Impacts of Internal Communication on Dynamic Schedules in Mega Highway Projects

by

Mohammad Amin Shamloo

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE

in

THE COLLEGE OF GRADUATE STUDIES

(Civil Engineering)

THE UNIVERSITY OF BRITISH COLUMBIA

(Okanagan)

June 2014

Abstract

Traditionally, construction project management has consisted of three main areas of focus: 1- cost, 2- schedule, and 3- quality. This style of project management primarily developed for new projects has changed during the development and maintenance of transportation infrastructure projects in past years. During this time, these management practices were used for projects that would replace, repair, or expand existent transportation infrastructure. This change in direction has ultimately remodeled current management practices, that focused on the mitigation of risks associated with quality, time and costs. Thus, it is crucial for today's project management teams to understand and effectively convey the relationships between communication, resources, and organizational hierarchy with scheduling conflicts.

The main focus of this study was to observe the relationships between communication, resources, and organizational hierarchy, and how they affect construction schedules. This study is presented as a case study on the Port Mann Highway 1 extension project (PMH1) in British Columbia, Canada. At the time of commission, the PMH1 project was the largest infrastructure project in North America, and was based on a design-build contract. The estimated cost for this project was initially set at 2.46 billion dollars, but with the changes initiated to date, the cost may total more than 3 billion dollars by the time of completion.

The two main variables that can affect the construction schedule have been identified as communication and resources. The managers of the general contractors through extensive interview processes have indicated that 77% and 62% of the factors that cause delay to the construction schedule are respectively communication and inexperienced labor force. It was also found that, by moving and replacing medium level managers in the organizational hierarchy, the delays to the construction schedule can be minimized. Based on these findings, a recommended solution has been proposed and validated by a second set of interviews with a second group of senior project managers. It is recommended that a strategized use of computer software be utilized in similar infrastructure projects, which will help management staff minimize costly delays and conflicts caused by miscommunication.

Preface

A paper based on this research was co-authored by Dr. Kasun Hewage and Dr. Russell Alan with the title *The Port Mann Highway 1 Project – A case Study on Linking Organizational Charts & Schedule Conflicts.* This paper has been published in the 2013 CSCE Annual Conference Proceedings, 4th Construction Speciality conference, CN-068.

A University of British Columbia Okanagan Behaviour Research Ethics Board certificate was received for this research. The UBC-BREB number is H13-00322.

Table of Contents

List of Tables

List of Figures

List of Equations

List of Abbreviations

CC	Construction Communication
CM	Construction Management
CS	Construction Schedule
ICT	Information and Communication Technology
IT	Information Technology
LF	Labor Force
FE	Field Engineer
FTA	Federal Transit Administration
JTD	Job to Date
OE	Office Engineer
OH	Organizational Hierarchy
MHRS	Man Hours
NCHRP	National Cooperative Highway Research Program
PM	Project Management
PMH1	Port Mann Highway 1 extension project
REB	Research Ethics Board

SUPT	Superintendent
T1	Tier One
T2	Tier Two
T3	Tier Three
UBC	University of British Columbia

Acknowledgments

I would like to thank the following people; without their continuous support this research would not have been possible.

First, I would like to thank Dr. Kasun Hewage which without his patience and guidance I would have been lost. I thank him for the energy and inspiration he gave me these past years during my research in the University of British Columbia (Okanagan).

I would like to thank Dr. Alan Russell who guided me through the difficult times and pointed me in the right direction. I value his mentorship and guidance throughout my research.

I would like to thank the managing staff of the general partnership of Kiewit/Flatiron, and the General contractor of the Port Mann Highway 1 extension project. Without their help and expertise this research would have not been possible.

Finally, and most importantly, my beloved family, who all believed in me and their positive comments gave me the vote of confidence I needed through the hard process of working and studying these past years. My father and mother, who supported me with their love, and my only sister who helped me through the hard times, by always making sure I have someone to talk to.

To My Family

Chapter 1: Introduction

1.1 Background

In traditional engineering project management, the three most important aspects of any project have been schedule, cost, and quality (Marshall and Rousey, 2009). A change in one factor could influence the other two. For example, if cost decreases then the schedule and quality of project could be affected. Project and construction management has the task of efficiently changing these values in a way to maximize the overall outcome of the project.

Traditional project management (PM) practice has evolved during the development of the U.S. transportation infrastructure (Sillars, 2009). During this era, PM practices were used for projects that would replace, repair, and expand current transportation infrastructure. The amount of uncertainties and complications due to having existing infrastructure present in the new projects has changed the way PM is been practiced today. Traditionally, PM was used for tailoring new and upcoming projects. This difference itself could change the practice, due to mitigating a larger risk when it comes to time and cost. New PM practices include all that was practiced in traditional PM practices and has additions to it due to the greater uncertainties present in recent projects in urban areas. This makes todays PM practices more complex than what was practiced traditionally.

In recent history, public demand has shifted toward delivering infrastructure projects more quickly, while still focusing on time and costs (Sillars, 2009). The demand for faster and less costly projects has not changed throughout history, but what has changed is the type of infrastructure projects. At present, most infrastructure projects are expanding and repairing existing ones. This change can create additional uncertainties, which directly has an impact on the time and cost. As an example of these types of projects, PM in the Port Mann Highway 1 extension project (PMH1) project has a new factor causing more uncertainties: this factor includes working alongside existing infrastructure that must be maintained, and can be added to similar projects that are practiced today. This new factor is different from what was previously

known as uncertainty. In the past, uncertainty was more associated with factors such as resources, labor and budget, but today; uncertainty for these types of projects is more associated to factors such as existing utilities, ground conditions, foot print, public safety, and employee safety. These factors could have a significant effect on time and cost, which did not exist in traditional PM in this detail.

This new era of PM has a novel demand; in order to meet this demand, traditional PM processes must be aligned with today's needs. PM has been evolving into a different entity where the roles and responsibilities of the project manager have expanded beyond the traditional cost, schedule, technical or quality known as "the Iron Triangle" (Atkinson, 1999). Today, project managers of complex projects must deal with not only the above effective parameters, but also other new constraints such as financing systems.

The PMH1 project was used as a case study to obtain data and present how project managers today deal with very complex transportation projects when it comes to scheduling conflicts, with emphasis placed on communication, labor force and the organizational structure of the delivery team. Due to the scale of the project, the PMH1 project, as a mega infrastructure project, has been divided into four different geographical segments, segments one through for, west to east respectively. This study focuses on the first of these segments. The scope of work in the first geographic segment treated in this case study includes widening the existing highway, constructing several new overpasses and expanding old ones, building new on and off ramps, environmental rehabilitations, and rehabilitating existing structures.

1.2 Problem Statement

It has been presented that the current needs of PM have changed significantly compared to that which was known in the traditional practice of PM. This change applies to all projects that involves repairing and expanding current infrastructure. This change has identified a new uncertainty. Uncertainties in these projects, where the construction site is on an existing and functioning infrastructure, are much greater than what was known as uncertainty in the traditional PM scope of work. In this study, the main challenge is to understand and define how

PM handles uncertainties, and what effects it has had on the practice today. The focus is on defining the variables that can affect schedule milestones and create delays on the project delivery date. Also, the organizational hierarchy (OH) of the project is studied to see how different variables may cause changes within the schedule, and if changes in the OH have any effect on bringing the schedule back on track.

1.3 Research Questions

The purpose of this study is to identify the practices used by the PM working on PMH1 and what difficulties have arose from the unknown uncertainty factors. These factors which can cause delay to the construction schedule will be identified and presented. Furthermore a solution will be recommended to help project managers identify these factors earlier in the construction phases. In order to further investigate the unknown uncertainties in mega highway construction projects, the following questions were addressed in this study:

1- What variables have the most impact on the project schedule and delivery date?
2- What variables can have effects on causing delays to the schedule?
3- What are the effects of communication on causing delay to the schedule?
4- How are OH changes related to schedule conflict and delays?

1.4 Research Objectives

The objective of this study is to identify the actions taken by management, including organizational changes, to help the project back on track when unforeseen events interrupt the schedule of the project. The main objectives of this research are to identify the impacts of communication, OH, and resource allocation to the project schedule.

1- Communication between the field and managing staff
    a. Identify the flow of communication between departments
    b. Identify the flow of communication from the field to office and office to field
    c. Identify the flow of communication from departments to project management

d. Propose a solution to minimize occurring problems with communication
e. When and how often senior project managers change the OH
    i. How do these changes help with schedule delays and conflicts
    ii. At what levels are these changes made

2- Hierarchy and resource influence on construction schedule
    a. Identify when there are hierarchy changes
    b. Identify at what levels do hierarchy changes have positive effects on the construction schedule (CS)
    c. Identify which resources can affect the CS

1.5 Research Deliverables

This research has five main deliverables. These key factors are aimed to assist and provide valuable information regarding the new factors which have an effect on the project schedule and organizational charts. The information provided will help to assist future academic work, and presents the new challenges that are facing PM teams in similar projects.

These research deliverables are as follows:

1- Identify the communication process in mega highway projects from the field to the office

2- Identify how changes in the OH affect the CS

3- Review the main reoccurring problems in construction management in current mega highway projects

4- Identify and analyze the variables that are causing delay in the CS in this case study

5- Develop and propose a solution that can help with CS delays

1.6 Thesis Structure

This thesis consists of six main chapters, each containing a number of sections and sub sections.

Figure 1.1 shows the structure of this thesis is presented.

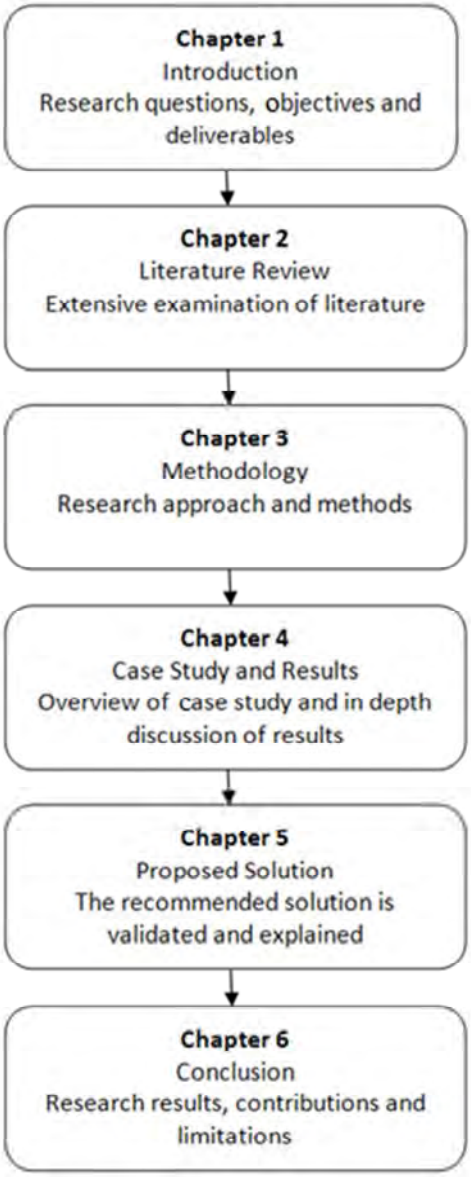

Figure 1.1: Thesis Structure

In the first chapter, the research is introduced by discussing the general context of the thesis, and by describing the scope, as well as some of the background research that will highlight the need for further investigation. Additionally, the purpose of this study will be explained, and the

research questions and hypothesis that are pertinent to this research will be presented. Finally, the significance of this research to the field of PM and the benefits that this thesis will have on the practice and research of PM will be described.

The second chapter is the literature review, which presents an extensive examination of the literature that describes PM practices regarding schedule conflicts and organizational charts.

The third chapter is dedicated to explaining the methods utilized to conduct the primary research for this thesis. It discusses the setting in which the study took place, the interviewee sample size which participated in the study, the materials and measurement instruments that were used to conduct the study, and the procedures followed for collecting and analyzing the data.

The fourth chapter is dedicated to explaining the selection of the case study. The project that has been chosen for the case study is studied and the project scope has been explained. The results of the research are also presented. The qualitative findings from the empirical investigation and the data analysis are presented. Descriptive analysis is presented as well as the major themes and patterns that had emerged from the behavioral observations and interviews. These results are then interpreted and discussed. This chapter is dedicated to understanding what the findings mean for all of the literature review, and it is in this chapter that the research questions are reviewed and clearly answered.

Chapter five discusses the proposed solution. In this chapter, the findings from chapter four are discussed and are used to propose a solution that will help PM in similar projects. The solution then is verified through expert interviews and adjusted. The retuned and final solution will be explained in depth in this chapter.

Chapter six will discuss the conclusions of this research study. This is where the key findings from the research are clearly defined and the major contributions to the field PM are discussed. This chapter also includes a discussion revolving around the limitations of this study and suggestions for future research initiatives. These suggestions will allow researchers to improve

on the methodology and to deepen our understanding of the new changes that have occurred in PM.

Chapter 2: Literature Review

Chapter 2 is organized in a manner that explains the definition of PM and how it has evolved during the years. It also presents the main variables that can affect and cause delay on the CS. The uncertainties that each variable brings to the construction industry and the effects it will have on the production side in similar projects are focused on. This chapter reviews research that has been conducted on similar projects, and would have similar variables that can affect the CS. To conclude the chapter, the common variables that have effects on the CS have been outlined and explained. These variables will be used to better understand and observe the case study for this research.

2.1 Construction Management

In traditional PM, the three elements of cost, schedule or time, as well as the quality or technical components, should be satisfied to achieve the project goals which are usually referred to as "the Iron Triangle" (Marshall and Rousey, 2009). In this way, PM might be defined as "the process of planning, organizing, and managing tasks and resources to accomplish a defined objective, usually within constraints of time, resources, and cost" (Marshall and Rousey, 2009). But since these early definitions, from 1950 to present day, there has been an evolution of definitions addressing different aspects of PM. Some of the available definitions for PM are as follows:

- PM is "the application of a collection of tools and techniques (such as the Critical Path Method and matrix organization) to direct the use of diverse resources toward the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of these tools and techniques structured to the task environment and life cycle (from conception to completion) of the task" (Oisen, 1950).

- "A specialized management technique, to plan and control projects under a strong single point of responsibility" (Burke, 1993).

- Reiss first described PM as “a project is a human activity that achieves a clear objective against a time scale” (Reiss, 1993). Then pointed that a simple description is not possible and proposed that “PM is a combination of management and planning and the management of change”.

- “To plan, coordinate and control the complex and diverse activities of modern industrial and commercial projects” (Lock, 1994).

- “The planning, organization, monitoring and control of all aspects of a project and the motivation of all involved to achieve the project objectives safely and within agreed time, cost and performance criteria. The project manager is the single point of responsibility for achieving this” (The UK Association of PM (APM), 1995).

- “The planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance” (The British Standard for PM BS6079, 1996).

- “The planning, organizing, directing, and controlling of company resources for the relatively short-term objective that has been established to complete specific goals and objectives. Furthermore, PM utilizes the systems approach to management by having functional personnel assigned to a specific project” (Kerzner, 2006).

- “Identification and management of risk” (Touran, 2006)

- “The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements” (Gray and Larson, 2008).

In definitions of PM, there seems to be a trend to use both effective factors like organization hierarchy and usage of different tools and techniques besides success criteria such as those considered in “the Iron Triangle”. This trend originally started from pioneers who first proposed these definitions, such as Oisen (1950), as well as recent researchers. This trend established its

momentum when current PM practices distanced themselves from those traditional methods during the expansion of U.S. transportation infrastructure in the 1950's. In this new era, replacement and maintenance of existing infrastructures were crucial, and focused more on time and cost. These projects were engaged in a new environment facing more limitations and complexity than before.

There have been some reports and research to address the existence and consequences of such complexities such as the one carried out by the National Cooperative Highway Research Program (NCHRP) Project 20-69: Guidance for Transportation PM (2009). Due to findings of this research, 20% of the projects over $5 million in construction costs were under budget and 35% of the time commissioned later than the scheduled time.

Atkinson (1999) proposed that the success criteria for PM should no longer be limited to these three elements of cost, time and quality. Thus, by expansion of the project managers responsibilities, other success criteria such as management of relational, cultural, and stakeholder benefits were introduced as a new framework to be considered by project managers (Cleland and Ireland, 2002).

Atkinson (1997) differentiated between failure factors such as poor planning, inaccurate estimating, lack of control, and an incomplete set of criteria for success. Atkinson (1999) argued that two different types of errors may exist within PM. The first group of errors may occur when something is done wrong, whereas the second type or group of errors happens when something was missed or could have been done better. He proposed that setting the Iron Triangle of PM (i.e. time, cost and quality) as the criteria of success belongs to the second type of errors. It means they are not wrong, but they are not as good as they could be, or something is missing. Atkinson (1997) suggested that besides the Iron triangle, three other criteria for success should be considered:

1- The information system: maintainability, reliability, validity, information quality use
2- Benefits (organization): improved efficiency, improved effectiveness, increased profits, strategic goals, organizational learning and reduced waste

3- Benefits (stakeholder community): Satisfied users, Social and Environmental impact, Personal development, Professional learning, Contractor's profits, Capital suppliers, Content project team, Economic impact to surrounding community

Atkinson (1997) called these four sets of PM success, as the Square-Route of success, which could reduce some second type errors and, therefore, instead of the Iron Triangle, the Square-Route of success criteria might provide a more realistic and balanced indication of success.

Winter and Smith (2006) argued that in new complex projects, project managers should change their directions and views. As part of their suggestions, project managers should consider external influences and limitations as part of the projects and not as uncertainties that are usually called risks. They should change their views of projects as static, linear, and discrete events to an understanding that projects are in nature interactive, interpersonal, and dynamic. They also proposed that projects should be considered as an end product with a certain purpose and not a system of predetermined parts. Their suggestions included that projects are in need of an integrated, multidisciplinary structure and governance while thoughtful, resourceful, and pragmatic applications shall be carried out instead of analytic tools in project completion.

Owens (2010) considered these new directions, and suggested an addition of two new factors to "the Iron Triangle" which were introduced as project context and project financing. He suggested that "project managers on complex projects now need to be able to optimize the available resources (cost and schedule) with the technical performance needs of the project (technical) while operating under both known and unknown constraints (context), all while accommodating the requirements of new financing partners and funding models (financing)". Owens (2010) defined those external influences which impact on the project's development and progress as: stakeholders, project specific, local issues, resource availability, environmental, legal/legislative, global/national, and unusual conditions. The project-specific category defined as those factors which are directly related to the project such as: maintaining capacity, work zone visualization, and intermodal facilities (Owens, 2010).

Owens (2010) defined maintaining capacity as a planning decision made by the owner, like lane closures, detours, and limitations forced on construction activities such as night-time, weekends, etc. The other two reflected the ability to alert the public of alterations to the normal traffic routes and existence of heavy construction activity, and if there are other modes of transportation involved.

Legal and legislative issues might have effect on schedule including procedural law or local acceptance. These might include permitting, zoning, and land acquisition. Unusual conditions are mainly unexpected weather changes and force majeure (catastrophic events such as terrorism).

2.2 The project schedule

The project schedule is usually considered as the timeframe for project completion. Overall time/deadline, uncertainties, milestones, control, resource availability, and all possible problems of managing and planning before and during the construction are among those variables which affect the project schedule. In general, the schedule or overall timeline of the project has the ability or potential to change the way managers look at their strategies to solve their problems.

The depth of the effects of different factors on project schedule might be understood when there is research that indicates that the projects over $5 million in construction costs were commissioned 35% of the time later than the scheduled time (NCHRP, 2009). A review of the performance of more than 26,500 transportation projects in 20 different U.S. states during 2001 to 2005 indicates that only 35% of them were completed on time (Crossett and Hines, 2007). Thomas et al. (1985) reported that delays were observed in more than one-third of public highway projects with an average of 44% overrun comparing with original contract time. World Bank also reported 35% delay in 88% of its international projects during the period of 1991 to 2007 (Gamez and Touran, 2009).

Schneck et al. (2009) also reported that the main cause of extra costs in major projects is the considerable uncertainty which exists in the budget and schedule. The U.S. Federal Transit

Administration (FTA), as a result of a conducted survey, reported cost overruns of 13 to 106% above original budget for almost 90% of major construction projects. Optimistic scenarios were found to be one of the main reasons for these discrepancies (FTA, 2003).

Many reports are available on the fact that delays are common in transportation projects (Gamez and Touran, 2009; Crosset and Hines, 2007). Dolson (1999) addressed the scheduling and project delay as the main challenge in PM when a well-scheduled project would be a valuable tool to eliminate many problems during the project life.

Optimistic scheduling has been found a major tool for those who want to push for project approval causing major delays and consequent problems (Flyvbjerg et al., 2004; Butts and Linton, 2009). Schedule performance was found to be an indicator of the successful management of construction projects (Ashley et al., 1987; Sandvido et al., 1992).

Poor planning and scheduling that do not consider sufficient floats due to perhaps optimistic scheduling will end up with over-expectant and untenable millstones, causing difficulties to meet these millstones by different parties. Accumulation of these small delays usually result in major schedule delays, thus impacting the overall delivery time of the project itself (Touran et al., 1994).

There are many factors involved causing delays. Utility relocations and adjustment are one of these factors which are very common in transportation projects. Chou et al. (2009) reported that very complex utility adjustments had been the cause of major project delays. They proposed that project managers should identify suitable strategies to coordinate related problems.

Kraus et al. (2008) have also investigated utility related issues and asked project managers to carefully study and analyze specific utility data and information from different sources such as utility accommodation stakeholders to prevent any conflicts of management during the life cycle of the project.

Weather might be considered as one of the conditions that commonly affects transportation projects. But despite its importance, it makes project planning very difficult when unusual local weather patterns occur in the project area. Martin and Does (2005) reported that an unusual wet season in Canada retroactively changes the CS of a bridge demolition project. Another weather related problem was reported by Casavant et al. (2007) when petroleum supplies were cut by a hurricane, which then was considered as force majeure (act of God) in the project.

Resource availability might be viewed externally, through the cost of obtaining resources or through external factors limiting their availability; internal limitations often occur when scheduling multiple resources at the same time.

2.3 Labor Force

Resource allocation which is usually crucial planning/construction period could be applied to labor, equipment, and material. Merrow et al. (1988) indicated that labor shortages during construction of transportation projects have a great impact on their delays. Limitation of availability of these resources including labor force (LF) might change the work flow, causing a decrease of available options for construction managers (McKim et al., 2000).

The resource availability includes all different types of recourses including material, equipment, and labor. Owens (2010) defined that for this category, the focus is more on the ability to procure material based on the demand, and not the cost of providing the equipment and labor based on the ability to obtain these resources and not their cost.

