BENEFITS OF INFORMATION TECHNOLOGY IN IMPROVING PRECONSTRUCTION EFFICIENCY

By

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To my family and friends

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STRATEGIC BENEFITS OF INFORMATION TECHNOLOGY IN IMPROVING THE PRECONSTRUCTION PROCESS

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The purpose of this thesis was to find out what issues and inefficiencies were observed in the preconstruction process, and how Information Technology could help overcome these problems. The main group which this thesis applied to was mid-sized construction companies expanding to new geographical areas. The main issues observed which led to inefficiency were the inability to do a proper search for subcontractors; lack of efficient communication with subcontractors; and also long turn-around times in getting information back. Advances in information technology and the industry's use of IT were cited along with recommendations as to which technology would ultimately work out best for the industry. An analysis of the impact of a web based preconstruction management service (WBPMS) was then provided to show the benefits that it can provide in each stage of the preconstruction process. Using System Dynamics, a model was created to show the effects that it would have on the construction industry as more general contractors and subcontractors adopted it. Even though the scope of this thesis covered mid-sized general contractors, the research

proved that using a WBPMS had the potential to have an impact on the efficiency of the construction industry as a whole.

CHAPTER 1
INTRODUCTION

Overview

As construction projects become ever more complex, the emphasis on preconstruction becomes even greater to set the project up for success. Given the new found importance of preconstruction, construction companies have devoted more employees to this construction phase. Unfortunately, the tools and training provided in the preconstruction phase are outdated. Given the advances that information technology (IT) has provided in terms of collaboration and connectivity, other industries have been able to quickly modify their business processes to further enhance the efficiency with which they conduct business and form supply chains. They have even automated many of their repetitive tasks to help their employees work faster. The construction industry on the other hand, is still performing preconstruction through the use of phones and fax machines due to its general aversion to change. As projects become ever more complex, the amount of time it takes to perform preconstruction increases, while efficiency and productivity decreases. This statement is especially true for mid-size companies that expand into a new geographical area that they have not been in before. While the industry as a whole can be classified as laggards in adopting and utilizing technology, there are a few that do see the potential and the benefits of integrating IT into their preconstruction division. This study will take a look at the benefits that IT is able to bring when compared to the traditional way of performing preconstruction.

Problem Statement

The purpose of this study is to find out what problems contractors face in performing preconstruction the traditional way; find out how IT can help improve the preconstruction process; and finally, find out what effects implementing IT into preconstruction will have for the industry through system dynamics. It is generally expected that the improvements that IT is able to bring in terms of communication, information sharing, and automation of certain repetitive tasks, will save time and money in performing preconstruction. The amount of time saved in preconstruction will aid in having the project start sooner; allow additional time for feasibility studies and reduce the costs of the preconstruction phase of projects. The results obtained will also serve as proof to other construction companies of the need to implement IT into their preconstruction processes.

Research Objectives

The results obtained from this study will help construction companies understand the benefits and the time savings resulting from the further implementation of IT into their preconstruction processes. So far no significant studies have been performed to determine the potential benefits that IT can bring to preconstruction. Comparison studies and case studies have been performed on the impact of IT in other industries to show the efficiency and productivity gains that are achieved, but there does not appear to be any conducted within the construction industry on preconstruction. The construction industry is slowly moving towards using technology in the preconstruction process to improve communication and the exchange of information. The goal of this study is to show the potential benefits and time savings realized and present a premise for all construction companies to modify their preconstruction processes.

Organization

This study will be divided into seven chapters. Chapter 2 will focus on current literature on the state of information technology use in construction as well as an overview of system dynamics. Chapter 3 will provide the research methodology for this study. Chapter 4 will focus on how preconstruction is traditionally performed in construction and what the potential inefficiencies are. Chapter 5 will focus on how preconstruction is performed through an electronic approach. Chapter 6 will analyze the effect that IT will have on preconstruction. Finally, Chapter 7 will provide conclusions, recommendations, and suggestions for future research.

CHAPTER 2
LITERATURE REVIEW

This chapter will serve as a background covering several disciplines. It will focus on the nature of the industry and its inherent conservative nature; on who the main participants are and how information flows between them; and also who the primary technology adopters are. After that, the focus will change towards a historical outlook and progression of the advancements in IT, including messaging, Groupware Systems, Model Based Approaches, and Web based approaches as they relate to construction. Additionally, solutions that have been put forth in previous studies will be analyzed to see if they can be applied to preconstruction. Finally an overview of what system dynamics is will be provided as preface to Chapter 6.

The Nature of the Industry

The construction industry in 2007 accounted for 4.1%, or $562.6 Billion, of the GDP (BEA 2008). It is a very fragmented industry consisting of multiple disciplines and trades coming together to achieve a unique undertaking. The use of Information Technology to facilitate communication is a relatively new approach for the construction industry (Ramcharan 1997, Zaheer et al. 1997). Unfortunately, due to a lack of standardization, the ability to communicate and send or receive information has been limited to the traditional phone, fax and to some degree, the e-mail method, between different entities in the industry. There are a few key barriers which have resulted in the construction industry not adopting Information Technology as rapidly as other industries. Reviewing the works of Alshawi (2003), Ingirige (2003), Ramcharan (1997), Pries and Janzsen (1995) provides the following reasons why IT is hard to adopt by the construction industry:

- Fragmentation of the industry, and the small size of the companies within this industry, 65% have 5 employees or less (BLS 2009), makes it harder to implement an industry wide IT solution
- Inability to share information efficiently due to a lack of standardization in terms of software, and communication
- Lack of interoperability among construction software packages
- The conservative nature of the industry and its resistance to change
- Having to perform the same process on paper to meet legal and audit requirements

Lately however, the industry has begun to change their resistance towards technology. As projects continue to become complex, owners are beginning to demand the use of information technology to improve the sharing of information and communications (Boryslawski 2006). As a result, general contractors are being forced to improve their technology skills, and their implementation of IT. By doing so, they are changing the face of the industry, as other general contractor's attempt to mimic the successful ones. In addition, this change is trickling down towards subcontractors, as general contractors have started to require more electronic communications and submission of a data to further implement information technology into their business processes.

Participants in the Construction Industry

Primarily, there are three major participants that take part in the construction process – the owner, the architects/engineers (designers), and the contractor (Mincks and Johnston 2004). Aside from these main participants, other participants include consultants, subcontractors, materials and equipment suppliers, financing, bonding agencies, and public agencies (Ramcharan 1997; Zaheer et al. 1997). Since the

majority of the actual construction is subcontracted instead of being self-performed, subcontractors and suppliers also play a major role in the construction industry (Carty 1995). For the purpose of this study, only the relationship between the contractor and subcontractors will be considered since the preconstruction process involves the transfer of information and communication between these two parties the most.

Flow of information

Within the construction industry, there is a certain chain of command that each participant has to follow. This chain of command arises from the agreements and legal obligation each participant has with one-another. Figure 2-1 represents the relationships between these different participants in a traditional delivery system.

Figure 2-1 shows that there is a direct relationship between the subcontractor and the contractor. During preconstruction, the amount of communication and information transfer between the contractor and the subcontractor are vast. From the submission of

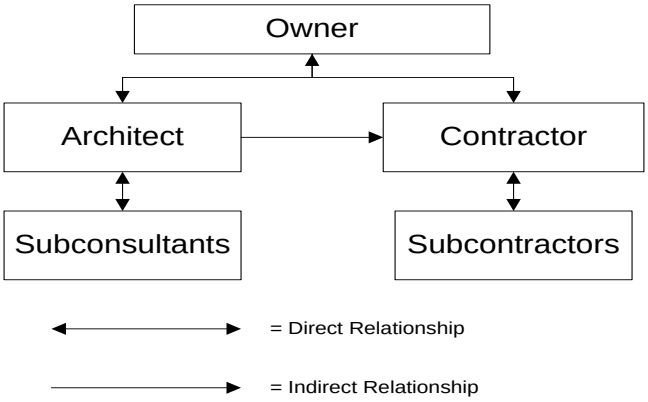

Figure 2-1. The Traditional Construction Delivery System (Adapted from: Mincks and Johnston 2004)

the project information sheet, to contract documents and bid requirements, to receiving bids and proposals, there is a constant flow of information between the contractor and subcontractor. There are times however when information has to reach farther up or

down the chain of command. In the event that a subcontractor has questions regarding the design, the subcontractor has to submit the question to the contractor, and have the contractor submit the question to the architect. The subcontractor has to then wait for the answer to arrive to the contractor, so that it can then be passed down to the subcontractor. Having the means of being able to exchange information in an efficient manner can provide benefits throughout the life of the project (Ramcharan 1997; Zaheer et al. 1997). This is especially true between the contractor and subcontractor, as the delay in information transfer from one participant, can delay the work of the other participant.

The Preconstruction Process

A clear definition of preconstruction has not been established for the industry. Different construction companies have a different view of what is considered to be preconstruction as well. Preconstruction essentially consists of all activities that occur before the start of the construction phase such as estimating, scheduling, constructability, and procuring. Several researchers have indicated that preconstruction can be broken down into three stages of planning: pre-bid planning, preconstruction planning, and during construction planning (Cormican 1985; Laufer 1993; Shapira et al. (1993), followed up on Cormican's definition and set out to research the amount of time construction company personnel spent in the pre-bid and preconstruction planning phase. It was noted that during pre-bid, which by using Cormican's definition this study would fall into, "Cost & Cash Flow" (estimating), and "Organization & Contract" (procuring), scored 88.5% and 58% respectively in terms of relative time invested (Laufer 1993, Shapira et al. 1993). Since there is a need for communication across the

company with subcontractors for estimating and procuring purposes, these two areas can benefit from the use of IT.

Looking at it from the viewpoint of the construction industry, the preconstruction process can be as basic as estimating the cost of a project to something more sophisticated. A summary of services that construction companies normally perform as part of their preconstruction services are as follows:

- Estimating
- Purchasing/Procuring and putting together subcontracts
- Performing constructability reviews
- Performing value engineering and analysis
- Performing coordination review
- Assessing Risk
- Performing safety analysis
- Creating the schedule
- Sustainability analysis

In terms of communication, the first two bullets (Estimating, Purchasing/Procuring and putting together subcontracts) heavily rely on subcontractors. Again, the ability to exchange information quickly allows the preconstruction team, and also the subcontractor, to have quicker turnaround times resulting in a more efficient and more optimized preconstruction process.

Adopters of Information Technology

Ramcharan (1997and Zaheer et al. (1997) identified a specific group within the industry that is most likely to adopt new technologies and implement it in their processes. These so called “Lead users” normally know what the problems are, and what they will be in the future, and are usually the first to implement a solution. As a result of their visionary thinking, they are able to pull ahead of the competition. As other company’s begin to take note of the achievements and successes that these lead users

have had, they too begin to follow the methods the lead users took to catch up to the rest of the competition. This creates a feedback loop to where the industry as a whole begins to improve to remain competitive with one-another. An analysis of this feedback loop will be provided in Chapter 6.

The next section will focus on advances in IT in terms of communication and collaboration. It will provide an introduction to each technological innovation which can improve the exchange of information, review works by other researchers who have looked into this subject, and provide conclusions as to which technology works out best for the construction industry.

Advances in IT

Advances in Information Technology have allowed companies in other industries to communicate more effectively, collaborate more efficiently, and to automate many of their tasks. Information is critical in construction where delays and miscommunication can have severe cost and duration impacts on a project (Ramcharan 1997, Zaheer et al. 1997). An analysis of each technology is provided to highlight the benefits and drawbacks each one has in the construction industry.

Messaging

The ability to communicate quickly and efficiently in today's information driven world allows a company to thrive and be more competitive. E-mail, which forms a communication channel, has become one of the preferred methods of communication. It is quick, efficient in reaching multiple recipients simultaneously, and allows for quicker feedback and turnaround times. Information such as CAD files can even be attached making it an excellent tool to transfer and coordinate information (Noguchi 1995). While E-mail does have its advantages in terms of speed and being able to reach multiple

recipients simultaneously, it has certain limitations which makes it an ineffective tool for communication for the construction industry. Since there is a constant back and forth communication relating to a specific subject, e-mail has a tough time showing each of the email threads effectively (Ramcharan 1997, Zaheer et al. 1997). This can lead to large amounts of time backtracking through email threads looking for specific information. Also, since information inside an e-mail can only be viewed by the intended parties which the e-mail was sent to, along with the originator of the e-mail, potential problems can arise if that person is no longer available to access the account in order to access the information. This can lead to the possibility of information loss or having to re-enter information. As projects have become ever more complex, construction company's have begun to look towards technology to solve the issue of detailed record keeping, communication, and information sharing. A system was needed to centralize information so that it could be easily accessed by members of the project team. Groupware became the answer to the construction industry's needs.

