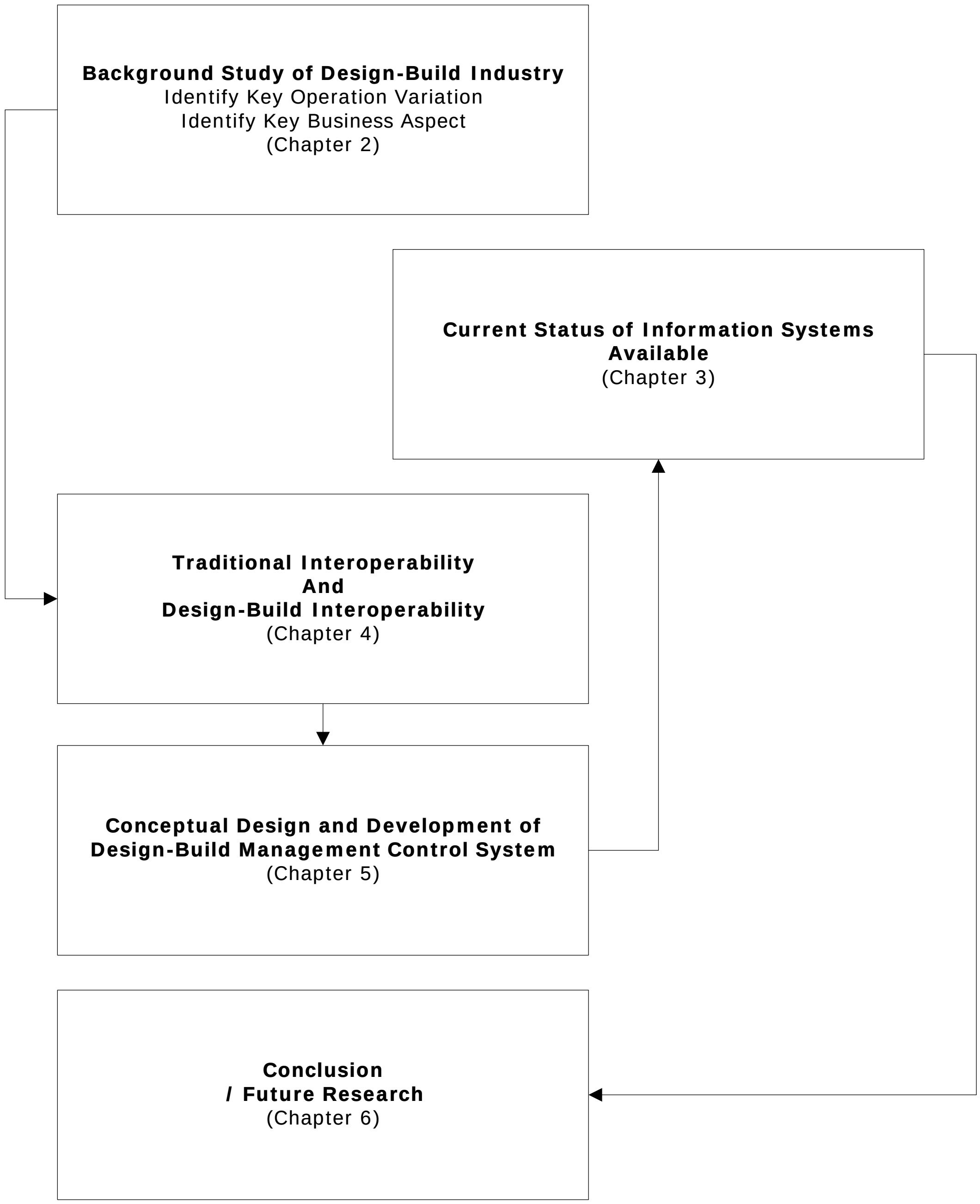

Figure 2
Study Outline

1.8 Research Contribution

The primary contribution of this research is to create consideration and a potential direction the information technology industry can take in satisfying the needs of the design-build construction industry. The resulting assessment is not meant as the "end all" solution to all issues that face the industry, rather posed merely as a possible consideration along with other ideas, processes, and systems currently available. I would consider the contribution successful if the reader is able to apply <u>any</u> of the ideas and theories of this paper in a practical manner to their business systems. In addition, I would consider the research a contribution if as a result of this paper the reader is able to pose questions such as:

- Is our information technology truly designed for the specifics of managing our business?
- Do we face issues of interoperability? If so at what cost?
- Does our information technology help us succeed at what we do? Does it help to lower our risk, does it document our decisions, and does it ensure conformity to our business processes?
- Does our information technology improve our chances of project success with continued use?

Chapter 2

DESIGN-BUILD VARIATIONS

AND BUSINESS ATTRIBUTES

2.1 Purpose

The purpose of this chapter is to gain an understanding of the business attributes and contractual variations unique to design-build. This is important to understand in order to consider the vast scope of requirements needed to design an information management control system for the industry. This chapter is comprised of two sections. This first section describes the operational and contractual variations and the second section details the unique business attributes.

Design-Build comes in many forms. Not only are there endless variations of contractual formation types that fall under the design-build delivery model there are several business entity variations as well. A design-build entity can be formed on a project by project basis by contractually binding the Architectural / Engineering entity with a Contractor entity for the purpose of completing a single project or it can be performed by an ongoing business entity containing complete facilities services from design to construction. Additionally, each of these business entities can use various forms of contracts on a project by project basis. Depending on the business entity type and the contract variation selected there are several key business attributes that differentiate design-build from other project delivery methods.

2.2 Design-Build Business Entity Variations

Design-Build can be accomplished via many different business variations. According to Jeffery L. Beard author of 'Design-Build Planning Through Development', there are five basic business entity variations of a Design-Build Firm. Below are five basic descriptions of each business entity type:

1. Joint Venture Design-Builder – This is a design-build entity that has been formed via a contractual agreement between two or more parties for the purpose of carrying out design-build service. Generally the contract between the two parties would be formed on a project by project basis.

2. Constructor Led Design-Builder – This is a design-build entity in which a constructor hires design services via a sub-contractual arrangement. With this entity the Architectural /Engineering (A/E) can be either contracted with financial risk or without.

3. Designer Led Design-Builder – This is a design-build entity in which an A/E entity provides and is responsible for all aspects of the project including those outside of design services. The A/E is responsible for construction cost, schedule, and means and methods of construction.

4. Integrated Firm Design-Builder – This is a design-build entity that is in the business of providing A/E services and construction services "truly" under one

roof. These entities are not formed on a project by project basis; rather they are a single established entity that can provide all required construction services to an Owner. With the exception of any services rendered to an Owner prior to contracting with an Integrated Design-Builders (such as programming or conceptual design); these entities can accept all risk of the construction project including design, schedule, construction cost, and the means and methods of construction.

5. Developer-Led Design-Builder – This is a design-build entity in which a developer accepts the risk of construction services and separately contracts for A/E and construction services.[4]

In addition to the alternative types of design-build business entity formations there are alternative contract variations.

2.3 Design-Build Contracts Types and Operational Variations

There are several alternative methods to contracting a design-build project. Beard lists three basic types of "operational variations". The basic difference between the variations is the timing of the contract formation within the design life cycle. All Design-Build entities described above can contract a project using any of the operational variations.

Design-build can be utilized in its purist operational form such as direct design-build to formats such as bridging contract that more closely resembles a traditional design-bid-build. All operational variations can have slightly alternative methodologies; below is a basic listing of the alternative types.

1. Direct Design-Build – In this form of design-build, the Design-Builder is contracted with the Owner at the inception of the project. The Design-Builder works with the Owner from the earliest stages including project scope, programming and conceptual design solutions through project completion.

2. Design Criteria Design-Build – In this form of design-build, the Owner may complete the early stages of a typical design life cycle. The Owner presents a Design-Builder with a defined list of problems and parameter for design. The owner states to the Design-Builder a list of measurable performance criteria that need to be met. This type of procurement is most often used in the competitive design-build selection process in which the Owner details a program and design parameters in a Request for Proposal (RFP). Levels of Owner details can vary with this approach. Design-Builders respond to the RFP with their own design solutions.

3. Preliminary Design-Build – In this form of design-build the Owner completes some degree of design prior to contracting with the Design-Builder. Design completeness may vary; for example the design may be limited to single line drawings or may be much further defined in conceptual drawings or schematic

design. The Design-Builder is contracted to complete the project from the already completed design and criteria given.[5]

4. Bridging Design-Build – This form of design-build is what Beard refers to as a “mutation” position between design-build delivery and traditional design-bid-build. Using this approach the Owner presents the Design-Builder with partially complete designs (30% to 80%); the Design-Builder is contracted to complete the design and construction of the project with the given design percentage.

Figure 3 graphically shows the basic variations of design-build’s operational variations. These basic variations come with numerous alternatives. For example, preliminary design-build could expand over several alternative levels of completed design detail presented to the Design-Builder. Making issues for the information system design more complex is the fact that projects can be managed with a hybrid approach within the same contract where one portion of the project uses a design-build methodology that utilizes performance specification while other aspects of the project are contracted in a more traditional approach with prescriptive specifications tied more closely to design-bid-build operational variations.

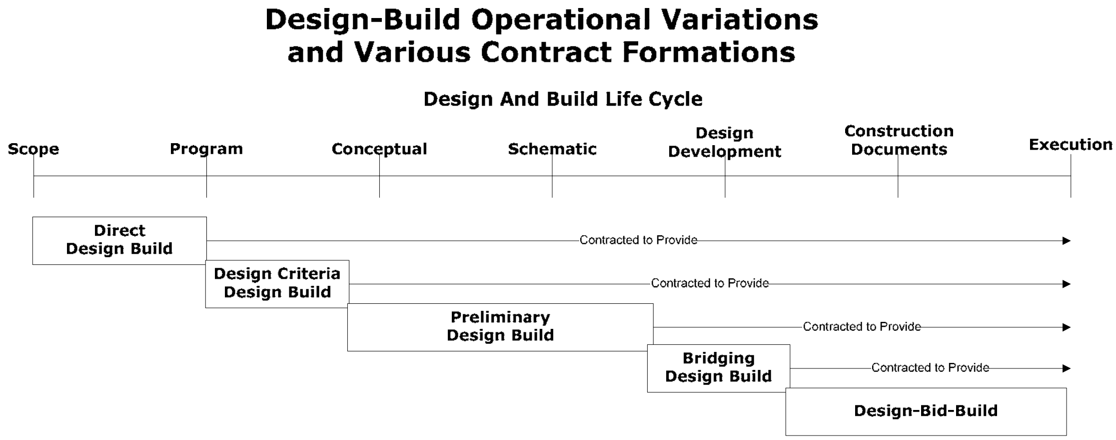

Figure 3
Design-Build Operation Variation and Contracted Service
(Note: Design-Bid-Build is shown only to graphically display comparison with design-build other contract types)

2.4 Key Advantages and Unique Business Attributes of Design-Build

Design-Build is quickly becoming a more popular method of design and construction contracting for many reasons. Design-Build Institute of America list several advantages of design-build over the more traditional method of design-bid-build:

1. Single Responsibility - Both the Design and Construction are the responsibility of a single entity. Litigation issues are removed between Designer and Constructor allowing the Owner to focus on scope, need definitions, and decision making rather then coordination between Designer and Constructor.

2. Quality – The Owners expectations and needs are documented with performance specifications and the Design-Builder responsibility to produce an end product in accordance to those specifications. The Design-Builder warrants that the design is free from error rather than the Owner as in the traditional

system. This allows the design-builder to focus on quality and project performance.

3. Cost Savings – Design and construction teams working and communicating as a team can better evaluate alternative methods and material options more efficiently. Value engineering and constructability are utilized continuously and more effectively when design and construction teams work together.

4. Time Savings - Design and construction can be overlapped (Fast Tracking). Material / equipment procurement and construction can begin before designs are fully complete. The resulting time savings can lead to reduce project cost and earlier facilities utilization.

5. Early Knowledge of Firm Cost – Guaranteed construction cost can be known far earlier using design-build than other delivery systems because the entity responsible for design is continuously able to better estimate cost based on the current project details. Having the design and construction services under one entity allows for the Design-Builder to guarantee those costs earlier in the project. Owners can decide to proceed with a project prior to substantial design expenditures and with superior knowledge of a project’s final cost at a substantially earlier phase.

6. Improved Risk Management - Performance aspects of cost, schedule, and quality and responsibility of risk are more appropriately balanced. Individual risks are managed by the party in the best position to manage those risks. Change orders due to omissions and errors are reduced because the Design-Builder has the single source responsibility of designing and producing a functional facility[6].

A 2005 study completed by PinnacleOne Pulse (one of the nation's leading construction consulting firms) surveyed 167 public owners involved in construction projects throughout the United States that choose to utilize design-build delivery methodology. The study revealed that the primary reason public Owners would choose design-build is to reduce the Owner’s risk associated with construction projects. Other reasons included:

1. Reduced Risk to Owner - 66 Percent
2. Reducing Costs of Project - 57 percent.
3. Reduced Length of Project - 38 percent [7]

design-build reduces risk, cost overruns, and potential length mainly by using a contractual method that unites the Architect / Engineer with the Contractor. With A/E and Contractor contractually bond to a “single responsibility” for the cost, quality, and length of a project the design-build projects are delivered with less litigation, fewer change orders and lower cost. A 2005 study conducted by the department of

Architectural Engineering at Penn State University revealed that required change orders on design-build projects were 90% less than what was required on equivalent design-bid-build projects. The survey estimated that the resulting decrease in change orders resulted in a net cost savings of over 1.7 million over the 120 projects studied[8]. The change order savings was not only attributed to less change order but was also the result of a 50% reduction in the average size of change orders and a 77% reduction in the number of field generated change orders (oppose to an Owner generated). Field generated change orders are typically due to design errors or poor project coordination and can usually be avoided[9].

With the use of design-build on the rise even reluctant A/E and Contractors are considering the alternative delivery option; however, to the A/E the new methodology can present ten times the monetary risk over the traditional design-bid-build methodology. This increased risk, mostly due to being the single point of responsibility for cost, quality and schedule, has a related payoff. If these risks are managed correctly design-build delivery method can be more profitable than the traditional approach. Most A/E Firms agree that design-build can be more profitable to a Firm than the traditional methods[10].

Chapter 3

INFORMATION SYSTEM PRESENTLY AVAILABLE

3.1 Purpose

The purpose of this chapter is to document the information systems that are currently available for use in design-build project management and to document where and why those applications fail the industry.

3.2 Business Systems Presently Available to Design-Build

There are many applications created to assist in the activities of a design-build project including scheduling, accounting, and contract documentation applications. These applications however have two major shortcomings to the Design-Builder. First these applications have not been designed to support the unique business aspects of the design-build industry and secondly using these separate applications create "silos of data" that cannot easily be shared between each application (non-interoperability). According to an article published by Marquette University the reason for these disparate applications is that there is not a single software application that can do all of the required functionality needed for design and construction projects. Due to their functional complexity construction software has evolved to support only one or two limited business functions. Further more, applications have not been developed with open architecture and data information sharing is accomplished only via third party data exchange programs that are costly to develop and difficult to maintain. As a result design and construction companies have a tremendous amount of information duplication and manual re-entry[11].

3.3 Application Not Specifically Created for Design- Build

There is a long list of information technology applications currently being used by the design-build industry, often these applications have been designed to support either a general function for non-specific industries (such as accounting) or have been designed to support the more traditional delivery model of design-bid-build.

Scheduling applications such as Primavera and Microsoft Project Management were designed to support the generic function of project scheduling. For example, Peachtree accounting software has been designed to support the general accounting function for any type of industry that can adapt their accounting system to utilize this application. These applications are used by various industries and utilized in relatively the same manner. An Information Technology department will utilize Primavera scheduling software in the same manner that a construction company would. Other applications such as Timberline Construction have been designed specifically for the construction industry; however, these applications have not been designed to support the specifics of the design-build industry - most notably leaving a significant gap in control and management of the design side of a project required by design-build.