Patrick et al. (1999) in a case study of a major road construction project in the United Kingdom, including the 5.2 km of dual carriageway, used a cellular type of structure, and proposed that besides the discipline, the second aspect of co-ordination would be the dynamical allocation of resources to overcome new uncertainties in segmental and autonomous projects. The authors showed that by use of a horizontal type of organization, decentralized multi-disciplinary teams can co-ordinate effectively to adapt dynamic resource allocation. It was proposed that, to

overcome this problem, adaptability and flexibility should be encouraged to reallocate resources and schedules in order to respond to unexpected events.

2.4 Construction Communications

The design and construction phases of the projects are periods in which decision makers should evaluate and control all aspects of the project continuously to prevent problems that might cause delays, thus affecting the overall duration of the project (Flyvbjerg et al. 2004). Kog et al. (1999) reported that one of those measures that would have a definite impact on quality of schedule is the frequency of personnel meetings (besides the project manager's experience) and the time that he spends on the project.

Alshawi and Ingirige (2003) indicated that "the highest level of interaction across organizations generally occurs between the middle level managers in an organization". The communication among these middle level managers which usually is known as "knowledge workers" brings the highest potential return on investment for the project. Cornick (1996) reported that about two-thirds of existing problems in the construction industry can be related to a lack of proper communication, and the way that information and data were usually exchanged in these projects. For example, an inefficient use of paper documents including architectural and engineering drawings, details of construction specifications and other reports of quantities and materials. Kagioglou et al. (1998) also reported that based on their research, 85% of common problems in this industry can be addressed as process-related, and not product-related issues.

Effective construction communication (CC) can be considered as an output of proper organizational setup in projects. It has been reported that a systematic organizational design can lead to a better performance of the project (Tatum, 1984). Levitt (1984) also has reported that a change in organizational structures of the project where managers can smoothly find their place and adjust in new arrangement will definitely reduce difficulties of managing complex projects. Proper organization is just one part of the problem in communication among different levels of the PM team. A well designed line of communication would work not only for internal purposes but also for other parties such as contractors and designers. Pate (2000) showed that providing

these definitive lines of communication have a major impact on delivering the projects on time and within the designated budget.

It is well understood that providing autonomy for different segments of a project will bring many positive opportunities to the PM, as stated by Anthony et al. (1992): “by granting more autonomy to segments of a complex operation, one gains a better utilization of local knowledge, quicker responses to needs, and improved motivation to succeed through clearly identified responsibility”. Conversely, as Patrick et al. (1999) reported “decentralization might bring the risk of inconsistency and contradictory action unless activities can be coordinated effectively”. They also reported that some large projects had experienced difficulties with internal communications and planning.

One of the key aspects of co-ordination in decentralized organizations was described by Peters and Waterman (1982) as “discipline”, where both tight and lose control can be exercised simultaneously: “. . . autonomy is the product of discipline. The discipline (a few shared values) provides the framework. It gives people confidence (to experiment, for instance) stemming from stable expectations about what really counts”.

Jolivet and Navarre (1996) explained that for co-ordination in decentralized organizations, the classic management approach such as pyramidal and functional specification of tasks, standardization of procedures and regulation by hierarchy should be changed in a way to provide suitable environment for autonomous teams to build self-organizing principles and performance control.

In traditional top-down managerial control and functional based methods with vertical functional team orientation, usually an authoritarian and adversarial manner is exercised. The OH divides the work into functional groups where their performance is measured by the quantity of the job done by them and their efficiency; that which is not being done in the right place or at the right time or any overall goal effectiveness is also considered. This type of approach leaves room for internal conflicts. Whereas, autonomous self-managing teams in the horizontal organization would be responsible for all operations in given geographical locations of the project. The

performance of these multifunctional teams was still measured based on the overall project objectives (Jolivet and Navarre 1996).

Problems with communication has been reported between teams in a case study of a major road (A13) construction project in the United Kingdom, including the construction of a completely new section of road involving 5.2 km of dual carriageway using this cellular type of structure (Patrick et al., 1999). The teams were still often pulling in different directions causing the project to fall behind schedule. They proposed the causes of these problems as:

1- Poor communication: “through the increased delegation, top management often did not know what was happening on site. The engineers as the team leaders now felt that they had an inadequate knowledge of what their teams were doing. Moreover, there were still influences of the previous culture whereby everybody wanted their part of the operation to look good so they covered up the problems and only reported the good aspects of performance” (Patrick et al., 1999).

2- Poor Information: poor communication causes wrong or inaccurate information.

3- Inaccurate planning: wrong information causes wrong or inaccurate planning ending problems with scheduling.

4- Training/education issues: Lack of multi-functional personnel.

5- Motivation issues: the bonuses were paid based on old efficiency-based performance and not team performance.

Poor communication and a lack of appropriate uses of new technology such as information technology (IT) have been studied and reported by many researchers (Brandon, 2000; FIATECH, 2007). It was reported that the construction industry is well behind other industries, such as manufacturing and transportation regarding the application of IT, and automation at the field level. Operational projects with similar factors such as outdoor activity, team involvement,

different locations, and safety hazards like military operations have been more successful in usage of real-time communications between different levels of authorities or commands between the field and the office (Allen, 2004). Others have reported the importance of effective communication in the improvement of productivity, as well as for better cooperation among different levels of decision makers in manufacturing (Neil and Knack, 1984).

Hewage and Ruwanpura (2006a; 2006b) have reported that the effects of new technology have not been properly investigated in the construction industry. They conducted a series of observations and interviews with 101 construction workers in four construction projects in Alberta for a period of more than two years. They have reported that based on these studies, 45% of construction workers were not satisfied with the utilized methods of communication in the project, and addressed it as the main problem in regards to the low project productivity and worker satisfaction. This problem was identified as the third most critical factor when 51 managers and construction experts were interviewed. Senior managers confirmed that despite their attempts to solve this problem, they still could not prevent these inefficiencies, even using everyday meetings, radios to foremen, and internet connections to site offices. Based on their interviews with workers and managers they addressed some of existing communication problems such as (Hewage and Ruwanpura, 2006a; 2006b):

- Problem with clarity of instruction and technical details reported by workers

- Lack of proper instruction and supervision of the workers reported by foremen due to their other duties

- Lack of access to real-time head office information despite spending about 15% of foremen time.

- Workers wish to have fresh information of 3D drawings plus time factor (4D drawings), and other information such as technical, safety, weather, isometric views of the end product or its outcomes.

- Construction workers expressed their interest to have better information regarding sudden changes in working areas and delays in equipment and material availability.

Hewage and Ruwanpura (2006b) and Silva et al. (2008) suggested application of IT and other management techniques to deal with on-site communication problems. Other researchers have reported this problem, and found that just one fifth of the necessary information is forwarded to workers (Bowden et al., 2006; Mohamed and Stewart, 2003). Bateman and Snell (1999) also indicated that due to the presence of the many managerial layers in organizational charts of the projects, only 20% of the essential information reaches the workers from top managements after passing through these multi-layer systems. This information usually passes through superintendents (SUPT), foremen, and at the very end of the communication line, to the field workers.

Hewage and Ruwanpura (2009) introduced a communication tool or as they named it, an "information booth", to improve communication between the site management and the workers. They also tested this tool in a construction project. They observed that:

- There is a need for "a mobile, real-time, rugged information source" to prevent confusion at the site and provide effectiveness in available communication tools.

- Workers were not informed about the weather changes, and often had to spend valuable time to return to the site trailer to change their clothes several times a day.

- Office managers did not possess real-time progress information of the site, and received this information only from site managers such as foremen in large construction sites (with more than 100 workers in a single shift).

- Difficulties of managers with "assigning workers, machinery, materials, and tools due to congestion and material handling problems" in the peak periods of very large sites.

- It was found that there is a need for a “real-time information system to track materials, tools, and machinery”.

Hewage and Ruwanpura (2009) reported the results of the pilot test of this “information booth”. They found that this information booth could increase efficiency, productivity and worker satisfaction significantly. They reported that, for example, the construction productivity on the wall formwork could be increased by 0.07 m^2 (h worker). It was also indicated a 0.15 m^2 (h worker) increase on the third and fourth lifts of a wall. Regarding the efficiency (tool time), it could be increased by 9%, and thus result in a 4% reduction idle time, 3% moving time, and 1% socializing time. Construction workers expressed 12% more satisfaction improvement over the information flow and the communication process due to the application of the information booth. Moreover, all construction companies that participated in this research gave positive reviews regarding the implementation of this system.

Tai et al. (2009) have reported the results of their study on the status of Chinese large-scale construction projects (more than £3.3 million). Only projects which were under construction or completed after 2004 were selected. The questionnaire for this purpose was designed using a telephone survey with 13 people (four owners, two designers, and seven contractors) regarding the state of communications in large-scale construction projects. Then a total of 36 questionnaires were sent out with 32 valid replies. A total of 21 projects were investigated: seven housing projects, five transportation projects, six power projects, two water projects, and one industrial processing project.

To study the performance of construction projects, Tai et al. (2009) investigated three aspects of projects (schedule, cost, and a mix of quality and safety). They weighted them 0.3, 0.3, and 0.4 respectively. Each parameter had five options which had a score that ranged from 1-5 (1 being the worst to 5 being the best). The average performance score for construction projects found to be 3.35, with a maximum of 4.23 and a minimum of 2.87.

The effectiveness of construction project communication methods was also investigated, and five categories were considered, namely: information overload, the lack of information, accuracy, timeliness, and completeness of information. Based on available research, the indicators for communications effectiveness score were chosen to be: accuracy, timeliness, completeness, procedures, barriers, and understanding (Thomas, 1996). The weights of these five parameters were used as it was suggested by Thomas (1996) to be 0.2, 0.19, 0.24, 0.19, and 0.18, respectively, with options that ranged from 1-5 (1 being the worst and 5 being the best). The average score of the effectiveness of communication was found to be 3.24, with a maximum of 4.08 and a minimum of 2.67.

Tai et al. (2009) found that 55% of communication data was collected by face-to-face meetings, 26% by letters, 10% by telephone, and 5% by fax. Regarding the medium, 79% of the information was paper-based, 13% audio and only 8% electronic. They estimated 19.1% in improvement of the communications might enhance the performance by 10.0%.
Based on the survey, they defined the following reasons as the main communication problems:

- Lack of good communication mechanisms.
- Weak organizational structure of construction team.
- Lack of uniform standards for construction information.
- Lack of support for advanced communication technologies.

Tai et al. (2009) proposed that due to the inter-related nature of some of these factors, they need to be addressed as an integrated solution to improve communication. Among their suggestions, to progress in this direction, the following must be considered:

- Better use of existing IT tools in search of new organizational forms for project teams.

- Proposing a uniform communication standard of construction information for the industry as a whole.

- Finding solutions for the legal issues of electronic communications.

Mohamed and Stewart (2003) monitored the performance of implemented IT in a large multidisciplinary construction project. They administered their questionnaire with 27 different items to 42 project participants including managers, designers, and administrators to check the performance of IT in the projects. To compare the results, they used a scale ranging from 1 to 5 where 1 was representing a low/strong disagreement, and 5 displaying high/strong agreement.

This research concluded that general project participants were in favor of the positive effects of IT tools on operational indicators, such as document transfer and handling by indicating a scale value of 4.12 and enhanced coordination and communication by a value of 3.81. The results for the reduction of the response time to answer queries found to be 3.8. Based on the analysis of the questionnaires, the overall operational perspective shows a value of 74%. But it seems that participants were not happy with the level and frequency of IT training by showing a score not more than 2.52, and their evaluation for IT support was 2.98.

They also found that these three groups of managers, designers, and administrators have not had a meaningful difference in their evaluation except for the issue of the user friendliness of the web based system. Administrators seemed to have difficulty in their adaptation with the new system, whereas the other two groups of designers and managers showed fewer problems with the system due to the fact that they have already had problems with less user-friendly applications in their disposal.

Mohamed and Stewart (2003) categorized all parameters involved in five different perspectives as:

1- Operational
2- Benefits
3- Technology/system

4- Strategic competitiveness
5- User orientation

They found that scores for these 5 perspectives are rated as: 74%, 65%, 73%, 69%, and 55%, respectively. Assuming that all of these perspectives equally contribute to the overall performance of the IT in this project, the overall performance was found to be 68%. They mentioned that based on each organization's priorities the weight of any of these perspectives might be changed.

Some research has addressed the communication in construction projects based on social science theories and behavioral studies. Adriaanse and Voordijk (2005) studied obstacles and preconditions of proper application of information and communication technology (ICT) to improve inter-organizational communication in construction industry. They explained that to understand the differences between traditional functionalist approach and modern radical humanist approach towards ICT, one should look at the paradigms behind these approaches. Therefore, they adopted the method of meta-triangulation, which has been proven to be suitable in exploration of complex phenomena when there are different paradigms around. They proposed two different methods for analyzing these paradigms. They proposed the agency theory to study and analyze traditional functionalist paradigm. To study and analyze the radical humanist paradigm, they proposed the application of Habermas' critical social theory on social action. Having these two methods of analysis, they could study both traditional and modern views towards application of ICT (Adriaanse and Voordijk, 2005). The major factors that were studied in regards to these two paradigms, which assumed to be the most effective on inter-organizational communication in construction projects were: the "contract", the "frames of reference" and the "interests" of the parties involved. From a functionalist point of view, ICT should be solely used as a distribution tool for information. The agency theory can be used to investigate communication from this perspective, where only the relationship between employer and employee is discussed based on their economic ties. Whereas, from a critical social perspective, the flow of information or any information system should be analyzed based on an organizational or social system context where there would be potential for social actions. They provided models of actions and validity claims to formulate a suitable base for research in inter-

organizational communication and ICT. They found common grounds in models of actions related with both ICT and inter-organizational communication showing new directions for ICT development for construction industry.

2.5 Literature Review Summary

From the literature review done in this chapter it can be seen that PM has evolved from what it was set out to be in the beginning, only focusing on the Iron triangle, cost, time, and quality. It can be seen and concluded that today's PM has a greater scope to deal with. Amongst them it can be highlighted that the variables that pose the most challenge that can affect the CS are as below:

1- Communication
    a. Poor planning
    b. Optimistic scheduling
    c. Poor communication

2- Organization
    a. Centralized (Vertical)
    b. De-Centralized (Horizontal)

3- Weather
    a. Wet weather
    b. Weather uncertainties

4- Utility relocations
    a. Unknown utilities
    b. Utility locations
    c. Utility conflicts

5- Resource availability

a. Labor shortage
b. Training and education
c. Equipment availability
d. Material availability

6- Third Party
    a. Permits
    b. Night shift work
    c. Detours
    d. Procedural law or local acceptance
    e. Zoning and land acquisition

Based on these findings, these variables have been implemented in the interviews and observations taken from the PMH1 PM team. The variables above are the summary of what researchers have found in similar projects. These commonalities discovered in similar projects such as the PMH1 project can affect the CS. These findings, in combination with the observations made on the PMH1 project, and which have been described in this thesis, were used to prepare questions that can help define the problems that management bodies have experienced on this project. These observations regarding the variables that seem to be having the greatest effect on the CS are defined and highlighted in this thesis.

The literature reviews, observations and interviews combined together help in understanding how these variables have effects on the CS and how there effects can be minimized or controlled in a manner to help the PM team overcome CS delays.

Chapter 3: Research Methodology

Chapter three is organized in a manner to describe the methodology chosen for this research and explains the approach taken to achieve the results. A multi-phased approach to data collection was utilized for this research such as interviews, observations, and a comprehensive literature review. The flowchart in Figure 3.1 provides a high-level summary of the methodology used in this research. Section 3.1 will explain the general methods used in the research. In chapter four, data is compiled, analyzed and presented in a variety of methods.

3.1 Methodology Overview

Figure 3.1 represents the overall process of this research. The research goals were first decided on and the literature review process was then initiated. The literature review process was focused on six different topics:

1- Project management
2- Construction schedule
3- Construction delay
4- Organizational hierarchy
5- Communication
6- Labor force.

The above topics were studied to identify previous findings and research. Based on these findings, the research objectives and deliverables were fine-tuned.

To obtain the data needed, a case study was chosen to be analyzed. In this study, three areas were focused on:

1- Effects of the organizational charts on delay
2- Effects of communication on delay
3- Effects of labor force on delay.

The data collection process was based on the researcher's observations on site and construction meetings. Also, several different interviews were conducted to gather more information from the managing staff. The data collection process was a lengthy progression, due to the need of identifying the variables that affected CS, and to validate the proposed solution from senior project management staff in different segments of the case study.

The data gathered from the first set of interviews were used to identify the variables that caused CS delay. Based on the analysis a solution was proposed. The solution was then explained to senior project management staff of different segments. A second set of interviews was conducted to validate the proposed solution.

Finally, Figure 3.1 illustrates the last stage of the methodology, which is presenting the results and findings of the research. The recommended solution will be thoroughly explained in chapter 5. Chapter 6 is the conclusion of the research. The results, limitations and future research areas will be discussed in this chapter.

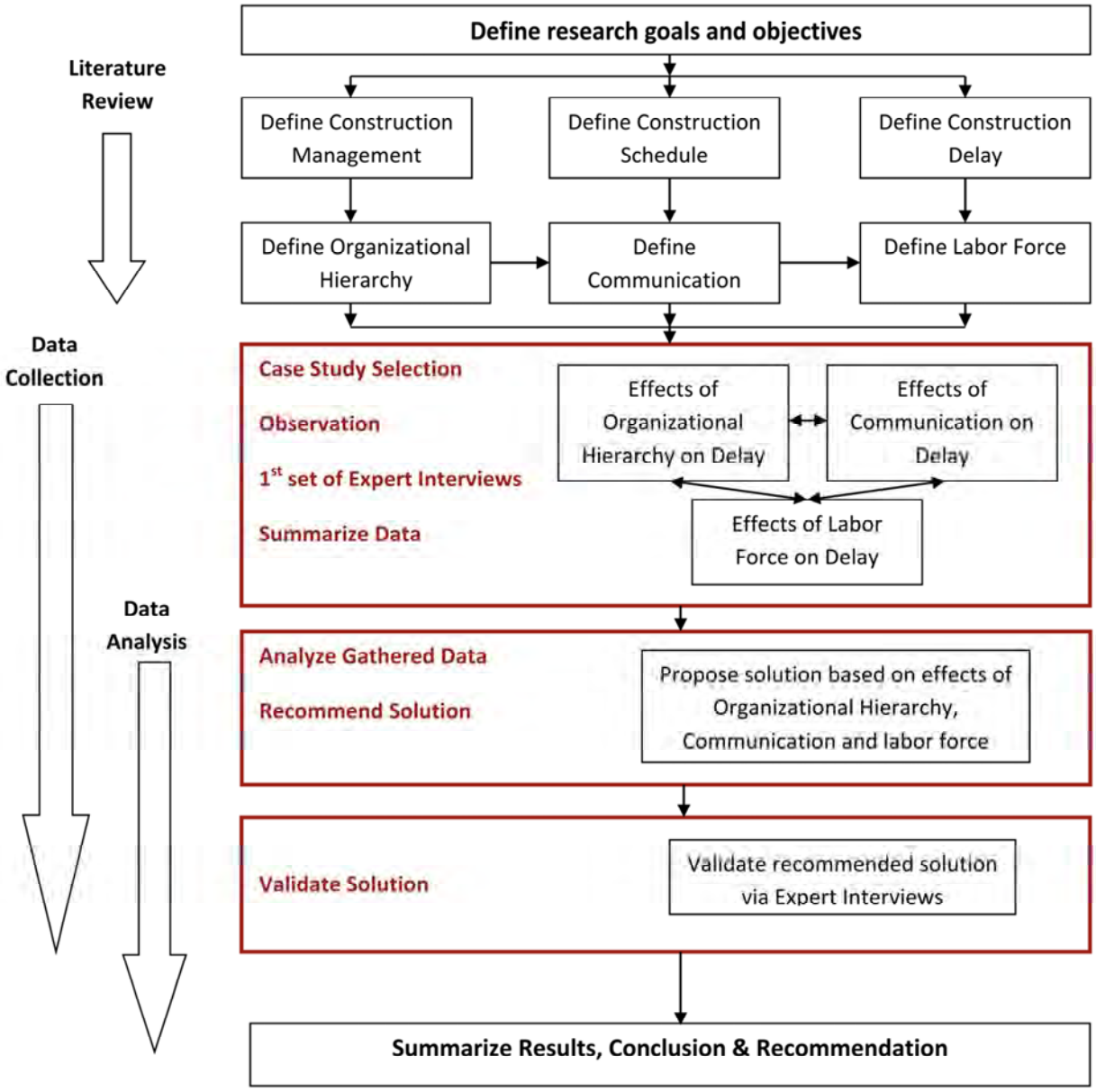

Figure 3.1: Research Methodology Flowchart

3.2 Rational for Research Methods

The methodology used to gather the information required for this research was based on a multi-phased approach. This multiple-phased approach included the use of literature reviews, interviews, and observations.

The literature review gave insight to topics most research has been focused on, as well as what solutions and problems have occurred. It also presented which aspects need more thorough investigation. The interviews with the experts gave much needed insight as to where experts practicing PM identify problems, and what solutions have been practiced to overcome these issues in the field. Observations supported the researcher by giving better insight on what processes occur on a day to day basis in a project of this size and magnitude. Also, daily observations better illustrated how problems occurred, how these issues were explained and presented, and then finally solved.

These methods helped in understanding the problems presented, namely, how does changing organizational charts relate and link to solving schedule conflicts, and what main factors cause schedule delays? The methods used gave a better understanding of the problem and helped to achieve a solution during the research phase.

3.3 Selection of the Case Study

The case study chosen for the research of this thesis was the PMH1 project. Only one case study, rather than several, was chosen due to the sheer size of the project. The PMH1 project was the biggest infrastructure project in North America, with a budget in excess of 3 billion dollars and a total of four geographical segments. The segment chosen for closer study was segment 1, which had a total budget of approximately 300 million dollars.

Initially the senior management of PMH1 were contacted and asked to see if they were willing to participate in this research project. Also, upon their agreement, they were asked to give a general background of the project.

3.4 Observations

In order to better understand the processes taken by the management team in accordance to schedule delays and organizational charts, the author took part in different meetings. These meetings were in regards to the project schedule, communication between different departments, and the allocation of resources.

3.4.1 Setting

The observations took place in three different types of meetings. These meetings had three sets of tiers of management involved. Each tier represents seniority of management, with tier one being the least senior and tier three being the most senior in this project. The first set of meetings was in regards to scheduling within a given department, for example: earth works, drainage, structures, etc.; these meetings had a range of 5-10 attendees. The second set of observations took place to discuss the schedule of the segment. In these meeting, all departments were present and the overall schedule of the segment was studied. These meetings had an average of 30-50 attendees. The last set of meetings was in regards to the segments schedule; as well it was to provide solutions for the conflicts that had occurred in the previous meetings. These meetings had an average of 5-10 attendees.