Groupware systems – Model Based

Groupware is "software that enables users to work collaboratively on projects or files via a network" (Merriam-Webster 2009). It can also be considered as technology that serves to improve group productivity (Briggs and Nunamaker 1995). There are two methods of approaching groupware, a model based system or a web-based system (Kim 2003). A model based system is defined as one in which data is centralized in a database, on the company's server. This was primarily the solution from IT consulting company's in an attempt to help bring IT into the construction industry. In order to access such a system, software had to be written that could communicate with the centralized information that is stored in the database. An easy example to make sense

of a model based system would be Prolog or Expedition. When either of these pieces of advanced software packages are executed, the software immediately connects to a database housed on the company's server. It then allows the user to store or retrieve information, using the software as a gateway into the database. The benefits of using such a system over messaging include:

- Sharing of documents
- Improving communication between team members
- Eliminating the loss of information should a team member leave
- Broadcasting the latest version of information within the company

While the benefits of using a model-based group system is certainly better than E-mail, telephone, and fax, it also has certain disadvantages that makes it difficult to implement across the construction industry. A major problem with this system is that the software must be available in order to access the system. Everyone within the industry would have to have the same software installed in order to be able to communicate and collaborate. Aside from having the software, there are other technical complexities involved. This includes hardware and operating system limitations, and a host of other issues dealing with connecting over a firewall or a proxy. Each one of these technical difficulties alone is enough to discourage the implementation of such a system. Furthermore, what good is such a system if everyone implements their system in a different way? How would these systems communicate with one-another's database? These systems would have to be interoperable in terms of communication and connectivity. A visual example of this issue is shown in Figure 2-2. A solution that was created to help with this issue was proposed by Froese (2003). Without getting into too

much technical detail, he proposed that in order to achieve compatibility between databases in different organizations, information should be written in a structured form that the industry agrees upon, so that information can be easily exchanged from one database an organization has, into another. As for the actual exchange of information, he proposed using a common language, known as XML, that all applications can use to talk to each other in order to make communication possible (Froese 2003). Due to the fragmented nature of the industry and the incompatibility between these different systems, company's have had to abandon the idea of seamlessly connecting to one-another. Instead, in order to communicate, phone, fax, and e-mail was once again used. As far as preconstruction is concerned, a much easier way of collaborating is not to use an application base where everyone has their own database, but to use a web-based system with only one universal database.

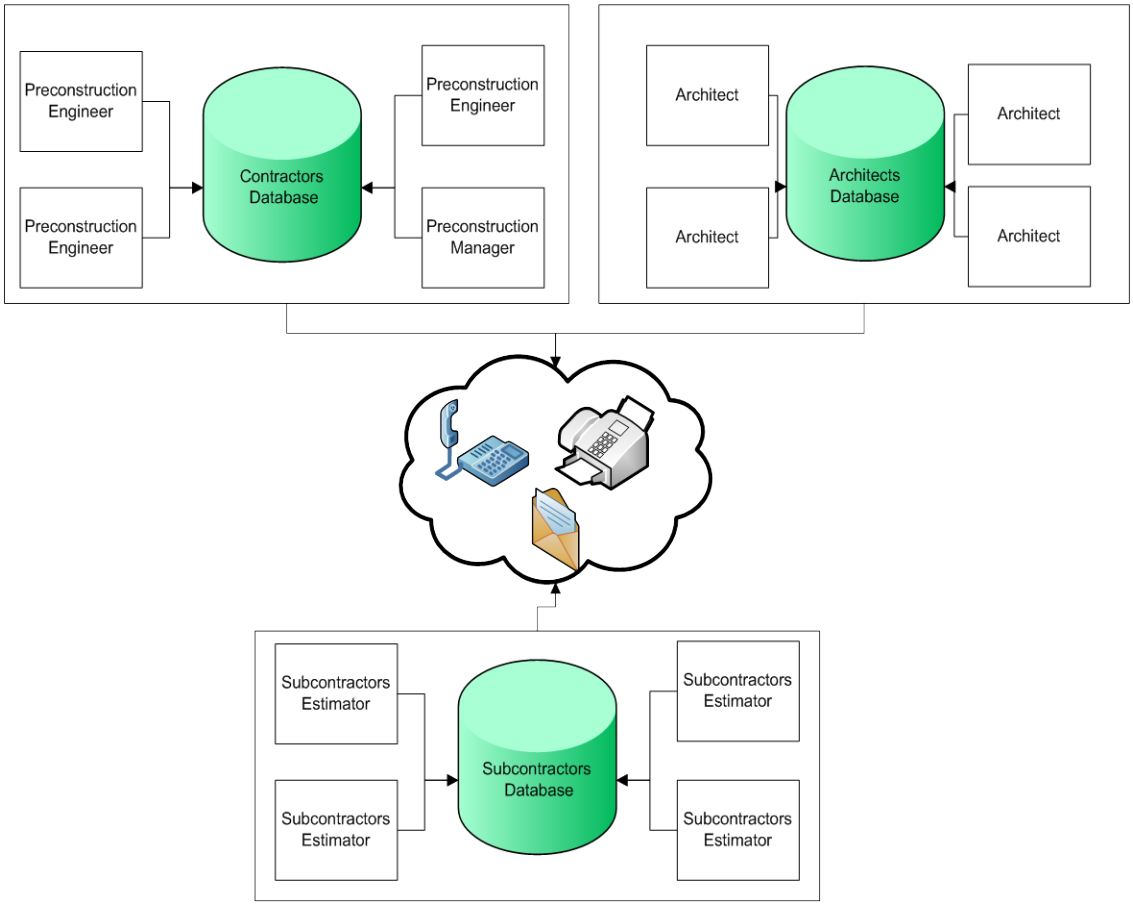

Figure 2-2. Communication difficulties amongst project participants

Groupware Systems - Web Based System

In a web based system, there is no longer the issue of hardware or software or interoperability. Information can be stored in one universal database, and can easily be accessed through a standard web browser. All parties in the construction industry can create their own private online workspace in this database, and can then invite those that are part of the project into their online workspace. By doing so, communication and collaboration becomes much easier to accomplish. Alshawi and Ingirige (2003) found that the benefits that can be realized through a web interface are:

- Speed up the distribution of information and documents between members of the construction industry
- Reduce the risk of errors and rework by ensuring that the project team is working with the most current drawings and other documents
- Eliminate the risk of losing important files, by maintaining all current and past versions in one central location
- Improve team communication by enabling team members to raise and respond to queries in a structured way
- Maintain a complete log of all communications for tracking purposes

The ability to share information across a company and their entire supply chains allows everyone to better interact with one-another, and to form better business relationships. Collaboration can be shared amongst all parties within the construction industry to ensure a smoother operation of the project. A simple example of this would be if a subcontractor realizes a mistake in the drawings. The subcontractor can then send an electronic request for information (e-RFI), to the general contractor. The general contractor can then accumulate these e-RFI's, and send them to the architect. Once the architect replies, the information can quickly be turned around and can be sent to all subcontractors affected by the mistake in the drawings.

The use of iSqft.com

iSqft.com is a web-based groupware system/ WBPMS that was designed primarily for preconstruction. It allows general contractors and subcontractors to work together in an online workspace. It greatly improves the way in which general contractors and subcontractors find one-another, communicate, exchange information, and work together to help smooth out the preconstruction process for both participants.

System Dynamics

System Dynamics was created by J. Forester as a way of modeling and analyzing the behavior of complex social systems (Rodrigues and Bowers 1996). It has the ability

to provide an overall picture of how different elements within a system interact and what influences each element will have on one-another over time. There are a few key components of system dynamics that need to be explained. First and foremost is the idea of casual loops. Within system dynamics, every element has a cause and effect relationship on one-another. It is through these relationships that different elements can be brought in to view its effects on the model as a whole (Chapman 1998). A simple example of a casual loop (cause and effect) would be the population of wolves against rabbits, also known as a predator-prey model. If wolves are introduced in a forest, the population of rabbits will decrease over time because wolves eat rabbits. Multiple feedback loops are defined as “closed chains of cause and effect links in which information about the result of actions is fed back to generate further action” (Chritamara 2002, Ogunlana et al. 2002). There are two types of feedback loops that are found in system dynamics – positive feedback loops, and negative feedback loops. Positive feedback loops generate growth, while negative feedback loops act a reducer. A negative feedback loop in a sense brings the system back to its original state. Continuing the wolves against rabbits example, as more wolves eat rabbits, wolves will begin to increase in population and eat more rabbits. This is a positive feedback loop. As the population of rabbits begins to decline rapidly however, the population of wolves will also decline as well due to a lack of rabbits (starvation). This is a negative feedback loop.

Conclusions

As stated earlier, the construction industry is very fragmented, and there is no set standardization for the use of technology, or for the exchange of information. Due to the complexities of projects, legal requirements, the need to remain competitive and

attractive to owners, the industry is beginning to change their conservative and traditional attitudes towards technology and change. While the strategic benefits that Information Technology has provided in the construction phase have been measured, there still appears to be no research done on the preconstruction side. Given the industry's newly placed importance on preconstruction, this study will look at the strategic benefits that IT can bring to preconstruction and to the industry.

CHAPTER 3
METHODOLOGY

Overview

The methodology used in this study is geared toward showing the strategic benefits that IT has brought to the preconstruction phase of a construction company's work. Lead users as mentioned in Chapter 2 will be targeted, as they are the first to implement solutions to a problem, are more open towards technology, and are able to be influential enough to cause a change in the industry. Since mid-sized companies tend to expand into new geographical areas, they are the prime users who will benefit from using IT in preconstruction. Therefore, mid-sized lead users will be the target of an interview. The interview will be performed with preconstruction engineers who have performed the process of preconstruction before a web based preconstruction management system (WBPMS), and after. Their needs as far as communication and information needs will be analyzed. Chapter 4 will be a walkthrough of how preconstruction engineers perform their work the traditional way. It will conclude by highlighting the issues that are seen without using a WBPMS. Chapter 5 will follow the same outline as Chapter 4 and will show how preconstruction can be simplified using WBPMS. A framework model using system dynamics will be created to show what effects the use of IT has had and will have for the industry.

Detailed Process and Limitations

First off, the goal was to find out how preconstruction was performed traditionally, and what issues were consistently noticed in every project. This was successfully accomplished through both the author's own experience as a preconstruction engineer, and also through phone interviews with other preconstruction engineers. Each step of

the preconstruction process was carefully reviewed to see what similarities in problems existed in terms of information exchange and communication. The next step was to obtain a list of companies, as well as names of preconstruction engineers, from iSqft.com, a provider of WBMPS. Unfortunately, authorization to release information was not received at the time of this writing, nor could anyone be located that could provide any usable information. Several companies were found that were featured on their website that use iSqft, and an attempt was made to contact them. Out of the companies contacted, two companies managed to discuss their experiences with the author. The next step was to ask a set of questions during the phone interview. These questions dealt with the following issues:

- How was preconstruction performed before iSqft.com?
- How was preconstruction performed after iSqft.com?
- How long did the training process take?
- What benefits were witnessed after iSqft.com in terms of communication and information exchange?
- What effects did iSqft.com have on preconstruction in terms of schedule?
- What effects did iSqft.com have on the company?
- What effects did iSqft.com have on subcontractors?
- What effects will iSqft.com have for the industry?

The companies were able to answer many of the questions asked and provide valuable insights as to how a WBPMS had positively affected their company, the number of projects they were able to get done, as well as better relationships with subcontractors. While no quantifiable data was ever recorded by the company's, system dynamics was strategically used to model a process to determine the amount of money savings, number of projects completed, as well as answer the question of what a WBPMS would do for the industry.

A software package called Stella was used to create such a model. This model shows the relationships and the feedback loops that arise in the interaction between general contractor and subcontractor and the spread of iSqft.com within the construction industry.