Although Timberline Software includes many aspects of project management, the modules are designed for use in a construction project beginning at the construction documents phase of the design-build project life cycle. The figure below shows Timberline's estimating module that begins with details of the first level of MasterFormat.

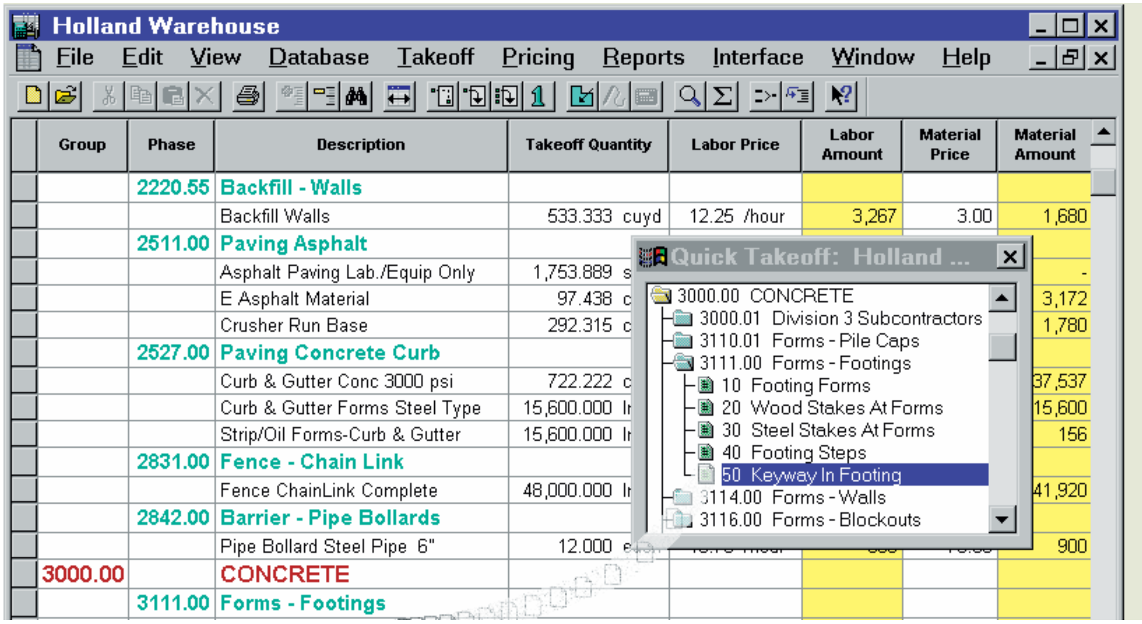

Figure 4
Timberline Estimating Module
Showing Estimating Options Beginning With MasterFormat Details[12].

MasterFormat building classification system, developed by Construction Specification Institute (CSI) and Construction Specification Canada (CSC), is the leading standard for organizing nonresidential construction specifications[13]. MasterFormat is the Contractors' system of choice because it is trade based and most easily divides subcontracted work packages into applicable trades. This building classification system however is not suitable for use during the design phase of a project that is needed for the design-build delivery model.

Uniformat classification system was originally developed by American Institute of Architect (AIA) and The General Services Administration (GSA). The current version Uniformat II was developed by the Nation Institute of Standards and Technology (NIST).

Architects prefer to use Uniformat design services because of its hierarchal approach to creating a Construction Information Classification System that allows the designer to define a building throughout the various phases of the design process.

An integrated design-builder using the Timberline suit of tools would be required to complete the design side of the design-build life cycle and manually begin the process of entering data to begin controlling the construction side of the design-build life cycle. Preliminary schedules, estimates, and account data would be lost when transitioning from the Design Development phase to Contract Document phase. Although this software attempts to integrate this data between project management activity modules (or various applications) there is no integration of data along the design-build project life cycle – particularly between the design side and the construction side. The diagram below attempts to graphically display the design-build life cycle and the first point in the project that a user could begin to use Timberline compared with the origination point of a true design-build information management system.

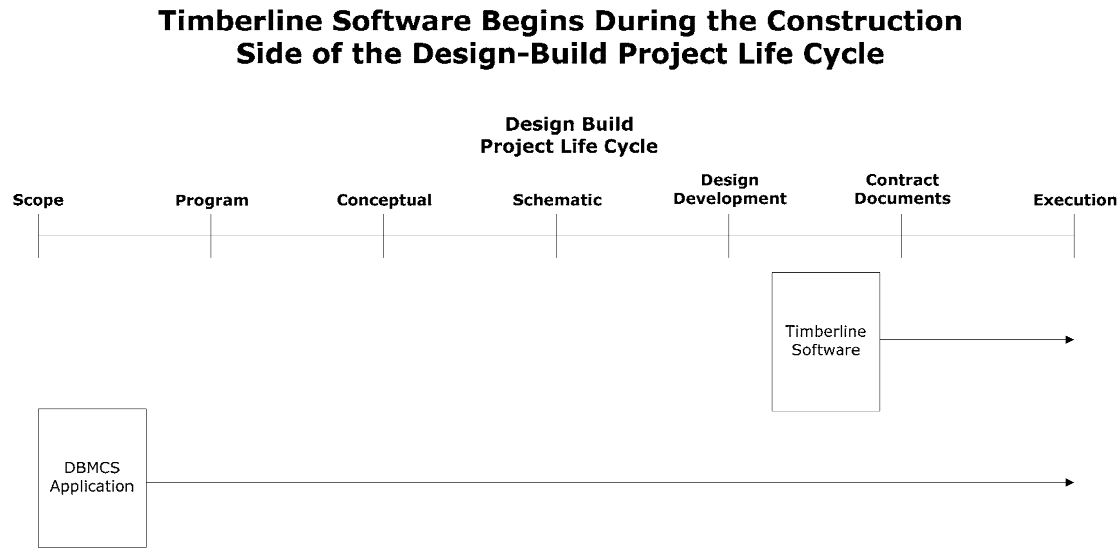

Figure 5
Design-Build Life Cycle and Timberline Software
Design-Build Life Cycle Showing Timberline Software Begin point. DBMCS Designed to Support Entire Life Cycle by Supporting the Design Side of Life Cycle.

Any project data detailed in the early phases of the design-build project such as scope, program, conceptual, and schematic is either discarded or must be manually processed to the Timberline applications.

These software applications have increased efficiencies, controls, and project reporting of the business enterprises; however, the next generation of software development is for business applications to be tailored specifically to control / manage a company's entire project business process from inception to completion. The future of information technology systems is to provide a company with a single source application that is tailored specifically to an individual company and its business process. An application that is unique for both the external business process of the industry supported as well as the company's internal work processes. These applications will be created to support, document, report, and drive the best practice work process for an individual company throughout their entire business cycle. These applications will seamlessly connect company data to all applications designed to control work functions.

3.4 Silos of Data and Interoperability

Although the construction industry has recognized the advantages of collaborative design-build construction processes, the industry has yet to obtain an information system that is able to integrate A/E services with construction services.   Presently, A/E services are conducting their processes utilizing tools designed for their A/E activities whilst construction services are completing their activities with separate tools created specifically for the construction process only. Unfortunately, data from the preliminary work processes performed by the A/E services cannot be used with the disparate systems utilized by the construction service. Even when design-build services are conducted under one roof via a single entity, the tools being used have been developed to support a more traditional style of contracting for both the A/E and the Contractor.

Not only are the tools used by the industry not designed for an integrated design-build industry, the legacy tools used by both A/E and construction services have not been fully integrated within the traditional system. Each software package is utilized independently of the other system. Scheduling modifications were not tied directly to account software and contracts may or may not have been based on sequential events in the schedule. This creates "silos" of data and information that is not shared from one business process to another.

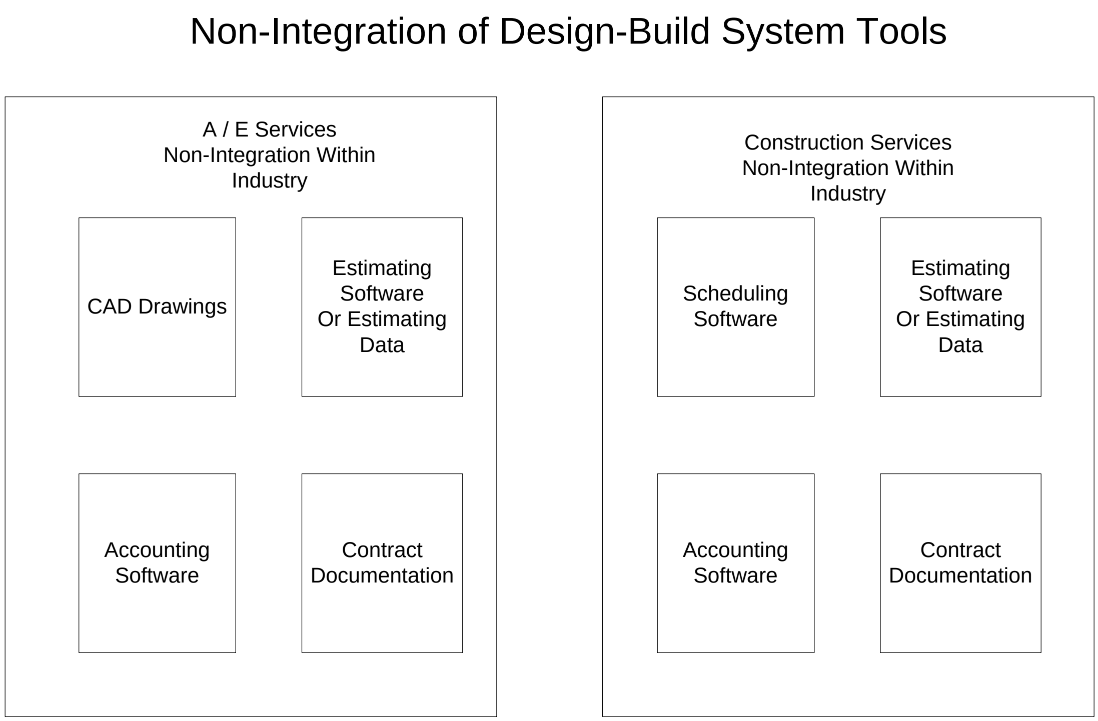

Figure 6
Non-Integration of Design-Build System Tools
Under the traditional form of contracting, information tools were not integrated within the industry. Design-Build further emphasizes the problem because it attempts to use non-integrated tools used for separate services within an integrated system

The following is an example of functions within the design and construction companies and some of the software systems which are typically used by a single firm:

• Estimating – Timberline, MC2, WinEst, Microsoft Excel

• Scheduling – Primavera P3, Primavera SureTrak, Microsoft Project

• Project Administration – Primavera's Expedition, Meridian's Prolog, Microsoft Word

• Accounting – Bidtek, Timberline's Job Cost

• Business Development – Microsoft Access

• Human Resources – Microsoft Access

• Executive Management – Microsoft Excel

The above list is not complete because there are many other software producers and in-house systems that have been developed and implemented. Even the software vendors that distribute products for a variety of functions do not generally have a seamless integration of data. According to the research conducted by Saeed Karshenas PHD at Marquette University, "the data exchange between two (or more software business modules) is not a simple and ubiquitous transformation. This lack of data sharing between platforms cause inefficiencies (referred to as non-interoperability) in a construction company's operations by requiring manual re-entry of data and multiple storage of the same data in various business units. The exchange of reliable information on a timely basis is cited as one of the major problems in the completion of projects on time and within budget."[14]

There are other reasons and benefits to interoperability. Below is a list of some of the benefits for data integration:

- Ability to Make Decisions Based Upon Complete Information – Integration gives managers access to comprehensive project information in their other corporate systems. Being able to look at information from more than one project and statistically compare that information is difficult to do with non-integrated tools[15].

- Ability to Make Quicker Decisions – Managers can make more timely business decisions based upon “real-time” project data.

- Increased Operational Efficiency – With integrated systems, there is no need for a “one-size fits all” approach. Instead, each employee can use the best tool for their particular job while the organization still benefits from integrated systems.

- Reduced Administrative Costs – Integration eliminates the need for someone to manually enter important information into different systems.

- Increase Collaboration Between Departments – Integration keeps everyone aware of developments in other departments, increasing communication and collaboration[16].

- Application Synergy - Application synergy is a term used to describe a scenario in which an application performing one task becomes more efficient due to its interaction with another application. For example Microsoft Project management scheduling software becomes a more effective tool if it can be linked with accounting software that is notified when there is a payment date change do to a project schedule adjustments.

- Enforced Best Business Practice – Applications that combine all various business process of an organization can begin to enforce and document best practice business processes. For example a scheduling change of more than 3 days can trigger an immediate sign-off from management and notify the contractual software of pending changes.

Mark Erler vice president of Panattoni Construction, an integrated design-build firm that specializes in commercial, industrial, office and manufacturing facilities, uses the following suite of software tools:

- WinEst Construction Estimating
- Timberline Gold Construction Accounting package
- Prolog 6.0 Construction Project Management software
- Microsoft Project 2000 CPM Scheduling
- AutoCad 2000[17]

In addition to these applications Panattoni created an internally developed application for estimating. For Panattoni Construction none of these applications have the ability to transfer data from one to another except via a manual processes. Erler agrees there are shortcomings to their current software available to support the design-build process and he is continually researching the latest solutions. He has researched the latest software and sees several companies that have offered collaboration solutions to his existing problem; however, these collaboration software packages are mainly software platforms that allow for files to be placed in a shared location for all stakeholders to view. The current collaboration applications do not supply Panattoni with seamless data transfer in which a change to a schedule could be immediately available to the accounting software[18].

In an article titled “Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry” published by NIST, the author suggests that the cost of poorly integrated data within the design and construction industry cost as much as $15.8 billion annually. The NIST defines poor data integration as “interoperability”.

> Interoperability is defined as the ability to manage and communicate electronic product and project data between collaborating firms’ and within individual companies’ design, construction, maintenance, and business process systems. Interoperability problems in the capital facilities industry stem from the highly fragmented nature of the industry…

The NIST summarizes the justification for this cost as:[19]

> The cost of inadequate interoperability is quantified by comparing current business activities and costs with a hypothetical counterfactual scenario in which electronic data exchange, management, and access are fluid and seamless. This implies that information need only be entered into electronic systems only once, and it is then available to all stakeholders instantaneously through information technology networks on an as needed basis.

Interoperability is even a larger issue for an Integrated Design-Builder, not only is there an issue of using disparate software applications that cannot share information, many of the applications used cannot be used in both design phases and construction phases. Applications such as Timberline Construction Software have mostly been designed to support a construction project beginning at the construction documents stage of the project life cycle. The earlier phases (design side) of the design-build life cycle are not considered or supported by the system to the detail required by a Design-Builder. The result is application data that has to be manually transferred or lost when transitioning from the design phase to the construction phase.

Chapter 4

INTEROPERABILITY

4.1 Purpose

The purpose of this chapter is to document literature reviews concerning interoperability and to discuss the information technologies current solutions to overcome interoperability in the industry.

4.2 The Information Technology Industry Solution for Interoperability

The information technology industry has recognized the issues that face the construction industry concerning the use of disparate, non-integrated software applications. As discussed, the issue of interoperability is heighten when applied to the design-build industry that further complicates the issue by considering the data needs to be shared between design business processes and construction business processes. A major contributory factor to poor project performance in the construction industry is known to be the lack of integration and coordination between the different disciplines involved in various stages of the procurement process[20].