The first set of meetings had the first and second tier (T1 and T2) of the management's involvement with the engineers and superintendents (SUPT) present in order to input the production rates and standings. Table 3.1 the summaries of attendance is presented. These meetings took place every day, and the author attended these meeting for one year daily. These sets of meetings were the daily 'play of the day' meetings. Play of the day meetings were meetings where the managing staff and field staff would review the next three days work schedule and coordinate resources between departments. Conflicts between different crews would be minimized in these meetings. These meetings discussed the schedule of the day and what was planned for the next three days. The allocations of resources were discussed as well. In these meetings, all staff that were directly or indirectly responsible for field operations were present. The significance of these meetings was that the field engineers (FE) and the SUPT would bring up the issues they were having in the field. The author observed how problems were

brought up and resolved daily. The problems that were not resolved were taken to the second set of meetings and discussed in more depth. The problems that were brought up in these meetings were regarding resources (material, equipment, and labor force), planning (schedule conflicts between different crews due to congestion) and construction progress (where each department would stand in regards to the CS).

The second set of meetings had the first, second, and third tiers (T3) of management involved, though the meeting itself was mostly run by the second tier of management. These meetings took place once a week. The author attended these meetings for one year weekly. These meetings were focused on the project schedule. These meetings discussed the project schedule for the next 120 days. In these meetings, existing and/or potential tasks that might have had conflicts or delays were discussed and resolved. The participants of these meeting were all three tiers of management, lead engineers, and project schedulers. The author observed at which level of severity issues would elevate from the first set of meetings to the second set of meetings. Mostly, CS conflicts that occurred between departments were discussed in these meetings. The critical path of the CS was discussed, and the effects of the decisions were discussed. The decisions regarding any problems were discussed in this meeting. If the problems that had risen in this meeting could affect the critical path of the CS, the issues were then sent to be resolved in the third set of meetings.

The third set of meetings attended was the weekly managerial update meetings. These meetings included only the three tiers of management and were mainly focused on resolving reoccurring problems. These discussions mainly dealt with project schedule and cost. These meetings helped management solve existing schedule conflicts, and to also forecast future ones before taking place. Based on the schedule itself and the importance of each task, decisions were made to resolve conflicting tasks on the schedule. Being part of these meetings helped the author identify how information flows between disciplines, and how problems are being resolved. It also helped the author in identifying key variables that caused delay to the CS. These meetings took place once a week. The author attended these meetings weekly for one year.

Table 3.1 presents the summary of staff attendance for each meeting.

Table 3.1: Meeting Attendance

Meeting Attendance							
Meeting	T1	T2	T3	SUPT	FE	LE	PS
1st Set	X	X		X	X		
2nd Set	X	X	X			X	X
3rd Set	X	X	X				

3.4.2 Sample/Participation

Attending these different meetings discussed in Section 3.3; the author was able to first understand the process that management was taking when it came to scheduling, and secondly, finding and allocating which experts should be interviewed for the defined purpose of the research.

3.4.3 Measurement Instrument

The author used daily journals and notes to measure the level of influence and input of different staff members attending the schedule meetings. The staff members were divided in to two categories: field and office representatives. This process was to help identify the most influential people when it came to the decision-making processes for scheduling and OH matters.

3.4.4 Data Analysis

The author conducted a basic review of the daily journal and notes to get a general sense of the content observed. The next step involved a more in-depth analysis of the content to better categorize the staff members intended for interviews.

3.5 Expert Interviews

The interview process was based on two sets of different interview types in total, the first being "First Expert Interviews" included two separate interviews for the three tiers of management. The first set of interviews was general questions of the project; these questions were the same for all three tiers of management. The second set of interview questions were specific questions in regards to the tier of management. These questions were mainly focused on the level of

responsibility and the effect the managers had on the project. Appendix C illustrates both sets of interview questions. Table 3.2 represents the expert interview process below.

Table 3.2: Expert Interview Process

First Expert Interviews		Number of Interviewees	Validating the Recommended Solution Interviews		Number of Interviewees
Tier 1	General Specific	6	Segment 1	Specific	1
Tier 2	General Specific	5	Segment 2	Specific	1
Tier 3	General Specific	2	Segment 4	Specific	1

The expert interviews taken place were at total of 16 interviews. The number of interviewees was not substantial in comparison to other researches with similar methodologies, but in the methodology used in the research the quality of the interviews is much greater. This is due to not having questionnaire sent to unknown participants. The author had the chance to know each interviewee during the time of the observations. The process of collecting information from the interviews was greater than just an interview which would have taken 30 minutes, it had many follow ups to be able to understand exactly what the interviews meant. Due to this reason the quality of the interviews are greater and helps minimize the effect of fewer interviews.

3.5.1 First Expert Interviews

Based on the literature review completed, the author designed questions for the interview process. Kraska (2010) explains that quantitative studies produced results that can measure different characteristics of a targeted population. Also, it can generalize the data obtained in similar situations, provide explanations for predictions, and explain causal relationships. Trochim and Donnelly (2008) explained that quantitative research can be categorized in the following three ways:

1- True experimental design: The most important aspect of this type of design is that it includes randomization, experimental control, experimental treatments hypothesis testing, experimental and control groups, and standardized research instrument (Kraska,

2010). This method is the most comprehensive quantitative method. This method is good for establishing cause and effect relationships between variables.

2- Quasi experimental design: This method is used when it is not possible to assign random assignments to groups. This lack of control on randomization threatens the internal and external validity of the quasi design (Kraska, 2010).

3- Non-experimental research design: This method is used where the variable under question has already occurred. The method includes causal comparative method, survey method and the correlation method (Kraska, 2010).

The survey was conducted in the form of interview questions from experts in the field of project management. Appendix A presents the sets of interview questions asked from different tiers of managers. The questions were designed in a manner to help the author identify the process that is practiced on the PMH1 project. Also, the interviews posed questions to identify which of these variables had the most effect in causing CS delays.

Welkowitz et al. (2006) have discussed that sample size and power (level of confidence) are the most important factor in statistical studies. Sample size is a very important factor when doing a statistical study due to it determining the accuracy of the sample statistics. The sample size was determined by the following equation:

$$d = \frac{\pi_1 - \pi_0}{\sqrt{\pi_0(1 - \pi_0)}}$$

Equation 3.1: Calculating d value

$$N = (\frac{\delta}{d})^2$$

Equation 3.2: Calculating sample size

$d =$ Sample size effect

$N =$ Sample size

$\pi_1 =$ Proportion of the organizations considered in the most possible scenario

$\pi_0 =$ Proportion of the organizations considered in the possible scenario

$\alpha =$ Significance criterion

$\delta =$ Function of significance criterion α and power

Based on the discussions with the senior project management team, most general contractors use project management practices in similar projects. Based on their inputs, about 90% of the general contractors apply project management practices. Based on this information, the following hypothesis was reached:

$H_0 =$ The proportion of organizations using project management is $\pi_0 = 0.65$ of the organizations.

$H_1 =$ The most likely proportion of organizations using project management practices is $\pi_1 = 0.95$.

From equation 1: $d = 0.78$

With a desired $\alpha = 0.05$ and a power of 0.80 from the table "δ as a function of significance criterion α and power" (Welkowitz et al., 2006), for one tailed test, $\delta = 2.49$.

From equation 2: $N = 10.27$

The number of total responses to this interview survey was 13. Based on the responses, the power of the test can be calculated based on equation 3 (Welkowitz et al., 2006).

$$\delta = d\sqrt{N}$$

Equation 3.3: Calculating δ

From equation 3: $\delta = 3.21$

With a desired $\alpha = 0.05$ and $\delta = 3.21$, from the table "δ as a function of significance criterion α and power" (Welkowitz et al., 2006), for one tailed test of the power 0.94.

Based on the above calculations with a total of 13 interviewees, the power is 0.94 and the probability of type 2 error is 0.06.

3.5.2 Designing the Interview Questions

The interview questions were set up in two sections. The first section was more general in nature and focused on the variables such as utilities, third parties, and the LF. These questions were asked from all three tiers of management. The reasoning behind asking these questions from all tiers of management was to see if all levels of management agreed on the same variables as problematic.

The second section of the interview questions were specific questions asked from each tier of management. These questions helped to identify the flow of information from the field to the office. Also, it illustrated the flow of information between different tiers of management. It was important to see the information that is considered important when brought in from the field, and what information is important to find its way from the first tier of management to the next. These questions also pertained to the way the OH is changed, and what effects it would have on the CS. It was important to see how fast the OH can be changed and what effects it would have in minimizing the delay. The other aspects of these questions were to identify the decision-making process. It was important to see what decisions are made at what levels and to see how this process moves up the chain of command.

The second phase of interview questions can be categorized as follows:

1- Communication
    a. Field to office
    b. Different levels of management
    c. Department to department
2- Organizational hierarchy
3- Decision-making process
4- Variables affecting construction schedule delay

The author spent the first month observing the process that occurred on the construction site, from planning and scheduling to execution. This helped the author to identify the key personnel who would have more insight on the project. Based on the hierarchy of the PMH1 project, the managing staffs were divided into three categories.

In order to gain knowledge and insight about the specifics of the process involved (including observing the project schedule, modifying the schedule and organizational charts, and making changes to the organizational charts) the author identified the experts in these matters based on the procedure illustrated above.

3.5.3 Participants

An expert sampling procedure was utilized by the author ; the participants were reached through emails and in person. The recruitment letter used to recruit the participants on the PMH1 project is shown in Appendix A. The participants included three groups of management: T1, T2 and T3. Each tier represents seniority of management, with tier one being the least senior and tier three being the most senior in this project. Figure 3.2 below illustrates the hierarchy of the three different tiers of management. The number of staff presented in the diagram below is not exact due to limitations of consent from the general contractors at PMH1.

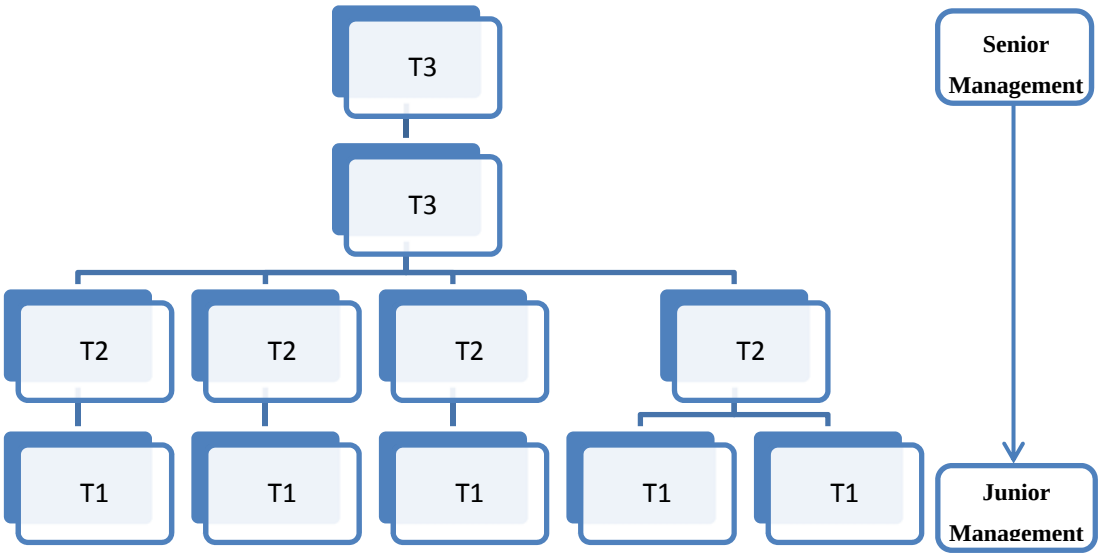

Figure 3.2: Three Tier Hierarchy

To be able to conduct the interviews, the author had to obtain the University of British Columbia's (UBC) Research Ethics Board (REB) approval. The recruitment letter and the consent forms were also approved by the UBC REB. Once the interview questions were finalized, they were submitted to the UBC REB for approval as well. After all the approvals were obtained, the author started the recruitment process. Out of the 17 managing staff that was on the first segment of the PMH1 project, 13 of them gave consent for being interviewed. The details of the participants are presented in Table 3.3 below.

T1 managers had 5 to 10 years construction experience, and managed the FE and OE. Figure 3.3 represents the hierarchy chain for the first tier of management. The number of staff working for the first tier of management is not exact in this diagram due to limitations of consent from the general contractors at PMH1. These staff were responsible for the departments cost, schedule, and contracts. With the help of the engineers, they tracked the occurring costs and production progress. They also forecasted the job schedule and budget every month and quarter. This management level had more oversight on the disciplines schedule. This tier was aware of the day-to-day completion of scheduled tasks, and had closer communication with the FEs.

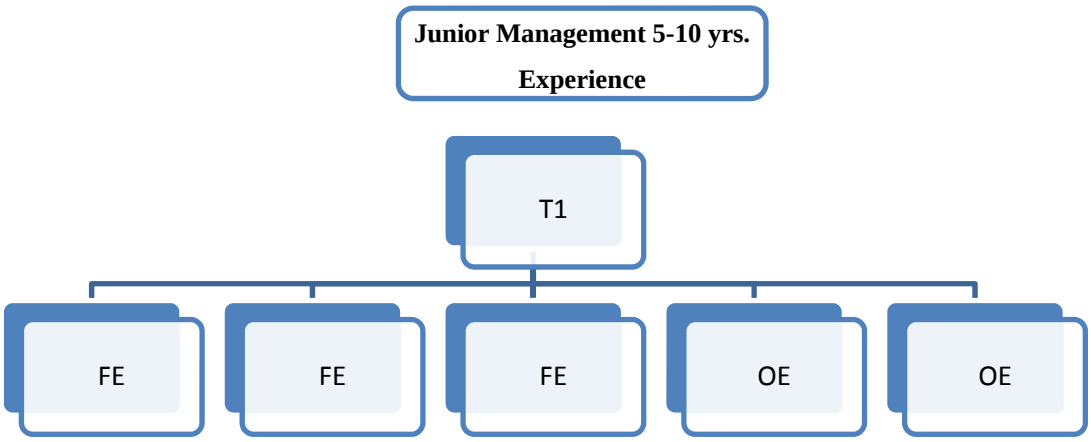

Figure 3.3: Tier 1 Hierarchy

T2 managers had 10 to 15 years of experience. They over saw the T1 managers and field SIs. Figure 3.3 represents the hierarchy process of T2 management. The number of staff presented in the diagram below is not exact due to limitations of consent from the general contractors at PMH1.The second tier managers oversaw the schedule and budget monthly and quarterly reports. After approval and edits, the reports were submitted to the third tier of managers. Second tier managers had close relations with the field SIs. They were aware of the work progress through the tracking systems in place by the engineers and had daily meetings with the field SUPT. T2 managers were also responsible for a geographical section of the project, the intention being to help oversee milestones and major conflicts. Information regarding work progress and schedule was obtained through meetings and one-on-one discussions with T1 managers and SIs. T2 managers were department heads which oversaw the department's progress, schedule, and cost. These departments were such as drainage, structures, earthworks, sub-contractors, etc. The T2 manager of the department would have the most experience in that discipline. The T1 managers working under the T2 manager would be only focusing on the departments needs when it came to schedule, cost, and construction process.

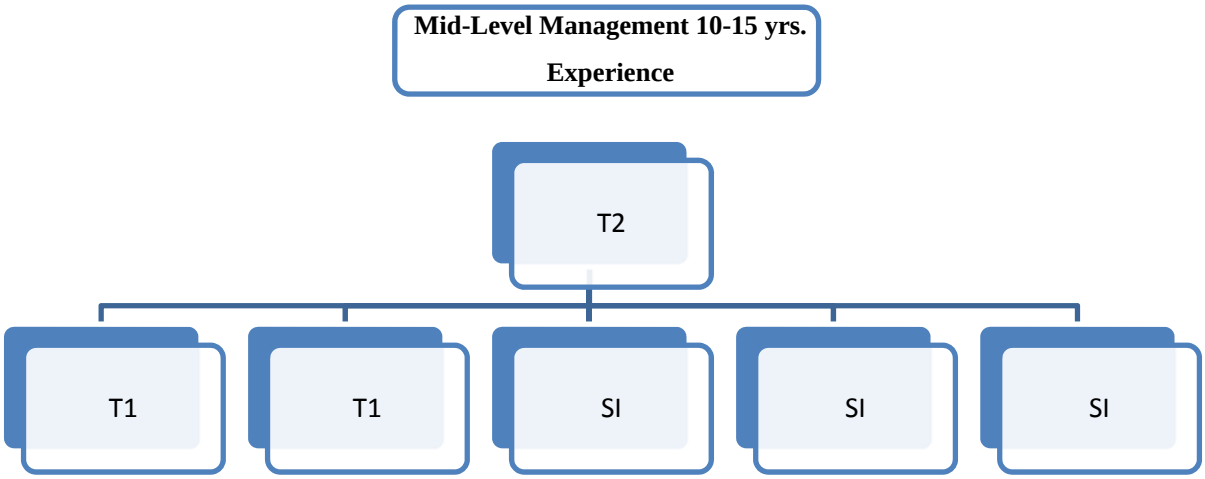

Figure 3.4: Tier 2 Hierarchy

T3 was the project and construction managers of the project, and were responsible for all work within a specific segment. T3 managers had than 20 years of experience. Figure 3.4 represents the hierarchy chain for the third tier of management. The number of staff working for the third tier of management is not exact in this diagram due to limitations of consent from the general contractors at PMH1.They held weekly meetings with the second tier of managers for schedule and cost updates. The decision-making process was initiated from the first tier of management, and depending on the significance and or the schedule effects they would have, it was brought up to the second and third tiers of management. T1 managers communicated and reported to the second tier of management. They would inform them of daily issues and potentially problematic situations. T2 managers would discuss the upcoming problems within the second tier management team. If any problems in terms of schedule, resources, labor needs and help was required it would initially be resolved within this tier of management. If the problems were not resolved, then the next step was to hold meetings amongst the second tier and third tier of management to reach a solution. The division of management staff into three different levels helped with identifying the flow of information and the levels where specific events problems were addressed.

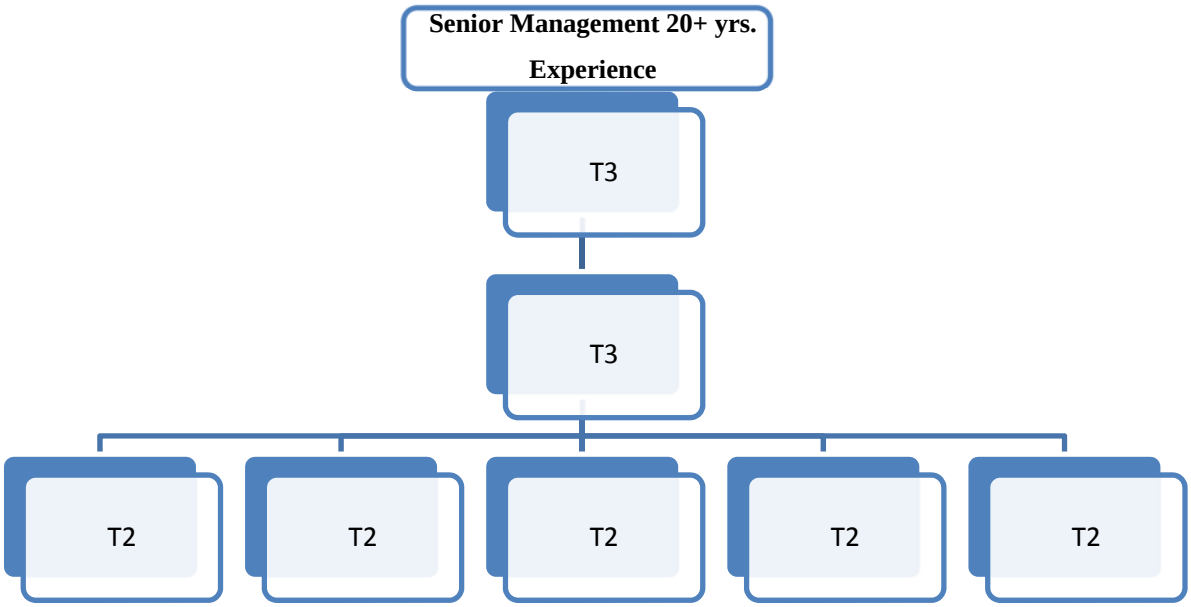

Figure 3.5: Tier 3 Hierarchy

The author chose these participants due to the responsibilities they had on the project. Also, the decision-making process was made and initiated within these tiers of managers which allowed the author to better understand the flow of information from the field to the office and from the office to the field.

3.5.4 Setting

The interviews were conducted in different times according to the interviewee's convenience. For the comfort of the interviewee's, most of the interviews were taken in the interviewee's offices. The author 's intent was to have informal and relaxed interviews. This allowed for some time for the author to go over the research objectives with the participants prior to the actual interview process.

3.5.5 Data Collection Procedure

A total of 13 interviews were performed in person upon receiving consent from the participants. Appendix B is the consent form used for these interviews. Appendix F is the approved UBC ethics certificate obtained by the author . Table 3.3 presents the details of the participants. Out of

the 13 participants, a total of 6 of the participants were from the first tier of mangers and a total of 5 participants were from the second tier of mangers. The project and construction managers were from the third tier of mangers. Each interview began with a brief summary of the purpose and scope of the research study. The interviews were no longer than 35-45 minutes. A de-briefing form was provided to the participants informing them about the scope of the research and possible sources in regards to the study. The data from the interviews were kept in a secure filing cabinet.

Table 3.3 : Interview Participant Summary

Number of Participants	Tier of Management	Years of Experience	Number of People Managing
6	1	5 - 10	5 - 10
5	2	10 - 15	10 - 25
2	3	20+	75 - 100

3.5.6 Measurement Instrument

Structured interviews were conducted with experts with experience in the field of PM. The interviews focused on variables that can effect operation schedule and cause delays. Also, questions regarding how changes to the OH can be effective to help maintain the schedule were asked during the interviews. The questions were divided in to two sections: general and specific questions.

General questions were asked from all interviewees but each tier of management had their own specific questions. The interview questions can be found in Appendix C. The general interview questions were mainly focused on the overall process of the PMH1 project procedure, in consideration of operations and decision-making. The problems that were occurring due to third parties and sub-contractors were also queried. It was important to see how different levels of management view occurring problems in order to find a trend. It was also asked of the

management interviewees if general problems that had occurred, and how they would change their procedures in different projects to minimize reoccurring problems.

The specific questions asked in the interviews were based on the level of responsibility each tier of management possessed. The questions were categorized in a manner to find which variables (as defined based on the literature review of this thesis) had the most effect on the CS, which caused more delays, and which caused conflicts. These questions were also aimed to see how information would flow from the field to the office and from the office to the field. This was important to the author , as it allowed for the identification of where the decision-making process was taking place. Furthermore, it helped the author to identify how fast problems were relayed to the different tiers of management.