CHAPTER 4
TRADITIONAL METHOD OF PERFORMING PRECONSTRUCTION

Background Information

Preconstruction consists of all activities that must be accomplished before breaking ground. A subset of these activities includes:

1. Finding Subcontractors
    1.1. Prequalifying Subcontractors
    1.2. Determining Project Interest
2. Submission of Contract Documents
3. Submission of a scope of work document
4. Receiving bids back from subcontractors
    4.1. Analyzing for completeness and accuracy
5. Performing bid leveling and analysis
6. Choosing the best subcontractor

Finding Subcontractors

Currently the industry has very limited options in their search for subcontractors. Depending on the size of the general contractor, their search paths may be easy, or it may be quite difficult. For smaller sized general contractors, it has been noted that the general contractor normally performs work in one geographic area that is close to their home office. Given that many of these projects are geographically centralized, the general contractor forms a bond with local subcontractors. Through this bond, the general contractor knows exactly who the subcontractors are; what they are capable of, what their strengths and weaknesses are; and finally who to call upon should the project require specific specializations. While a smaller sized general contractor will not have

difficulty finding subcontractors, a larger sized general contractor however will. The primary reason for this difficulty is because a larger sized general contractor works in multiple geographic locations. Such an expansion results in unfamiliarity with the local region as far as subcontractors, quality of work, and their capabilities. Current methods of searching outside of the known geographic area are very limited. These methods involve using either the business directory of the particular state or city the project is located in, or through the use of a bluebook service. The main issue that arises when searching is finding someone who matches the project requirements.

Prequalifying Subcontractors

When a list of potential subcontractors has been obtained, the next step is to perform a filtering process to see who matches the project and who does not. This usually involves cold calling the subcontracting company and asking the estimator a list of questions about the company size, bonding capacity, and previous types of projects performed. Should the results prove to be satisfactory, a more detailed prequalification form is sent to be completed by the subcontracting company. A few problems arise at this point. Considering that prequalification forms normally ask for private information about the company and previous projects completed, subcontractors are wary of completing such a form, due to a lack of trust and relationship between the subcontractor and the general contractor. Subsequently, this struggle occurs between the general contractor and the subcontractor to finally get a completed prequalification form. The next step that the general contractor has to perform is to analyze the prequalification form to see if the company can handle such a project. Additionally, the general contractor has to contact references the subcontractor has listed and find out from them about the performance of the subcontractor in specific key areas important to

the project. Such key areas include but are not limited to the subcontractor's manpower capabilities, site cleanliness, scheduling skills, accuracy of estimate, quality of work, and overall reputation of subcontractor. Overall, this entire process of finding subcontractors and being able to prequalify them is a time consuming process that can take a matter of weeks to accomplish.

Determining Project Interest

Subcontractors usually have to accept to be onboard a project. Their reasons for choosing to not participate are often varied. One of the main reasons is that they may have too much work, or that the project is a bit remote to their primary area. The latter arises from a user's limited ability to do a proper search to see how far subcontractors are willing to travel. While business directories provide a list of companies that are within the project area, it does not provide information as far as a subcontractor's preferred geographical area of work.

Submission of Contract Documents

Contract documents which include but are not limited to, plans, specifications, request for proposals, and schedules, are placed on an FTP site for download, submitted to a reprographic company, or sent via courier to subcontractors. Subcontractors that are computer literate do not have any problems accessing online FTP storage locations. The lesser computer literate subcontractors often present a problem to the general contractor. There is an even greater hassle if technical issues come up such as accessing the FTP storage location from behind a firewall. Assuming that no technical issues arise, the general contractor has to either spend time walking the subcontractor step by step through the process of accessing the FTP site, or has to spend its own cash in sending the contract documents via courier. Three major

problems are present during the submission of contract documents. One major problem is that it may become costly having to send contract documents via courier. Another is that there is no way to confirm whether the subcontractors have received and viewed the complete contract documents or not. Since a trail is not left of what the subcontractors have seen and have not seen, this leaves open the possibility of an incorrect proposal/bid by the estimator or an outright denial of being responsible for something that they claim they did not receive. The final problem that arises is related to what happens when there is an update to the drawings or there is an addendum to the contract documents. Should the process of sending updated information via courier be repeated adding further cost? A secondary problem presented by an update is that all parties have to be notified that an update has taken place. This involves emailing, faxing, and then following up with a phone call, multiple subcontractors in every affected trade, and asking them to review the latest updates and to update their bids to reflect the new changes. If it is a public job, it becomes imperative that everyone is notified of an addendum or change, or the entire bidding system is disqualified and the procedure has to start from the very beginning as subcontractors can assert that the bidding was not fair.

Submission of Scope of Work Document

Similar to submitting plans and specifications, sending any other type of information is a bit time consuming for the non-technology literate person. Depending on the size and scope of what is being sent, it can be sent either as an email, fax, hard copy, online FTP storage location, or via phone. The issue that arises with email is that there is no way to find out whether the email has been received by the intended party, or whether it went into the junk mail folder. Furthermore, it is not possible to find out

whether the email was read without doing a follow up phone call if a reply was not sent back or without using read receipt. With a fax, a confirmation sheet is received to show a successful transmission. Such a feedback legally works as having been sent to the intended party. A follow up phone call is normally performed to ensure that the correct party did actually receive the fax. This again adds to inefficiency. If information is going to be sent via hard copy, it is either certified or sent with something that can be tracked for legal purposes, and again adds to cost. FTP storage is ideal, as multiple people can access the information from a centralized location. The only downside is that it is quite difficult to track who has accessed the information and who has not.

Another important item that the general contractor communicates to the subcontractor is a scope of work checklist. The scope of work carefully defines for the subcontractor what is to be included and excluded in their bid/ proposal, outlines exactly what the responsibilities of the subcontractor are, along with other contractual expectations. Minks and Johnston (2004) further explain that a scope of work must include:

- Description of the work relating to the construction documents, including drawing and specification reference; reference should include dates of the documents, document numbers, and dates of the addenda
- Additional work to be performed by the subcontractor, beyond the specification sections
- Exclusions from work described in the construction documents, as per the subcontractor's bid
- Any additional specific information relating to the project, such as schedule dates or delivery dates
- Description of included alternates and negotiated additions or deletions to the agreement

The subcontractor is to review this scope of work and include the necessary items in their bid and is to adhere to the rules and regulations set forth by the general contractor. It is normally sent in a checklist format so that the subcontractor can confirm line by line as to whether an item is included, or a specific condition set by the general contractor will be complied with. As Minks and Johnston noted, there will also be sections in which the subcontractor gets to write in the prices of alternates, additions, or deletions. Once the scope of work checklist is written and finalized, it is then submitted to the subcontractor via fax to review, complete, and return to the sender along with their bid/ proposal. Figure 4-1 shows an example of a scope of work checklist that is submitted.

Receiving Bids Back from Subcontractors

Receiving information back can be a hassle. Many follow-up phone calls are placed before the due date of the proposal as well as on the day is due as a reminder. The process becomes a bit more difficult for contractors who require that their subcontractors enter into their own Contractor controlled/ Owner Controlled insurance program (OCIP, CCIP). OCIP is defined as the owner buying insurance for all subcontractors on the job, whereas CCIP is where the contractor buys insurance for all subcontractors on the job. The type of information then required from the subcontractors include such risk assessment documents as OSHA 300 logs for the last few years, complete audited financial documents of previous years including income statement, balance sheet, and cash-flow statements. A subcontractor may be reluctant to send such documents to a general contractor whom they have never worked with before, just in order to be included in their OCIP/CCIP program.

Trade Specific Scope	INCLUDED	COMMENTS
Subcontractor shall be responsible for all labor, material, equipment and supervision necessary to perform this work for the project as required and in accordance with the Contract Documents. This work includes, but is not limited to, the following:	☐ Y ☐ N	
General Items	☐ Y ☐ N	
Provide installation of all materials and systems in accordance with manufacturer's instructions and approved submittals	☐ Y ☐ N	
Provide proof of installation qualification and certification from specified manufacturers.	☐ Y ☐ N	
Provide all product data, shop drawings, samples and manufacturer's certificates as required by the contract documents.	☐ Y ☐ N	
Subcontractor to field verify dimensions for fencing prior to start of fabrication.	☐ Y ☐ N	
Subcontractor is responsible for coordinating all deliveries with GC. Subcontractor to have manpower onsite to handle all material deliveries.	☐ Y ☐ N	
Provide required protection over adjacent surfaces during scope of work.	☐ Y ☐ N	
Provide replacement of all damaged or unusable materials due to own negligence.	☐ Y ☐ N	
Fencing	☐ Y ☐ N	
Subcontractor is responsible to provide all materials, equipment, labor, and accessories required for a complete and functional installation of the heavy-duty industrial type chain-link fencing and Gates per sheet A-1.01 and A-.050 including, but not limited to, the following:	☐ Y ☐ N	
Furnish and Install 8 FT galvanized high fencing with privacy slats in Electrical Yard and Concrete Generator pad area	☐ Y ☐ N	
Provide all manual Chain-Link fence gates as shown in Contract Documents.	☐ Y ☐ N	
Fencing contractor to coordinate with owner and Contract Documents to ensure correct type of lock and correct set of keys are installed and provided for chain-link fence.	☐ Y ☐ N	
Subcontractor is responsible for setting all posts in straight lines, plumb with faces and tops in accurate alignment per the Contract Documents.	☐ Y ☐ N	
Provide all coring and/or cutting required for setting of the fencing and gate posts.	☐ Y ☐ N	
Provide all concrete work required for a complete installation of the fencing and gate posts per the Contract Documents.	☐ Y ☐ N	
Subcontractor is responsible for restoring all finished surfaces to eliminate evidence of any cutting, welding, and/or grinding performed during the installation of this scope of work for proper shop fitting and/or jointing per the Contract Documents.	☐ Y ☐ N	
Tabulation		
Subtotal	**$0**	
Tax		
Bond		
TOTAL		
Schedule - Provide Durations		
Acknowledgement of commitment to the overall Project Schedule, including durations and milestone dates, identified in **Project Schedule dated 09/26/2007**.	INCLUDED	
Award Date		
Shop Drawings / Submittals (from date of award)	wks	
Material leadtime (from date of approved submittals)	wks	
Installation of your scope of work	wks	
Unit Prices		
At the sole option of the Contractor, the following unit prices/wage rates may be used to adjust the base amount.	☐ Y ☐ N	
Subcontractor specifically acknowledges that the following unit prices include freight, labor, labor burden, fringes, material, equipment, tax, permits, fees, bond and mark-up for overhead and profit as indicated. In addition, all unit prices/wage rates are not to exceed the amounts included herein, and are good for the duration of the project.	INCLUDED	
The following labor rates include **burden, fringes, bond, and O&P**	☐ Y ☐ N	
Foreman ($/HR)	$	
Foreman Overtime Rate ($/HR)	$	
Laborer ($/HR)	$	
Laborer Overtime Rate ($/HR)	$	
The following unit costs are all inclusive: **freight, material, tax, labor, burden, fringes, bond, equipment, O&P, etc.**	☐ Y ☐ N	
LF of extra fencing - 8 FT high with slats ($/LF)	$	
Chain-link doors - 6'x8' ($/Ea.)	$	

Figure 4-1. Example of a scope of work checklist

Analyzing for Completeness and Accuracy

When the information is received, it is typically checked for accuracy. This is achieved by looking at the proposal that has been submitted, checking the quantity that the estimator saw and comparing it with the in-house analysis of what those quantities should be. Should the quantities substantially differ, then the estimator has either missed a portion or has exceeded them in the areas in which the work is required. In such a scenario, the general contractor has to contact the subcontractor and work with the subcontractor to see how their estimate was obtained and where they might have gone wrong, and then they to wait all over again for a new estimate to be prepared. The next step is to check for completeness. Completeness has two factors associated with it: completeness of scope and agreement to non-scope related items. Completeness of scope is a check to see whether all items that are needed for a particular trade are included in the proposal. For example, a roofer may leave out the millwork for the roof when asked to include it in their proposal. Again, this requires a follow-up phone call for a new proposal to include it in. As for the non-scope related items, subcontractors tend to leave certain line items blank as they feel they are taking on too much risk. Since general contractors require complete agreement to everything specified in the scope of work, a follow up phone-call has to be placed to talk about each one of those line items. This process takes place until a complete scope of work checklist is received. Figure 4-2 shows an example of a completed scope of work ready for bid-leveling and analysis. The boxes which indicate a dollar value instead of “Included” would be the result of the subcontractor initially leaving the item blank or excluding it resulting in a follow up phone call.