The Information Technology industry has attempted to resolve these issues using one of three methods

- Data Transfer (Import / Export function) between business applications

- Single Source Application Design – A single source database that can store data in a method that can be used by several business applications.

- Collaboration Software – application that give the user a place holder to share information with all stakeholders

4.3 Interoperability Solution 1: Data Transfer (Import / Export function) between business applications

Many Information Technology companies have posed data transfer models as a solution to non-interoperability. One company, Primavera System solution is shown in Figure 7 (from Primavera Systems) from a business white paper located on the Primavera web site. In this white paper Primavera poses their solution to non-integration as a series of import / export functionality to various applications and/or modules[21].

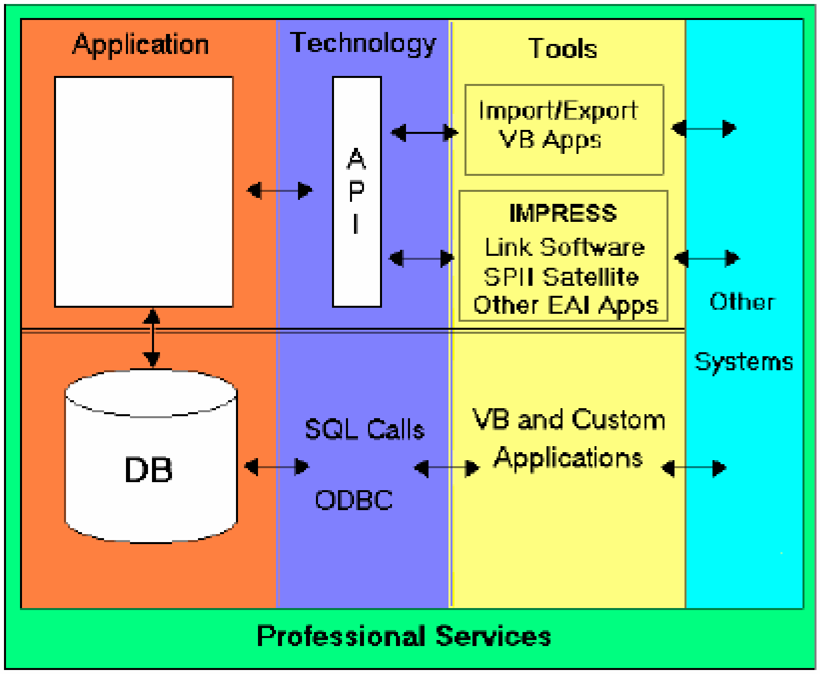

Figure 7
Primavera System's Approach to Integration
Diagram from Primavera Systems whitepaper documenting Primavera solution to the issue of non-integrated tools within the industry.

Primavera solution is to integrate data by creating custom interfaces along with imports and export data functionality to various applications that require the data. The figure below conceptualizes Primavera's approach to data integration.

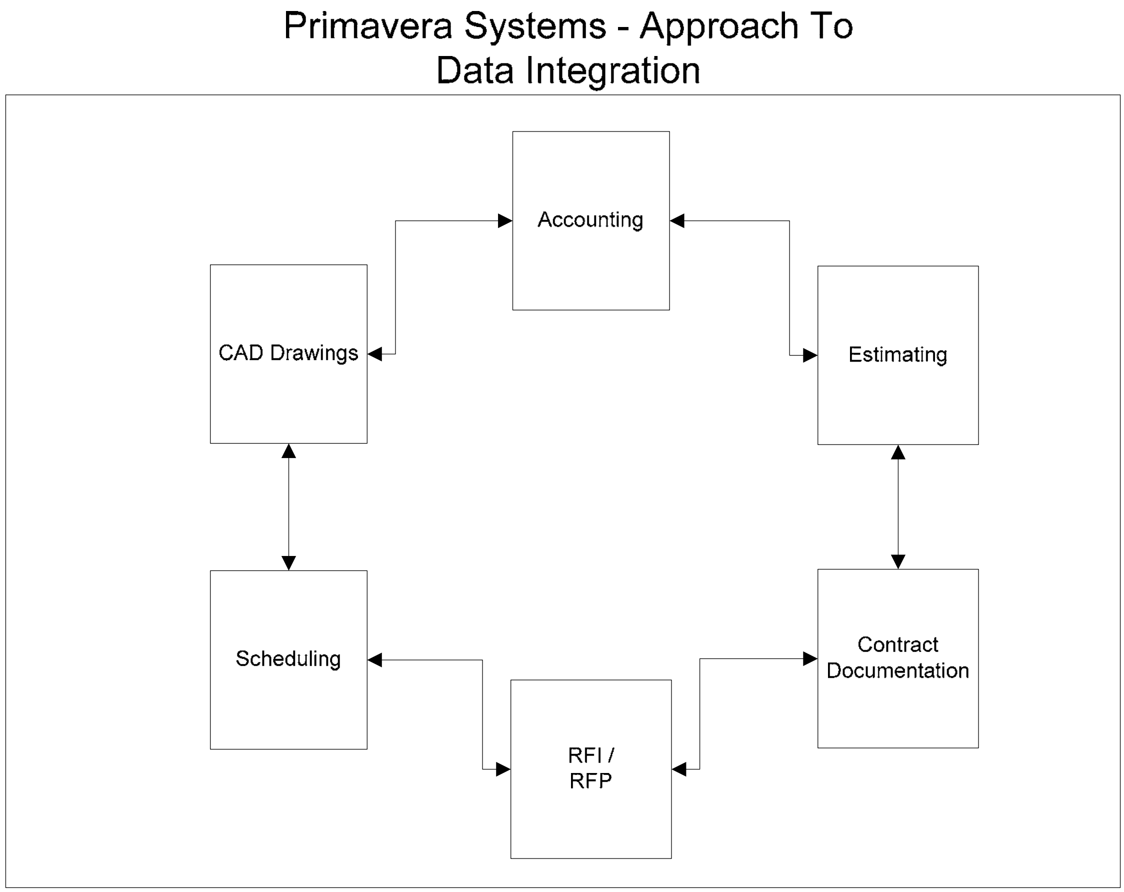

Figure 8
Analysis of Primavera System Approach
Diagram showing Primavera Systems solution to the non-integrated data. Integration achieved via import / export data functionality passed between various modules / applications.

The Primavera approach has several major shortcomings from the Design-Builder's perspective:

1. Data redundancy – Applications store similar or often the same data in various applications. Import / export functionality creates the risk of various applications containing less up to date information than one of the other applications.

2. Passing data from one application / module does not allow for a system that in always updated and can contain additional built-in quality controls. This is a requirement in development of a true management control system.

3. Primavera is only integrating data between various project management activity modules and does not consider the need to integrate data throughout alternative phases of the design-build life cycle.

4. It is costly process to create export / import functionality on an annual basis[22]. Yearly updates to each software application need to be considered with each change. In other words this is not a process that can be created in one year, rolled out for use, and never updated. Consistent communication between various manufactures of software must be coordinated. Many of the applications do not use the concept of open architecture design – meaning that many aspects of the application may be un-accessible for use to the creator of the data transfer process.

4.4 Interoperability Solution 2: Single Source Data Format

Having a single source data format means that your project data has a central repository that can be used by any business application process used by the company. There are two approaches that have been attempted by the Information Technology industry to resolve interoperability using single source data format. The first solution is to create software application that encompasses more than one business activity. The second solution is to create company specific database that store data into a primary database useable by all company business applications. The later systems are called Enterprise Resource Planning (ERP) systems because they are created to tie together all company / enterprise data into one database that can be used by multiple functional software and other databases.

4.4.1 Single Source Application Performing Multiple Tasks

Single source applications are applications that perform more than one business function within a single system. An example of this type of application being used by the construction industry is Meridian Systems. Meridian Systems Reliance application designed specifically for the management of construction contracts. Meridian System attempts to integrate the management of construction contracting, accounting systems, and scheduling via a single source database. Internal to their own software application exist project management modules (such as scheduling) that can be output / generated from the single source database structure. This gives Meridian Systems the ability to be a true management control system because data modification made can be seamlessly updated in the various project management modules and company business process / procedures could theoretically be added to the system; however Meridian Systems (like Timberline) begins it first level of details at the construction documents phase of a project. Meridian has no link to design-side life cycle data such as preliminary schedules and estimates. Therefore project management activity module integration is achieved; however the life cycle data integration is not.

Some construction companies have found the use of off-the-shelf project management software not to be as easy as advertised and reluctant to replace all other types of software being used by a company. Eric Hoffman of Hoffman Construction, for example, said that his company chose to have its own project software custom-built because it was too difficult to integrate the off-the-shelf management software with their current accounting software stating "We were happy with the accounting software we had, and we didn't want to change that." The company decided that giving up their accounting software in the name of integrations would have amounted to an “inverted set of priorities”. The software was not accommodating enough to his company’s business process[23].

There are other applications in existence that have attempted to integrated various application processes into one system however there is not yet a single software system that can do all the functions required by the construction industry. According to Saeed Karshenas, PH.D at Marquette University this is mainly due to the following circumstances unique to the construction industry:

- No Two Construction Projects Are the Same - Unlike manufacturing, construction projects vary from project to project. In addition to differences in building design and construction, differing site conditions, weather and variety of project delivery methods can also contribute to a project's uniqueness.

- Varied Construction Company Structure and Operations - Construction companies themselves are varied and construction companies' business structures can come in many forms. There is not a standard structure or organization chart and often the same job title can have differing responsibilities. Also, differing contracting methods can affect the process; some companies self-perform work with their own crews whereas others act only as contract administrators.

- Varied Data Storage - Data is acquired in a variety of ways. Paper forms and computer systems are the most prevalent; however, the degree of computer usage can vary among contractors. Additional data can be acquired through plans and specifications, pictures and product samples, to name a few.

- Varied Reporting Formats - There are a variety of reporting formats and there are differing types of reporting and data collection forms used. Contractors vary in the form requirements; some of the typical forms used for data collection are Daily Reports, Time Sheets, Change Order Logs and Submittal/Transmittal Logs[24].

4.4.2 Single Source Company Specific Database - Enterprise Resource Planning (ERP) Systems

These systems are called Enterprise Resource Planning (ERP) systems because they are created to tie together all company / enterprise data into one database that can be used by multiple functional software and other databases. Examples of these types of system are SAP, Oracle, PeopleSoft, and J.D. Edwards. These types of system are used throughout the business world in relatively the same manner – they are created by a company as a "first layer" application that stores relevant data that can be exported or shared with relevant business applications for further data processing. For example a business organization can create an Oracle ERP data receptacle for all relevant company data / information. From that main ERP system data can be transferred to various business applications such as Microsoft project software in order to output desired results.

ERP do attempt to create a central repository for all project management activities however there are several drawbacks to these types of system:

- Recreating Required Inputs – In order to seamlessly convert data from an ERP to a business application for further processing all relative inputs to that business system need to be encapsulated within the ERP system. Because this is usually not possible most ERP system are created only to contain high level company details and are not used as the input device for to all business applications.

- Costly to implement – ERP implementations range from $2 million to $130 million and take at least six months for even simple business processes.

- Consistent Update Requirements – as with data transfer methods, such as those suggested by Primavera, business applications go through annual changes and modifications. Keeping up with the new requirements needed to be considered is not an easy task. In addition many business applications are not open source data applications in which data can be processed directly to the destination application[25].

4.5 Interoperability Solution 3: Collaboration Applications

A collaboration application is an application that is put in place to improve communications amount stakeholders on any project. The four leading collaboration software providers in the construction industry are[26]:

- Autodesk Buzzsaw (Industry Leader)[27]
- Meridian Project Systems
- Constructware
- Citadon
- BIW Technologies (United Kingdom Industry Leader)[28]

All of these application providers are attempting to resolve the problem in relatively the same manner. They have recognized the issue of facing the industry and have provided users with a relatively straight forward means of data collaboration. The user is given a portal internet application that can be used as a central repository for all business date. This central repository in NOT a single source data repository as discussed above; rather it is a central repository of separate business application data that can be accessed by multiple users for various needs.

According to Autodesk Collaboration Software white paper they have recognized that design-build, in contrast with the more traditional construction methods, has more highly complex communication needs where all stakeholders need to make changes to the project that have the potential to cause significant issues. Autodesk Buzzsaw is an[29]:

> Online collaboration service that establishes one secure internet location where all project documentation is saved. Team members use the site to share, update, track and archive material. Buzzsaw automatically detects when a newer version of a file has been uploaded so users can be confident that they are always working from the latest version.

Constructware recognizes the issue facing the construction industry stating poor communication as the most significant issue that can be improved on the current status of construction projects. Constructware solution to this issue is similar to the other collaboration software providers. Constructware provides potential users with internet storage facility for all individual application data[30]:

Constructware has been designed specifically for intensive inter-team communication and collaboration. Any type of data or document can be uploaded and viewed by other members of the project team. Excel spreadsheets, schedules, correspondence, faxed documents, photos and other sources of information are uploaded and available to all parties in a structured way. CAD drawings can be stored, viewed, marked up and routed without the need to load native CAD software on individual PCs. Related documents can be linked within the system and routed to companies that have shared responsibility on an issue.

According to a 2006 survey conducted by Building Design and Construction only 8.2% of respondents believe that project collaboration software will have a leading impact on designing and constructing buildings[31]. This may be due in part to the fact that collaboration software is currently only a communication tool. The above listed collaboration software is not a central data repository but rather a file storage and file sharing repository. The latest files are check-out from this repository and manipulated on the individual users local machine within a business application (also present on the local computer). A user updating the latest schedule would be required to have the latest version of the scheduling application available on their local system in order to make changes. Changes would be made and then uploaded back to the collaboration software storage facility for other users. Therefore, collaboration software does not resolve any issues of interoperability - collaboration software simply makes the data from various applications is available to multiple users.

Chapter 5

CONCEPTUAL DEVELOPMENT OF A DESIGN-BUILD MANAGEMENT CONTROL SYSTEM

5.1 Purpose

The purpose of this chapter is to introduce a conceptually developed alternative solution to the current information system available for use in the design-build industry. The basis of this system was to create a system that could overcome the limitations of the systems described in the previous chapters. This chapter will review all the business aspects that the system needs to support and document how each aspect can be supported with the proposed systems.

5.2 Conceptual Design of the Design-Build Management Control System

The Design-Build Management Control System (DBMCS) is a conceptual internet based business application designed specifically for an Integrated Design-Builder. Although the system could be used by the other design-build entity types; primarily the focus was on development of a system particular to the truly integrated operation. This is because many of the other business entity variations of design-build that form on a project by project basis continue to operate under the more traditional means of construction. Although these operations are contractually tied they may continue to operate as separate entities for most business processes.

The DBMCS application has been designed to specifically support an Integrated Design-Builders typical business operation and improve the shortcomings of the current information technology applications available to the industry. In order to accomplish this, the DBMCS will be required to:

- **Achieve Seamless Interoperability -** Achieve complete Interoperability of all various design-build business application modules including scheduling, accounting / cost control, estimating, contract formation

- **Achieve "Design-Build Interoperability" –** For an application to achieve design-build interoperability the work-flow of the Architect / Engineer (A/E) with Constructor must be seamless. Project data created during the design phase of the project must be usable and maintainable as the project passes into the construction phase.