3.5.7 Data Collection and Analysis

In order to carefully collect the data, the author read out questions and wrote down the responses. Hesitations and grammatical errors were not included as they were not significant in helping with the research. The author categorized the interview questions into three tiers, and used the data gathered from interviews in excel sheets for creating a summary of responses. The author analyzed the transcripts individually before merging the comprehensive results from each one. After carefully scanning the transcripts, the author looked for common themes and categories; based on commonalities, the author placed each into one of the three defined tiers. The next step involved organizing the themes into patterns that would help in answering the research questions.

3.5.8 Data Collection Procedure

The management staff working on segment one of PMH1 were divided into three levels, based on management seniority and responsibility. The reasoning behind dividing the management into three levels was based on the observations taken by the author while present on site. This was done in order to ease the understanding of the flow of information between managing staff and departments.

3.5.9 Tier One

T1 or level one contained management personnel charged with managing 5 to10 engineers whose responsibilities were within one department (e.g. earth works, drainage, lighting, structures, etc.) and which involved construction scheduling and costs. The hierarchy chain is illustrated above in Figure 3.5. This management level had more oversight on the disciplines schedule. This tier was aware of the day-to-day completion of scheduled tasks, and had closer communication with the FEs.

3.5.10 Tier Two

The T2 was management personnel responsible for 5 to 10 field Sis, all of whom were in a single department. The hierarchy chain is illustrated above in Figure 3.5. They were also responsible for tier one managers. These managers were mostly involved with the first level managers and the SIs. T2 managers were also responsible for a geographical section of the project, the intention being to help oversee milestones and major conflicts. Information regarding work progress and schedule was obtained through meetings and one-on-one discussions with level one managers and SIs.

3.5.11 Tier Three

The T3 was for the project and construction managers responsible for all work within a specific segment. The hierarchy chain is illustrated above in Figure 3.5. T1 managers communicated and reported to the second tier of management. They would inform them of daily issues and what seemed problematic. T2 managers would discuss the upcoming problems within the second tier management team. If any problems in terms of schedule, resources, labor needs occurred, it would initially be resolved within this tier of management. If the problems were not resolved, the next step was to hold meetings amongst the second tier and third tier of management to come to a solution. The division of management staffs into three different levels helped with identifying the flow of information and the levels where specific events/problems were addressed.

Interviews were held with individuals' at all three levels, and both general and specific questions were posed. The questions posed were focused on determining how problems escalated from the field to the project office and forward along the chain of command.

3.6 First Interview data summary and analysis

In order to understand the interview results, the content of the interviews were summarized into tabular formats. This process helped the author understand what areas were found to be common amongst the interviewees, and those which were different. From the gathered information, the data are presented in a manner so a general trend of areas could be observed. The general areas were once again orientated into a spreadsheet presenting the results of the first series of interviews. These general areas were based on the variables that had effects on the CS and the OH.

3.6.1 Measurement Instrument

The gathered information from the interviews and observations were compiled into three different sections for each tier of management. All tiers were then summed up and presented such that the general areas of commonality were illustrated in a tabular format. All areas that were identified in the expert interviews were also presented in a spread sheet. Also the data collected from the interviews for each tier was presented separately to identify the differences between each tier of management.

3.6.2 Data Analysis

The data gathered from the expert interviews were analyzed one by one. Each tier of management had their expert comments and suggestions; the comments of the interviewees were then compared to one another and analyzed. This process was done for each tier of management. When the comparisons were completed the results were then discussed and presented.

3.7 Fine Tuning Solution Proposal

Based on the results gathered from the interviews and data analysis, solutions were analyzed to see which would have the most effect on dealing with the areas of concern. The best solution was then chosen. The solution was based on the interviews, observation, and literature review conducted in previous sections.

3.7.1 Measurement Instrument

From the data summary, the different responses to the interview questions were compared and the common areas were identified. These interviews suggested that these variables have the most effects on the CS. Based on the common variables, solutions were proposed to quickly identify problems.

3.7.2 Data Analysis

The variables that cause delays in the CS were identified, and solutions that could swiftly highlight problems were proposed. The solutions were compared, and the solution with the most effect and that encompassed the most problems was chosen. The recommended solution, based on the data analysis, was in theory achievable and possible. The author conducted a second set of interviews from additional senior management in other segments of the project in order to validate the functionality of the solution.

3.8 Second Expert Interviews

In order to validate the proposed solution, the author conducted a second interview process with the senior management of segments 1, 2 and 4 of the PMH1 project. All 3 segments had similarities in the respective scope of work. This allowed for a more accurate validation of the proposed solution. Each segment had a total budget in excess of 300 million dollars. The similarities between segments 1 and 4 were greater due to the span of highway they covered. Segment 1 was more congested in terms of the public use of the highway and population density. Segment 2 was smaller in the span of the highway it covered, but had many more difficult

structures to construct in very little space. This process validates the functionality and possibility of the recommended solution for similar projects.

3.8.1 Participants

The sampling procedure used by the author was expert sampling. These samples were reached through emails and in person. The participants included only the senior management of the PMH1 project. The extrapolation of these participants' input, in regards to having the most experience in terms of years and responsibility, was the most efficient method to understand if the proposed solution would be a helpful tool in similar projects to minimize CS delay. Appendix A shows the recruitment letter used to recruit the participants. The author also received approval from the UBC ethics board on the amendment to the original ethics certificate obtained. Appendix G is the approved ethics certificate for the amendment in the interview process. The participants in the second interview were part of the third tier of managers. They were responsible for segments 1, 2, and 4 of the PMH1 project. These managers also communicated between one another regarding their segments; this discussion of the problems found from segment one, as well as the ideas resulting from brainstorming solutions to these past problems, between these first sets of interviewees was a positive outcome of this research. This also helped to validate the process of the proposed solution due to the managers' deep knowledge of the PMH1 project as a whole.

3.8.2 Setting

The interviews were conducted at different times, according to the interviewees' convenience. For the comfort of the interviewee, most of the interviews were taken in the interviewee's offices. The author 's intent was to have informal and relaxed interviews.

3.8.3 Data Collection Procedure

A total of 4 interviews were done in person, upon receiving informed consent. Each interview began with a brief summary of the purpose and scope of the research study. The interviews were no longer than 35-45 minutes. A de-briefing form was provided to the participants informing

them about the scope of the research and possible sources in regards to the study. The data from the interviews were kept in a secure filing cabinet.

3.8.4 Measurement Instrument

Structured interviews were conducted with experts with experience in the PM field. The interviews focused on the recommended solution and its functionality. The author ’s intent was to observe if the recommended solution was practical and if it could be utilized in similar projects.

3.9 Validating recommended solution

The recommended solution was proposed to senior managements from the other three segments of the project for validation. Based on the results of the interviews, the solution was optimized to best fit what the experts commented on for a plausible solution.

3.9.1 Data Analysis

The author summarized the information from the second set of interviews into a tabular format. This allowed for better understanding of the results, as well as to easily identify the common areas of interest between the interviewees. From this table, the changes necessary to the recommended solution were made.

3.9.2 Recommended solution

Based on the data analysis and information gathered from the expert interviews, the author was able to validate the first set of results and justify the proposed recommendations.

3.10 Result Summary, Conclusion and Recommendation

Based on the literature review, observations and expert interviews, the author was able to identify key variables that are most effective in CS in terms of delay. These results will be

discussed more in detail in chapters 4. Chapter 5 will present the recommended solution. In chapter 6 the results and the conclusion will be discussed and summarized.

Chapter 4: Case Study and Data Analysis

Chapter 4 is organized in a manner to illustrate the reasoning behind choosing the case study, the importance of the case study itself, and how the literature review is linked to the chosen case study. Subsequently, section 4.2 presents the case study's construction scope; and in section 4.3 and 4.4 the results gathered from the observations and interviews have been presented and discussed.

4.1 Background

The chosen case study for this research was the PMH1 project. This project encompassed the main aspects of interest to the author and the questions posed for this research. Firstly, it was an infrastructure project within urban areas. This aspect alone enclosed most of the variables outlined in the literature review such as: weather, utility conflicts, permitting, zoning, and resource availability. The second reason was due to the size of the project: the hierarchy of the project was a complex one that has highlighted the other variables indicated in the literature review, such as communication, planning, and organizational arrangement. These two factors were the main reasoning behind choosing the PMH1 project as the case study.

The importance of the case study was mainly the sheer size of the project, which would emphasize on the level of planning, the complexity of the CS, the communication required between disciplines, and the financial cost of the project. The PMH1 project is estimated to have cost around 3 billion dollars, which would mean the slightest delays in the CS can be very costly for the general contractor. The project spanned between five different municipalities which posed many challenges in obtaining permits and designing detours. These aspects made the case study interesting, important, and challenging.

The literature review completed for this research touched on areas that fall within the parameters of this case study. Being in a congested urban area, the PMH1 project was involved with the maintenance, expansion and the construction of new structures which all were amongst the key

elements of new PM criteria. This project allowed the author to understand the challenges of PM in these conditions, which also allowed for validation of the researched variables posed by many researchers in similar projects affecting the CS. The literature review gave the author the needed background to understand the challenges that can occur on projects in this magnitude.

The PMH1 project size and magnitude was in a manner that satisfied the rational for choosing it as the sole case study for this research. Each segment of the project was similar to a dozen projects of the size of 25-35 million dollars; therefore this one case study acted as several case studies. The OH of the PMH1 project was very complex. The PMH1 project used a decentralized OH. Each segment was run by a project manager, and each segment itself was a decentralized OH as well. The OH of each segment was in a manner that each department or section was independent and had its own team of administrators. The second tiers of managers were project managers of their own department. Only in major issues was the hierarchy of the OH consulted. This type of OH is mostly used in bigger projects. The complex OH and the sheer size of the project was one of the reasons the PMH1 project was used as the case study, in addition to being the biggest infrastructure project in North America at the time.

The Port Mann Bridge was first built in the 1960s. At this point in time, the population of the greater Vancouver area was around 800,000 people; today, the vehicular traffic crossing the bridge per week is estimated to be around 800,000. The PMH1 project is located between several cities in the lower main land in British Columbia, Canada. The project spans from McGill Street in Vancouver, through the Cities of Burnaby, Coquitlam, Surrey, and ends at 216 Street in Langley for a total length of approximately 37 kilometres (the project scope is illustrated in Figure 4.1 below). It is an expansion highway project that increases the existing highway lanes to four, and in some locations, five lanes in each direction. This project is designed to address the growing congestion of the highway, and to improve and ease the flow of traffic in the greater Vancouver region. The project seeks improvements in transit, roads, bridges, drainage, and environmental habitats. The project also includes the construction of a new ten lane bridge which replaces the old Port Mann Bridge. Some of the existing overpasses are maintained and rehabilitated. This project is owned and operated by the British Columbia Ministry of Transportation.

Figure 4.1- PMH1 Geographical Scope (PMH1project.com)

The project is divided into 4 segments, where in this research; the focus is on the first segment which is from the Cassiar Tunnel to the Brunette Avenue overpass. Figure 4.1 presents the overview of segment 1 of the PMH1 project. Three of the segments contain the construction of new overpasses, the expansion of the existing highway to four and five lanes, and maintaining some of the existing overpasses. New intersections were constructed in several areas. Dozens of culverts were constructed that run under the highway for streams, animal crossings, and fish habitat. The third segment of the project only focuses on the construction of the new ten lane-wide Port Mann Bridge and the demolition of the old and existing Port Mann Bridge. This project alone will help to reduce up to 33% of the traffic congestion of the Trans-Canada Highway. This section of the Trans-Canada Highway will be tolled and operated by the Ministry of Transportation. Figure 4.2 below is an aerial photo of the first segment of the PMH1 project.

Figure 4.2: Overview of Segment 1 of the Port Mann Highway Expansion project

4.2 PMH1 Contractors

This project is being implemented by Transportation Investment Corporation (TI Corp), which is a public crown corporation. The responsibility of TI Corp is to oversee the building of the project and the collection of tolls to recoup project costs. The main contractor that has entered into a contract with TI Corp is Kiewit/Flatiron General Partnership. Trans/Canada Flow Tolling Inc. (TC Flow) is the toll operator.

The PMH1 project is based on a design-build contract with Kiewit/Flatiron General Partnership. Kiewit Infrastructure is amongst the companies under Peter Kiewit & Sons (PKS) Corporation. PKS was first established in British Columbia in the 1940s and has earned a reputation as a leading contractor in Canada. The last mega infrastructure project that PKS worked on was the Sea to Sky project, which was completed before 2010 for the Vancouver winter Olympics. Flatiron is a division and a subsidiary of Hochtief, which is also a leading construction contractor in the continent.

TC Flow will be responsible for the tolling operations. TC Flow is a consortium of Egis Projects and Sanef. This consortium combines the joint strength of global tolling expertise which has already been applied to the Golden Ears Bridge (which connects the cities of Langley and Maple Ridge and Pitt Meadows).

4.3 Snap Shot of PMH1

Below are selected features of the project which present the scope and size of the project through all four segments:

- Widening of HWY1: One additional lane added in each direction plus an HOV lane

- Upgrading Interchanges: Seven Highway 1 overpasses are being widened, Nine Highway 1 interchanges are being replaced

- New special purpose ramps at five locations: More HOV lanes at ramps, Transit only ramps, truck only raps,

- New Port Mann Bridge: A new 10-lane bridge; with a capacity of five lanes of traffic in each direction (including one HOV lane) and the ability to accommodate light rail rapid transit in the future.

- Cycling and pedestrian access: Cycling and pedestrian measures will be incorporated into all new structures where they connect to existing or planned infrastructure.

- Transportation improvements: Congestion-reduction measures, expanded high occupancy vehicle lanes, transit and commercial vehicle priority measures, and improvements to the cycling network are implemented.

- Environmental improvements: These environmental projects will address four key objectives: enhancement, compensation, construction timing and protection/restoration.

Figure 4.3: The New Port Mann Bridge

Figure 4.3 shows the construction of the new Port Mann Bridge. The new Port Mann Bridge connects the City of Surrey and Coquitlam. It also connects the Vancouver Island area to the main land. It has a total of 10 lanes. The construction of the bridge with all functioning lanes will be finalized when the old Port Mann Bridge is demolished.

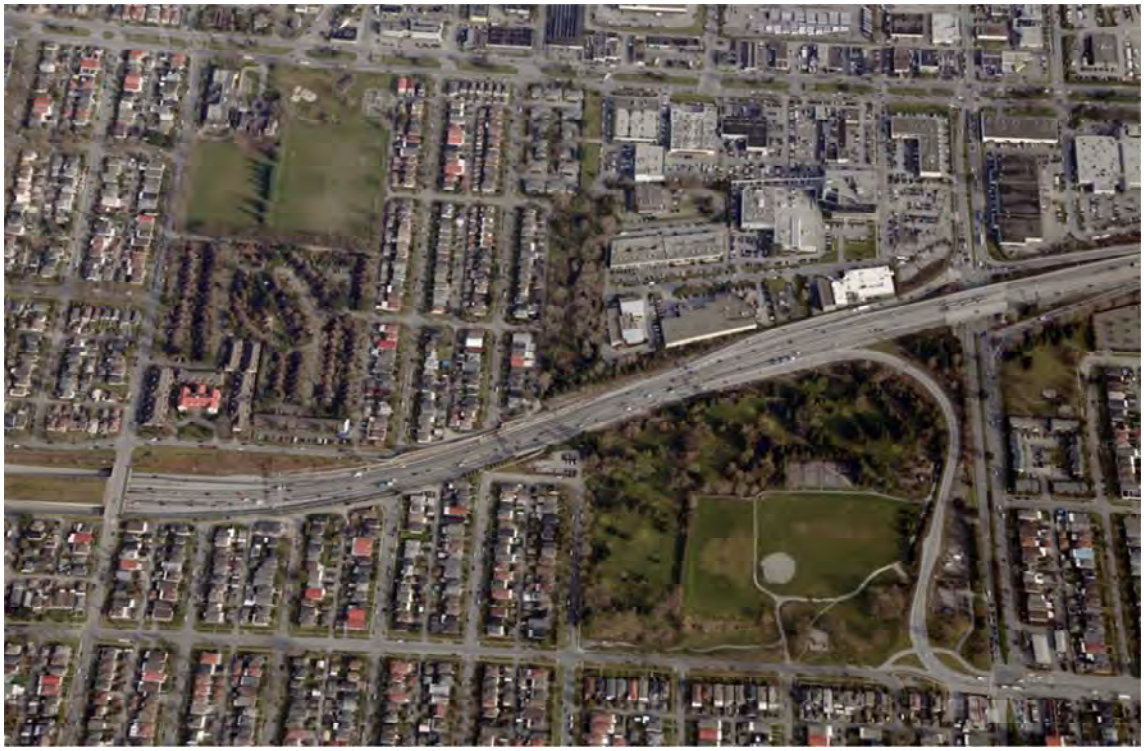

Figure 4.4: 1st Avenue East Bound Exit

Figure 4.4 presents the expansion of Highway 1 by the Cassiar tunnels and the expanded 1st Ave overpass. The 1st Ave overpass was widened to handle three lanes of traffic in each direction. This was an addition of one lane in each direction. The highway stretch in section was widened as well to a total of six lanes. The existing utilities in this stretch of the highway created conflicts with the construction of the third lanes in each direction. Dealing with third parties to relocate the utilities was challenging, and the relocation of utilities along the highway can affect the CS. Obtaining permits for longer hours of highway closures during the night in order to finish the work was challenging, and can also affect the CS significantly. Special events that occurred in the City of Vancouver would directly impact the closure times.

Figure 4.5: Boundary Rd. Overpass Widening

Figure 4.5 shows the expansion of the Boundary Rd. overpass. This area of the highway had two lanes in each direction previously. With the expansion of the overpass, the Trans-Canada highway will have 3 lanes in each direction. The added lane will be an HOV lane. The Boundary Rd. overpass expansion can be seen on the right side of Figure 4.5. The expansion of the Sky train over pass can be seen on the left hand side of Figure 4.5. The difficulties in this area were space, traffic congestion, and obtaining longer closures for the night shift work. The Boundary WB on ramp was rebuilt to match the new configuration of the highway. The disciplines that worked in this area alone were structures, drainage, lighting, utilities, earth works, sidewalks, walls, and signage. With the little space in this area, it can be seen how conflict can cause schedule delay. Poor communications in areas like this can cause delays in the CS.

Figure 4.6: Grandview Highway New Overpass

Figure 4.6 presents the new Grandview highway overpass. This overpass will direct westbound highway traffic onto the Grandview highway and will also direct traffic from the Grandview highway to the east bound Trans-Canada highway traffic. The Grandview highway has a new HOV lane configured which is connected to the Trans-Canada highway via a newly built overpass. Additionally, a newly built overpass will direct traffic from the west bound highway to the Grandview highway. In this area, the construction sites were cramped close to each other. Many different disciplines worked in this area alongside each other. Permits and night shift closures were important in meeting the CS communication between different departments, and were crucial to avoid conflicts and over resourcing construction sites.

Figure 4.7: Willingdon Ave. New Overpass

Figure 4.7 shows the new Willingdon Ave. overpass. It also shows the new off and on ramps onto and off of the Trans-Canada highway. The areas in between the on and off ramps are for added environmental habitats. Willingdon Ave. has one of the most congested traffic areas in the lower mainland. Constructing the Willingdon Ave. overpass with three lanes of traffic in each direction in addition to two turning lanes in each direction in a very congested area was very complex in its nature. The CS had many milestones that had to be met to not cause any delays in the schedule's critical path. This required superb planning and execution. Obtaining permitting for night shift work and day shift work could have been challenging. Construction space caused many conflicts between different disciplines. Communication and planning were important factors in completing the job.

Figure 4.8: Kensington Ave. New Overpass

Figure 4.8 presents the New Kensington overpass and the new west bound on and off ramps. The newly built east bound on ramp can be seen on the bottom right hand corner of figure 4.8. This area had many challenges in regards to the ground conditions. The design changed numerous times before the construction phase was completed. These changes affected the CS and caused delays. The original design of preloading the area for settlement control did not work and the design had to change to meet the bad ground conditions. Piles were used to stabilize the north section of Kensington Avenue. More than 1500 piles were used for the stabilization process of the existing ground. This change in design significantly caused delays in the CS. Managing sub-contractors and communicating effectively between disciplines was quite difficult at times in this section of the project. The existing Kensington overpass was demolished and a new overpass was built. The scheduling and planning to switch traffic and obtain permits in a timely manner to ensure smooth CS was difficult.

Figure 4.9: Gaglardi Way New Overpass

Figure 4.9 shows the new Gaglardi Way overpass. It also shows the new added environmental habitat on the south east side. The existing Gaglardi over pass was demolished in steps to allow for the flow of traffic and the construction of the new overpass. New on and off ramps were built for the west and east bound traffic. The staging of construction processes was important in the planning stages to minimize delays and conflicts. Coordinating different disciplines in this area was challenging due to the available space for work.

4.4 Discussion of Results

After the interviews were completed, the author analyzed the data; within the findings, the commonalities among all three tiers of management were found. Some of these variables are well known and are general to all transportation projects, such as weather and availability of resources. Of particular interest was identifying variables in the form of initially unknown constraints for the PMH1 project, but which may also be applicable to other large scale transportation projects. Also examined was the flow of information in order to engage its effectiveness and how it could be improved.

The results from the interviews regarding the main variables and factors that affected the schedule are presented in Tables 4.1 through 4.3 for the three management levels, ranked in order of importance. In Table 4.1 the results from the interviews regarding the first tier of management is presented.

4.4.1 Tier 1 Management Interview Results

In Table 4.1, it can be seen that most T1 managers cited number 1 and 2 of the total 6 indicated variables that can cause delays in the CS. Communication and obtaining permits were the most important factors contributing to schedule delays. Both these variables had received 67% of the importance in regards to delays based on T1 managers.

Table 4.1 – Tier 1 Management Interview Results

Tier 1 Management		
no.	**Variables**	**Most Effect on Schedule (%)**
1	Communication	67%
2	Permits	67%
3	Weather	50%
4	Third Party	33%
5	Resources	33%
6	Suppliers	33%

The percentages allocated for each variable were calculated by the mean of the responses from the T1 management team.

From the results in Table 4.1, communication was the most important factor in regards to causing delays in the CS. In the interviews, most managers stated that there was inadequate communication when it came to the importance of some activities compared to others. The schedule might show a positive float for both activities in question, but there should be a logical flow of work, prioritizing each activity. The second most important factor was obtaining permits from utility owners and municipalities. This caused difficulties due to the long periods of time

involved, which would delay the schedule. Obtaining permits from the ministry and the municipalities for closures on the highway and the time allowed directly impacted the construction process.