Trade Specific Scope	SUBCONTRACTOR A	SUBCONTRACTOR B
Subcontractor shall be responsible for all labor, material, equipment and supervision necessary to perform this work for the project as required and in accordance with the Contract Documents. This work includes, but is not limited to, the following:	INCLUDED	INCLUDED
General Items	INCLUDED	INCLUDED
Provide installation of all materials and systems in accordance with manufacturer's instructions and approved submittals	INCLUDED	INCLUDED
Provide proof of installation qualification and certification from specified manufacturers.	INCLUDED	INCLUDED
Provide all product data, shop drawings, samples and manufacturer's certificates as required by the contract documents.	INCLUDED	INCLUDED
Subcontractor to field verify dimensions for fencing prior to start of fabrication.	INCLUDED	INCLUDED
Subcontractor is responsible for coordinating all deliveries with GC. Subcontractor to have manpower onsite to handle all material deliveries.	INCLUDED	INCLUDED
Provide required protection over adjacent surfaces during scope of work.	INCLUDED	INCLUDED
Provide replacement of all damaged or unusable materials due to own negligence.	INCLUDED	INCLUDED
Fencing	INCLUDED	INCLUDED
Subcontractor is responsible to provide all materials, equipment, labor, and accessories required for a complete and functional installation of the heavy-duty industrial type chain-link fencing and Gates per sheet A-1.01 and A-.050 including, but not limited to, the following:	INCLUDED	INCLUDED
Furnish and Install 8 FT galvanized high fencing with privacy slats in Electrical Yard and Concrete Generator pad area	INCLUDED	INCLUDED
Provide all manual Chain-Link fence gates as shown in Contract Documents.	INCLUDED	INCLUDED
Fencing contractor to coordinate with owner and Contract Documents to ensure correct type of lock and correct set of keys are installed and provided for chain-link fence.	INCLUDED	INCLUDED
Subcontractor is responsible for setting all posts in straight lines, plumb with faces and tops in accurate alignment per the Contract Documents.	INCLUDED	INCLUDED
Provide all coring and/or cutting required for setting of the fencing and gate posts.	INCLUDED	INCLUDED
Provide all concrete work required for a complete installation of the fencing and gate posts per the Contract Documents.	INCLUDED	**$2,368**
Subcontractor is responsible for restoring all finished surfaces to eliminate evidence of any cutting, welding, and/or grinding performed during the installation of this scope of work for proper shop fitting and/or jointing per the Contract Documents.	INCLUDED	**$550**
Tabulation		
Subtotal	**$12,450**	**$16,279**
Tax	INCLUDED	INCLUDED
Bond	N/A	N/A
TOTAL	**$12,450**	**$16,279**
Schedule - Provide Durations		
Acknowledgement of commitment to the overall Project Schedule, including durations and milestone dates, identified in **Project Schedule dated 09/26/2007**.	INCLUDED	INCLUDED
Award Date		
Shop Drawings / Submittals (from date of award)	1 WEEK	1 WEEK
Material leadtime (from date of approved submittals)	2 WEEKS	2 WEEKS
Installation of your scope of work	1 WEEK	1 WEEK
Unit Prices		
At the sole option of the Contractor, the following unit prices/wage rates may be used to adjust the base amount.	INCLUDED	INCLUDED
Subcontractor specifically acknowledges that the following unit prices include freight, labor, labor burden, fringes, material, equipment, tax, permits, fees, bond and mark-up for overhead and profit as indicated. In addition, all unit prices/wage rates are not to exceed the amounts included herein, and are good for the duration of the project.	INCLUDED	INCLUDED
The following labor rates include **burden, fringes, bond, and O&P**	INCLUDED	INCLUDED
Foreman ($/HR)	$40	$50
Foreman Overtime Rate ($/HR)	$60	$75
Laborer ($/HR)	$20	$30
Laborer Overtime Rate ($/HR)	$30	$45
The following unit costs are all inclusive: **freight, material, tax, labor, burden, fringes, bond, equipment, O&P, etc.**	INCLUDED	INCLUDED
LF of extra fencing - 8 FT high with slats ($/LF)	$22	$20
Chain-link doors - 6'x8' ($/Ea.)	$400	$700

Figure 4-2. Bid leveling analysis

Performing Bid Leveling and Analysis

After the proposals and the scope of work checklist are received and are deemed to be complete, a proper “apples-to-apples” analysis can be performed. This involves comparing subcontractor’s scope of work submissions with one another to see who has the most complete scope and offers the best price. This process becomes painless once everyone has included all that was required of them in their scope of work and have submitted a complete proposal agreeing to each line item in the scope of work checklist and a proper quote.

Conclusions

Figure 4-3 shows the redundancy and difficulty in trying to locate a subcontractor in a new territory, and then having to prequalify the subcontractor for a specified project. Figure 4-4 depicts the next two steps in preconstruction whereby information has to be sent to the subcontractor. While the process may seem straightforward, it is actually quite time-consuming to verify whether all bidders have successfully accessed the contract documents. It becomes even more difficult, if there is an addendum or an update, since these steps have to be repeated all over again per bidder, per trade. Figure 4-5 represents the final steps in the preconstruction process. In this step, the information is received from the subcontractors, and a bid analysis is performed. Again, gathering complete information from subcontractors takes quite a bit of work and time due to a lack of trust in subcontractors. In the next chapter, the focus will shift towards what current solutions are out there to help improve the efficiency of the preconstruction process and improve productivity.