- **Document, Improve, and Assist in Managing Design-Build Key Business Aspects -** Information Technology system should be designed to enhance the chances of achieving a successful project. The design-build delivery method was created to improve construction projects therefore an information technology application created for the industry should be able to assist in ensuring that those key attributes are achieved. The DBMCS should help management meet the key business attributes of design-build including:

a. **Single Responsibility:** A/E and Constructor have a single responsibility to deliver a project that meets the Owners needs, within budget, and is on time. DBMCS should assist and document that both the A/E and Constructor are in mutual agreement to quality, budget, and schedule at all phases of the project life cycle.

b. **Project Quality:** Design-Build allows for an Owner to spend more time focusing on Owner needs early in a project. DBMCS should assist in documenting Owners needs and ensure that those needs are meet (or addressed) at every phase of the design-build life cycle.

c. **Cost Savings /Time Saving:** 57% of Owners choose design-build delivery with the goal of reducing project cost. 38% of Owners sited reduce length of schedule[32]. Design-Build is often chosen by Owners for its ability to shorten the project life cycle and reduce project cost. Fast Tracking is a form of design-build in which construction begins prior to portions of the design being complete. DBMCS must be able to support a fast-tracked design-build construction project with complete interoperability at all phases of the project life cycle.

d. **Early Knowledge of Completed Project Cost:** One the major benefits of design-build are early knowledge of project cost can be known in advance of other delivery options[33]. DBMCS must assist a company in producing to an owner an accurate (within life cycle percentages) estimate of completed project cost. While early (in the project life cycle) knowledge of total cost is important to Owners, it is even more important to the Design-Builder. Early knowledge of cost may be the single most important factor in determination of profitable / successful projects vs. non-profitable / unsuccessful projects.

e. **Improved Risk Management:** A majority of owners (53%) choose design-build in order to reduce Owner risk on a project[34]. Much of this risk to the Owner is lowered due to the A/E and Constructor single responsibility; however portions of this risk is transferred to the Design-Builder that is now responsible cost, schedule, and quality of the entire project. The DBMCS must assist in reducing the risk to the Design-Builder.

- **Useable for All Variations of Specialized Design-Build Contracts:** As discussed in an earlier section design-build has many different contracting variations. A DBMCS should be flexible enough to support any contractual methodology without risk of losing project interoperability.

- **Improve Communication With Project Stakeholders:** Communication is a key to success of a design-build construction project. The DBMCS should ensure that all stakeholder requirements are communicated and documented at every phase of the life cycle.

5.3 DBMCS Requirement 1: Achieve Seamless Interoperability

The DBMCS is designed to store individual project data in a central repository so that all output functionality including scheduling, estimating, account, contracting can be output from the source data rather than each application storing its required data in various formats. This is an alterative approach to that of each disparate business application storing data in its own required format. This approach is also different from that to the Enterprise Resource Planning (ERP) Systems in that the application business modules are part of the DBMCS. An ERP system attempts to generate data that can be used by all various applications via export/import processes; the DBMCS internally uses its own business process modules (such as scheduling). It should be noted that the DBMCS can still work with a company specific ERP; however it is suggested that the ERP contain only information outside of the scope of the actual construction project. The DBMSC becomes a single source application (as described above) that can control the project data requirements for any design-build project throughout the project life cycle. The ERP system may still be required but on a limited scale; controlling items specific to the organization but outside the scope of the construction project data.

Using this approach provides the user with a more seamless integration of tools, allows for an instantly adjusted project alternative output based on new input to the system, builds in company specific system requirements, and controls quality over all project data regardless of the were a change to the data is made. Data change to a schedule can instantly reflect a change to an estimate. Additionally, company project business procedures can be enforced / controlled within the system because the data is contained with in a single repository. Figure 9 shows that the DBMCS shares one central construction project database that contains all necessary data elements needed by various business application modules.

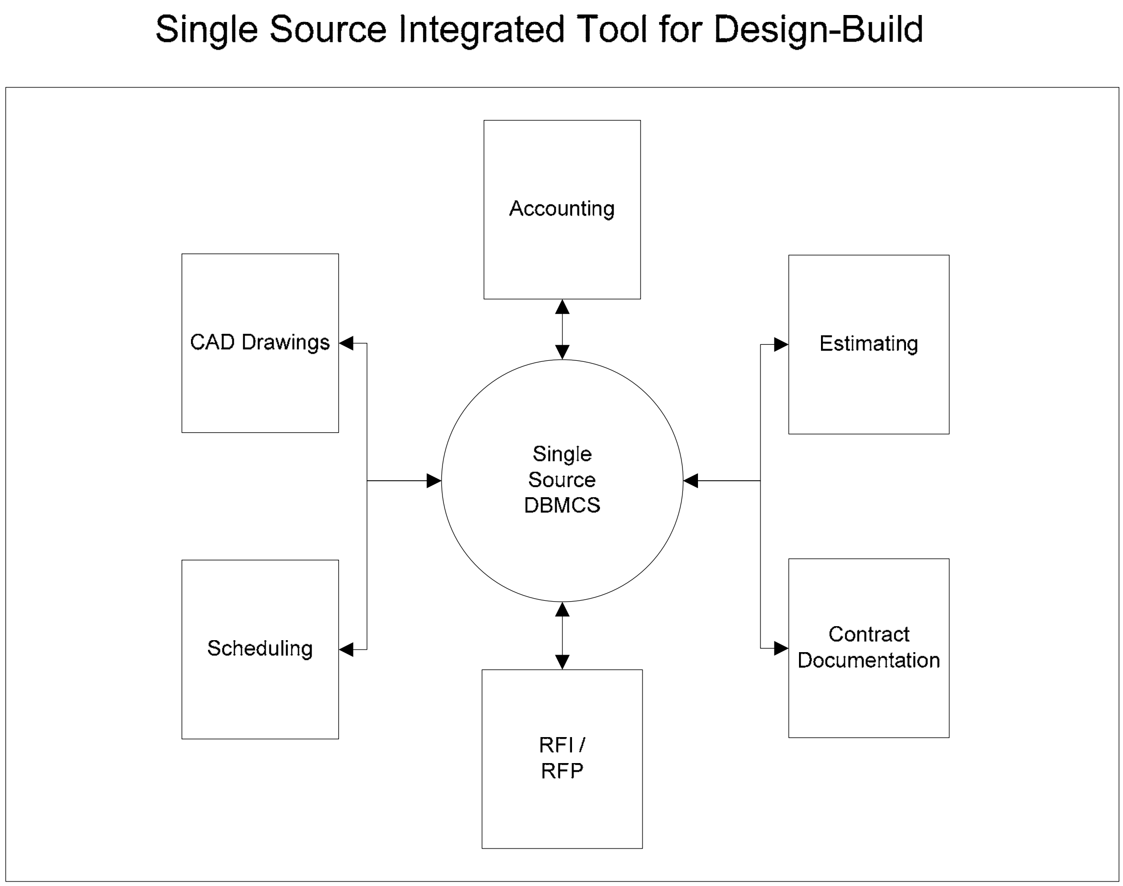

Figure 9
Single Source DBMCS Data Repository
A system designed to support the design-build industry work flow and promote synergy among various applications.

5.4 DBMCS Requirement 2: Achieve "Design-Build Interoperability"

DBMCS not only integrates the data contained in various project management activity modules (estimating, scheduling, accounting, etc) it also integrates the data processed in various life-cycle phases a design-build project. Data created early in the design-phase of the life-cycle is useable and available during the later phases of the project. This is accomplished by creating a single data repository that contains not only the data need to output schedules, estimates, accounting and contract documentation, additionally it contains hierarchal information data that moves along the design-build life cycle. This hierarchal process allows for data early in a project to be integrated (and usable) late in the project. The details of how this is accomplished are discussed in detail later in this paper. In summary the data is stored within a single data repository that is capable of outputting all construction management reporting requirements at any point in the design-build project life cycle allowing data created in the early stages to integrate (and build) into the data required in the later stages. Having data contained in a single source repository is essential in development of a true management control system. Supporting this side of the life cycle give the Design-Builder the ability to seamlessly merge the design data with the construction data.

In order to achieve seamless interoperability and "design-build interoperability" the DBMCS must be cable of describing the current project (in a useable data format) at any point in time during the design-build life cycle. This was accomplished from a business methodology with the creation of the DBMCS Construction Information Classification

System and the DBMCS iterative process and from a technology methodology with the use of XML data storage format.

5.4.1 DBMCS Construction Information Classification Systems - Uniformat II and MasterFormat

To create a single data repository capable of outputting all design-build project management activities at any point in time during the project life cycle required careful consideration. The basis for this single data repository is the “DBMCS Construction Information Classification System”. The Construction Information Classification System is used to describing any structure / project being controlled by the DBMCS at any point in the design-build life cycle. The DBMCS requires a Construction Information Classification System that can integrate the A/E work process and management activities with the construction process.

Although several Construction Information Classification Systems exist in the design and construction industry, the two most widely accepted systems are Uniformat and MasterFormat. Uniformat has been the system of choice for design services because of its hierarchal approach to creating a Construction Information Classification System that allows the designer to define a building throughout the various phases of the design process. MasterFormat is the Contractors’ system of choice because it is trade based and most easily divides subcontracted work packages into applicable trades.

The Construction Information Classification System used by the DBMCS is a combination of the Uniformat / MasterFormat Construction Information Classification System. The combined Construction Information Classification System of Uniformat / MasterFormat is the creation of Robert P. Charette, co-chairman of the ASTM Task Group that developed UNIFORMAT II.[35] This system was chosen because it is a hierarchal format that will allow the system to be continuously integrated work processes (scheduling, accounting, estimating, etc) throughout all phases of the design-build life cycle. A model for this system is shown in the figure below.

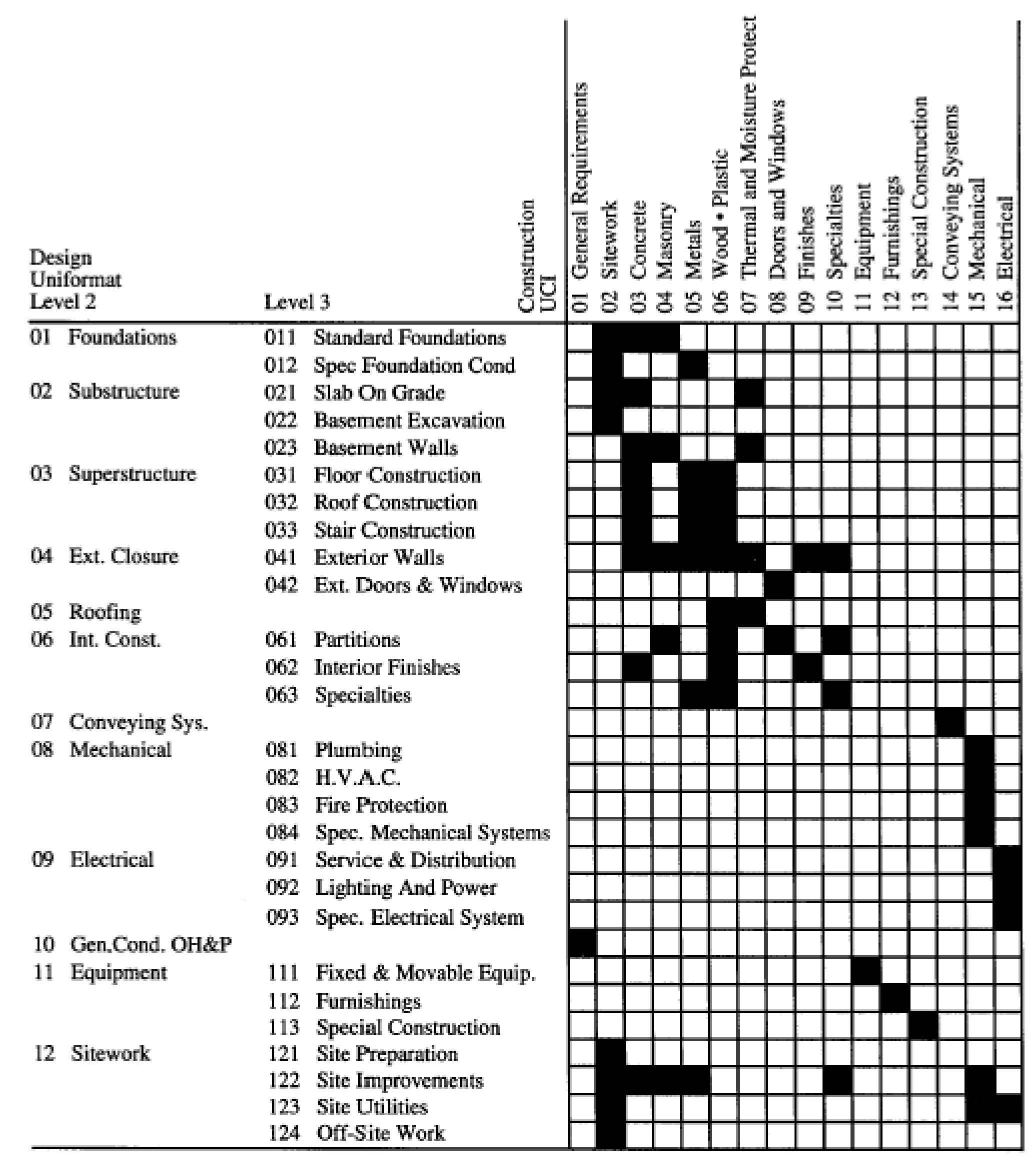

Figure 10
Charette's Construction Information Classification System
Robert P. Charette's Construction Information Classification System as described in Uniformat II Elemental Classifications. A combined Uniformat / MasterFormat 95 system developed by the ASTM Task Group

Charette's graphical representation is an attempt to show how Uniformat can be linked with MasterFormat to create one Building Construction Information Classification System. Using this linked system a Design-Builder can describe any construction project at any point in time of the design-build life cycle. Charette links the disparate systems of Uniformat and MasterFormat by graphically displaying connections. For example Uniformat Level 3 Standard Foundation is made up of three MasterFormat95 sections: Sitework, Concrete, and Masonry.

Charette's Construction Information Classification System was created using MasterFormat 95. The DBMCS has updated this Construction Information Classification System to support MasterFormat 2004 and to add some of the missing details reported in Charette's system. Figure 11 shows the connection of the DBMCS Construction Information Classification System with the supported MasterFormat 2004 for A Substructure and B Shell. The full version of this Figure can be seen at the end of this document with full details of all Uniformat and MasterFormat Levels (Appendix A). The grid below excludes Uniformat Level Four for simplification purposes; however the DBMCS itself does contain this level and associated MasterFormat 95 details.

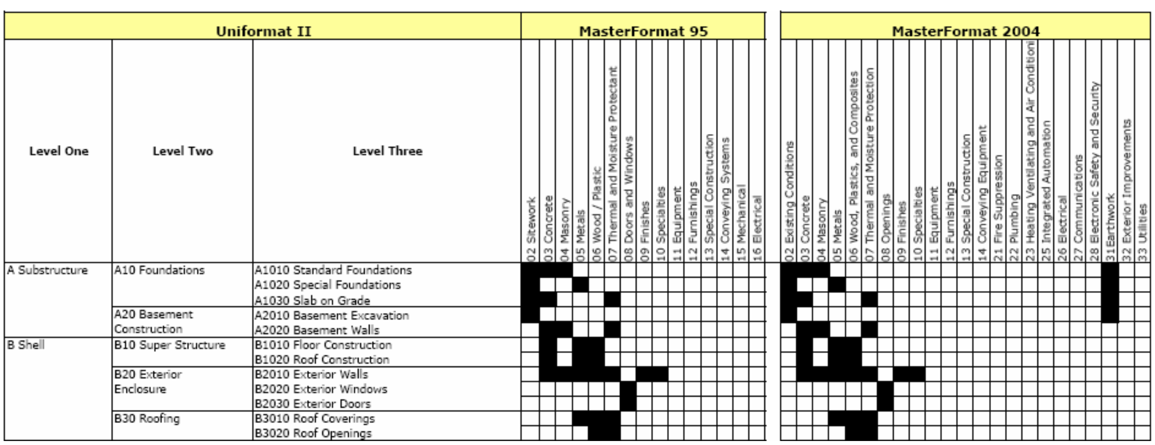

Figure 11
DBMCS Construction Information Classification System
A combined Uniformat / MasterFormat 2004 System (note: this figure only shows the details for A Substructure and B Shell. The entire grid can is available at the end of this document titled full version of Figure 5.3.B - full version).