The third variable causing delays was weather, which 50% of the tier one mangers cited. The first tier of managers believed that the constant weather changes in the area directly impacted the progression of construction. Due to the wet nature of the lower mainland in British Columbia, certain activities in the schedule would be delayed that would also delay other predecessors. For example, the wet weather had the most impact in the paving stages of the project.

The fourth variable that was found to cause delays was the third parties. This factor had 33% importance in regards to schedule delay based on the interviews. This factor was in regards to the utility owners and the conflicts that the utilities had with the new configuration of the highway. Many of the existing utilities had to be removed and/or relocated based on the new configuration of the highway.

The fifth and sixth variables, both scoring 33% in importance in regards to causing delay to the CS, were resources and suppliers, respectively. Resources were mainly the availability of the skilled and experienced LF. The availability of machinery and materials was not as high of an impact, compared to the LF based on the interviews with the tier one managers. The delivery of supplies did impact schedule delays as well. If a certain task was to be started on a certain date, and the supplies needed to complete the task were not delivered on time, the schedule would be impacted.

Based on these interviews, it can be seen that the most important factors causing delays in the PMH1 project based on the first tier of management were communication and obtaining permits (numbers 1 and 2 in Table 4.1). Based on their experience, these two factors reoccurred often, and had the most impact to the schedule.

The above results were obtained from the interviews taken with the first tier of management of the first segment of the PMH1 Project.

Figure 4.10 below shows the allocation of each variable that the T1 management brought up as factors that could affect the CS. These variables are normalized in a pie chart.

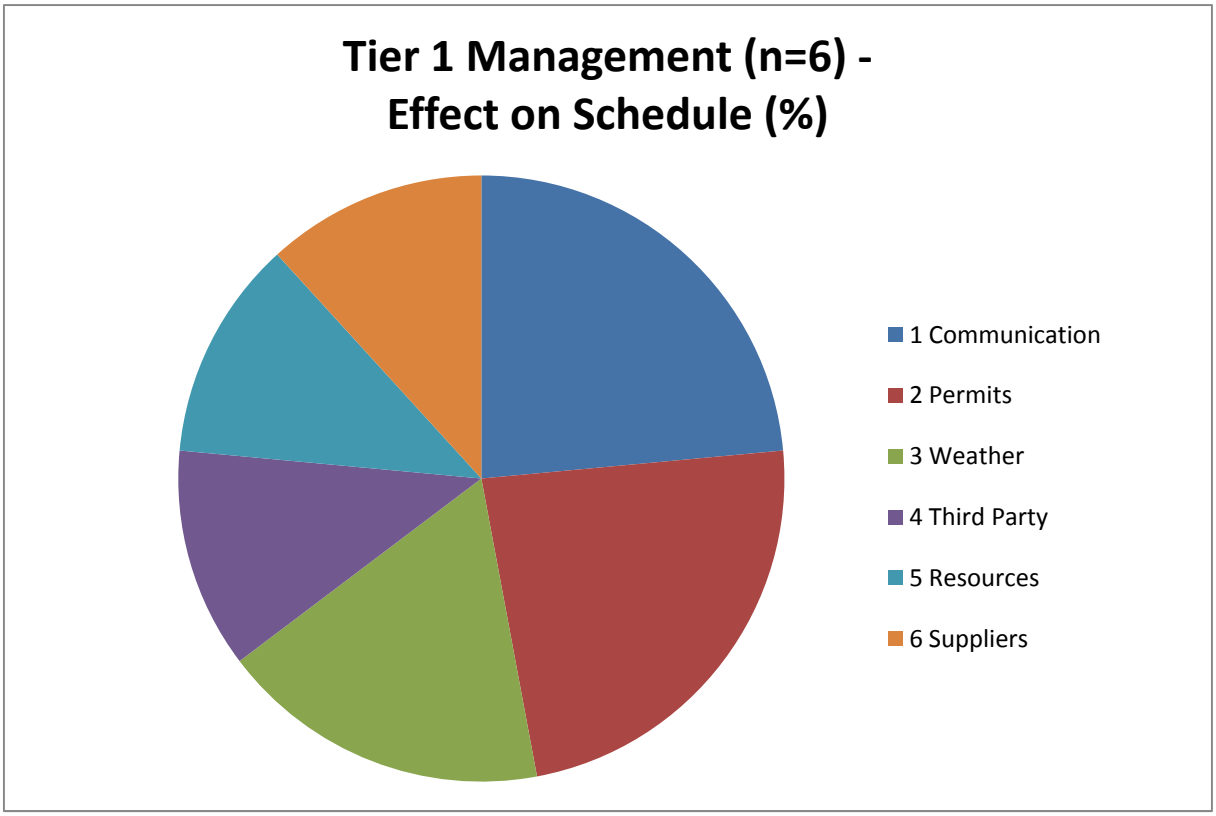

Figure 4.10: Tier 1 Management Interview Results

The most important variables that were mentioned by this tier of managers were communication and obtaining permits. This Tier of management believed that these two factors had the most effect on the CS.

In Table 4.2 below, the responses regarding the change in the OH in regards to affecting CS delay can be seen. The actual hierarchy chart used in the PMH1 project cannot be published in this research due to not having consent from the general contractors. The changes made in the OH are staff replacements. The actual OH was not under question when it came to OH changes. All tiers of management believed by replacing certain mangers the poor communication between managers and departments can be resolved and the negative effect on the CS can be minimized.

T1 managers believed that the changes in T2 and T3 of the OH have the most positive effect on the CS delay. T1 managers believed the flow of communication from bottom up was not effective due to T2 and T3 mangers. They believed by changing certain T2 and T3 mangers the poor communication between tiers of management will be resolved.

Table 4.2: Tier 1 Management Hierarchy Change Interview Response

Tier 1 Management		
no.	**Hierarchy change**	**Most Effect on Schedule (%)**
1	Tier 1	40%
2	Tier 2	60%
3	Tier 3	60%

4.4.2 Tier 2 Management Interview Results

Below in Table 4.3, the results are presented from the interviews taken from the second tier of management on the first segment of the PMH1 project. The formulas that were used to calculate theses values are stated in Equations 3.1 and 3.2 above.

Table 4.3- Tier 2 Management Interview Results

Tier 2 Management		
no.	**Variables**	**Most Effect on Schedule (%)**
1	Communication	80%
2	Resources	80%
3	Third Party	60%
4	Weather	20%
5	Permits	20%
6	Suppliers	20%

As observed from Table 4.3, communication and resources were identified as the most significant factors contributing to schedule delay by tier two managers. As it can be seen in

Table 4.3, items 1 and 2, communication and resources have both received 80% importance based on the interviews. More specifically, those who were interviewed brought up the issue of communication between disciplines and prioritizing work in the same area. For example, having drainage and electrical disciplines working in the same location was quite impossible at times due to both disciplines requiring to excavate, and thus occupy more space. Work space is one of the most challenging constraints to deal with, according to most managers. Working on a highway that has live traffic on it twenty-four hours a day and seven days a week poses significant challenges. Space conflicts results in one discipline waiting, while the other completes its task, thus causing significant delays.

Number 2 in Table 4.3, which received 80% importance in the conducted interviews, was resources. Resources are quite hard to obtain according to most tier two managers. Finding an experienced labor force is also difficult, which poses a great challenge. Safety concerns from senior management require constant craft training due to not having the proper experience. An inexperienced labor force also delays the schedule, due to making tasks take longer than they would under circumstances were the labor force is experienced.

Number 3 in Table 4.3 is the variable of third parties. While level one management brought up obtaining permits as a more important problem, the second level of management chose the variable of third parties. The second level of management finds that having third parties meet the projects schedule is hard at times, and has caused delays to the schedule. Third parties that are involved in the PMH1 project include sub-contractors, suppliers, utility owners, and municipalities. Sub-contractors that would not follow the safety policies adopted in this project delay schedule due to job shut-downs. Training sub-contractors to meet all requirements of safety policies also has caused delays. The need to move certain utilities due to conflicts with new highway design and new structures have been challenging. The main challenge is having everyone involved commit to the schedule proposed and allocating certain tasks as high priority.

Number 4 in Table 4.3 was weather. Weather can cause major delays in the progression of the project. The rain seasons affect the progression of paving, and in the Vancouver area the weather

is quite wet. Second level managers believe that the weather has caused some delays in the PMH1 project.

Getting permits for construction from municipalities takes time and will also cause delays. Permits were number 5 in importance as shown above in Table 4.3. The time allocated for lane closures affects production rate and delays in the schedule. For example, constructing a new on ramp can be done in a much shorter time if there is a full closure rather than having an eight hour lane closure for two weeks. Obtaining permits which might help the contractor speed up production can be difficult at times.

Number 6 in regards to importance in variables that cause delay in the CS is the suppliers, based on the interviews conducted from the second level managers in the PMH1 project. Supplier delivery is an important factor in starting and finishing tasks based on the CS.

It can be seen from the results of the interviews taken from the second tier of management in the PMH1 project that the most effective factors that can cause delays in the CS are communication and resources. The importance of communication in affecting the CS was in regards to the internal communication between different disciplines and departments in the project. In some cases, these communication flaws can be resolved by changing the hierarchy format, as stated by several mangers.

Figure 4.11 below depicts the allocation of each variable that the T2 management has brought up as factors that can affect the CS. These variables are normalized in a pie chart.

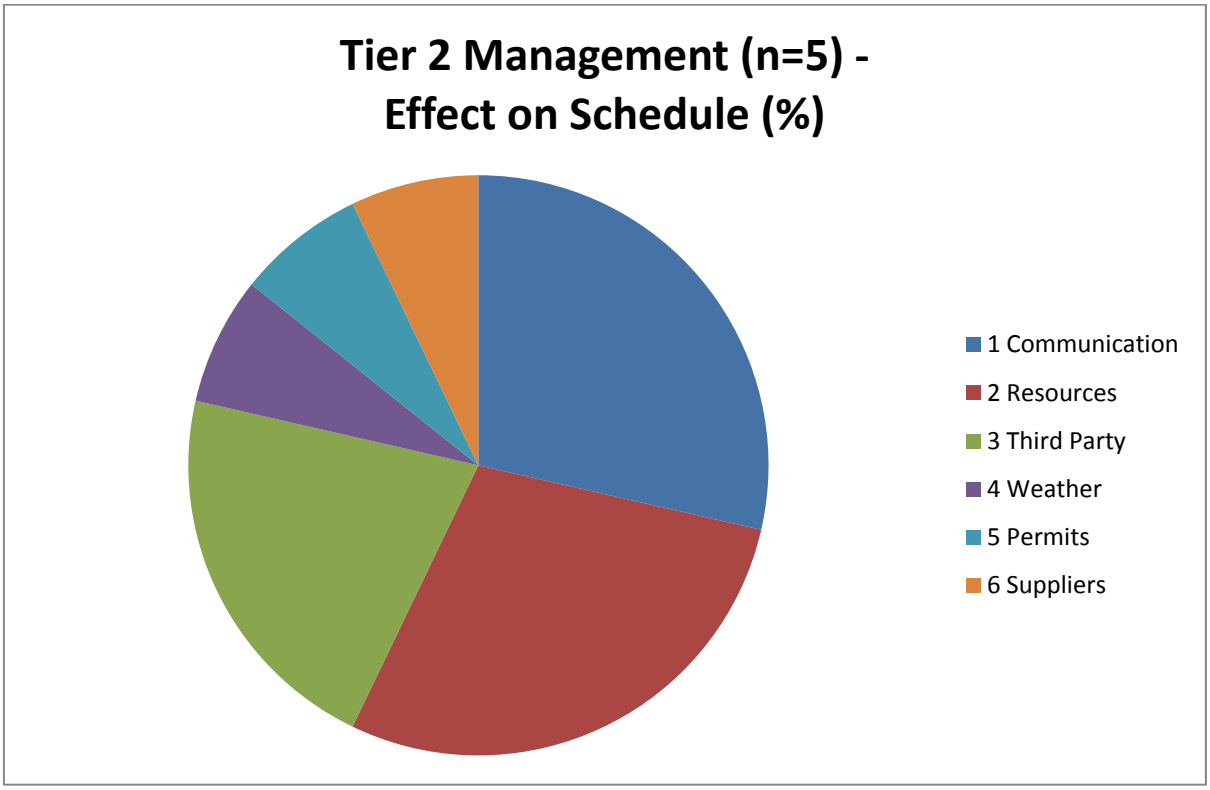

Figure 4.11: Tier 2 Management Interview Results

Figure 4.11 shows the results of the interviews with the second tier of management. This tier of management believed that communication and resources are the main factors of schedule delays.

In Table 4.4 below, are the responses regarding the change in the OH in regards to affecting any delays in CS. T2 managers believed that the changes in T2 of the OH have the most positive effect on the CS delay. They also believed that the changes in T1 and T3 can be positive. Half of the T2 managers on the PMH1 believed that changes in the T1 and T3 of management can affect the CS delays. T2 managers believed that by changing managers in the T2 level the negative effect on the CS can be reduced and better communication between managers and departments can be achieved. T2 mangers did not think by changing the OH itself the problems reoccurring can be fixed, they believed by moving staff in the OH the effect will be much greater in minimizing delay in the CS.

Table 4.4: Tier 2 Management Hierarchy Change Interview Responses

Tier 2 Management		
no.	**Hierarchy change**	**Most Effect on Schedule (%)**
1	Tier 1	50%
2	Tier 2	67%
3	Tier 3	50%

4.4.3 Tier 3 Management Interview Results

T3 results are presented in Table 4.5. Number 1 and 2 variables in Table 4.5 indicate that the T3 of management also sees communication and resources as the main factors in causing delays in the CS. This tier of management referred to communication as the flow of information from the field to the office and from the office to the field. If the flow of information from the field to the office can be relayed to the managing staff more quickly, then the solutions provided can be granted and relayed back to the field in a timely manner, and therefore minimizing delays in the schedule. The formulas that were used to calculate theses values are stated in Equations 1 and 2 above.

Table 4.5- Tier 3 Management Interview Results

Tier 3 Management		
no.	**Variables**	**Most Effect on Schedule (%)**
1	Communication	100%
2	Resources	100%
3	Third Party	50%
4	Weather	50%
5	Permits	50%
6	Suppliers	0%

T3 managers shared the same view as tier two managers in terms of the top 2 contributors to schedule delay. They indicated that relaying information down to the first level of management and making changes on the ground were often challenging. Having SIs focus on areas that are critical to the schedule at times can be difficult due to conflicts with other disciplines. Again, the issue of space and having enough work opened up to occupy the labor force for each discipline was difficult at times. The number 1 factor that T3 management also agreed on was communication.

The number 2 variable that caused delays in the PMH1 project based on the third Tier of management was resources. The third tier of management referred to the LF when discussing resources, and believed that material and equipment availability was not as affecting as the LF when it came to delaying the CS. Not having a skilled labor force also made it difficult to keep every discipline occupied. Training the labor force in more than one trade is key, due to the possibility of shifting focus from one area to another. Having a rounded, as well as an experienced, labor force would have allowed for the shifting of specialized workers from one discipline to another in times of need.

Number 3 to 5 in Table 4.5 had 50% importance in delaying CS in the opinions of the third tier managers. Obtaining permits in a timely manner is important in regards to starting tasks on schedule. Communicating the status of permits to mangers in a timely manner can help in minimizing the delays they can cause. Senior managers can facilitate the speed permits that are obtained if they are informed earlier on. Moreover, weather certainly has effects on the delays to the CS, but senior managers state that the delays caused by weather are mostly captured in the CS based on historical data. Third parties as well can affect the CS and cause delays. The management of sub-contractors and utility relocations require the first and second tiers of management foresight to minimize the delays they can cause. Third tier management believe that by applying the correct hierarchy, the effects delaying the CS can be minimized due to the above mentioned variables: third parties, permits, and weather.

T3 management did not consider suppliers as having much effect on the CS. They believed if the work is planned correctly, then the delivery dates will be on time and will not affect the CS.

Figure 4.12 below is presenting the allocation of each variable that the T3 management has brought up as factors that can affect the CS. These variables are normalized in a pie chart.

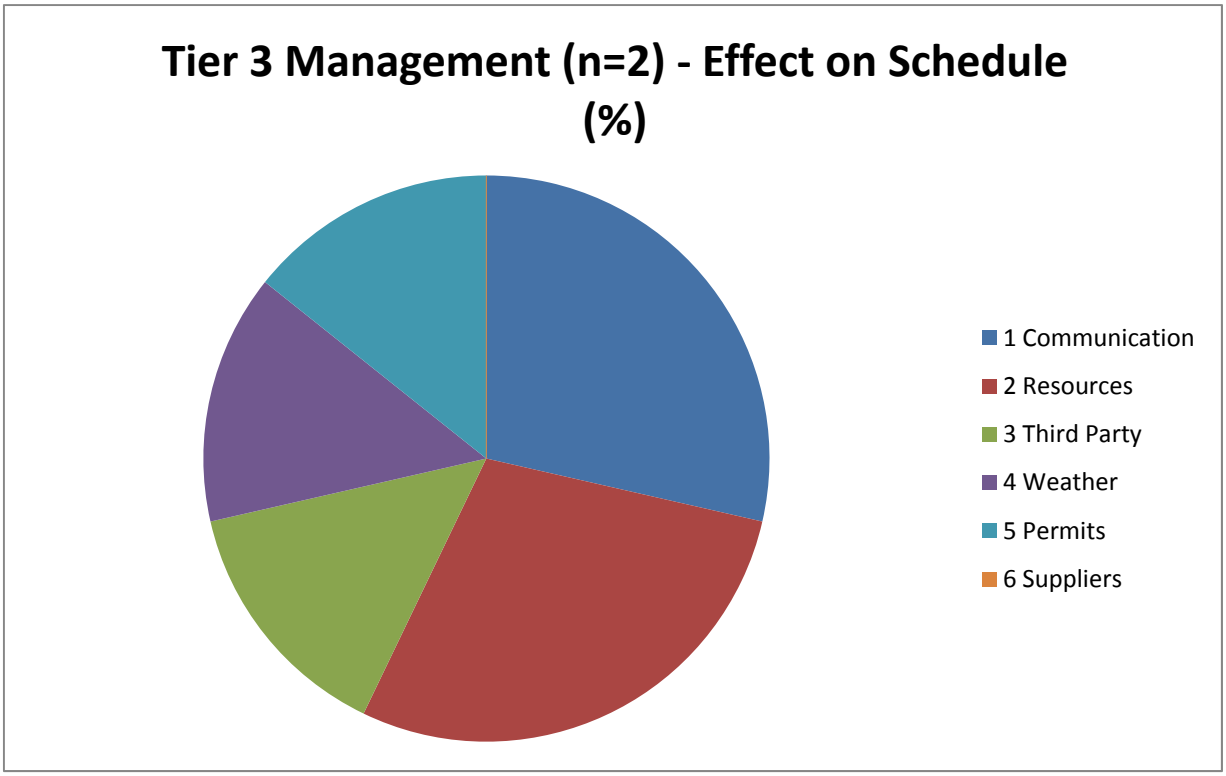

Figure 4.12: Tier 3 Management Interview Results

Figure 4.12 represents the results of interviews from the third tier of management. This tier of management believed that communication and resources were the main cause of CS delays. The third and second tiers of management both believed that the main factor was poor communication when it came to causing delays to the schedule.

In Table 4.6 below, the responses regarding the change in the OH in regards to affecting CS delays are shown. T3 managers believed that the changes in T2 of the OH have the most positive effect on the CS delay. They also believed that the changes in T1 and T3 can be positive. In their opinion, changing the first and third tiers of managers in regards to the experience they have had previously on the PMH1 has made differences on CS delays. They also believe that different managers have different communication skills, and hence, depending on the department they are managing, some might be affective and some might not be. Based on the outputs of the

departments, it will be beneficial to have changes in the organizational charts. They believed if a certain department is having difficulty meeting the CS one of the problems can be the managing staff and by rotating and switching managers the problems can be resolved. T3 managers believed medium level changes have the most effect on the CS, and by changing certain managers the delay on the CS can be minimized. T3 managers believed certain managers are good for certain phases of the project and by having the rotate production and communication between departments can be more effective. One example one of the T3 mangers brought up was that certain mangers can function best when work is at its peak and can execute the plan flawlessly but might not be great in planning work ahead of time. Where certain mangers are better when work is not at its peak and they can plan for future work.

Table 4.6: Tier 3 Management Hierarchy Change Interview Responses

Tier 3 Management		
no.	**Hierarchy change**	**Most Effect on Schedule (%)**
1	Tier 1	50%
2	Tier 2	100%
3	Tier 3	50%

4.4.4 All Tiers of Management Interview Results

Table 4.7 illustrates the comparison in the responses obtained from the interviews conducted from the different Tiers of management in the PMH1 project. It can be seen that all three tiers of management believed that communication and resources can have the most impact on the CS. Based on the responsibilities within each Tier of management, it is interesting to see the differences of importance they have given to the respective variables. Tier one and two managers had various views on the effects that the variables from numbers 3 to 6 had, as shown below in Table 4.7. Yet it can be seen that tier one and tier three mangers believed in the same level of importance for the same factors.

Table 4.7: Comparison of Results of all Tiers of Management

Comparison of Results in Each Tier of Management				
Rank	**Variables**	**Most Effect on Schedule (%)**		
		Tier 1	**Tier 2**	**Tier 3**
1	Communication	67%	80%	100%
2	Resources	33%	80%	100%
3	Third Party	33%	60%	50%
4	Permits	67%	20%	50%
5	Weather	50%	20%	50%
6	Suppliers	33%	20%	0%

Presented above in Table 4.7 is the combined view of all interviewed managers in the PMH1 project. Communication and resources were dominant factors in the opinions of the majority of the managers. These two factors have had the most effect on causing delays to the overall schedule based on the interviews.

It can be seen below in Table 4.8, third parties, which includes the relocation of utilities and the management of sub-contractors, are nearly as important as obtaining permits when it comes to factors that cause delays to the CS.

In Table 4.8, it can be seen that there are differences and variations in the responses from the three different tiers of management. These variations can be from the level of involvement of each tier of management in regards to the factor in question. It also can be due to viewing the problems and factors differently from the other managing staff. However, Table 4.8 shows that the interviewed managers have the same point of view in the same tier of management. This might illustrate the differences that have occurred in the results extrapolated from the interviews can be due to the level of involvement in each given factor, and could also be due to the level of experience in similar projects.

Table 4.8- Combined Results of all Tiers of Management Interviews

All Tiers of Management		
no.	**Variables**	**Most Effect on Schedule (%)**
1	Communication	77%
2	Resources	62%
3	Third Party	48%
4	Permits	46%
5	Weather	38%
6	Suppliers	23%

The interview results mainly suggest that the main factor in having delays can be concluded from the lack of communication and resources. A lack in communication being the first factor in causing delays to the CS can result from over-tasking resources, which would result in not having high quality communication. It is important to have high quality communication in projects that have very complex critical paths constrained by many variables that have great effect on the overall schedule. The communication between disciplines and departments is very important in helping minimizing delays and conflicts between them. In this segment, the decision to change the OH to allow for more supervision over the schedule was made to help with the lack of communication. The decision was made after several meetings and discussions between T2 and T3 mangers, they believed by adding a senior manager to supervise the schedule and the progress of work there will be better communication between different departments.