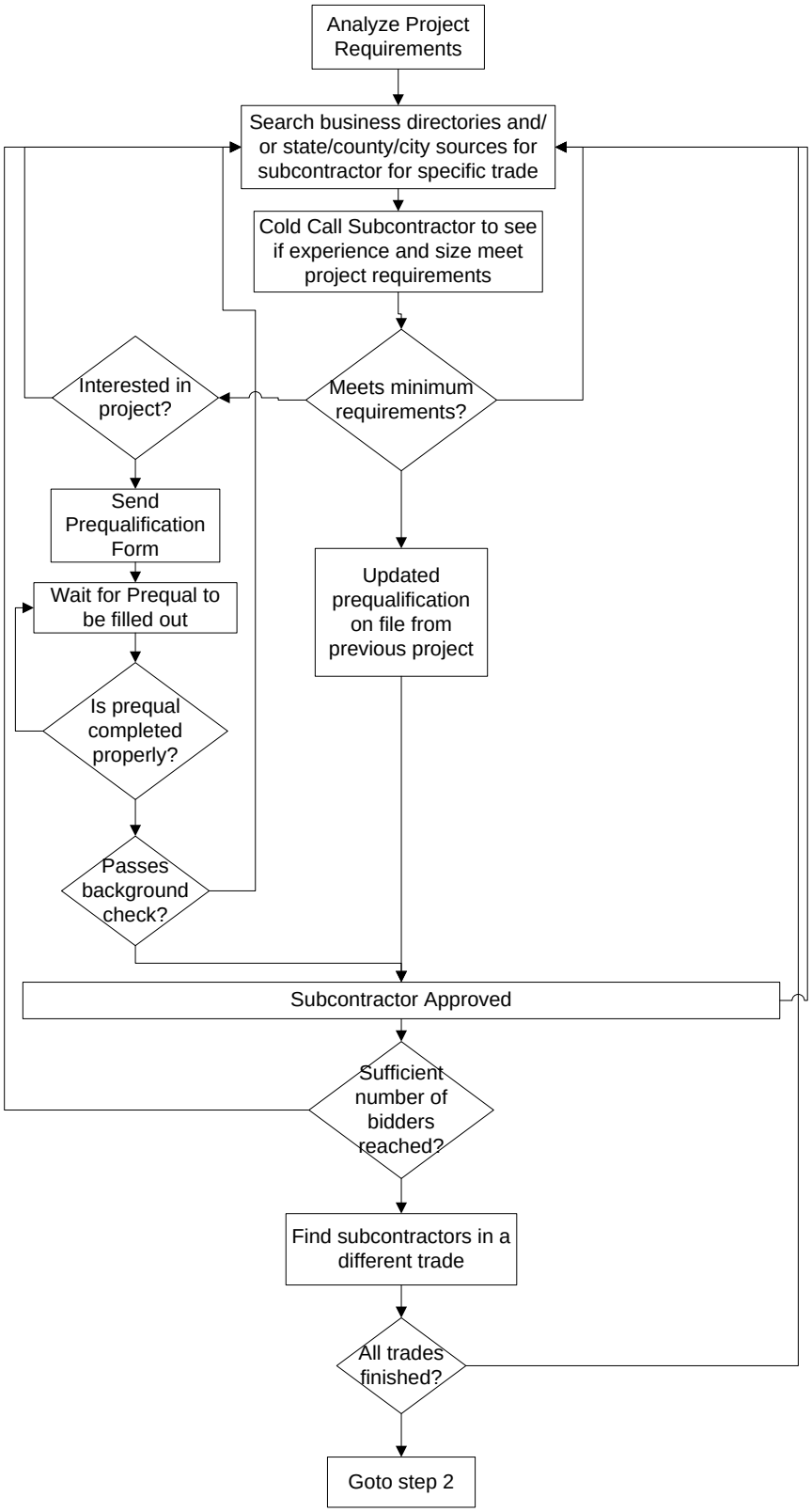

Figure 4-3. Procedures in Step 1

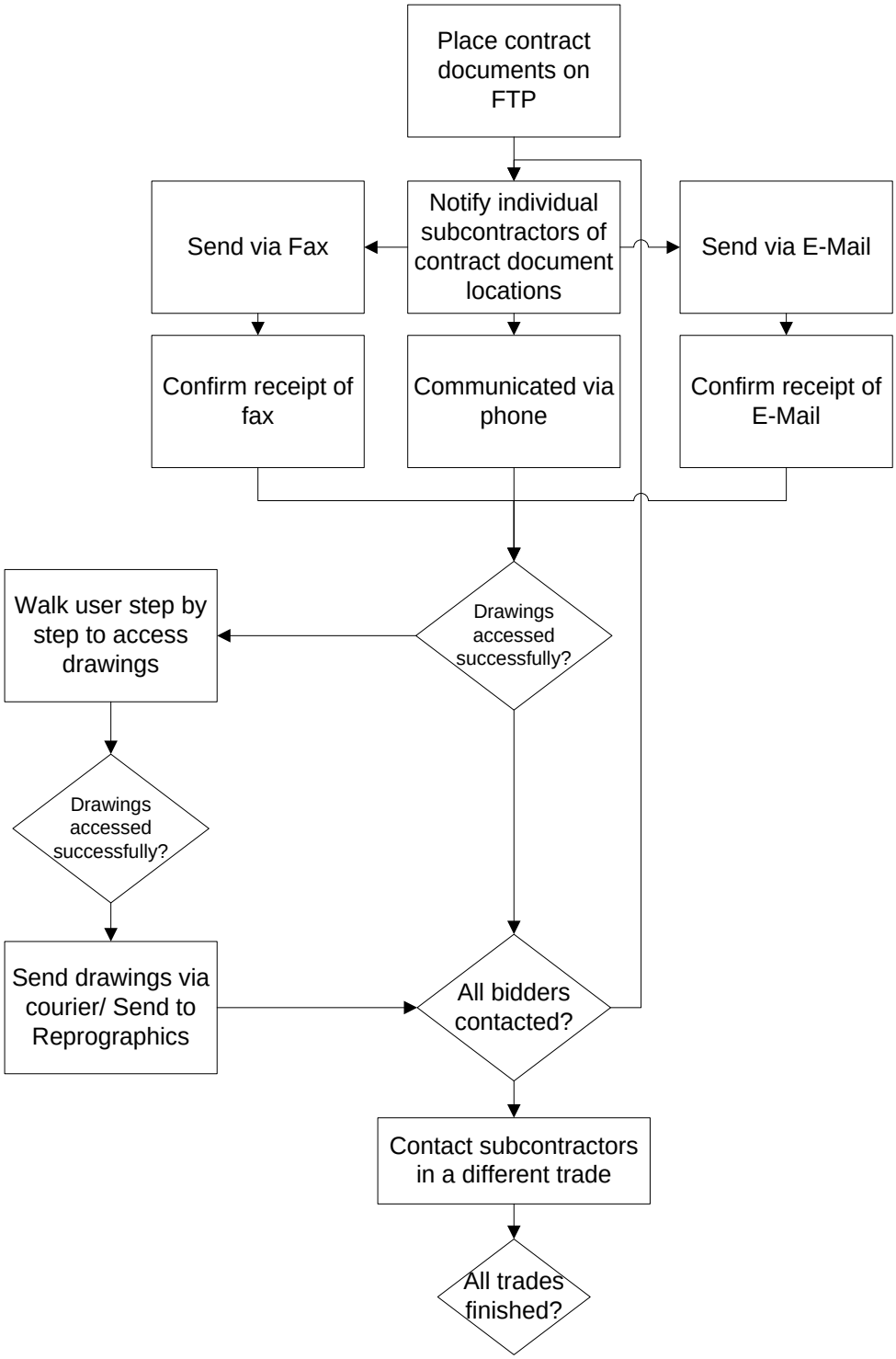

Figure 4-4. Procedures in step 2 and step 3

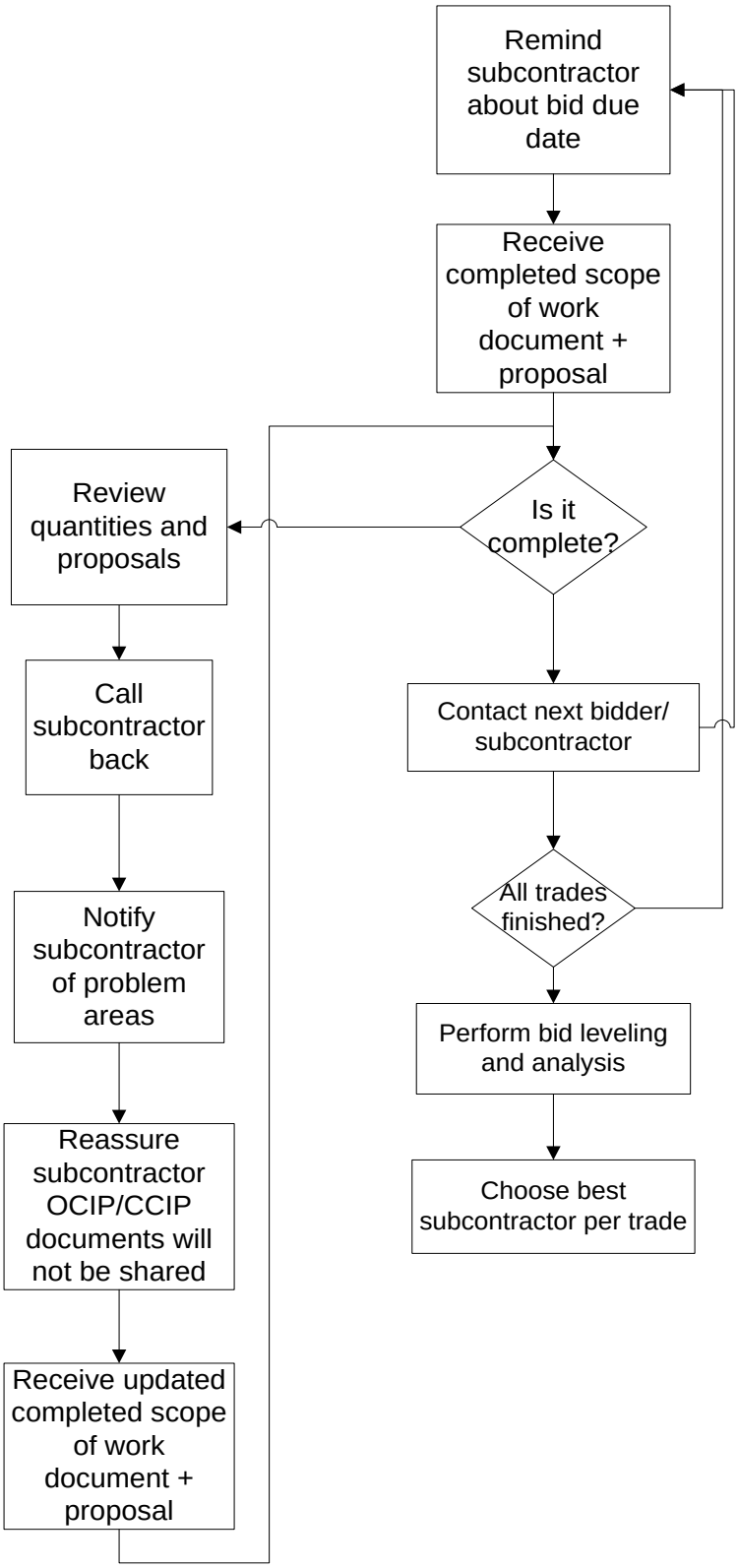

Figure 4-5. Receiving information back and performing bid level analysis

CHAPTER 5
OPTIMIZED METHOD OF PERFORMING PRECONSTRUCTION

This chapter will focus on how WBPMS can help preconstruction engineers overcome many of the mundane and productivity lowering obstacles witnessed in the previous chapter. The outline of this chapter will follow the same outline used in the previous chapter so as to make it easier to reference between the traditional method, and the IT method:

1. Finding Subcontractors
    1.1. Prequalifying Subcontractors
    1.2. Determining Project Interest
2. Submission of Contract Documents
3. Submission of a scope of work document
4. Receiving bids back from subcontractors
    4.1. Analyzing for completeness and accuracy
5. Performing bid leveling and analysis
6. Choosing the best subcontractor

Finding Subcontractors

In this section of preconstruction, two main components are needed. One is to have access to ample data on file for each subcontractor, and two to have a strong search system. As noted in Chapter 4, a company that attempts to perform a project in a new geographical area often does not know who to call upon. A more efficient way of finding subcontractors would be to use an online service whereby subcontractors are also members of this site. By joining such an online service, the general contractor will then will take advantage of the fact that each subcontractor has an online profile that

they have filled out themselves. Each profile contains the answers to many of the questions that were going to be asked on the phone, as well as answers to many of the questions that were going to be asked in the prequalification packet. Looking at it from a subcontractor's point of view, they would much rather fill out one prequalification form and have it presented to all general contractor's than to individually introduce the company over the phone and fill out prequalification packets for them. Aside from the hassles of getting a completed prequalification packet back from the subcontractor, there is also the problem of finding a subcontractor willing to travel to a specific area. Again as noted in Chapter 2, if a subcontractor, after receiving the project information sheet, realizes that the project is 50 miles away, for example, the subcontractor may decline leading the preconstruction engineer to have to go back to finding a subcontractor willing to travel out to the jobsite location. Under this new method, subcontractors list specifically which cities, villages, metro areas they normally perform work in. It may not even be a distance issue, it could potentially be a jurisdictional issue if it is in a union state.

Prequalifying Subcontractors

Under this new method, prequalifying subcontractors for a project becomes even easier since all the information needed to screen subcontractors are already available. The only thing preconstruction engineers need to do is to review each subcontractor profile and create an online list of those that seem to be a perfect fit for the project. There is no longer the need to cold call individual subcontractors, nor wait for prequalification packets to be completed and sent back.

Determining Project Interest

This portion of finding subcontractors becomes much easier. Since subcontractors have been carefully screened, the ones that are now in the online list are the ones that are most likely to accept to being a bidding participant on the project. The next step is to send out a project information sheet to allow the subcontractor to become acquainted with the project. Under the traditional method and on a public job for example, the project information sheet would have to be sent individually one by one to each subcontractor via fax, since the fax provides confirmation. This again is inefficient because it takes large amounts of time having to send individual faxes and collect the confirmation page. With a WBPMS, the project information sheet is sent to all subcontractors in the online list all at once. Subcontractors are automatically notified by e-mail to login to view the project information sheet. Upon viewing, the WBPMS will then mark which subcontractors have taken a look at the project information sheet and which ones have not. Not only that, an immediate response can be given by the subcontractor to accept or not to accept the invitation. As an added benefit, should the subcontractor accept the invitation, the need to call the subcontractor to remind him/her about an upcoming bid date is also eliminated since a WBMPS can add the bid date to the subcontractor's online calendar.

Submission of Contract Documents

To improve sending contract documents, an online storage location is the most ideal solution which all members of the project can easily access. The traditional method of printing and sending to subcontractors via courier is inefficient in both time and in cost. As noted in the previous chapter, some contractors upload documents to an FTP location, and then help the subcontractor manually walk through the steps of

accessing the FTP site. Each project normally has a different FTP address meaning that the general contractor has to manually walk the subcontractor through the information for every project. The better method is to upload it to an online project storage location. A WBPMS again provides such a service. Why is this ideal over FTP or sending information the traditional way? The reasons this is ideal include:

- Wait times and costs are significantly reduced having information sent via courier
- No need to walk the subcontractor through accessing information on FTP site
- Ability to confirm that the subcontractor has viewed the drawings

By using this web based project management system, subcontractor activities with regards to drawing access is noted. The general contractor will know which subcontractors have accessed the drawings and which have not. Furthermore, if a subcontractor forgets to check a specific folder or a specific drawing, the general contractor can easily see this and notify the subcontractor. This in return leads to a more precise proposal/bid by the estimator.

In the event that there an update or an addendum to the contract documents is generated, sending such an update using this online system is much easier to handle. As noted in the Chapter 4, having to resend updates via courier is costly. Placing it on an FTP site and then emailing or calling each individual subcontractor to view new information, is also a hassle. Under this new system, all subcontractors are automatically notified if an update has occurred. Not only that, the general contractor can also broadcast a message with this update, and all subcontractors who are part of the project will automatically receive it. This one-to-many style communications speeds up the transfer of information, provides everyone with the same information, and provides a guarantee knowing that the information was successfully transmitted to all

subcontractors. This further minimizes the potential for subcontractors to seek to have the bidding system disqualified, or seek legal action against the general contractor, by stating that the bidding was unfair.

Submission of Scope of Work Document

Sending miscellaneous information such as a scope of work for a subcontractor to review is a very important task. The purpose of sending this document is so that the subcontractor knows exactly what is to be included in their scope and what rules and regulations the subcontractor must follow on the project. Since this document needs to be sent to all subcontractors, sending it again follows the one-to-many rule. By submitting the same scope of work to all of the subcontractors in every trade, the general contractor can rest assured knowing that all subcontractors know exactly what to include, and not only that, there is no longer the need to follow up with each individual subcontractor to see if they have received the scope of work document.

Receiving bids back from subcontractors

As noted in the previous chapter, receiving information is a major hassle. This web enabled system helps by chronologically listing for the subcontractors which bids/proposals are due when and for which general contractor. This in itself frees up the general contractor's time of having to contact individual subcontractors to inform them of an upcoming bid date. Secondly, subcontractors can easily see a list of things that they must send back to the general contractor. The subcontractor now has one medium for submitting information back.

Analyzing for Completeness and Accuracy

This preconstruction step is also fairly time consuming if IT is not used. Subcontractors have a tendency to leave out certain information which may put their company at risk. An example of this would be agreeing to certain line items on a scope of work. Typically, when a subcontractor is asked to fill out a scope of work document, meaning whether they are going to include/agree to or exclude/ not agree to a certain line item, those line items which may be risky may be left blank. By leaving them blank, the subcontractor is able to make it appear that they are not responsible for a specific line item without officially excluding it (if they exclude they believe they might not get the job). A way in which IT is able to help the general contractor in receiving completed scope of works is to use digital forms. Digital forms are electronic forms that have logic behind them. As an example, instead of faxing a scope of work document over to be filled in by hand, the form can be created digitally so that not only can the subcontractor easily fill it out online, but also in the event the subcontractor leaves out a question, whether inadvertently or purposely, the system will notify the user to answer all the question otherwise the bid/ proposal will not get submitted back to the general contractor. By using such a system, the general contractor will have all of the information upfront to make a proper comparison between subcontractors. Another main item that a scope of work document usually asks is unit prices. The unit prices that are normally requested include material and also labor costs. The reason general contractors ask for this sort of information is that if there needs to be an addition or a deduction to a subcontractors scope, unit prices are already locked in place and the subcontractor cannot submit different numbers in order to inflate their earnings. This is again another section that subcontractors feel hesitant about in filling out information.