Note: The mapping of Uniformat to MasterFormat shown in Figure 12 excludes Uniformat Level 4 that is used by the DBMCS in order to simplify the concept. Figure 12 shows the mapping of part of A Substructure with the inclusion of Uniformat Level four. The full version of this mapping can be found at the end of this document.

Uniformat Level Four To Master Format - A Substructue

Uniformat		MasterFormat 2004																						
Level Three	Level Four	02 Existing Conditions	03 Concrete	04 Masonry	05 Metals	06 Wood, Plastics, and Composites	07 Thermal and Moisture Protection	08 Openings	09 Finishes	10 Specialties	11 Equipment	12 Furnishings	13 Special Construction	14 Conveying Equipment	21 Fire Suppression	22 Plumbing	23 Heating Ventilating and Air Conditioning	25 Integrated Automation	26 Electrical	27 Communications	28 Electronic Safety and Security	31Earthwork	32 Exterior Improvements	33 Utilities
A1010 Standard Foundations	A1011 Wall Foundations	■	■	■																		■		
	A1012 Column Foundations & Pile Caps	■	■																			■		
	A1013 Perimeter Drainage & Insulation						■															■		■
A1020 Special Foundations	A1021 Pile Foundations	■	■																			■		
	A1022 Grade Beams	■	■																			■		
	A1023 Caissons	■	■																					
	A1024 Underprinting	■	■																					
	A1025 Dewatering																					■		
	A1026 Raft Foundations	■	■																					
	A1027 Pressure Injected Grouting	■	■																					
	A1029 Other Special Conditions	■																				■		

Figure 12
DBMCS Construction Information
Classification System (Unifomat Level Four)
DBMCS Construction Information Classification System with the inclusion of Uniformat Level Four as used by the application. (Note: a full version of this mapping can be seen at the end of this document)

The DBMCS Construction Information Classification System contains the following hierarchal order: Uniformat Level 1 > Uniformat Level 2 > Uniformat Level 3 > Uniformat Level 4 > MasterFormat Level 1 > MasterFormat Level 2. Figure 12 graphically shows how the system is connected at the change over point from Uniformat to MasterFormat.

Important to note that although one section of Uniformat is connected to MasterFormat, the entire MasterFormat Division would not be available - only the MasterFormat division that equates to the connected Uniformat division. For example Uniformat Level Four A1035 Under-Slab Drainage & Insulation would have MasterFormat Division 33 Utilities available to add as detail. The entire section would not be seen in making the connection - only the applicable section 33 46 00 Subdrainage with the applicable subsections. This would make the job cost number A1035_33_46_19 for Underslab Drainage once the user "drill-down" to the lower level.

33 46 00	**Subdrainage**		
33 46 13	Foundation Drainage		
		33 46 13.13	Foundation Drainage Piping
		33 46 16.16	Geocomposite Foundation Drainage
33 46 16	Subdrainage Piping		
		33 46 16.13	Subdrainage Piping
		33 46 16.16	Geocomposite Subdrainage
		33 46 16.19	Pipe Underdrains
33 46 19	Underslab Drainage		
		33 46 19.13	Underslab Drainage Piping
		33 46 19.16	Geocomposite Underslab Drainage
33 46 23	Drainage Layers		
		33 46 23.16	Gravel Drainage Layers
		33 46 23.19	Geosynthetic Drainage Layers
33 46 26	Geotextile Subsurface Drainage Filtration		

Figure 13
MasterFormat Section 33 46 00 and Children Activities

Other sections of the project would also have access to MasterFormat Division 33 but only via the correct link to Uniformat. For example Electric Utilities Service would be available via G Building Site Work > G40 Site Electrical Utilities > G4010 Electrical

Distribution > MasterFormat Division 33 Utilities - making its job code G4010_33_71_73.

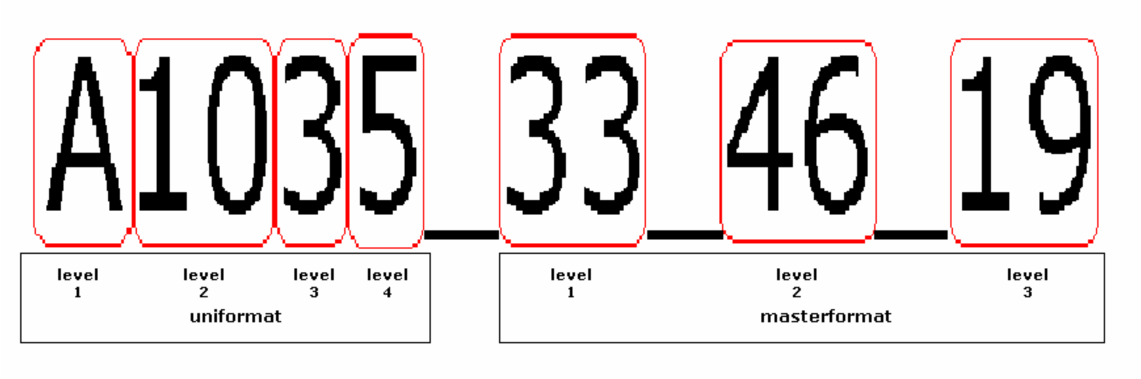

Figure 14
Job Code in DBMCS
Showing the job code for Under-Slab Drainage as created through the DBMCS

This hierarchal order is a required order of the system that is enforced on every project. This does not mean that all levels of the project are required to be described at the same level of details; it only means that for the project to be described at Uniformat Level 4 (for example) the user of the system must access this detail by first going through the corresponding previous levels of details. For example, if the project manager decided on a standard Wall Foundation for a given project that Wall Foundation could be added to the project within the DBMCS application only after the corresponding previous levels of Uniformat were added to the project. In Information Technology terms these corresponding Uniformat Levels would be described as the ancestors to Uniformat Level Four A1011 Wall Foundation. The project Manager would be required to first add the eldest ancestor to A Substructure. Once A Substructure was added the "children" of A Substructure would be available – A10 Foundations and A20 Basements. Users of the DBMCS system are not required to fully detail all ancestor added; however relevant details should be provided based on what is know at that point of the design-build project life cycle.

5.4.2 DBMCS Construction Information Classification Systems and Design-Build Life Cycle

The DBMCS is not only attempting to integrated the data of various business application modules used in the construction industry it is also attempting to integrate the data throughout the life cycle of the project. Primavera approach to data integration may be able to partially overcome "silos of data" between various applications; however it does not overcome the issue of "silo of data" created between various phases of the design-build life cycle. The DMBCS attempts to integrate both various project management activity modules and data in alternative phases of the life cycle.

During the early phases of the project when few details are known the project can be detailed at high levels using Uniformat. As the project progresses and details are added, the Construction Information Classification System can continue to add details to previously entered high level details using lower levels of Uniformat combined with high levels of MasterFormat. This will also satisfy the unique requirement of allowing Design-Builders to detail one section of the project with detailed prescriptive specifications to MasterFormat level. The existing Uniformat Construction Information Classification System is limited at detailed levels and does not go beyond the design development process as outlined in Figure 15 below. The DBMCS will enable specifications at MasterFormat level while other portions of the project can be performance based at various levels utilizing levels not detailed past Uniformat.

The figure below estimates the Uniformat levels with the corresponding phases of the design-build life cycle. For example: A project being managed by the DBMCS would be expected to be described to levels of Uniformat Level Three at the Conceptual Stage of the design-build life cycle.

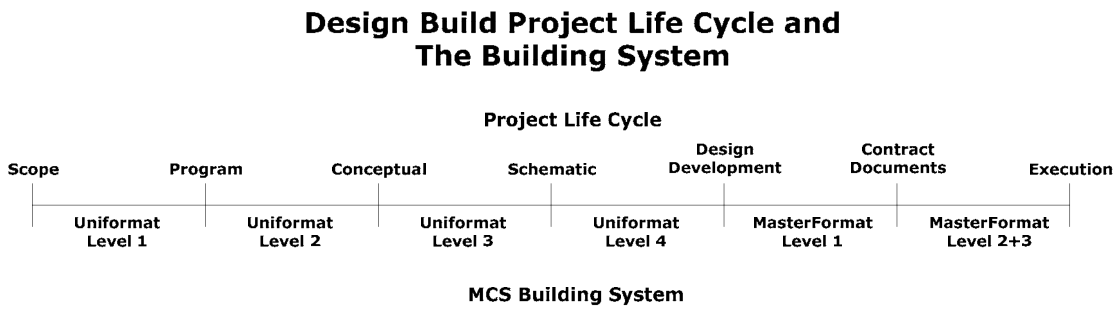

Figure 15
Design-Build Life Cycle and DMCS Construction Information Classification System
The design-build life cycle timeline with the expected corresponding details of the DBMCS Construction Information Classification System.

The Construction Information Classification System begins with the project details that occur during the scope and program stage of the project. During the conceptual and schematic stages information about the project is added and the system begins to define the project through the first level of Uniformat. As more information and requirements are added to the project, the system can continue to add the same details between Levels two through four via Uniformat. Using this system the building details can be maintained in the system during all stages of the design-build project life cycle. Furthermore, if certain portions of the project have additional details at any point of the life cycle, the system can maintain integration throughout the project at all times.

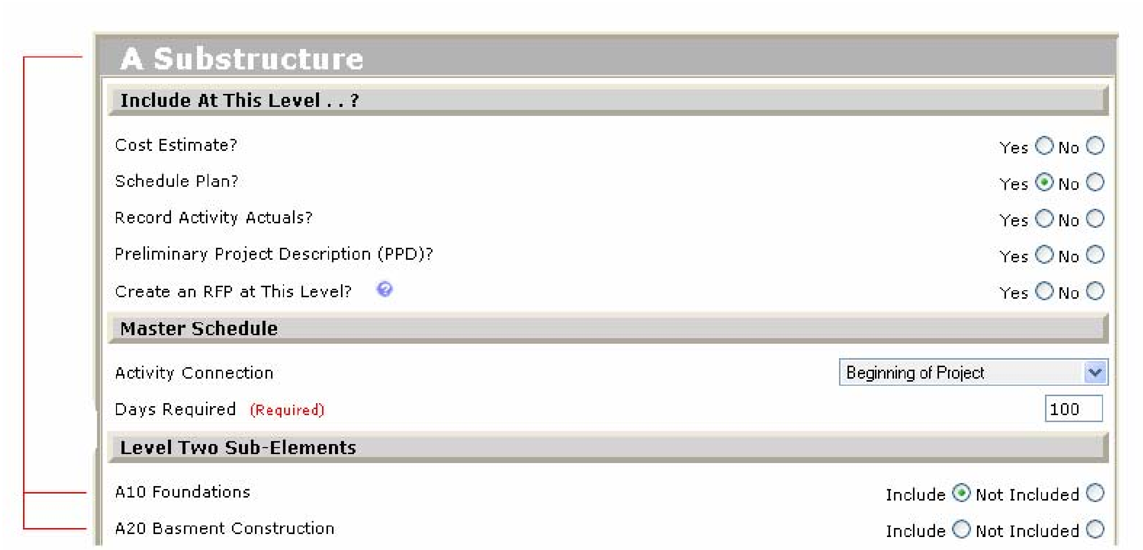

Figure 16
DBMCS A Substructure Page
A Substructure Page (Uniformat Level One) has been added to the Project. The only available details that can be added are the children of A Substructure – A10 Foundations and A20 Basement Construction (Uniformat Level Two).

When a structure has been defined through Uniformat Level four, the DBMCS allows for additional levels of MasterFormat to be included with supplementary detail. Only the applicable MasterFormat categories defined in the grid system described in the figure presented in the previous section of this paper are available to the Level 4 Uniformat item. For example, Uniformat 1011 Wall Foundations has MasterFormat activities referred to as children that include 02 Site Work, 03 Concrete, and 04 Masonry. These are the corresponding MasterFormat trade activities that can make up Uniformat 1011 Wall Foundations.

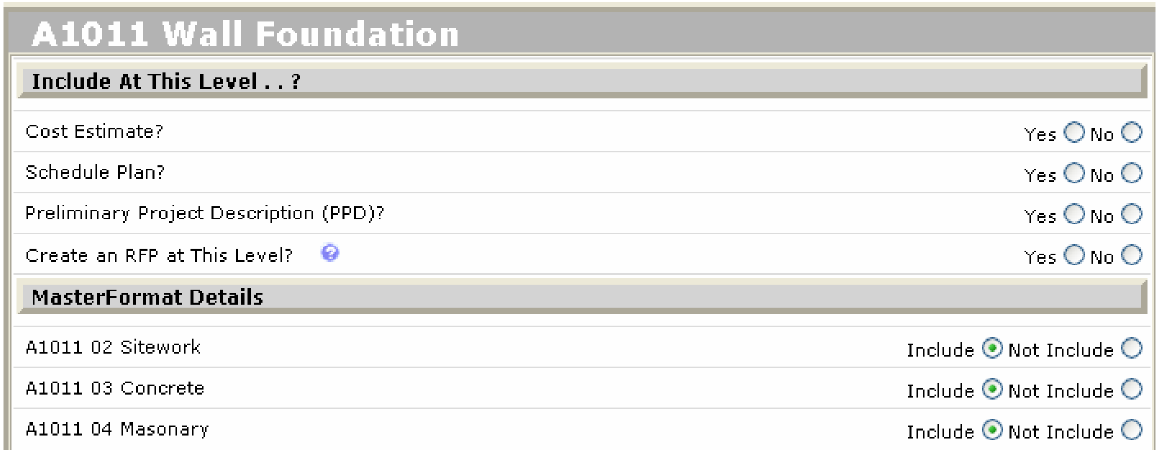

Figure 17
DBMCS A1011 Wall Foundation Page
The user has the option to further define the Wall Foundation by adding the children activities of MasterFormat such as 02 Site Work, 03 Concrete, and 04 Masonry.

The Construction Information Classification System is designed to allow a process in which the DBMCS can control the design-build process from beginning to end. Each individual step within the build system will continue to process the particular activity regardless of the current stage of the project life cycle or the variation of contract formation used.

The system begins with defining the project in the scope and program stage. During the conceptual stage, high level details are defined and the activities of the A/E service can define these details within the system by beginning to describe the building with high level Uniformat. The known details and/or requirements of the project progresses along with the design-build project life cycle. As more information is determined and developed regarding the building requirements, further details can be added to the control the system. This iterative process continues for each portion of the project until all project stakeholder requirements have been satisfied to the level of detail required to create a work package.

5.4.3 The Iterative Process of the DBMCS

An iterative process of defining, planning, and analyzing requirements should continue throughout the entire life cycle until stakeholder requirements have been satisfied and such requirements are contracted. Once stakeholder requirements have been met the Design-Builder can determine if the current needs should be further defined or if the appropriate details have been accumulated to contract a complete work package.

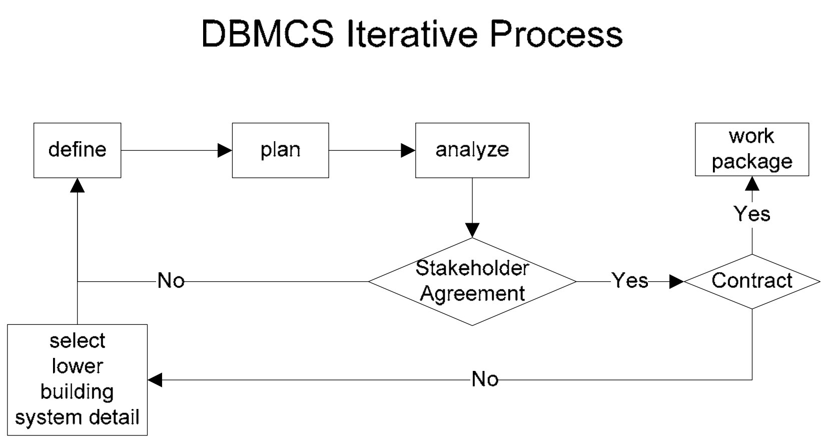

Figure 18
DBMCS Iterative Process
The iterative process is used to define the project. All new details are added when meeting stakeholder requirements. Details can continue to be added until contract formation occurs.