Also, the second factor that has effects on the schedule is resources (mainly labor force). Senior management brought up the issue of not having an experienced labor force. The majority of the labor force working on the PMH1 project is young, and the age difference between the experienced and the inexperienced ones is quite large. The experienced labor force is close to the age of retirement, and it seems that this gap can be an industry problem. Not having a fully-fledged experienced working force has an effect on the schedule. Many training classes are in place to keep the craft force up to date. This learning curve will also slow down production.

Safety policies that are being practiced in the project also require constant training and workshops. Factors such as safety, inexperienced labor, and the age gap between experienced and inexperienced labor force have an effect on the overall schedule.

Figure 4.13 below presents the allocation of each variable that all tiers of management brought up as factors that can affect the CS.

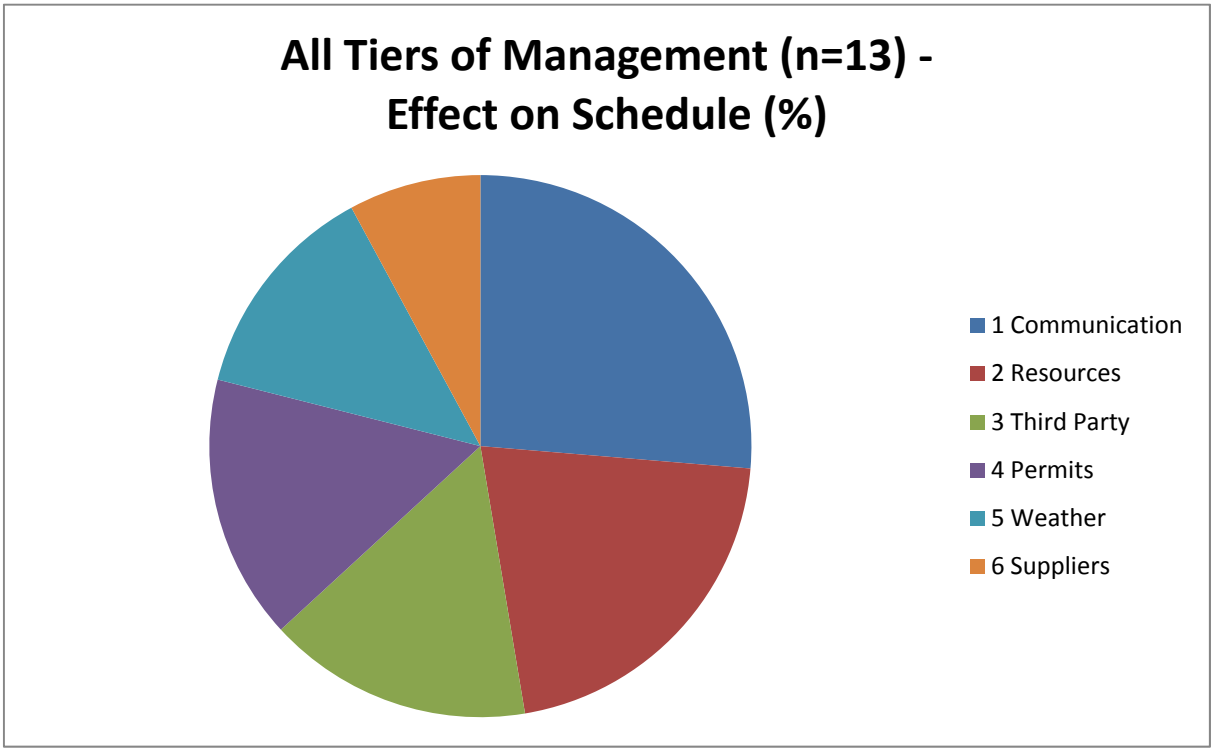

Figure 4.13: All Tiers of Management Interview Results

The top three variables identified in the interview process was communication, resources and third parties. Managers believed that poor communication was an important factor in causing delays to the CS.

In Table 4.9 below, the results of the interviews regarding hierarchy changes in the OH is presented. Table 4.9 is the summation of all interviewees from T1 to T3 of management.

The interview results suggest that the second tier changes in the OH have the greatest effect in terms of bringing production back on schedule. The second tier of management has direct

contact with the field SIs who are running the production in the field. The communication between this tier and the field allows for better resolving of the majority of problems that can affect the production rate and schedule. Making the right changes in the OH regarding this level of management can significantly change the course of production.

Table 4.9: All Tiers of Management Hierarchy Change Interview Responses

All Tiers of Management		
no.	**Hierarchy change**	**Most Effect on Schedule (%)**
1	Tier 1	47%
2	Tier 2	76%
3	Tier 3	53%

In conclusion, the interview results show that the main factors that have the most effect on the CS are communication and labor force. The interview results also showed that the main effects in the positive change in regards to the CS are those made in the second tier of management due to the exposure they have through the project.

Chapter 5: Recommended Solution for Minimizing Construction Schedule Delay

Chapter 5 is organized to illustrate the reasoning behind the choosing, the importance, and the validation of the recommended solution. This chapter first outlines the proposed solution based on the interview results discussed in chapter 4. Secondly, it describes the logic of the recommended solution. Finally, it will validate the functionality of the logic for the recommended solution via a second set of interviews.

5.1 Overview of Recommended Solution

The results obtained from the interviews and literature review showed similar commonalities between the variables that can have effects on the CS. The main variables which can cause delay to the CS based on the interviews were communication, resources (mainly LF) and the OH. To help minimize the effect of these variables on the CS, the author has identified that the root cause can be communication itself. A tool that could communicate with senior management can help minimize the effects that the mentioned variables could have on the CS. Communication itself is a general and broad term, but if we divide it in to the following categories we can provide the logic for a tool that can help identify areas of attention earlier. This would help to minimize conflicts and delay in the CS. The factor of communication in this research is based on the internal communications of the project: it does not include the external communication issues that can occur. The internal communications are the flow of information between different departments and disciplines and the flow of information from the field to the office and the office to the field. These categories are as follows:

1- Original CS
2- Current CS
3- Man hours (MHRS) spent on tasks identified on the CS
4- Budget MHRS of each task
5- Actual MHRS spent on each task
6- Budget for permanent materials

7- Actual cost of permanent materials
8- Availability of resources based on time and date
    a. Resources can be materials, labor force, machinery, etc.
9- Supply deliveries
10- Permits
11- Sub-contractor progress

The categories above are some variables that can reflect the situation of the CS, whether it results in delays or progressions. If the above items are tracked daily and reflect the changes they can make on the CS, then senior management can become aware earlier of which tasks may be delayed and which tasks, if not completed in time, would jeopardize other ongoing tasks.

Each task identified on the CS has budgeted MHRS, cost, permitting time, and allowable schedule time. These are the estimates prior to the start of the project. If the actual expenditure is tracked and compared to what was estimated daily, the differences between budgeted and actuality will define the progress of work in comparison to the CS. Most projects have a tracking system for each item mentioned above, but not all of them track these items daily and reflect them on the CS. What is practiced today on the PMH1 project is that engineers track each item separately and a summary of results are gathered at the end of each month, thus showing the distribution of MHRS, cost, permanent materials expenditure, sub-contractor work progress and permitting times in comparison to the original project estimates. Yet none of the tracking methods above are connected internally to result in something more useful to present to the management. If the items mentioned above are connected and highlighted, then the problems that occur in one item may be reflected on the other. This will allow the management to take action earlier, rather than later, to minimize delays. For example, the number of MHRS spent on a given task can be compared to what was budgeted for it and the difference can be examined. It can be seen that, for example, due to the delivery time of material and/or obtaining permits, it has required more MHRS to complete a given task. This information will allow managers to take steps to minimize the delay on the CS.

5.2 Logic Overview

The author proposes the layout of a software logic that can relate all categories above, and present a forecasted schedule, cost, and time when needed for management. This logic framework will help to fill the gaps in the current communications systems used for the PMH1 project, as well as similar projects. Figure 5.1 presents the inputs that can be given to the program and illustrates the outputs.

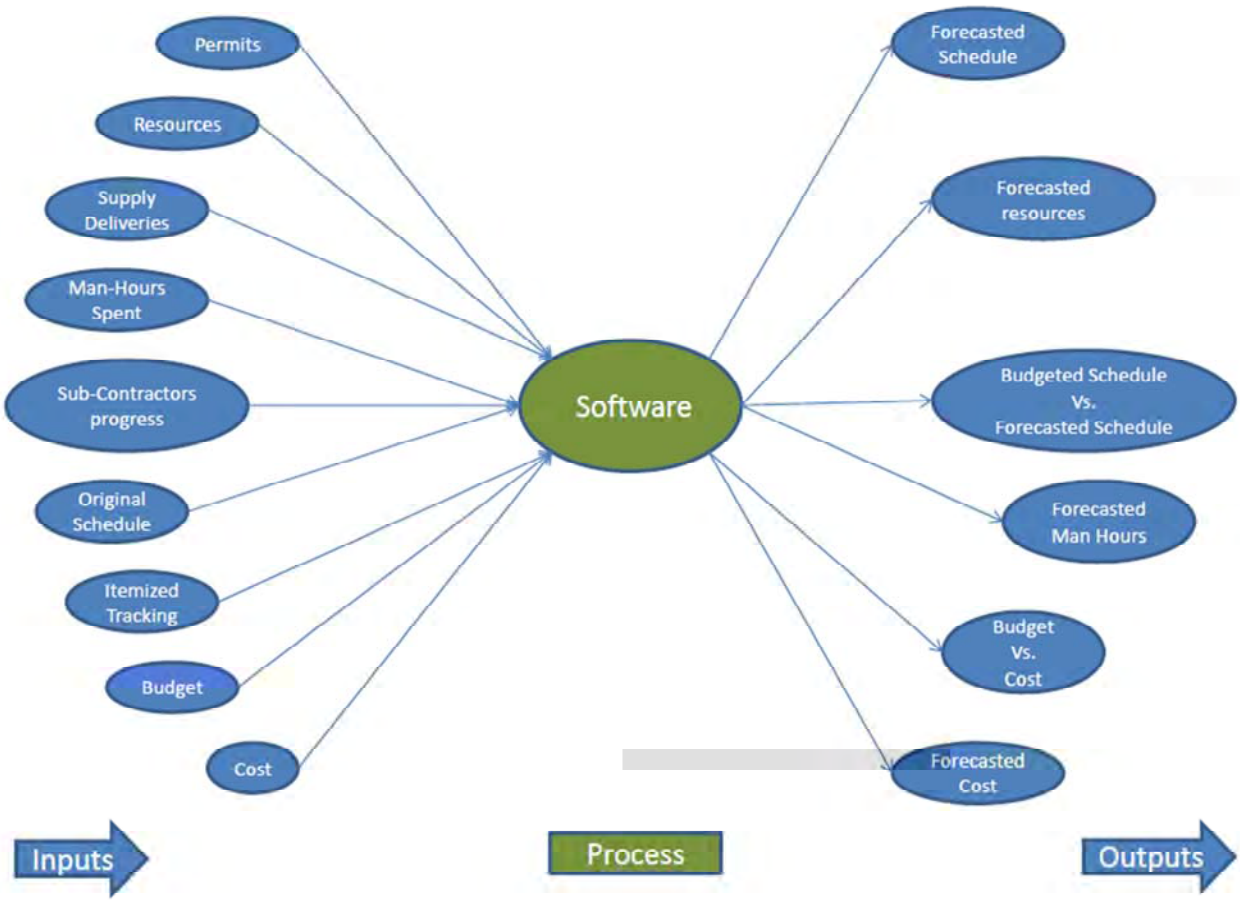

Figure 5.1: Inputs and Outputs of Proposed Software Logic

The inputs that can be given to the software for processing are as follows:

1- Permits
2- Resources
3- Supply deliveries
4- Man-Hour expenditure
5- Sub-Contractor progress
6- Original Schedule
7- Itemized Tracking
8- Budget
9- Cost

All the inputs mentioned above are connected to time. Having this commonality between the variables connects them in a way that they all can affect one another.

The outputs that can be expected from the software are as follows:

1- Forecasted Schedule
2- Forecasted resources
3- Budgeted schedule Vs. Forecasted schedule
4- Forecasted MHRS
5- Budget vs. Cost
6- Forecasted Cost

5.3 Input Overview

The inputs have been organized in such a way that they are all dependent on time (which would directly or indirectly affect the CS). The first input in Figure 5.1 is permits; applications for permits are initiated prior to the beginning of a task. Delays in obtaining the needed permits will cause delays in the CS. By inputting the estimated time and actual times of acquiring a permit, the software will be able to make changes on the CS. The changes made on the CS will reflect on

the forecasted CS. The output of the software will present the forecasted schedule, and illustrate the progress and/or delays caused in the schedule.

The second item on the inputs section of Figure 5.1 is resources. Resources are a summation of LF, machinery and materials. The number and availability of labor and machinery will directly affect the CS. The PMH1 project was designed with a CS based on the client's criteria and constraints. The number of labor and machinery for a given task was estimated based on previous jobs similar to the PMH1 project. Every job with all its similarities differs from one another. This proposed logic has the ability to present the differences of starting a task and finishing it on a daily basis, illustrating to the senior management which areas are of concern, and which areas are over-resourced. This information will allow for quicker decision-making in order to minimize the delay caused by labor or machinery shortages. For example, the materials that are required for embankment or are sub-grade are inputted daily. This will allow for planning the needs of the project based on the timing of delivery of material from different material quarry. This will allow for either changing current contracts with different pits on material availability, or will give the management the option of changing pits. This can also improve costs depending on the contracts that are in place with different pits.

Thirdly, supplier delivery times are acknowledged in the input section of the logic software. Supply delivery timing is crucial for projects such as the PMH1 project. It is crucial that the needed supplies for each task to arrive on time and to be available when needed. These inputs will help management to see which suppliers would need more time in advance for ordering materials. Due to inputting daily, the software will track all received items and can be very helpful if a supplier is not meeting its obligations based on the contract they have with the general contractor. This will allow management to mitigate occurring problems much more quickly than in a monthly or quarterly summary. The tracking of delivery times will allow the software to forecast a more realistic CS and inform management of the delays or progress caused by delivery times.

Fourth is the amount of MHRS being spent on the different tasks in the project, and is listed in the input section of the logic in Figure 5.1. MHRS are based on the allocation of the LF for each

task and the amount of time required finishing the task. The PMH1 project was estimated for a total of MHRS. Inputting the MHRS that each discipline is spending on given tasks based on the daily activities will allow management to see which tasks are over-budget. This will allow management to see if any tasks are using more MHRS in order to achieve completion, and ask for the reasoning behind it from the responsible managers. This will also allow the software to forecast the CS based on the actual work being completed daily. The management will have daily access to this information, which will allow for quicker replies in the decision-making process. This will allow third tier management to ask for more detail from the second and first tier management in regards to why more or less MHRS are being spent on a given task. It will make it much easier to change the OH by observing the areas that are challenging for the responsible managers.

The fifth factor in Figure 5.1 is managing sub-contractors. Managing sub-contractor progress and payments can be made much easier if tracked daily. The progress made by the sub-contractor will have its effects on the CS; hence, the software will be able to forecast the schedule based on these inputs. It also will allow management to know how sub-contractors are doing in comparison to their contract. This function will allow management to keep invoices or change sub-contractors where they see fit.

Sixth in the input section of Figure 5.1 is the original CS with which the job was designed. The original CS is what was given to the client when the project was awarded. Having this inputted in the software will allow for the comparison of daily inputs to that which was initially planned. This will help in forecasting the schedule, and also show management bodies where the project sits in comparison to what was originally planned. Based on this information, management can make the necessary changes to minimize any delays to the schedule. The changes can be on the OH, sub-contractors, suppliers, LF and third parties.

The seventh factor listed in Figure 5.1 is itemized tracking. Every discipline will be required to itemize the tasks they are responsible for based on the schedule. Daily tracking of these tasks will show the progress of each discipline. This progress will allow the software to forecast the CS accordingly. The difference between the forecasted schedule and the project schedule can be

illustrated, allowing engineers and management bodies to make necessary changes when required to minimize any ongoing problems.

Finally, budget and cost are also tracked daily. The budget itself was defined when the contract was awarded, and is a finite amount. Therefore, tracking the actual cost of operations on the project is very crucial. This allows management to be aware of daily costs, as well as the difference of occurring costs and the budget. Changes can be made to minimize the differences or allow for better planning to optimize the production for decreased costs. In the PMH1 project, these costs are only reviewed weekly and monthly. Daily tracking of costs will allow for a more exact and precise cost control. This is very helpful for senior management to be able to view the costs that have occurred in comparison with where the CS shows work progress: they can make necessary decisions much more swiftly.

5.4 Output Overview

Based on the given inputs, the software with its logic will have the capability to use the inputs to give needed information that can be helpful to the managing staff.

The first factor and item the software can provide management bodies, is a forecasted daily schedule. The benefits of having a daily forecasted schedule is that it provides management with the construction progress, and shows what tasks are causing delays, as well as which have the potential to beat the scheduled completion date. This will help communication between disciplines in regards to predecessor tasks, and what tasks are suspending the progression of work. This factor will help decision-makers to identify potential tasks that might delay the CS.

The second item in the output section of Figure 5.1 is forecasted resources. The software will also show the resources needed for tasks based on what was needed on similar tasks on the CS. This will allow for early planning for upcoming work in regards to what machinery is needed, what material should be purchased, and how many MHRS (based on previous work) is required to complete the task.

The third item in the output section of Figure 5.1 is forecasted schedule vs. budgeted schedule. The difference between forecasted schedule and budgeted schedule will communicate to management what areas need attention. This function also provides third tier management which areas require stronger management. It also warns management bodies if any critical sections of the project (based on the budgeted schedule) might have conflicts and thus cause delays in important milestones.

The fourth item in Figure 5.1 is the forecasted MHRS that remain to complete the job. Forecasted MHRS will show management if certain tasks have problems in meeting their budget in regards to the MHRS that was allocated to them for completion. This function will allow second tier management to make decisions in regards to the SUPT running the work in the field. Man hour allocation per task is an indicative result as to what is occurring in the field. Going over budget can be due to inaccurate estimates, untrained LF, and/or a lack of experienced supervision in the field. These factors will help management to make the correct decision in a timely manner due to daily inputs. The delays and over-expenditure, compared to the designed budget, will allow for quicker responses from management.

Finally cost vs. budget and forecasted cost is provided in the output section of Figure 5.1. The comparison between budget and actual cost illustrates to management which areas need attention, and require immediate action. It is crucial for management to be aware of all costs. If cost expenditure can be available daily, based on job to date (JTD) values, it will be helpful for the decision-making process. This function, alongside the forecasted cost of the project, will help in making decisions early on in the project in order to minimize areas that will negatively affect the project profit. It also will help identify areas that are costing more than predicted when the project was first awarded.

The above explained inputs and outputs are functions that can communicate project progresses to management bodies on a daily basis. There is less need for meetings, emailing, phone conversation, and face to face conversation for project updates when they are readily available to all levels of management. This logic will help to reduce the time spent in communicating problems and issues that are causing delay and conflicts in the CS. It can help management to

identify a need for training the LF, to make proper changes in the organizational charts, and to form a better communication between departments and managers in regards to work progress, conflicts, delays, and cost. The decision-making process becomes easier and will be based on current JTD data which can help to minimize delays and conflicts in the CS.

5.5 Recommended Solution Logic

Figure 5.2 presents the logic of the recommended software. The solution presented in section 5.1 uses the logic of receiving given factors and transferring them into time based factors that can be placed on the CS. By doing so all factors can be defined and compared based on time. This function will help understand the effects each factor has on the CS. After these factors have been transformed as time based factors, the program can then compare them with the job schedule. The program will compare the JTD schedule and the actual progress of work. This information and comparison then can be presented as outputs. These outputs can be as follows:

1- Forecasted Schedule
2- Construction Schedule Vs. Forecasted Schedule
3- Forecasted MHRS
4- Forecasted MHRS Vs. Budgeted MHRS

Figure 5.2 represents the interaction between these factors, and is an example of a Task A that a subcontractor is responsible for executing. To be able to start the construction phase, the subcontractor requires permits and materials. Figure 5.2 presents how each given factor has steps that are required to be completed before the subcontractor can start construction. Each of these factors and steps are in a way connected to time, which may be tracked. These tracked times for each step of each factor can be compared to the construction schedule. This comparison show any delay in the CS. These factors can vary depending on each discipline and departments tasks, but they are presented in steps that can be related to time. Having all given factors to the recommended solution presented based on time; the logic can analyze the given data in a manner that can help with communication and construction schedule delays.

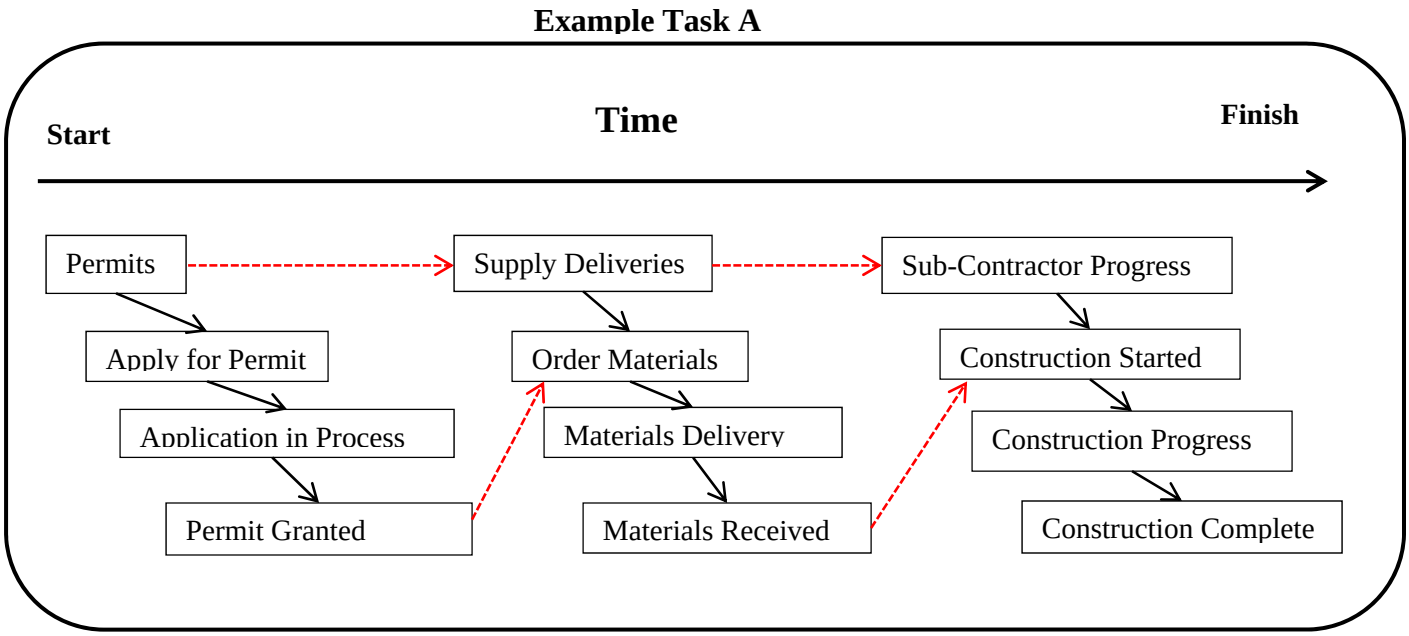

Figure 5.2: Factor Interaction

Figure 5.3 presents the interaction between the different sections of the recommended solutions logic. The first section is the different factors and is followed by inputting their data into the system. The next step is the process of comparing the given data to the construction schedule. This section can have many more functions, for example, construction cost and budget can be easily analyzed as well. The last section is the output of the logic, which can include the construction forecasted schedule, forecasted schedule comparison with the construction schedule, forecasted man hours to complete the project, and a comparison between the forecasted man hours and budgeted man hours. These outputs are the main uses of tool management to address the problems in the field. This software will update management bodies daily, and will allow them to know where the project is in comparison to the job schedule and budget. It will allow management to take action faster in order to minimize negative effects (in terms of schedule and cost) to the project in terms of. It also will help and minimize poor communication between different tiers of management.