The main reason for this is because subcontractors feel that they are taking too much risk should they commit to unit prices in the event of market escalation. The inefficiencies of having to call subcontractors constantly and have to wait on them to resend the scope of work completely filled out is eliminated. As far as accuracy, the general contractor knows that the subcontractor has taken a look at the scope of work document, and has reviewed it line by line.

Performing Bid Leveling and Analysis

The process of bid leveling and analysis is much easier to accomplish with digital smart forms. In the event that a subcontractor cannot furnish something that is being asked in the scope of work, the form can ask them to provide a “plug-in” number for that specific item. A plug-in item can be termed as a number that could be added onto the subcontractors bid to have that specific subcontractor perform that portion of the work that was excluded. This number is usually calculated either by using an educated guess of how much it would cost, or the subcontractor may contact another subcontractor to find out how much the price is. In any event, when bids are sent back, the system can easily display what each subcontractor had answered on their scope of work and what their prices were. The system can then add up each subcontractor’s bid/proposal price plus any other plug-in numbers, taxes, bond amounts to reach a final price. The system can then display in order which subcontractor has the lowest price with the most inclusions. The winning subcontractor can then be easily picked out and contracted with.

Conclusions

The use of IT/WBPMS solves the following key areas:

- Time: Finding subcontractors easily

- Time: Communicating information all at once to multiple participants
- Time: The elimination of having to remind subcontractors to fix a deliverable or send information back
- Time: Reducing turn-around times
- Cost: Amount of time preconstruction engineers accrue working on a given project
- In the next chapter, a system dynamics model will be created to show the effects of a WBMPS(iSqft.com as an example) on the interaction between the general contractor and subcontractor, the construction company, and the industry.

CHAPTER 6
SYSTEM DYNAMICS

Before diving into the system dynamics model, a more simplified flowchart model, shown in Figure 6-1, will be discussed. The general contractor and subcontractor are shown implementing iSqft. Given the improvements in turn-around times and having information available quicker, both the general contractor and the subcontractor are able to quickly get their work accomplished. By doing so, they are able to finish their tasks quicker resulting in the project going through preconstruction at a quicker rate. When management realizes that the project is completed sooner than anticipated, the company has to look for more work to keep the preconstruction engineers busy. This efficiency in getting work accomplished at a faster rate allows both the general contractor and subcontractor to tackle more projects, and as a result the company begins to expand. This expansion in return brings more money for the company. As other companies begin to see that their competitor has an advantage over them and are succeeding, this will create a feedback loop. They too will follow suit and implement iSqft to try and keep up. As this trend continues, the industry as a whole will become more efficient.

Stella Model

Using Stella, a system dynamics software, the system dynamics flowchart shown in Figure 6-1was created. To use this software, certain assumptions had to be made since the data was either not made available by companies, or they were not authorized to provide the information. The assumptions were as follows:

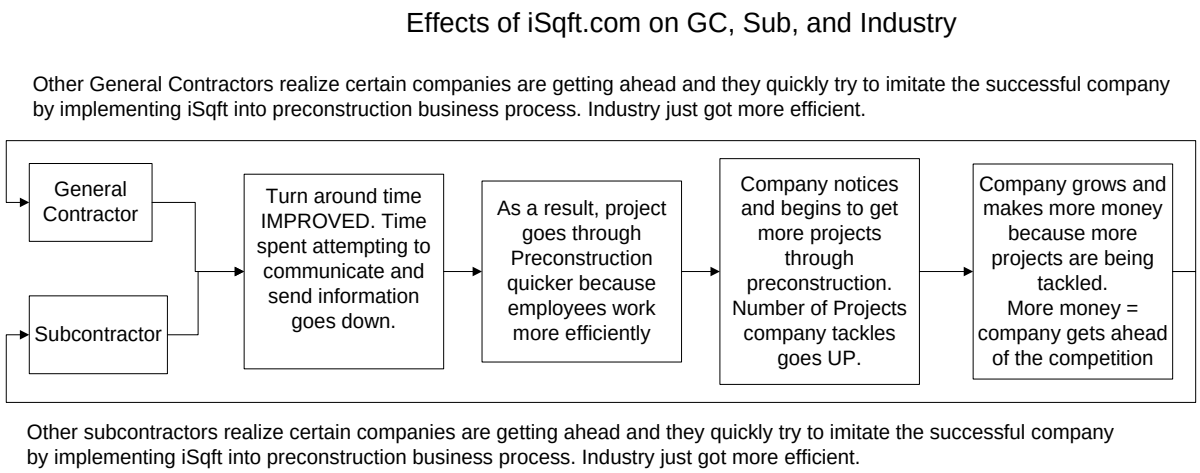

Figure 6-1. Simplified version of the System Dynamics model

General Assumptions:

This model is assuming that the majority of work that the company does is negotiated and not hard bid. This means that the company is not looking for work, but has constant work coming in. Furthermore, this model assumes that all preconstruction engineers are busy with current projects, and cannot take on any more work unless projects are able to go through preconstruction faster.

Rate of General Contractors:

Formula:

$$\left(\left(GeneralContractors_{using_{iSqft}} \times .01\right) + 0.05 \times \left(\frac{Money_{Savings}}{1000000}\right) + \left(Subcontractors_{using_{iSqft}} \times .15\right)\right)$$

Explanation:

It is assumed that 1% of those who join iSqft will be those who were referred by a fellow general contractors already using iSqft. This is a classic feedback loop. Another 5% will join for every $1 million dollars that is saved in the industry, and 15% will join based on their interactions with subcontractors.

Since the number of subcontractors exceeds the number of general contractors in the industry, they have a greater opportunity of spreading the word about the benefits of a WBPMS in terms of communication and exchange of information. .

Rate of Sub Contractors:

Formula:

$$\left(Subcontractors_{using_{iSqft}} \times .1\right) + 0.1 \times \left(\frac{Money_{Savings}}{100000}\right) + \left(GeneralContractors_{using_{iSqft}} \times .2\right)$$

Explanation:

It is assumed that 10% of those that join iSqft will be those who were referred by fellow subcontractors already using iSqft. This is a classic feedback loop. This feedback loop is higher for subcontractors because there are many different types of subcontractors who are not in direct competition with each other and therefore they can help one-another out. Another 10% will join for every $100,000 dollars that is saved in the industry, because they too would like to save money, and 20% will join based on their interactions with the general contractor using iSqft. The reason that they will join is because they will get a glimpse of how preconstruction becomes easier, and will therefore use it to apply it to all of their projects.

Rate of Money Savings for Industry:

Formula:

$$\left(GeneralContractors_{using_{iSqft}} \times With_{iSqft} \times 20000\right) - \left(Without_{iSqft} \times GeneralContractors_{us}\right.$$

Explanation:

$20,000 is calculated by assuming that each project going through preconstruction requires 3 preconstruction engineers at a rate of $30/hour and 1 preconstruction manager at a rate of $35/hour. All four work 40 hours a week for four weeks. $Without_{iSqft}$ represents the number of projects accomplished without using iSqft in one year. $With_{iSqft}$ represents the number of projects that are completed in a year.

<u>Rate of Number of Projects:</u>

Formula:

$$(With_{iSqft} \times GeneralContractors_{using_{iSqft}}) - (GeneralContractors_{using_{iSqft}} \times without_{iSqft})$$

Explanation:

This formula calculates all of the extra projects that are accomplished by using iSqft within the industry.

Results

Given the above assumptions as part of the System Dynamics model, it is expected that the rate that General Contractors will use iSqft will be exponential. This is again based on interactions within the system. The more general contractors and subcontractors use iSqft, the more regular general contractors will change their preconstruction process and implement iSqft. The formula also takes into account companies which do not necessarily come into contact with anyone who uses iSqft directly, but through learning about other companies saving money and increasing the number of projects that they can complete. Figure 6-2 represents general contractors switching to iSqft. After year 9, the figure shows that the number is no longer increasing,

but it is constant. The reason for this is because all regular general contractors that do not use iSqft have all now switched.

Figure 6-3 shows the number of subcontractors switching to iSqft. It too follows the same pattern as the number of general contractors switching since it again is based on feedback loops from subcontractors who are already using it, as well as being dependent upon general contractors requesting that they use it. Figure 6-4 has the rate of increase overlaid. It is interesting to note that the rate at which subcontractors implement iSqft overtakes that of general contractors. The main reason for this is:

- The feedback loop between subcontractors is stronger because they can easily bring other subcontractors onboard since many are not in direct competition with one-another. To put simply, a concrete subcontractor can spread the message to subcontractors in a different trade and therefore, help one-another out.
- Those that do not use iSqft may be forced to use it since the general contractor uses it and as a result, they get to try it out.
- The rate at which subcontractors join based on money savings is set per $100,000 as opposed to general contractors which is per $1,000,000. The rationalization behind this is that $100,000 is considered to be a large amount for subcontractors to make the decision to switch.

Figure 6-5 represents the number of projects completed and money savings within the industry, if the value of $Without_{iSqft}$ = 9 (projects completed per year) and $With_{iSqft}$ = 10 (projects completed per year). As the value of $With_{iSqft}$ increases to 11 or 12, the line which represents the number of projects completed begins to overlay itself on top of money savings. This is shown in Figure 6-6. As the number of projects that can be completed with iSqft increases, meaning that $With_{iSqft} >$ 12 in a given year, the number of projects shown in Figure 6-7 will be plotted above money savings. This shows the efficiency in time that iSqft is able to bring to preconstruction in getting more work accomplished in a given year. Not only does it provide cost savings, but also

improves the number of projects that can be accomplished within a given year. Another interesting thing to take note is that the rate of adoption increases as the $With_{iSqft}$ increase in each figure. The greater the number increases, the quicker general contractors and subcontractors appear to adopt it. This sounds logically correct because more users will adopt something as its benefits are greater. On a final note, Figure 6-8 represents the system dynamics model shown in Figure 6-1.The complete set of equations, along with initializing variables for the Stella model in Figure 6-8 are listed in Appendix A.