Once stakeholder requirements have been met and the required levels of specifications are obtained to contract the work, then the applicable section of the project can be made available for a Request for Proposal (RFP).

Not all levels must be defined within the DBMCS; however there may be a benefit to enforcing this as a business process. Defining each level prior to adding lower level children details allows for the system to quality control all stakeholder requirements throughout all levels. Forcing the business rule of defining each level prior to continuing to add children details could give the Design-Builder the ability to enforce business review that each level of detail added conforms to the stakeholder requirements defined during addition of the parent activity. The DBMCS does not force each level to be defined however consideration should be given to the benefits of doing so.

In addition, not all portions of the project are required to be detailed at the same level. For example the Substructure may be contracted separately with several different detailed prescriptive specifications requiring system details to be defined through multiple levels of MasterFormat. However, the Shell portion of the project may be contracted with high level performance specifications that can be satisfied with only one sub-contract. The DBMCS in this case should be defined to the contract level for both activities of the project. The Substructure should continue with the Iterative Process through the appropriate MasterFormat level required - ensuring all required prescriptive specifications are detailed accordingly. The Shell, however, should continue the iterative process only to the required breakdown that can adequately provide the proper performance specification to be contractually met.

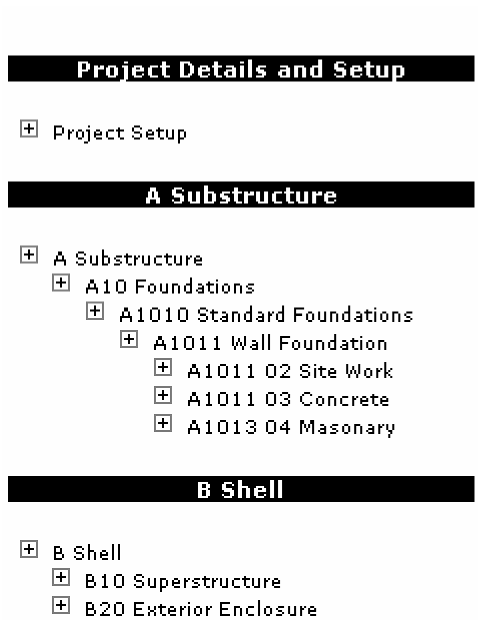

Figure 19
DBMCS Navigation Bar
A-Substructure defined with prescriptive specifications through MasterFormat Level 1 and Shell defined with performance specifications through Uniformat Level 2.

At any level of detail of the DBMCS, the Design-Builder can apply any desired system details to control the project. Scheduling, Estimating and Job Costing, Writing Specification (performance or prescriptive) can occur at any level of the DBMCS Construction Information Classification System.

When a design-build contract contains mixed levels of performance details along with some prescriptive requirements providing a building description utilizing a hierarchal format such as Uniformat to MasterFormat allows for one section of the project to contain minimal details for performance requirements (such as the substructure) while another section of the project (such as the structure) may contain more detailed descriptions.

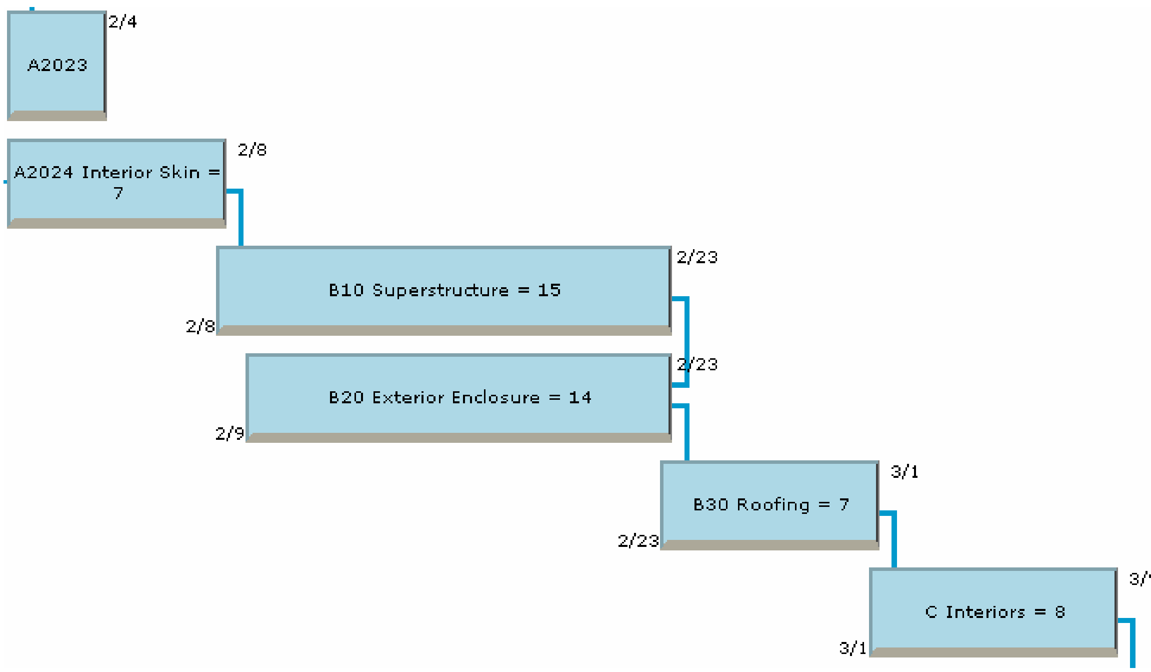

Figure 20
DBMCS Schedule Module
Substructure Uniformat Level 4 combined with Shell Uniformat Level 2 and Interiors Uniformat Level 1.

This system is designed to support the Design-Builder and should not be used to estimate and schedule individual subcontracted activities. The system is no longer required to define schedules and estimates once an element of the system has reached a point in the activity in which it is set-up as a work package and contracted. Individual subcontractors will have their own schedule of work and activities required to fall within the parameters of their contracted work package. However, if the Design-Builder is completing elements of the Construction Information Classification System in house, then the DBMCS should define those activities at the individual task level required.

The Design-Builder can achieve this by defining the particular element past the third level of MasterFormat. Once the element has been defined to this level the Design-Builder can add any child tasks with an individual description to schedule and estimate a work process.

5.4.4 The DBMCS Data Storage Format - Extensible Markup Language (XML)

Sections 5.4.1 to 5.4.3 describe the business methodology of how the DBMCS should be designed in order to achieve the proposed business requirements. Technologically, these business requirements are achieved with the use of a hierarchal XML (Extensible Markup Language) data storage format.

XML is a simple, very flexible text format data storage system. Originally designed for large-scale electronic publishing, XML now plays a more important role in the exchange of a wide variety of data on the Web and between various applications[36]. One of the other major benefits of XML is it simplistic approach to data relationships. Data can be formatted in a hierarchal family type relationship using parents, children, grandchildren, etc relationships. The figure below shows a sample XML data file with the practical relationships of a list of books and the related details of each book.

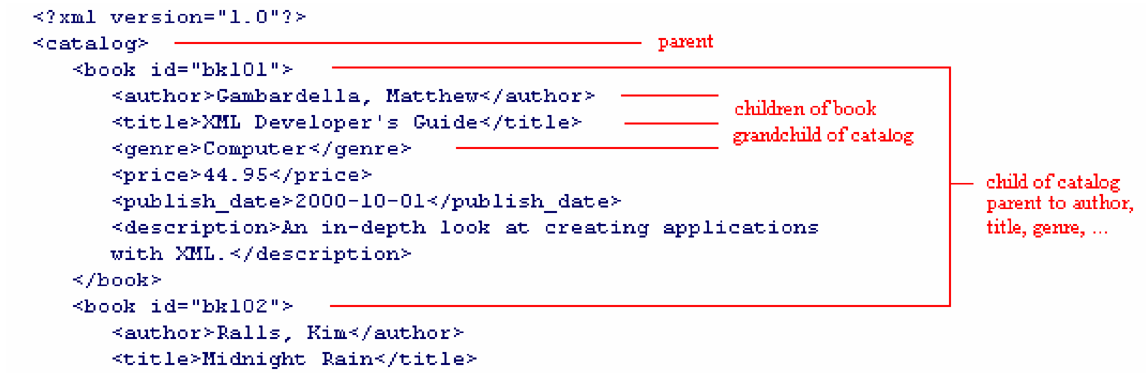

Figure 21
Sample XML Document
Showing family tree relationship for list of books in data storage as example[37]

The data relations are stored based on the hierarchal format. Each book has a related author, title, etc. and can be queried for data retrieval or calculated based on the inherent hierarchal format.

The DBMCS stores its data using a similar family tree type style that capsulate the design-build life and the DBMCS Construction Information Classification System described previously in this chapter.

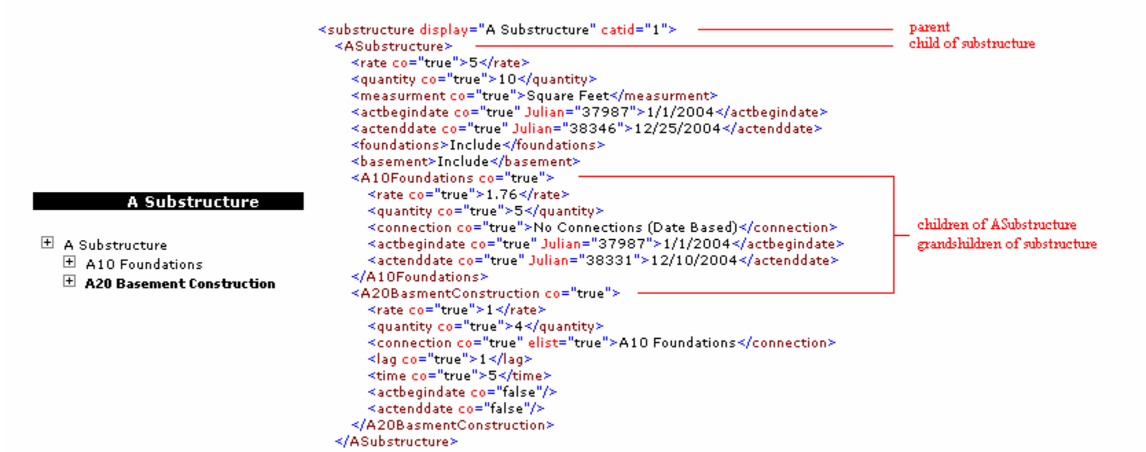

Figure 22
DBMCS Sample XML Document
Showing family tree relationship in the XML data storage of two levels of the Substructure portion of the DBMCS Construction Information Classification System.

This XML data storage schema is the key to the DBMCS. Allowing the information system to add details as a project progresses along the design-build life cycle the DBMCS iterative process. A Substructure's early phase data can overridden with the addition of A Substructures children data A10 Foundation and A20 Basement Construction as it is added in later phases of the project. Importantly the earlier phase data of A Substructure remains allowing for it to be used later in the project to assist in describing the children activities as they are added or at the end of the project to determine estimating accuracy as projects progress. For example, A Substructure early estimates can be set as a threshold estimates to the children activities added later in the project. Additionally an early level estimate accuracy percentage can be calculated based on comparing the details entered as the project progresses.

5.5 DBMC Requirement 3: Document, Improve, and Assist in Managing Design-Build Key Business Aspects

The goal of any new information system should be to assist and support in the management of business using the system; therefore a key ingredient of the DBMCS is that is must document, improve, and assist in managing all unique business advantages associated with design-build. Because the DBMCS stores project data from the earliest design phase to completion, the project data can be used be used not only to improve each stage of a current project but can be used to improve future projects.

5.5.1 DBMCS Key Business Aspect 1: Managing Single Responsibility

A/E and Constructor have a single responsibility to deliver a project that meets the Owners needs, is delivered within budget, and is on time. Many of the delays associated with the more traditional method of contracted were the result of issues between the Designer and Contractor. The design-build process takes full advantage of open communications among Designer and Contractor that were traditionally separated using design-bid-build. This is perhaps the most significant factoring advantage over traditional methods; The A/E is involved from the initial proposal through closeout. This continuity of involvement by A/E significantly increases the likelihood of completing the project in accordance with early expectations and proposed requirements[38].

The DBMCS must assist a Design-Builder in documentation of those responsibilities and ensure that Constructor and Designer are in agreement with the delivery requirements at every phase of the design-build life cycle. Much of this requirement is accomplished via the "iterative process" used by the DBMCS. At each phase of the project life cycle the system should enforce newly added levels of details to be in agreement with those already provided in the completed phases.

When early estimates and schedules are created in the preliminary process such items can be applied as base-lines when further details are added to the project – for example, if the designer estimated A Substructure at a cost of $300,000 the system could enforce that budget on future children details being added or mandate proper executive approval when budgets are in jeopardy. This life-cycle integration allows a company to maintain percentage variations as estimates progress from low-level details to high-level details in comparison to the actual results. These variations can be used on subsequent projects to help the Design-Builder conduct better estimates in the early phases of the project and properly manage the risk of budget overruns at each stage of the project. Lastly, stakeholder requirements can be continually maintained throughout the project. Enforcing project managers to define every level of the DBMCS Construction Information Classification System give the project the ability to ensure that as details are entered stakeholder requirement confirm with those entered during earlier phases of the project. Note the DBMCS does not enforce details to be entered at every level of the Construction Information Classification System; however there is justification for doing so when considering compliance with stakeholder requirements. The DBMCS has left this option to the discretion of the company business process.

5.5.2 DBMCS Key Business Aspect 2: Improve and Document Owner Quality Expectations

Using today current software tools available, project management activities are not continually up to date during the early phases of projects. As suggested by the NIST article discussed earlier in this document concerning interoperability, data should “only be entered into electronic systems once, and it is then available to all stakeholders instantaneously through information technology networks on an as needed basis”. Because the DBMCS has integrated the data along the project management life cycle the schedules, estimates, job costs are continually up to date. Project managers are not required to recreate schedules or estimates. The DBMCS is designed to allow the Project Manager to add the new information available and regenerate complete estimates, schedules and job cost immediately.

5.5.3 DBMCS Key Business Aspect 3: Cost / Time Savings (Support Fast Tracking Design-Build)

Fast-Tracking is a contract method in which one portion of a project is at a different phase of the life cycle then another portion. For example, a project that is fast tracked could theoretically have the Substructure in the execution phase while the Shell is still in the Design-Development stage. The DBMCS subsection allows for individual levels of detail to be continually added while maintaining a single schedule and a single estimate at any moment of the project.

The DBMCS integrates a scheduled timeline as details are added to a project. An early schedule may be planned to complete the Substructure in 30 days and then schedule to start the Shell at the completion of the Substructure.

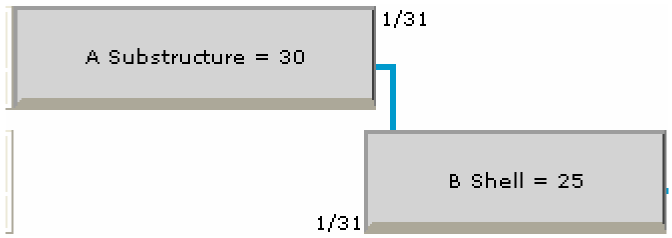

Figure 23
DBMSC Scheduling Module at High Level
DBMSC Scheduling Module showing high level details of B Shell Schedule to begin at the completion of A Substructure.