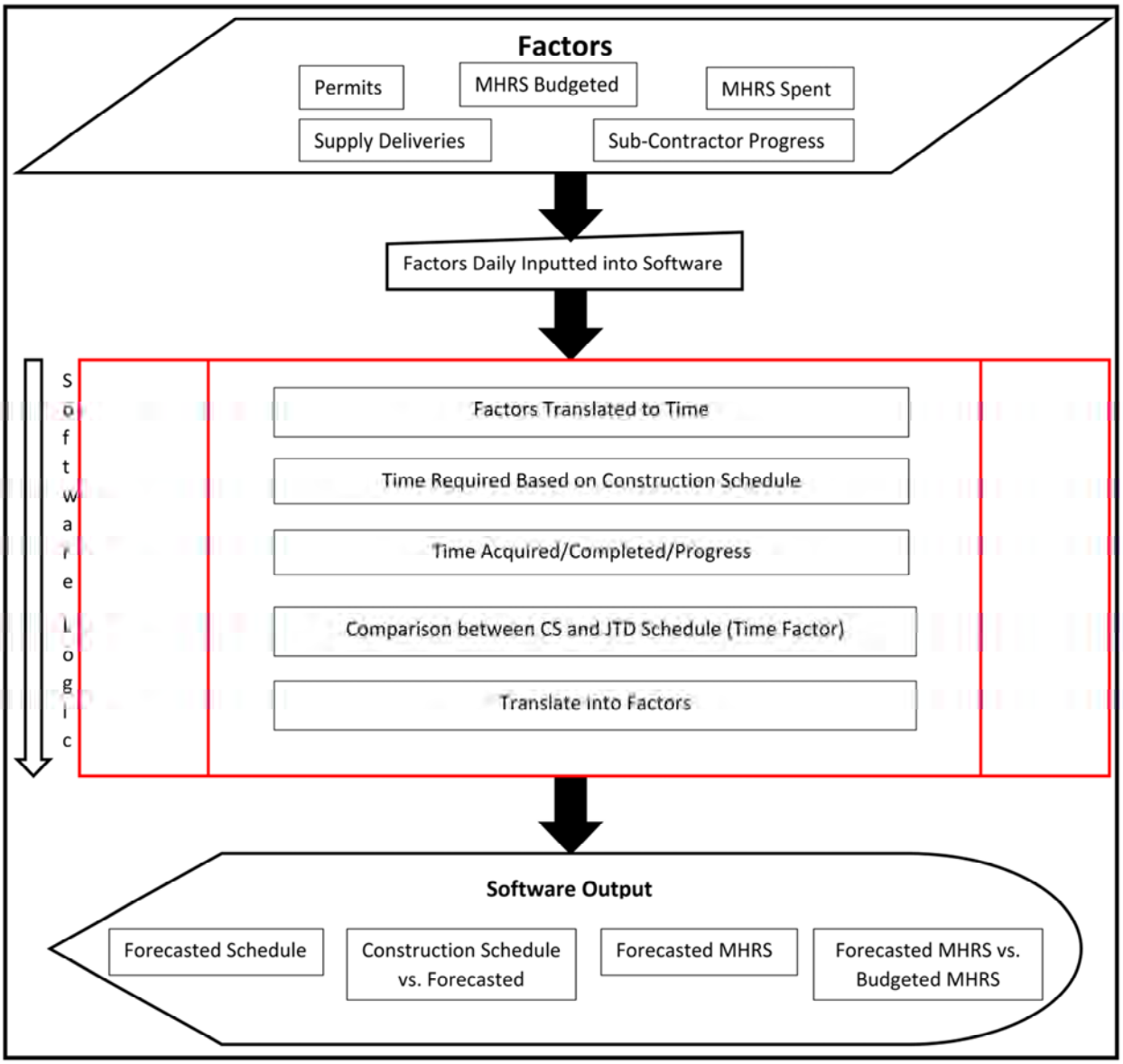

Figure 5.3: Recommended Solution Software Logic

Figure 5.4 presents the linking between different tiers of management in the current OH. It is presented that the flow of information is broken four times before reaching the project manager. The flow of communication starts from the field engineers and makes its way up to the T1 mangers and then based on the level of importance it is brought up to the T2 mangers. The T2 managers initially try to resolve problems amongst themselves and if the problem is reoccurring or is of more importance it is elevated to the construction manager and from there to the project manager. As it can be viewed the flow of communication can be slow at times and this can cause delay in the CS.

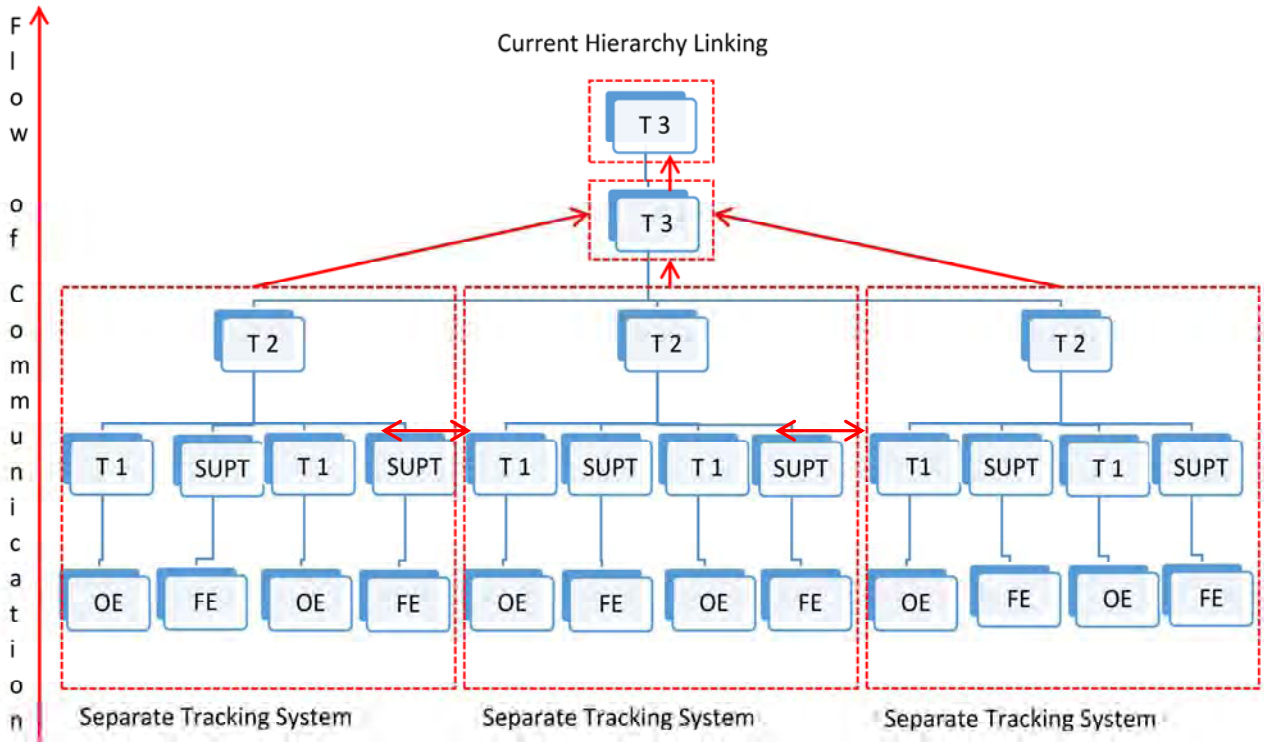

Figure 5.4: Current Hierarchy Linking Between Different Tiers of Management

Figure 5.5 presents how this software will help minimize poor communication between different tiers of management in different disciplines. As it can be seen, a major benefit of this software is that all tiers of management in all disciplines will have access data that is gathered from the field and inputted into the system. Managers of different disciplines will be able to see the required tasks, and how they may or may not suspend work.

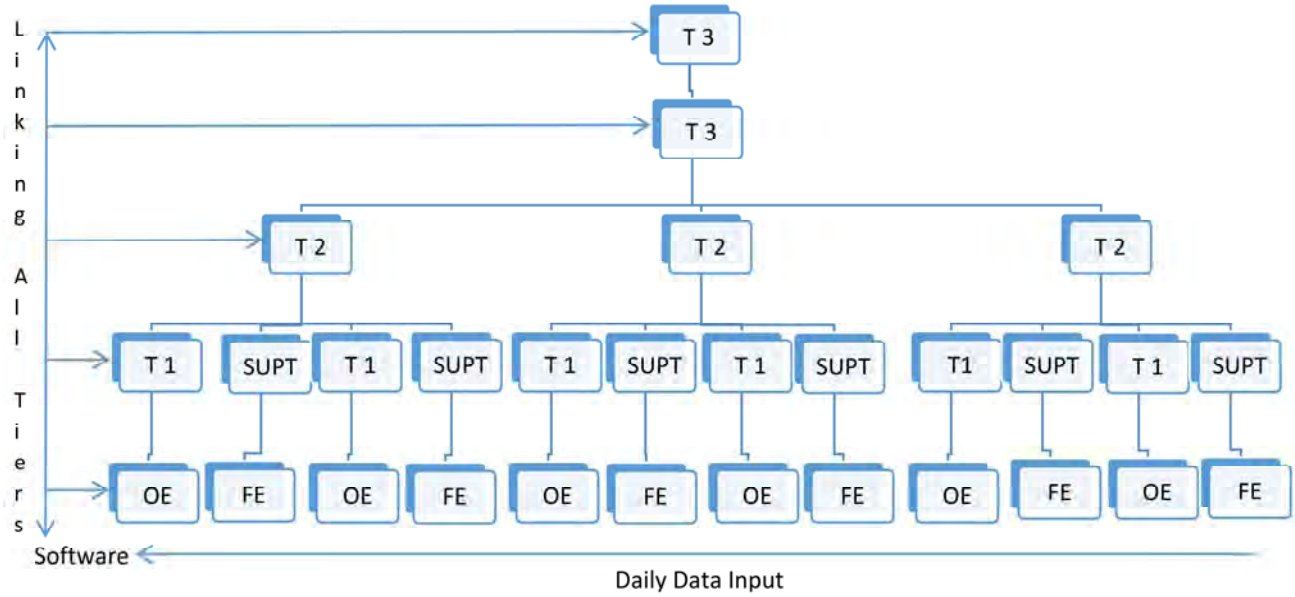

Figure 5.5: Recommended Solution Communication Logic

Allowing quicker awareness to tier two and three managers of the exact progress of work in the field will allow them to be more responsive to matters of concern in a timely manner, which will minimize and reduce negative effects.

5.6 Validating Recommended Solution

Based on the literature review, observations, and interviews, the author has proposed a solution that can help management teams in similar projects in dealing with poor communications in regards to CS delay and conflicts. To validate the proposed solution, the author conducted a second series of interviews with the senior managers of segments 4, 2 and 1 of the PMH1

project. These interviews were focused on the proposed solution and to see if management agrees on the effects that this solution would have on the CS delays and conflicts. The author interviewed the managers in the third tier of the management category. In total, 4 interviews were conducted with the senior management of segments 1, 2 and 4. The third tier management consisted of project or construction managers.

The questions asked in the interview were focused on verifying the effects that the proposed solution will have on communication, as well as its effects on the CS. The daily progress updates were one of the areas that made the proposed solution effective in identifying problematic areas.

Table 13 illustrates the outcome of the interviews in regards to the proposed solution. Based on these results, the proposed solution was edited and recommended. All managers interviewed agreed on the effects the following categories had on the CS, and that they optimized the communication between the department and the project as a whole: tracking work progress daily, tracking task costs daily, tracking MHRS spent on tasks daily, and updating the CS daily. Two of the three managers interviewed agreed that, on a daily basis, tracking permit approval lengths, supplier delivery wait time, and monitoring sub-contractor progress was beneficial to the CS.

Table 5.1: Proposed Solution Interview Results

no.	Inputs	Most Effect on Schedule (%)
1	Tracking Work Progress Daily	100%
2	Tracking Task Cost Daily	100%
3	Tracking Obtaining Permit Time	67%
4	Tracking Supplier Delivery Time	67%
5	Tracking Man Hours Spent on Tasks Daily	100%
6	Tracking Subcontractor Progress Daily	67%
7	Tracking Construction Schedule Daily	100%

Question 1 (see Appendix E) asked from the senior managers their opinions on having staff updates and to track activities daily, and if they agreed that the extra time spent would benefit in identifying delays and conflicts in the schedule. Item number 1 in Table 5.1 shows that 100% of

the managers believed that tracking work progress daily would have a positive effect in minimizing the delays caused in the CS. All managers agreed that it would be beneficial to have daily updates, but were concerned about the time it would take for the engineering staff to input the required data into the program. But, they agreed that if the user interface was made in a way to help reduce time spent on the program, it would be very beneficial to have all progress tracked daily. The managers were of the opinion that the daily tracking would help the production schedule of the project, due to the fact that it would allow the managers to see where problematic issues were taking place. Thus, this will allow managers to focus their efforts in resolving the problems. The daily tracking can be completed online by SUPT on site via tablets or from engineering staff from the office.

Question 4 of Appendix E asks the question of tracking the cost of tasks that are being over-resourced to complete a given task. It was asked to see if they think it is beneficial to see the difference in costs as to what was originally proposed, to what was being truly spent. Managers believed it would always be beneficial to see what each task is costing daily, and that would help to manage and plan better those tasks in order to minimize costs. 100% of the managers interviewed agreed on knowing the costs for over-resourcing any task is beneficial when it comes to making a decision.

Question 3 of Appendix E asks the managers what their thoughts are on having a program that can provide managers with the difference of forecasted schedule and the original project schedule on a daily basis. This function of the program will help to identify areas that management needs to focus on. All mangers agreed on the benefits of having knowledge of the current project schedule and found it beneficial to see the current delays and/or progresses in the CS. This function will allow managers to decide what areas need more resources, and which areas can use less. This will help with the CS and the cost of any given task.

Obtaining permits and supplies in a timely manner has a direct impact on the CS. Question 5 of Appendix E focuses on permits. The question was asked if it would beneficial to track these dates so areas that are causing delays would be noted. All mangers thought that it would be very beneficial to know which suppliers cause delays in delivery times, and that they can apply

pressure in accordance to the contract with the suppliers and, in some cases, apply fines. This will allow a timely delivery of supplies from contracted suppliers. They also agreed that it would be useful to know which permit applications had the longest waiting periods. They emphasized that they would like to know who to assign to follow up on obtaining permits, rather than assigning the responsibility with someone that might not have the proper channeling or communication skills.

Finally, it was asked if this software would help in the lack of communication between departments, and what issues were being experienced in production due to conflicting activities between departments. Managers responded positively to this question. It was brought up that depending on the user interface, this can help significantly with illustrating areas of conflict between departments and activities in the field.

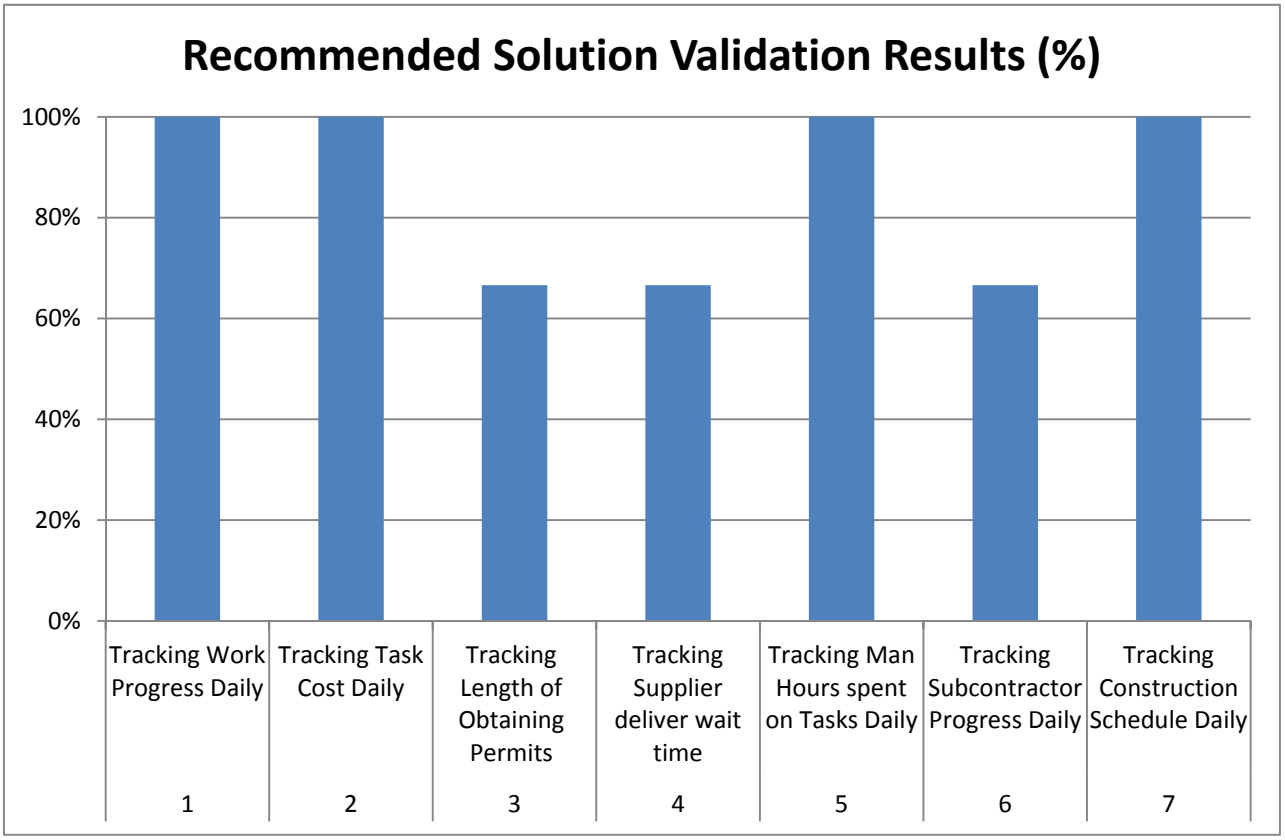

Figure 5.6: Recommended Solution Validation Results

The recommended solution was validated by a second round of interviews conducted from the third tier of managers in segment 1, 2, and 4 of the PM teams. Figure 5.6 illustrates the interview results. As it can be seen in Figure 5.6, 100% of the managers interviewed agreed that tracking work progress, cost, man hour expenditure, and current schedule would help in minimizing delays in the CS. They believed that this will allow for better communication between managers and departments. Additionally, problem areas will be noticed quicker, and senior management can make fast decisions to minimize conflicts and delays. They also believed this tool will allow them to change the hierarchy of the project in accordance with delays being caused to the schedule.

It was also brought up that this software would need to be implemented in the beginning of the project and there should be training classes for the staff using it. The time spent on the software daily was another cause of cautiousness.

5.7 Recommended Solution

Based on the observations, literature review, and interviews conducted on the PMH1 project, it was concluded and validated that the following recommended solution will have positive effects on identifying and alerting managers of CS delays and conflicts. This is done by communicating clearly what is happening on the project on a daily basis in regards to constructions schedule, construction cost, and construction progress. This method of communication between all departments and managing staff will allow for the early identification of occurring conflicts and delays.

The author recommends this solution to similar infrastructure projects. The recommended solution is a proposal that has been validated by the senior managing staff on the PMH1 project. This proposal describes that if the engineering staff tracks and inputs data daily in regards to:

1- Work progress
2- Costs
3- Man hour expenditure

4- Supplier delivery times
5- Permit approval times
6- Resource availability

Software can be written to use this information to present managers with the following:

1- forecasted schedule
2- forecasted cost
3- forecasted MHRS
4- forecasted resources

The above outputs can be given to managers and different departments and disciplines. This information will help in the decision-making process.

The proposed solution is a software logic that has the potential to be turned into a computer program that can analyze the given inputs and in return give daily management information in regards to the project. Based on the inputs given to the program, any user will be able to get information in regards to the location of the project's progress. Knowing the time spent, as well as the time needed to finish, an ongoing task (based on the JTD data inputted into the program) can help management bodies to decide on hierarchy changes which will minimize delays on the CS. The information provided with this program will help in the communication between disciplines, and will allow planning work to minimize conflicts between other department and disciplines.

Chapter 6: Conclusion and Recommendation

In this chapter, the conclusion of the research is presented. The strength and limitations of this study are presented and future research recommendations are made.

6.1 Conclusions

The progress and changes that have occurred during the past decades in the field of project management have been identified. The main variables that have the greatest effects in mega infrastructure projects have been presented. A study on one of the biggest infrastructure project of its time in North America has been conducted, and variables that have had effects on this project were discussed. This research is focused on identifying the variables that have had the most impact on the construction schedule on PMH1 and similar projects. The summary of this study are as follows:

- Review of the history of Project Management and where it stands today as a practice
- Identification of the main variables that have the most impact on the Construction Schedule
- Study of the PMH1 project
- Interviews with the management staff of the PMH1 project to identify variables that have effect on the Construction Schedule
- Recommendation of a solution to resolve and minimize impacts on Construction Schedule delays
- Validation of the recommended solution

In conclusion it was found that in the PMH1 project the main cause of delay to the CS are communication, resources and third parties. Changes to the OH can minimize the delay to the CS by changing and rotating medium level mangers depending on skill set and experience throughout the project. By introducing the recommended solution the flow of information

between mangers and different departments can be more effective and help minimize delays to the CS.