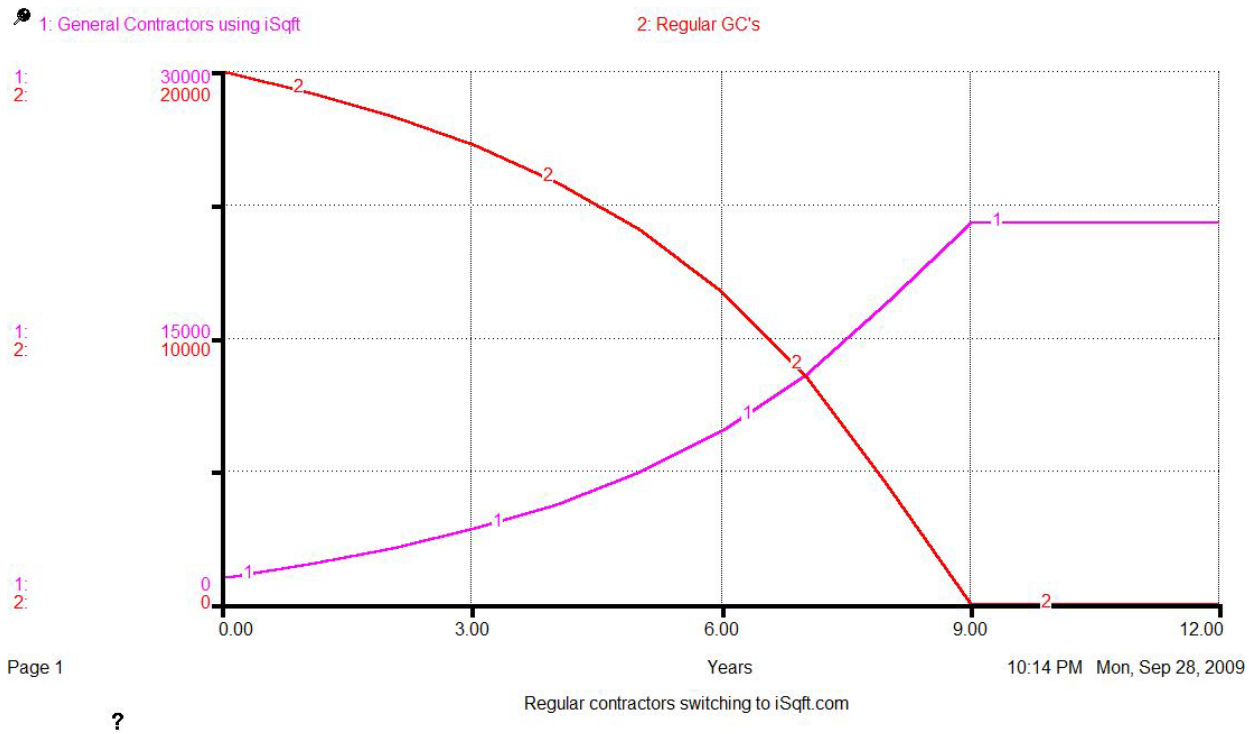

Figure 6-2. Regular Contractors switching to iSqft.com

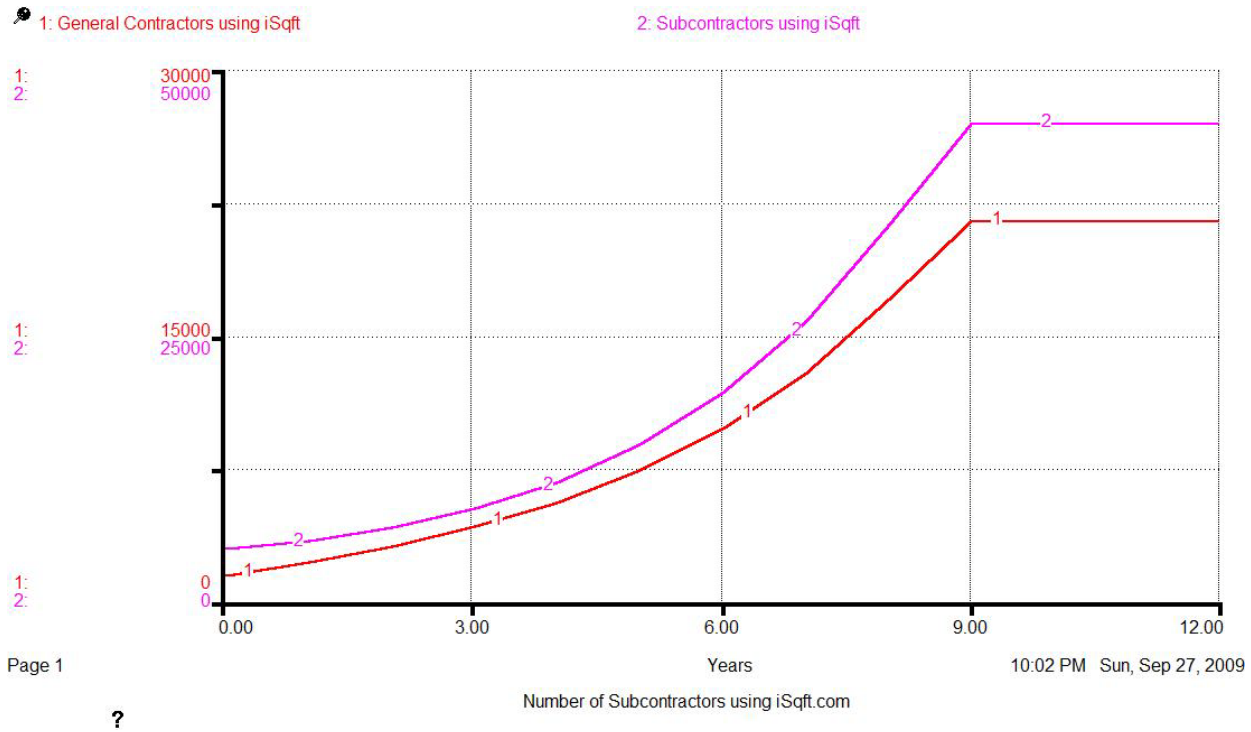

Figure 6-3. Subcontractors switching to iSqft.com

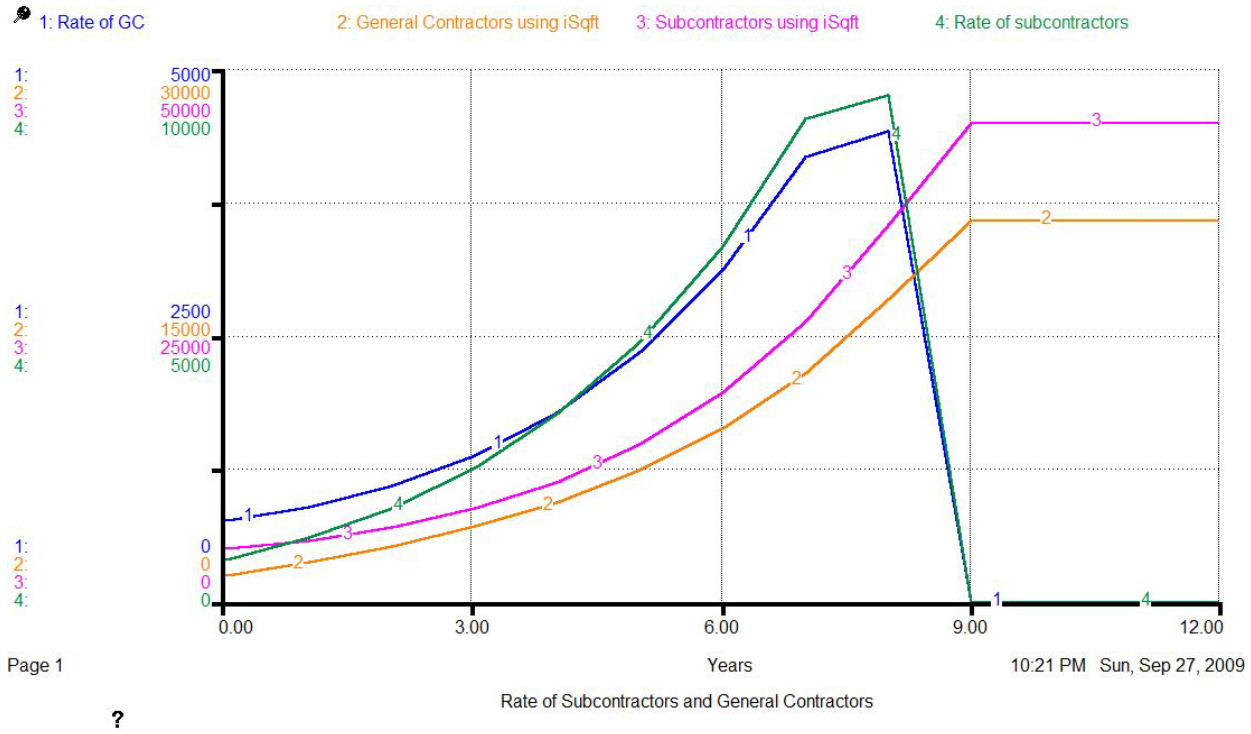

Figure 6-4. Rate of increase of subcontractors and general contractors over time

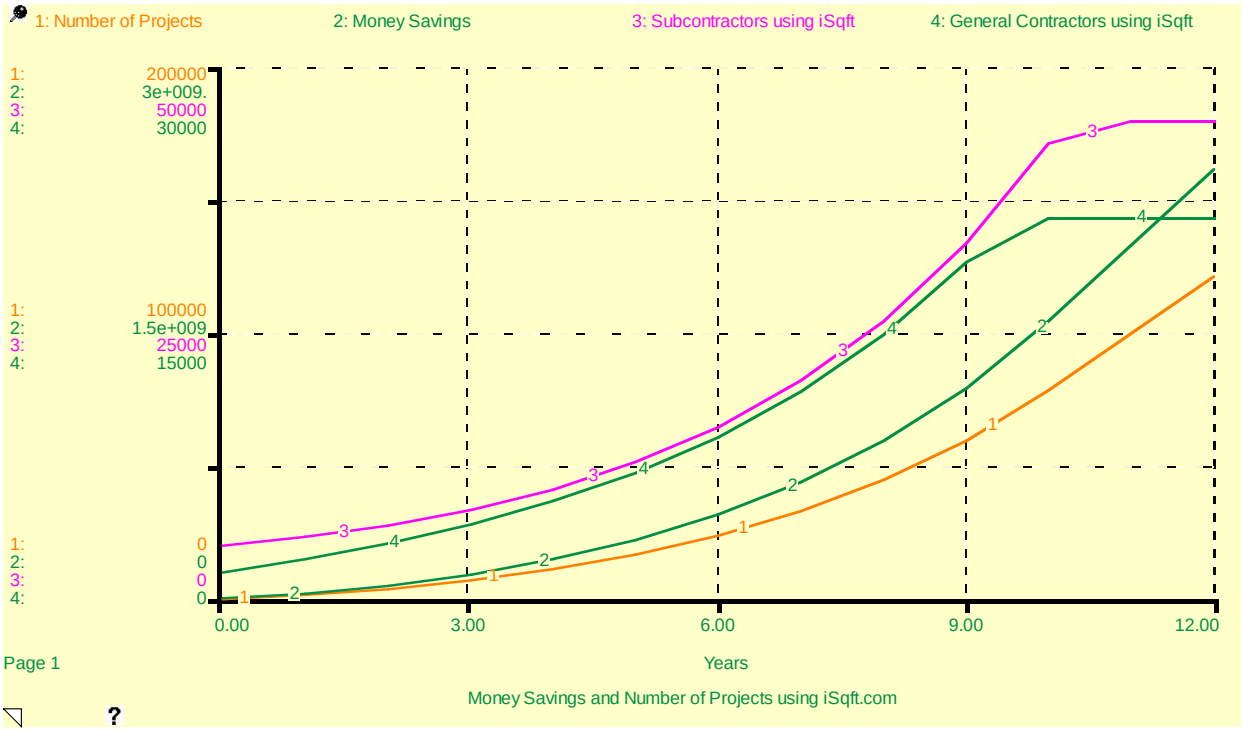

Figure 6-5. Increasing the number of extra projects iSqft can perform to 10

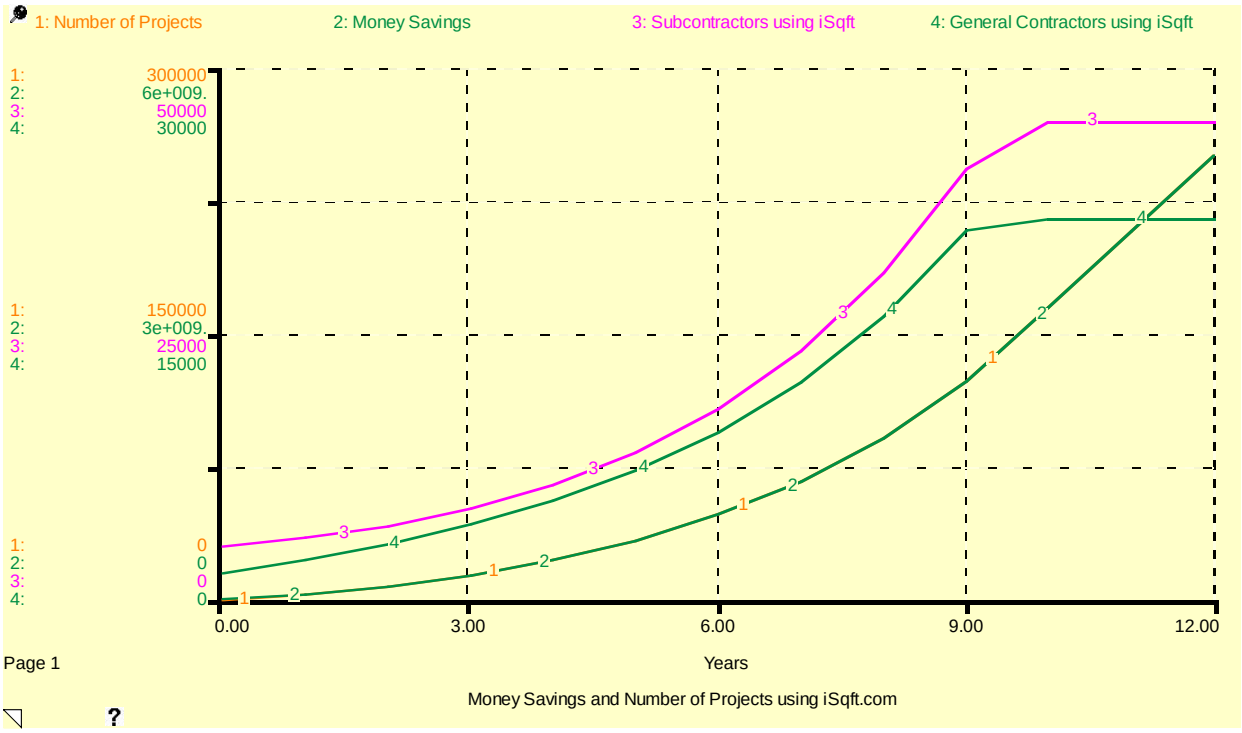

Figure 6-6. Increasing the number of extra projects iSqft can perform to 11

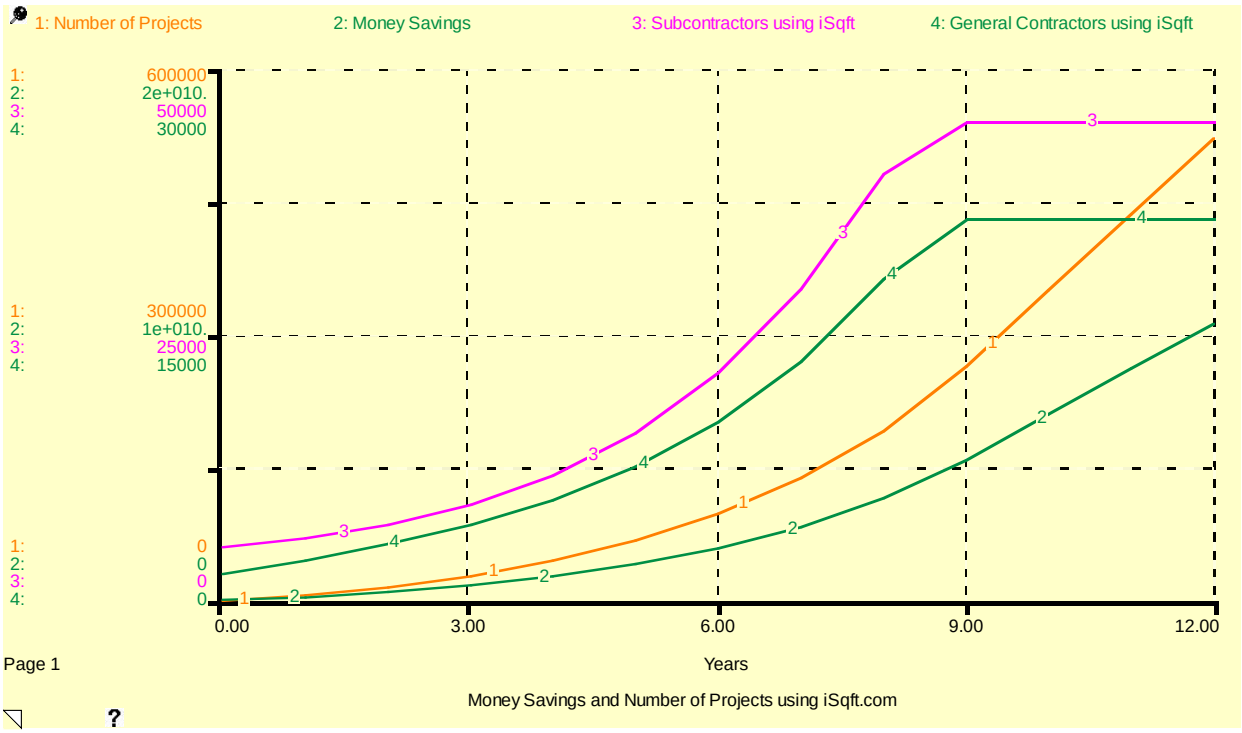

Figure 6-7. Increasing the number of extra projects iSqft can perform to 13

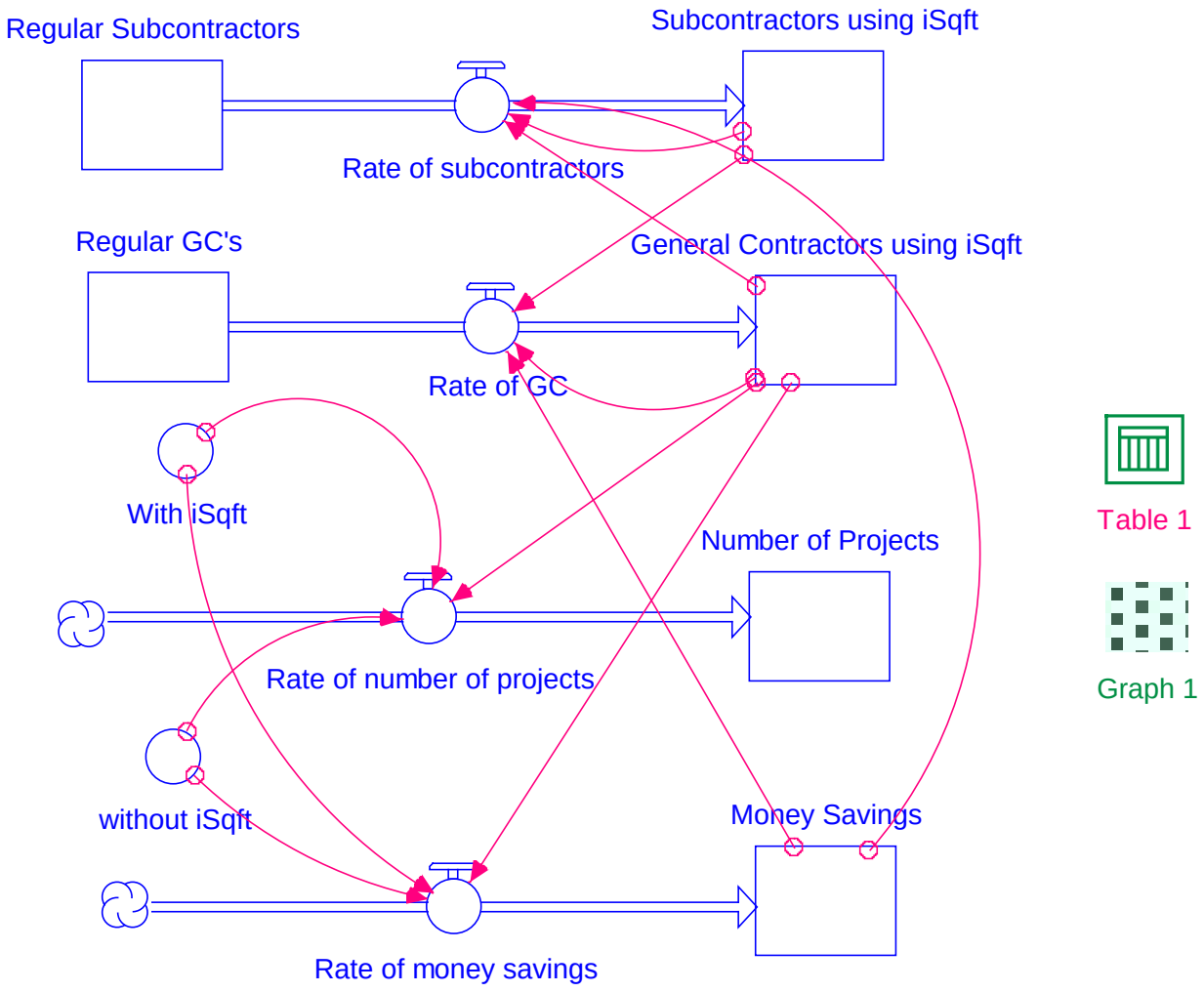

Figure 6-8. System Dynamics model within Stella

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

As stated earlier, the construction industry is a fragmented industry without a set standard for the use of technology in communicating, or for the exchange of information. A review of advancements in IT was presented as it applied to the construction industry, and it became clear that a web based groupware model, in this case a WBPMS, would be the best solution. Luckily as the industry begins to soften its stance against change and the use of technology, many companies will adapt their preconstruction processes to better incorporate IT and their use of a WBPMS. The issues of finding subcontractors, communicating information to multiple participants at once, sending information, waiting for information and communicating in general, will be substantially resolved. The reduction in time in performing preconstruction will be reduced, thanks to reduced turn-around times, and more projects can be performed. As the system dynamics model further highlighted, as more companies begin to shift in using IT in their preconstruction process, those that currently do not use it will begin to use it to stay competitive, and a result, the industry will become more efficient. Furthermore, the model also showed that as the number of extra projects that can be accomplished using a WBPMS increases, the rate at which subcontractors and general contractors adapt their preconstruction process also increases. To put it simply, the greater the benefits that such a system provides, the quicker the transformation rate of IT in preconstruction will be.

As for recommendations, I would highly recommend the use of a WBPMS to help solve the issues of communication and exchange of information outlined above. It is to each company's best interest to review the features that each WBPMS company offers,

and to make an educated decision as to which system is the easiest to use, integrates well with the current preconstruction process, and has the least amount of learning curve. Furthermore, construction companies do not necessarily need to implement all of the features of a WBPMS and change their processes as a result of doing so. Each company may opt to sign up for specific features of a WBPMS, while keeping the rest of their processes unchanged. As for further research, the following are potential areas to look into :