The DBMCS allows for the Substructure to move to later stages of the life cycle without the Shell having to be further defined. Theoretically, A Substructure could progress though the design development phase (which may be defined to MasterFormat details) without the B Shell progressing out of the conceptual stages. Within DBMCS, the components will adjust the existing timeline for each project taking into consideration the stage of other activities. For example, if B Shell was scheduled to start at the completion of A Shell, B Shell will seek out the latest “child” activity detailed to the Substructure and rearrange the schedule to reflect its completion stage within the existing outline of the project.

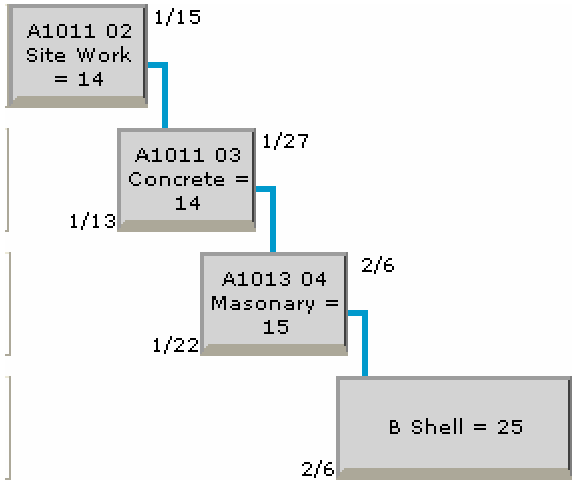

Figure 24
DBMSC Scheduling Module – Fast Track
DBMSC Scheduling Module showing a fast track schedule with the Substructure in design-development phase while the B Substructure is still in the Conceptual stage. The schedule and estimate can be maintained at any moment of the project even when fast tracking has various components at alternative phases.

Scheduling details of B Shell did not have to be redefined to accommodate a new schedule. The B Shell activity is simply re-connected automatically to the newly defined timeline of A Substructure's children activities. In or example, B Shell was previously connected to the completion of A Substructure. When the details of A Substructure were further defined the connection with B Shell was not lost. Unless the user of the DBMCS determines that a new connection to B Shell should be made the system will automatically re-connect the know facts and estimates of B Shell to the newly added details of A Substructure.

Using this method schedules and estimates are continually up to date with all currently known details of the project. If B Shell becomes further defined later in the project the DBMCS user would have the option of connecting that detail to the "youngest children" of any other part of the project.   For example if B Shell was being further defined by adding B10 Superstructure details the DBMCS user would be able to define B10's schedule connection to any of the latest children activities of A Substructure or to the entire activity itself.

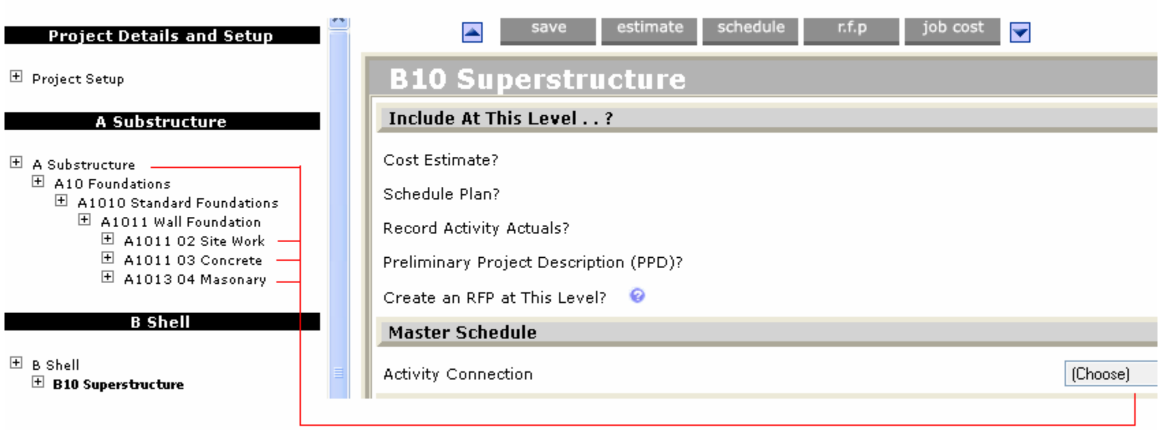

Figure 25
Adding Details to DBMCS
When adding details new connections are available. The red line connects to those activities are available to define the schedule connection of B10.

If it was now know that the B10 Superstructure can start 4 days prior to the completion of Wall Foundations 04 Masonry work then the user could link as shown in figure 26 and generate a new schedule as shown in figure 27 without any other change to the DBMSC system.

Figure 26
Superstructure With Activity Connection
B10 schedule activity further defined with new connection details. Output of schedule shown in Figure 27

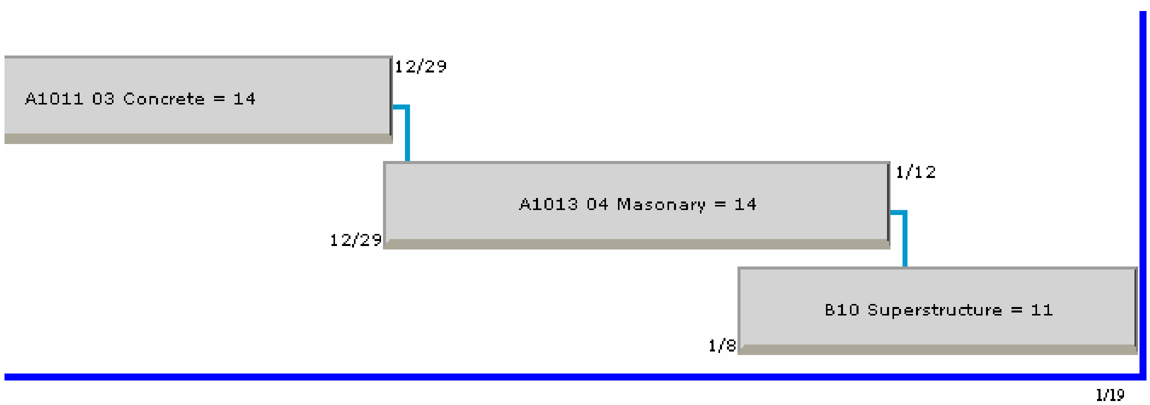

Figure 27
Schedule Output With New Connections
DBMSC Scheduling Module showing B10 schedule activity further defined with new connection details.

The DBMCS will continually adjust the schedule and the estimates at any moment regardless of each component being at equivalent stages of the design-build life cycle.

Job Code	Descriptions	Quantity	Unit	Rate	Cost
A	**A Substructure**				**30,000**
A10	A10 Foundations				30,000
A1010	A1010 Standard Foundations				30,000
A1011	A1011 Wall Foundation				30,000
A1011 02	A1011 02 Site Work	10000	VLF	1.20	12,000
A1011 03	A1011 03 Concrete	30000	Square Feet	.45	13,500
A1011 04	A1013 04 Masonary	15000	Each	.30	4,500
B	**B Shell**	**10000**	**Square Feet**	**5.25**	**52,500**

Figure 28
DBMSC Estimating Module
DBMSC Estimating Module - Fast Tracking has the Substructure estimated to the design-development phase while B Substructure is still estimated at the Conceptual phase. The estimate can be maintained at any moment of the project even when fast tracking has various components at alternative phases.

5.5.4 DBMCS Key Business Aspect 4: Improve Design-Builder Knowledge of Early Firm Cost

Owners often select design-build delivery because a Design-Builder can provide firm project cost earlier in a project that under traditional methods. To the Owner this means that they can move forward with go-no-go project business analysis earlier in a project and can obtain secure financing prior to designs being completed. To the Design-Builder; however this early firm cost (if guaranteed) can be considered the most important aspect of achieving a successful and profitable project vs. a failed non-profitable project. Mark Erler Vice President of Panattoni Construction (an integrated design-build firm that specializes in commercial, industrial, office and manufacturing facilities) agreed that “with design-build the name of the game is now how well Firms

can accurately estimate the total cost of a project early in the design-phase of a project.[39]"
The Design-Builder that can accurately estimate total project cost at the time of contract formation is the number one contributing factor to the success of the company.

Now that a single source application is used for all phases of the project the Design-Builder can utilize early project data later in the project and can also utilize detailed data from other projects (that used the same data storage format) early in the design stage via parametric estimating and scheduling. Figure 29 shows that using the same application to manage both the design phases and construction phases allows for early design data to be used later in the project and allows for historic data from other project to be used early in the design phase of the current managed project.

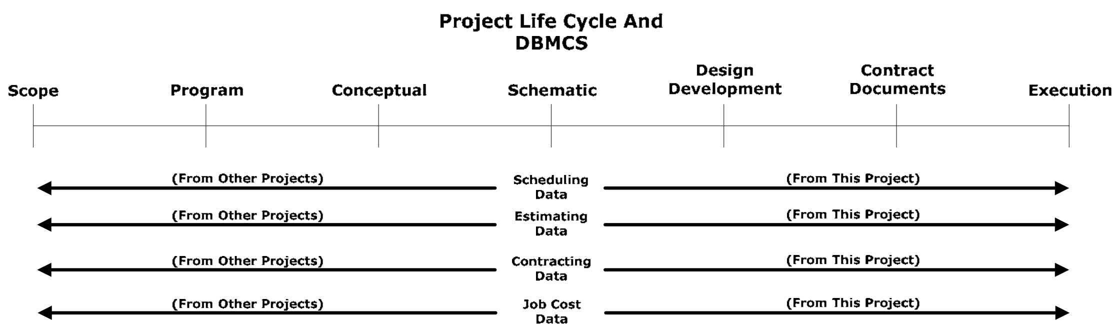

***Figure* 29**

Design-Build Life Cycle and Data Flow of The DBMCS

Early estimates during the design side of the life cycle can be used during later phases of the project. Detailed data (late in project – even to completion) can be used from other projects to provide more accurate preliminary estimates and schedules.

The data moving right to left is available because the DBMCS forces all project to be controlled in the same format. Because other projects have been controlled using the same format the DBMCS can use data from other company projects as a base line for the current project schedules and estimates. Because the DBMCS is hierarchal in the Construction Information Classification System control the details added early in the project can be used as baselines later in the same project.

A Company can establish project to project integration with the ability to manage each construction project with the DBMCS system. Each project manager will be utilizing the same application and process on all projects. The Skyscraper project in Atlanta will be managed and controlled within the same DBMCS outline as the Single Story Library in San Diego. Both projects will be comparable at relative levels of the systems details. Both the Skyscraper and the Library will have early level estimates and schedules consisting of corresponding items of Uniformat “A Substructure”. Both projects will be able to analyze actual performances against estimated performance. Executive Management can quickly compare the on-time schedule of the Library with that of the Skyscraper.

Using a hierarchal system to define a building allows for a project to use historical data to estimate and schedule projects in the preliminary stages when details are vague. Elemental estimates allow for a project to be estimated earlier in the project using actual costs from previous internal projects completed or other estimating sources such as RS Means. Similarly, the Canadian Institute of Quantity Surveyors publishes elemental estimating that is subdivided into categories similar to the Uniformat classification.

Because the Construction Information Classification System of the DBMCS is the same from project to project, high level detailed cost of predecessor projects can be used to determine low level detail cost of future projects. “A Substructure” can be estimated using square foot estimate of other completed projects total children activities. The figure below shows A Substructure total cost as a sum of all its children activities, using the same system from project to project allows for the system to better estimate early defined details because each project has been managed using the same system. Additionally, the schedule of a new project can be determined based on the total time spent on children activities from other projects. The figure below shows estimate output from the DBMCS for a project that has various portions of the project defined at various levels of detail.

Job Code	Descriptions	Quantity	Unit	Rate	Cost
A	**A Substructure**				**20,500**
A20	A20 Basement Construction				20,500
A2020	A2020 Basement Walls				13,300
A2021	A2021 Basement Wall Construction	4000	Square Feet	2.10	8,400
A2022	A2022 Moisture Protection	4000	Square Feet	.30	1,200
A2023	A2023 Basement Wall Insulation	4000	Square Feet	.70	2,800
A2024	A2024 Interior Skin	2000	Square Feet	.45	900
A2010	A2010 Basement Excavation				7,200
A2011	A2011 Excavation For Basement	2400	Linear Foot	2.00	4,800
A2012	A2012 Structure Back Fill	1000	Linear Foot	1.20	1,200
A2013	A2013 Shoring	1	Each	1200.00	1,200
B	**B Shell**				**143,180**
B10	B10 Superstructure	10000	Square Feet	8.00	80,000
B20	B20 Exterior Enclosure	14000	Square Feet	4.12	57,680
B30	B30 Roofing	1100	Square Feet	5.00	5,500
C	**C Interiors**	**4000**	**Square Feet**	**2.30**	**9,200**
D	**D Services**	**1200**	**VLF**	**5.00**	**6,000**
E	**E Equipment / Furnishings**	**1200**	**Linear Foot**	**3.00**	**3,600**
F	**F Special / Demolition**				
G	**G Site Work**				
				Building Elemental Cost Without Design Allowance	182,480
				Overhead (6%)	10,949
				Profit (5%)	9,124
				Building Construction Cost	202,553

Figure 30
DBMCS Estimate Output With Alternative Phase Details
DBMCS Estimate Output. Elemental cost estimates of a Construction Information Classification System with each section at various phases with known details. The total of "A Substructure" is derived from the total of all its children activities.

Because the data from this one project is stored in a hierarchal format and other projects enforce the same format, project to project data integration is achieved. Early high level estimates of A Substructure (on a new project) can use the summation of more detailed data from other projects.

5.5.5 DBMCS Key Business Aspect 5: Improve Risk Management

Because the DBMCS is hierarchal in nature the output of the individual work package and RFP is beneficial derivative of using the system. Because the system has continually defined the <u>all</u> stakeholders requirements throughout every level the output of the work package is as simple as a check of the box.

Because stakeholder requirements have been evaluated at every level in the DBMCS's iterative process (define > plan > analyze), the output of the work package can occur at the point in which all stakeholders have achieved final agreement on the level of details required for the project. Each new level of the DBMCS request that the system contain project description available at that phase of the project; these descriptions should be entered so that stakeholder agreement can be achieved as the project progresses. The stakeholders may not agree that the final level of detail has been achieved; they only need to agree that the description is meeting the current requirements of the project. Once the stakeholders agree on the level of detail for a particular section of the project, the RFP can be output from the system by selecting the option to "create an RFP at this level". Using this iterative process the system has the unique ability to continually define and ensure stakeholder requirements regardless whether those requirements are detailed enough to become a construction work package.