- Performing a cost benefit analysis as to which WBPMS provides the highest efficiency and productivity increase
- Having a construction company quantitatively record productivity data as they switch from the traditional method of performing preconstruction to the IT method of using a WBPMS
- Understanding what effects a WBPMS would have on different types of construction projects (i.e. healthcare, educational, multi-use…)
- Understanding what effects a WBPMS would have on different sized construction companies
- Measuring the learning curve and costs involved in having an entire preconstruction division change their method of performing preconstruction
- Adding other elements, such as learning curve period, to the system dynamics model to further enhance its results
- Finding ways of furthering the idea of WBPMS to better meet the needs of preconstruction engineers

APPENDIX A
SYSTEM DYNAMICS EQUATIONS

Below are the complete set of equations which Stella produced:

General_Contractors_using_iSqft(t) = General_Contractors_using_iSqft(t - dt) + (Rate_of_GC) * dt

INIT General_Contractors_using_iSqft = 1500

INFLOWS:

Rate_of_GC = ((General_Contractors_using_iSqft * .01) + 0.05*(Money_Savings/1000000) + (Subcontractors_using_iSqft * .15))

Money_Savings(t) = Money_Savings(t - dt) + (Rate_of_money_savings) * dt

INIT Money_Savings = 1

INFLOWS:

Rate_of_money_savings = (General_Contractors_using_iSqft * With_iSqft * 20000)- (without_iSqft* General_Contractors_using_iSqft*20000)

Number_of_Projects(t) = Number_of_Projects(t - dt) + (Rate_of_number_of_projects) * dt

INIT Number_of_Projects = 0

INFLOWS:

Rate_of_number_of_projects = (With_iSqft * General_Contractors_using_iSqft) - (General_Contractors_using_iSqft * without_iSqft)

Regular_GC's(t) = Regular_GC's(t - dt) + (- Rate_of_GC) * dt

INIT Regular_GC's = 20000

OUTFLOWS:

Rate_of_GC = ((General_Contractors_using_iSqft * .01) + 0.05*(Money_Savings/1000000) + (Subcontractors_using_iSqft * .15))

Regular_Subcontractors(t) = Regular_Subcontractors(t - dt) + (- Rate_of_subcontractors) * dt

INIT Regular_Subcontractors = 40000

OUTFLOWS:

Rate_of_subcontractors = (Subcontractors_using_iSqft *.1+ 0.19*(Money_Savings/100000) +(general_Contractors_using_iSqft * .2))

Subcontractors_using_iSqft(t) = Subcontractors_using_iSqft(t - dt) + (Rate_of_subcontractors) * dt

INIT Subcontractors_using_iSqft = 5000

INFLOWS:

Rate_of_subcontractors = (Subcontractors_using_iSqft *.1+ 0.19*(Money_Savings/100000)

+(general_Contractors_using_iSqft * .2))

without_iSqft = 9

With_iSqft = 12

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Sina Bazargan-Lari received a Bachelor Science in Building Construction in December 2008. He has completed an 8-month internship as well as a 3-month internship in the construction industry. He is scheduled to receive his Master of Science in Building Construction in December 2009.