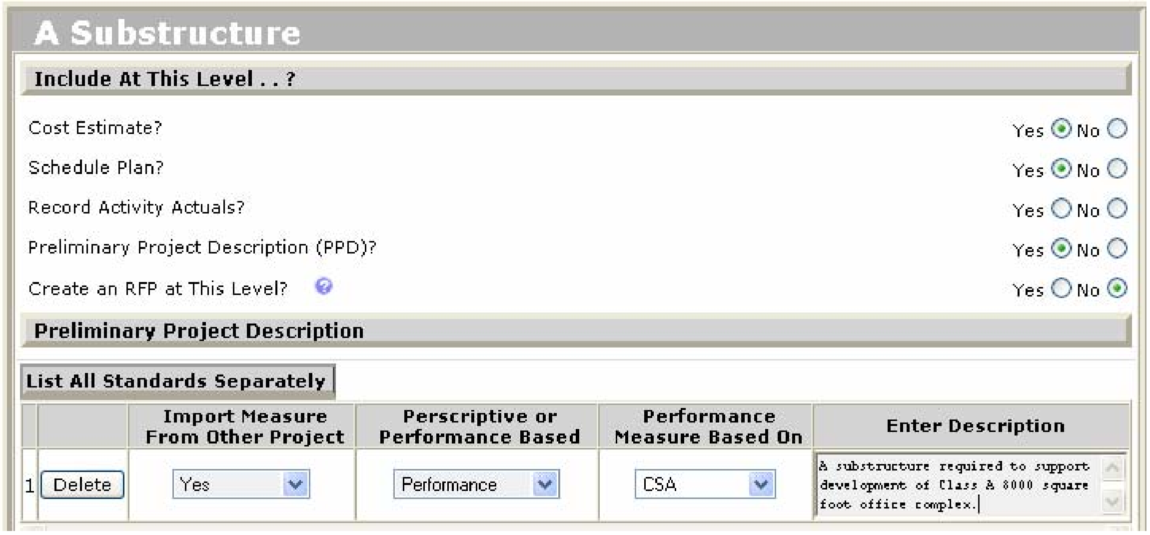

Figure 31
DBMCS Project Description Entries
A Substructure contains a performance specification that meets the project needs.

5.6 Useable for All Variations of Specialized Design-Build Contracts

As discussed earlier in this paper design-build comes in many alternative formats. Design-build can be utilized in its purist operational form such as direct design-build to formats such as bridging contract that more closely resembles a traditional design-bid-build – all forms were discussed earlier in this paper.

Making issues for information system design more complex is the fact that projects can be managed with a hybrid approach within the same contract where one portion of the project uses a design-build methodology that utilizes performance specification while other aspects of the project are contracted in a more traditional approach with prescriptive specifications tied more closely to design-bid-build operational variations.

The DBMCS can support all variations of contracting methods including alternative variations within the same contract. This is accomplished by the hierarchal Construction Information Classification System contained within the DBMCS. Each section of the system does not require the user to only define each required section of the project as required by the contract. If for example the contract required a standard foundation with detailed prescriptive specifications however allowed for a performance base resolution to the substructure than the user could immediately navigate to the applicable MasterFormat specification of a Standard Wall Foundation and maintain the required level prescriptive detail (to contracted level) for the shell. Using this approach any design-build contractual type (included a hybrid contract) can be supported by the DBMCS.

One of the major benefits of this approach will be realized on future projects. Even though the system user may not have defined all the high levels of the substructure in our example above – the data relationship of the lower level definitions is maintained in the system. This allows the data from this project, although only at defined at lower MasterFormat levels, to be used on future projects even if the future project regardless – as discussed earlier in the chapter.

5.7 Improve Communication with Project Stakeholders

Because the DBMCS requires all individual projects to be indexed in their corresponding hierarchal level the communication with Project Stakeholders is improved in two ways:

- Each project stakeholder can view the project data at the level they see fit. Because the project data maintains the hierarchal relationships, a mature project currently being scheduled at very detailed levels could be viewed by high level upper management at higher levels. For example upper management may only want to know the generalities of the project – for example that the substructure is behind schedule while at the same time the project manager requires to know exactly what details and specific task are behind schedule.
- As each new level of detail is added the project management can ensure that each level of new detail meets the requirements of the previous higher level already defined. At any point in time of the project the user can assess the how the current level of details agrees and corresponds to the earlier defined level of details. For example, if the project was transitioning from the higher levels of Uniformat to performance based MasterFormat specifications the system and the user can ensure that the new details meet the requirements defined in the previous level.

Additionally, because the DBMCS is an internet based application with self contain business modules (i.e. scheduling, accounting), the system can be accessed from any internet location in the world – regardless of that connection point containing all the various required application software as required by the collaboration software described earlier.

Chapter 6

CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The design-build construction industry has recognized the advantages of a collaborative contracting method; however it has not yet created information systems that can truly support the industry. Many software manufactures have attempted to modify existing applications; however a significant gap still exists between software developed to manager design phases, construction contracting, and execution of projects. The industry has recognized this as a problem and has attempted to integrate systems; this integration however has not completely resolved the issue that faced the more traditional construction methods and has certainly not resolved the more complex issues that face the design-build industry.

The DBMCS attempted to resolve both data integration between project management task modules and data integration of activities through the design-build life cycle. Using this conceptual approach to data storage and project management a design-builder may be able to create a true design-build management control system customizable to a particular company. Individual alternatives to the DBMCS's Construction Information Classification System may exist depending on a company's preference. The Uniformat to MasterFormat approach was selected in order to have a generic system that could be used by the design-build industry. Alternatives to the DBMCS's Construction Information Classification System could be created that better fit the unique aspects of a particular company or industry – the importance being the selection of a Construction Information Classification System that is hierarchal in nature and can be tied to the business life cycle.

6.2 Recommendations for Future Research

1. Detailed research of the DBMCS Construction Information Classification System (Uniformat / MasterFormat). The system of combining Uniformat to MasterFormat was selected because both systems were generally accepted by the design and construction industry. The combination of the system does have some issues however. Two of the major issues facing the Construction Information Classification System are the overlap of some classifications. First, Uniformat contains some classifications that should be considered exclusionary and some items that are not exclusionary when accessing lower levels of details. For example Uniformat Level Two has two sections: A10 Foundation and A20 Basement Construction. These two items appear to have exclusionary relationships; meaning that if A10 Foundations is selected then A20 Basement Construction should be excluded from the possibility of selection. Many other sections of Uniformat do not have the same exclusionary relationship. The DBMCS did not fully consider these details; however further research into the relations of the systems could prove useful.

2. Building Information Modeling – As discussed earlier in this paper, BIM in increasingly making inroads in the building construction projects. Two areas of potential research: a) Research the potential of using a Construction Information

Classification System similar the DBMCS Construction Information Classification System that would allow for BIM to go from conceptual line drawings to detailed construction documents and b) Research the potential of adding scheduling and accounting attributes to the detailed drawings specifications.

3. Review of current industry estimating data formats in comparison to the DBMSC Construction Information Classification System data format. Research how parametric estimating can improve the estimating accuracy of multiple projects that all use the same Construction Information Classification System to control projects. Additionally what is required to convert current estimating data available to the Construction Information Classification System used by the DBMCS? Lastly, what other variables should be available to make the parametric estimates more precise.

4. Best Practice Controls – This paper discussed that it was critical for the DBMCS to have a single data repository in order for the system to be a true management control system. Further research could be included to define what the best business practices are for a company using the DBMCS to manage a project. For example: scheduling changes should receive approval / sign-off from which project stakeholders? Research could move the DBMCS from a system that can output schedules, estimates, job cost to a system that ensure projects continually have proper project stakeholder approval with each change made to the system or project.

APPENDIX A: DBMCS Building Classification System - Full Version

Full Version of DBMCS Building System Combining Uniformat and MasterFormat

Uniformat II / MasterFormat 95

Level One	Level Two	Level Three	02 Sitework	03 Concrete	04 Masonry	05 Metals	06 Wood / Plastic	07 Thermal and Moisture Protectant	08 Doors and Windows	09 Finishes	10 Specialties	11 Equipment	12 Furnishings	13 Special Construction	14 Conveying Systems	15 Mechanical	16 Electrical
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 Super Structure	B1010 Floor Construction		■		■	■										
		B1020 Roof Construction		■		■	■										
	B20 Exterior Enclosure	B2010 Exterior Walls		■	■	■	■	■		■	■						
		B2020 Exterior Windows							■								
		B2030 Exterior Doors							■								
	B30 Roofing	B3010 Roof Coverings				■	■	■									
		B3020 Roof Openings					■	■									
C Interiors	C10 Interior Construction	C1010 Partitions			■		■		■		■						
		C1020 Interior Doors							■								
		C1030 Fittings				■	■										
	C20 Stairs	C2010 Stair Construction		■		■	■										
		C2020 Stair Finishes								■							
	C30 Interior Finishes	C3010 Wall finishes								■							
		C3020 Floor Finishes								■							
		C3030 Ceiling Finishes								■							
D Services	D10 Converying	D1010 Elevator and Lifts													■		
		D1020 Excalators and Moving Walks													■		
		D1090 Other Conveying Systems													■		
	D20 Plumbing	D2010 Plumbing Fixtures														■	
		D2020 Domestic Water Distribution														■	
		D2030 Sanitary Waste														■	
		D2040 Rain Water Drainage														■	
		D2090 Other Plumbing Systems														■	
	D30 HVAC	D3010 Energy Supply														■	
		D3020 Heat Generating Systems														■	
		D3030 Cooling Generating Systems														■	
		D3040 Distribution Systems														■	
		D3050 Terminal & Package Units														■	
		D3060 Controls & Instrumentation														■	
		D3070 Systems Testing & Balancing														■	
		D3090 Other HVAC Systems & Equipment														■	
	D40 Fire Protection	D4010 Sprinklers														■	
		D4020 Standpipes														■	
		D4030 Fire Protection Specialties														■	
		D4090 Other Fire Protection Systems														■	

MasterFormat 2004

Level Three	02 Existing Conditions	03 Concrete	04 Masonry	05 Metals	06 Wood, Plastics, and Composites	07 Thermal and Moisture Protection	08 Openings	09 Finishes	10 Specialties	11 Equipment	12 Furnishings	13 Special Construction	14 Conveying Equipment	21 Fire Suppression	22 Plumbing	23 Heating Ventilating and Air Conditioni	25 Integrated Automation	26 Electrical	27 Communications	28 Electronic Safety and Security	31Earthwork	32 Exterior Improvements	33 Utilities
A1010 Standard Foundations	■	■	■																		■		
A1020 Special Foundations	■			■																	■		
A1030 Slab on Grade	■	■				■															■		
A2010 Basement Excavation	■																				■		
A2020 Basement Walls		■	■			■																	
B1010 Floor Construction		■		■	■																		
B1020 Roof Construction		■		■	■																		
B2010 Exterior Walls		■	■	■	■	■		■	■														
B2020 Exterior Windows							■																
B2030 Exterior Doors							■																
B3010 Roof Coverings				■	■	■																	
B3020 Roof Openings					■	■																	
C1010 Partitions			■		■		■		■														
C1020 Interior Doors							■																
C1030 Fittings				■	■																		
C2010 Stair Construction		■		■	■																		
C2020 Stair Finishes								■															
C3010 Wall finishes								■															
C3020 Floor Finishes								■															
C3030 Ceiling Finishes								■															
D1010 Elevator and Lifts													■										
D1020 Excalators and Moving Walks													■										
D1090 Other Conveying Systems													■										
D2010 Plumbing Fixtures															■								
D2020 Domestic Water Distribution															■								
D2030 Sanitary Waste															■								
D2040 Rain Water Drainage															■								
D2090 Other Plumbing Systems															■								
D3010 Energy Supply																■							
D3020 Heat Generating Systems																■							
D3030 Cooling Generating Systems																■							
D3040 Distribution Systems																■							
D3050 Terminal & Package Units																■							
D3060 Controls & Instrumentation																■							
D3070 Systems Testing & Balancing																■							
D3090 Other HVAC Systems & Equipment																■							
D4010 Sprinklers														■									
D4020 Standpipes														■									
D4030 Fire Protection Specialties														■									
D4090 Other Fire Protection Systems														■									

Uniformat II / MasterFormat 95

Level One	Level Two	Level Three	02 Sitework	03 Concrete	04 Masonry	05 Metals	06 Wood / Plastic	07 Thermal and Moisture Protectant	08 Doors and Windows	09 Finishes	10 Specialties	11 Equipment	12 Furnishings	13 Special Construction	14 Conveying Systems	15 Mechanical	16 Electrical
	D50 Eletrical	D5010 Electrical Service & Distribution															X
		D5020 Lighting and Branch Wiring															X
		D5030 Communications & Security															X
		D5090 Other Electrical Systems															X
E Equipment and Furnishings	E10 Equipment	E1010 Commercial Equipment										X					
		E1020 Institutional Equipment										X					
		E1030 Vehicular Equipment										X					
		E1090 Other Equipment										X					
	E20 Furnishings	E2010 Fixed Furnishings											X				
		E2020 Movable Furnishings											X				
F Special Construction and Demolition	F10 Special Construction	F1010 Special Structures												X			
		F1020 Integrated Construction												X			
		F1030 Special Construction Systems												X			
		F1040 Special Facilities												X			
		F1050 Special Controls and Instuments												X			
	F20 Selective Building Demolition	F2010 Building Elements Demolition												X			
		F2020 Hazardous Components Abatement												X			
G Building Sitework	G10 Site Preparation	G1010 Site Clearing	X														
		G1020 Site Demolition and Relocations	X														
		G1030 Site Earthwork	X														
		G1040 Hazardous Waste Remediation	X														
	G20 Site Improvements	G2010 Roadways		X	X												
		G2020 Parking Lots		X	X												
		G2030 Pedestrian Paving		X	X												
		G2040 Site Development	X	X	X												
		G2050 Landscaping	X														
	G30 Site Mechanical Utilities	G3010 Water Supply	X														
		G3020 Sanitary Sewer	X														
		G3030 Storm Sewer	X														
		G3040 Heating Distribution	X														
		G3050 Cooling Distribution	X														
		G3060 Fuel Distribution	X														
		G3090 Other Site Mechanical Utilities	X														
	G40 Site Electrical Utilities	G4010 Electrical Distribution	X														
		G4020 Site Lighting	X														
		G4030 Site Communications & Security	X														
		G4090 Other Site Electrical Utilities	X														
	G90 Other Site Construction	G9010 Service and Pedestrian Tunnels	X														
		G9090 Other Site Systems & Equipment	X														

MasterFormat 2004

Level Three	02 Existing Conditions	03 Concrete	04 Masonry	05 Metals	06 Wood, Plastics, and Composites	07 Thermal and Moisture Protection	08 Openings	09 Finishes	10 Specialties	11 Equipment	12 Furnishings	13 Special Construction	14 Conveying Equipment	21 Fire Suppression	22 Plumbing	23 Heating Ventilating and Air Conditioning	25 Integrated Automation	26 Electrical	27 Communications	28 Electronic Safety and Security	31Earthwork	32 Exterior Improvements	33 Utilities
D5010 Electrical Service & Distribution																		X					
D5020 Lighting and Branch Wiring																		X					
D5030 Communications & Security																		X					
D5090 Other Electrical Systems																		X					
E1010 Commercial Equipment										X													
E1020 Institutional Equipment										X													
E1030 Vehicular Equipment										X													
E1090 Other Equipment										X													
E2010 Fixed Furnishings											X												
E2020 Movable Furnishings											X												
F1010 Special Structures												X											
F1020 Integrated Construction												X											
F1030 Special Construction Systems												X											
F1040 Special Facilities												X											
F1050 Special Controls and Instuments												X											
F2010 Building Elements Demolition	X											X											
F2020 Hazardous Components Abatement	X											X											
G1010 Site Clearing	X																				X		
G1020 Site Demolition and Relocations	X																				X		
G1030 Site Earthwork	X																				X		
G1040 Hazardous Waste Remediation	X																				X		
G2010 Roadways	X																					X	
G2020 Parking Lots	X																					X	
G2030 Pedestrian Paving	X																					X	
G2040 Site Development	X																					X	
G2050 Landscaping	X																					X	
G3010 Water Supply																							X
G3020 Sanitary Sewer																							X
G3030 Storm Sewer																							X
G3040 Heating Distribution																							X
G3050 Cooling Distribution																							X
G3060 Fuel Distribution																							X
G3090 Other Site Mechanical Utilities																							X
G4010 Electrical Distribution																							X
G4020 Site Lighting																							X
G4030 Site Communications & Security																							X
G4090 Other Site Electrical Utilities																							X
G9010 Service and Pedestrian Tunnels																					X		
G9090 Other Site Systems & Equipment										X													

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