6.2 Recommendations

The following are the recommendations made for minimizing schedule delay:

- The project managers are the key responsible personnel to insure the project is completed in regards to both time and the budget. Therefore, they should take the initiative to implement this recommended solution in their projects.
- The recommended solution requires all participating staff of the project to take part in completing all required tasks to insure the successfulness of the recommended solution.

6.3 Limitations of the Study

The following are the main limitations of the study:

- The sample size was calculated based on the initial study of the PMH1 project, which was obtained from expert opinion. Therefore, the validity of the results is dependent on the opinions of the selected interviewees.
- The sample size analysis was performed with good power (94%) and significance, however, better results would have been provided with a greater sample size.
- The PMH1 was a Design-Build contract; this study and its results were based on the PMH1 project. Different contract types and projects would have provided more in-depth results.
- To validate the recommended solution, managers from the different segments of the PMH1 project were used. Different managers from different projects would have provided more robust results.

6.4 Research Contribution

The following are the contributions of this study:

- Limited studies are done on the effects of communication and hierarchy changes on the construction schedule on infrastructure projects. Therefore, this study will be a stepping stone for future studies, especially for Canadian projects.
- Variables that effect construction schedule on infrastructure projects in BC, Canada have been identified and validated by professionals.
- The recommended solution in this study can be utilized to prevent and minimize construction schedule delays. The proposed tool will alert management earlier in the construction phase of potential delays in the construction schedule.
- Hierarchy changes, and the resulting effects, on the construction schedule have been identified. The level of changes made in the hierarchy which have greater affect in construction schedule have been noted and identified.

6.5 Future Research Recommendations

To help minimize construction schedule time, minimize costs and better communication in mega infrastructure projects the following are recommended future studies:

- At what stage in the project is it efficient to change the hierarchy of the project?
    - At what time in a construction project does making changes to the hierarchy have positive effects, and at what phase will it have a negative effect, to the construction schedule?
- What training will help impact the labor force?
    - How can the managing staff train an inexperienced labor force in time to have a positive effect in the construction schedule?
    - Which training classes are beneficial to the craft?
- How does team spirit and motivation affect the use of the software?
    - Would team motivation affect the quality of inputs in to the software?

    - Would team spirit affect the inputs into the software in terms of factual inputs?
- Optimize communication between different disciplines of a project.
    - What other tools can be used to better the level of communication between different disciplines in mega infrastructure projects?
    - What indicators can be used to insure adequate communication exists between disciplines at all times during the construction phases?
- Create the software from the recommended solution.
    - Develop computer software that can use the logic provided in the research to help and optimize the communication between different levels of management for mega infrastructure projects.
- More Case Studies
    - Study similar projects to allow for a better sample size
    - Study more companies to allow for a better understanding of industry practices

References

Allen, D. (2004). Establishing communications; vital key to success [online]. U.S. Army Signal Centre. Available from http://www.findarticles.com/p/articles/mi_m0PAA/is_4_28/ai_n6118581 [cited 6 March 2007].

Alshawi, M. and Ingirige, B. (2003), "Web-enabled project management: an emerging paradigm in construction", Automation in Construction, **12**(4), pp. 349-64.

Anthony, R., Dearden, J. and Govindarajan, V., Management Control Systems, (Second edition), Irwin, Homewood, Illinois,1992.

Atkinson RW. Effective Organizations, Re-framing the Thinking for Information Systems Projects Success, pp. 13-16, Cassell, London, 1997.

Atkinson, R. (1999). "Project management: Cost, time, and Quality, two best guesses and a phenomenon, its time to accept other success criteria," International Journal of Project Management, **17**(6), pp. 337-342.

Ashley, D., Lurie, C., and Jaselskis, E. (1987). "Determinants of Construction Project Success," *Project Management Journal*, PMI, **18**(2), pp. 69-79.

Association of Project Management (APM), Body of Knowledge (BoK), Revised January 1995 (Version 2).

Bateman, T.S., and Snell, S.A. (1999). Management: Building competitive advantage. 4th ed. McGraw-Hill, London.

Brandon, P. (2000). Construction IT: forward to what? Implementing IT to obtain a competitive advantage in the 21st century. *In* Proceedings of the International Conference on Construction Information Technology: 2000 (INCITE 2000), Hong Kong, 17–18 January 2000, Hong Kong Polytechnic University.

British Standard in Project Management, 6079, ISBN 0 58025594 8.

Bowden, S., Dorr, A., Thorpe, T., and Anumba, C. (2006). Mobile ICT support for construction process improvement. Automation in Construction, 15(5): pp. 66-676. doi:10.1016/j.autcon.2005.08.004.

Burke R. Project Management. John Wiley and Sons, Chichester, 1993.

Butts, G. and Linton, K. (2009). "The Joint Confidence Level Paradox: A History of Denial," 2009 *NASA Cost Symposium*, April 28.

Casavant, K., Jessup, E., and Holmgren, M. (2007). "Program Scoping/State of Practice for Washington State," WA-RD 680.1, Washington State Transportation Center, Pullman, Washington.

Chou, C., Caldas, C., O'Connor, J., Sroka, A., and Goldman, G. (2009). "Identification of Decision Drivers for the Strategy of Incorporating Utility Relocations into Highway Construction

Cleland, D. and Ireland, L. (2002). Project Management: Strategic Design and Implementation, McGraw-Hill Professional, ISBN-10: 0071393102.

Crossett, J. and L. Hines. (2007). "Comparing State DOTs Construction Project Cost and Schedule Performance," Task 37A, NCHRP Project 20-24, TRB, Washington, D.C.

Dolson, G. (1999). "Scheduling and Management Improvements Accelerate Roadway Design,"

Transportation Research Record 1652, pp. 92-97.

Federal Transit Administration (FTA) (2003). "Project and Construction Management Guidelines," retrieved from http://www.fta.dot.gov/documents/Construct_Proj_Mangmnt_CD.pdf. (As of November 24, 2009).

FIATECH. (2007). Fully integrated and automated technologies [online]. Available from www.fiatech.org [cited 12 November 2007].

Flyvbjerg, B., Holm, M., and Buhl, S. (2004). "What Causes Cost Overrun in Transport Infrastructure Projects?" *Transport Reviews*, 24(1), January, pp. 3-18.

Gamez, E. A. and Touran, A. (2009). "A Method of Risk ranking for International Transportation Projects," *Proceedings of 7th International Probabilistic Workshop*, pp. 187-203, November, Delft, Netherlands.

Gray, C. and Larson, E. (2008). Project Management: The Managerial Process, 4th Edition, McGraw-Hill/Irwin, ISBN-10: 0073525154.

Hewage and Ruwanpura (2009) "A novel solution for construction on-site communication – the information booth", Canadian Journal of Civil Engineers, **36**, pp. 659-671.

Hewage, K.N., Ruwanpura, J.Y., and Jergeas, G. (2008). IT usage in Alberta's building construction projects: Current status and challenges. Automation in Construction. **17**(8): 940–947. doi:10.1016/j.autcon.2008.03.002.

Hewage, K.N., and Ruwanpura, J.Y. (2006*a*). Carpentry worker issues and efficiencies related to construction productivity in Alberta's commercial construction projects. Canadian Journal of Civil Engineering, **33**(8): 1075–1089. doi:10.1139/L06-050.

Hewage, K.N., and Ruwanpura, J.Y. (2006*b*). Technology adoptability and adaptability issues related to communication in Alberta commercial construction projects. Proceedings of the 1stst International Construction Specialty Conference, Canadian Society for Civil Engineering, 23–26 May 2006, Calgary, Alberta.

Jolivet, F. and Navarre, C. (1996) Large-scale projects, self-organising and meta-rules: towards new forms of management. The International Journal of Project Management. **14**(5), pp. 265-271.

Kerzner, H. (2006). Project Management: A Systems Approach to Planning, Scheduling, and Controlling, 9th ed., John Wiley & Sons, Inc., New Jersey.

Kog, Y., Chua, D., Loh, P., and Jaselskis, E. (1999). "Key determinants for construction schedule performance," *International Journal of Project Management*, **17**(6), pp. 351–359.

Kraus, E., Quiroga, C., and Le, J. (2008). "Development of a Tool for Utility Conflict Data Management in the Project Development Process," TRB 2008 Annual Meeting CD-Rom, No. 08-0281, Washington, D.C.

Levitt, R. (1984). "Superprojects and Superheadaches: Balancing Technical Economies of Scale Against Management Diseconomies of Size and Complexity," Project Management Journal, PMI, **15**(4), pp. 82-89.

Lock D. Project Management, 5th ed. Gower, Aldershot, 1994.

Marshall, K. R. and Rousey, S. (2009). Guidance for Transportation Project management, NCHRP Web-Only Document 139, Transportation Research board, national Academies, Washington, D.C, pp. 217.

Martin, C. and Does, J. (2005). "Accelerating Highway Bridge Demolition: An Innovative

Approach," Innovations in Bridge Engineering (B) Session, *2005 Transportation Association of Canada*, Calgary, Alberta.

McKim, R., Hegazy, T., Attalla, M. (2000). "Project performance control in reconstruction," *Journal of Construction Engineering and Management*, **126**(2), pp. 137-141.

Merrow, E., McDonnell, L., and Arguden, R. (1988). "Understanding the Outcome of Mega-Projects: A Quantitative Analysis of Very Large Civilian Projects," ISBN: 0-8330-0843-9, RAND Corp., Santa Monica, California.

Mohamed, S., and Stewart, R.A. (2003). An empirical investigation of users' perceptions of web-based communication on a construction project. Automation in Construction, **12**(1): pp. 43-53. doi:10.1016/S0926-5805(02)00039-0.

M. Kagioglou, R. Cooper, G. Aouad, J. Hinks, M. Sexton, D. Sheath, Final Report: Process Control, University of Salford, 1998.

Neil, J.M., and Knack, L.E. (1984). Predicting productivity. Transactions of the American Association of Cost Engineers, **3**(H3): pp. 1-8.

Oisen, R.P. (1971). Can project management be defined? Project Management Quarterly, **2**(1), pp. 12-14.

Owens, J.A. (2010)" Project management for complex transportation projects", Master Thesis, Iowa State University.

Pate, W. (2000). "Innovative Design and Construction of Chesapeake and Delaware Canal Bridge," *Transportation Research Record 1696*, No. 5B0070, pp. 44-48.

Patrick B., Tomkins C., and A. Graves (1999) "Decentralised site management- a case study", International Journal of Project Management. **17**(2), pp.113-120.

Peters, T. and Waterman, R., In Search of Excellence: lessons from America's best-run companies, Harper & Row, New York, 1982.

Sanvido, V., Parfitt, K., Guvenis, M., and Coyle, M. (1992). “Critical Success Factors for Construction Projects,” *Journal of Construction Engineering and Management*, ASCE, **118**(1), March, pp. 94-111.

Schneck, D., Laver, R., and O'Connor, M. (2009). “Cost Contingencies, Development Basis and Project Application,” TRB 2009 Annual Meeting CD-ROM, #09-0316, Washington, D.C.

Sillars, D.N (2009). “Development of Decision Model for Selection of Appropriate Timely Delivery Techniques for Highway Projects,” Transportation Research Record 2098, pp. 18-28.

Silva L.P., Hewage K.N., Ruwanpura J.Y., and Wirasinghe, U.G.D. (2008). Total information system integration in construction projects. *In* Proceedings of the 1st International Construction Specialtly Conference. Canadian Society for Civil Engineering, Quebec City, Quebec, pp. 10–13.

Tai S., Wang Y., and C.J. Anumba (2009) “A survey on communications in large-scale construction projects in China”, Engineering, Journal of Construction and Architectural Management **16**(2). pp. 136-149.

Tatum, C. (1984). “Organizing Large Projects: How Managers Decide,” *Journal of Construction Engineering and Management*, ASCE, **110**(3), pp. 346–358.

T. Cornick, Quality Management for Building Design, Butterworth Architecture Management Guides, London, 1996.

Thomas, S. (1996), “An assessment tool for improving project team communications”, PhD dissertation, The University of Texas at Austin.

Thomas, H., Hester, W., Hunter, J., and Logan. P. (1985). “Comparative Analysis of Time and Schedule Performance on Highway Construction Projects Involving Contract Claims,” FHWA, Washington, D.C.

Touran, A. (2006). “Owners Risk Reduction Techniques Using a CM,” report submitted to *Construction Management Association of America*, August.

Touran, A., Bolster, P., and Thayer, S. (1994). “Risk Assessment in Fixed Guideway Construction,” Report FTA-MA-26-0022, Federal Transit Administration, Washington, D.C. Winter, M. and Smith, C. (2006). “Rethinking Project Management,” EPSRC Network 2004-2006, Final Report, EPSRC, Manchester, UK.

Welkowitz, J., Cohen, B.H, Ewen, R.B., 2006. Introductory statistics for the behavioral sciences, 6th ed. John Wiley and Sons, Hoboken, N.J.

Appendices

Appendix A – Recruitment Letter

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

The University of British Columbia
Faculty of Applied Science
School of Engineering
Okanagan Campus
3333 University Way
Kelowna, BC Canada V1V 1V7

Phone 250 807 8723
Fax 250 807 9850
www.ubc.ca/okanagan/engineering

RECRUITMENT LETTER

The Port Mann Highway 1 Project – A case study on linking organizational charts and schedule conflicts

Dear Sir / Madam:

The University of British Columbia – Okanagan (UBCO) is conducting an educational research project on improving and indicating where schedule conflicts take place and how the OH can have an effect in resolving the conflicts in Construction & Project management today.

The long-term goal of the proposed research program is to develop an understanding on where most conflicts occur, which variables in similar projects, and what process in eliminating them is best suited. This would facilitate the construction managers and clients to incorporate environmental and economical factors in to the project planning and scheduling to prevent foreseeable delays.

The initial research focus on schedule conflicts is in a global and local context, followed up with development of the framework for organizational charts effects on schedule. To achieve the research objective, the students will perform observations in active construction projects, and perform an extensive literature review to develop the framework.

The purpose of the interview is to assess the current practice of evading schedule conflicts and get a better idea on solutions proposed for each case. Interviews will take about 30 to 45 min to complete.

Research student Mohammad Amin Shamloo (Co-investigator) from UBCO will visit and stay in your construction site/design office and learn the scheduling processes. The maximum duration of stay shall be for 6 hours during working hours. Nothing will be video-recorded (digitally or audio-recorded). The data gathered by the researcher during the interviews, and observations will remain with UBCO and will not be disclosed to your employer or other third party without your permission.

We appreciate your cooperation and experienced knowledge to learn current practices in construction management and scheduling. Please help us to successfully conduct the project. If you would like to participate in this study, please contact Mohammad Amin Shamloo, co-investigator at 778.386.9119 or through email at ashamloo@alumni.ubc.ca to set up a date and time to meet and find out more about participating in this study. If you have any further questions, please contact Dr. Kasun Hewage (Principal Investigator) in the School of Engineering, University of British Columbia - Okanagan.

Thank you.

Sincerely,

Kasun Hewage, Ph.D., P.Eng.
Assistant Professor
Project & Construction Management
Kasun.hewage@ubc.ca
Phone: 250.807.8176

Co-investigator:
Mohammad Amin Shamloo
MASc Student
Project and Construction Management
UBCO
Ph: 778.386.9119
Email: ashamloo@interchange.ubc.ca

Appendix B – First Interview Consent Form

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

The University of British Columbia
Faculty of Applied Science
School of Engineering
Okanagan Campus
3333 University Way
Kelowna, BC Canada V1V 1V7

Phone 250 807 8723
Fax 250 807 9850
www.ubc.ca/okanagan/engineering

Consent Form

The Port Mann Highway 1 Project – A case study on linking organizational charts and schedule conflicts

Principal Investigator:

Name: Dr. Kasun Hewage, P.Eng.

Position: Assistant Professor, School of Engineering

Phone: 250-807-8176

Fax: 250-807-9850

Email: Kasun.Hewage@ubc.ca

Co-Investigator(s):

Names: Mohammad Amin Shamloo

Phone: 778-386-9119

E-mail: ashamloo@interchange.ubc.ca

Statistical data gathered in this research will be used for the research thesis of MASc degree of the co-investigator. The thesis is considered a public document. Total confidentiality and privacy of research participants will be protected in any publications and presentations. We have taken permission from the competent authority (project manager) of your company to conduct this research study.

Purpose:

The long-term goal of the proposed research program is to develop a methodology to optimize schedule conflicts for construction in Canada. This would facilitate the construction managers and clients to incorporate social and economical aspects in to the project schedule beyond the financial considerations. The initial research will review schedule conflicts in construction in global and local context for its developments and current trends. To achieve the research objective, the student will perform observations in active construction projects, and compile an extensive literature review to develop the framework. A comparison will then be made with what has been done in the past, what we are doing today and what should we do for future projects. You are being invited to take part in this research study to share your professional experiences in current status of construction management and scheduling techniques in the Port Mann Highway extension project. The research participants are construction managers and clients.

Study Procedures:

The data will be collected through an interviews process. You will be given the opportunity to participate in the interview process. It will be up to you to decide whether to participate in the interviews of this study.

Interviews: An interview will be held of about 30-45 minutes in the event of further information required and we may contact the same professional twice for clarification purposes. Interview questions will be based on your field of experience, its level and familiarity with information and communication technologies.

Potential Risks:

There are no known risks for the participants by providing their opinions in this research project.

Potential Benefits:

Benefits of this research to the construction industry as whole are:

1. Construction companies can incorporate aspects of schedule conflicts and the process to avoid them, which would be a value addition to the project.

2. Applications of dealing with schedule conflicts for mega projects would significantly reduce current drawbacks in CS which will enhance project outcome.

Confidentiality:

All documents will be identified only by code number and kept in a locked filing cabinet with the principal investigator. Subjects will not be identified by name in any reports of the completed study. All computer files will be password protected and data will be stored and maintained in a UBC facility by the principal investigator for at least 5 years then will be deleted from the database.

Contact for information about the study:

If you have any questions or desire further information with respect to this study, you may contact Dr. Kasun Hewage or one of his associates at 1-250-807-8176.

Contact for concerns about the rights of research subjects:

If you have any concerns about your rights as a research participant and/or your experiences while participating in this study you may contact the Research Subject Information Line in the UBC Office of Research Services at 1-604-822-8598 or the UBC Okanagan Research Services Office at 250-807-8832. If these numbers are long-distance, email RSIL@ors.ubc.ca or call toll-free 1-877-822-8598.

Copy of the finding of this research:

If you like to receive a copy of the finding/results of the research please provide your email address below.

_____

Consent:

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason and without any negative consequences on your employment. The information provided by you in the interviews will not be shared with any competent authority.

Your signature below indicates you consent to participate in this study and that you have received a copy of this consent form for your own records.

_____

Participant's Signature Date

_____

Printed Name of the Participant

Appendix C – First Interview Questions

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

The Port Mann Highway Project – A case study on linking organizational charts and schedule conflicts

Interview Script, 2013

Thank you for agreeing to participate in this interview. The purpose of the interview is to assess the current status of environmental and social factors in construction procurement. The survey should take approximately 30 minutes to complete. All information received will be treated in strictest confidence and in accordance with the UBCO code of conduct.

The intent of the interviews will be to get an idea of how decisions are made at each level and how the chain of command works. This will help identify how quickly issues are identified and based on what scenarios will the OH and Schedule change.

After all the interviews are completed a matrix will be made to identify all levels of decision-making, and based on what are these decisions made and what would the final outcome of each decision be.

General Questions:

1- What is the main challenge when working on a project in this capacity and size?

2- What would you consider in changing if you had the chance to do so in the past that would significantly help this project?

3- How are the municipalities and ministry of transportation helping with the project? (Closures, permits, etc.)

4- How are the Utility owners helping out? (Utility crossing agreements, permits, relocates, etc.)

5- How does working as a partnership affect the schedule?

6- How does working with different sub-contractors affect quality and schedule?

7- Does the hiring process affect the schedule? If so how is this prevented?

Specific Questions:

Level One (5 years plus Experience):

1- How are changes on the ORG Chart & Schedule calculated to see what effects it will have on:

   a. Cost & Budget?

   b. Production rate?

   c. Commitments made?

2- At what levels are decisions made and how are they approved? How are they communicated? What is the process?

   a. Departments VS. Departments?

   b. Area managers V.S department heads?

3- What are the variables that can have effects on milestones? How are these variables defined? What weights (priorities) are given to each variable?

4- What other info can make an effect on your decision?

   a. Maintenance
   b. Weather
   c. Resources
   d. Suppliers
   e. Time
   f. Responsibility
   g. Fish Window

Level Two (10 years plus Experience)

1- At what levels are decisions made and how are they approved?

   a. Departments VS. Departments?

   b. Area managers V.S department heads?

   c. Construction management VS. Area managers?

2- What are the variables that can have effects on milestones? How are these variables defined? What weights (priorities) are given to each variable?

3- What other info can make an effect on your decision?

   h. Maintenance
   i. Weather
   j. Resources
   k. Suppliers
   l. Time
   m. Responsibility

n. Fish Window

4- Based on what factors are decisions made to make certain changes on Org Charts & Schedules to have the required effect to meet requirements?

5- What are key characters that are looked into prior to making changes to the ORG Chart?

6- How does changing the ORG chart help meet milestones (Schedule)?

7- In what way can the changes in the ORG chart prevent schedule delays?

8- What was the process of setting landmark milestones in the PMH1 project? (Client obligations, Fish Window work, Materials, etc.)

9- What type of events can have effects on set milestones? (production delays, Supplier commitments, Subs, etc)

10- What types of actions are taken to prevent milestone changes? (Org Chart, Resources, Craft, etc.)

Level Three (Project Management)

1- At what level of seniority can changes (decisions) be reflected on ORG Charts?

a. Years of experience?

b. Types of projects worked on?

2- How does responsibility and experience collide?

3- At what levels are decisions made and how are they approved?

   a. Departments VS. Departments?

   b. Area managers V.S department heads?

   c. Construction management VS. Area managers?

   d. Project managers Segment VS. Segment?

   e. Project wide effect?

4- What are the variables that can have effects on milestones? How are these variables defined? What weights (priorities) are given to each variable?

5- How fast can changes be made on the ORG Chart and implemented throughout the project?

6- What kind of Changes in the ORG chart seems to have more effect? (Top level, medium level, or bottom level?)

7- Based on what factors are decisions made to make certain changes on Org Charts & Schedules to have the required effect to meet requirements?

8- What are key characters that are looked into prior to making changes to the ORG Chart?

9- How does changing the ORG chart help meet milestones (Schedule)?

10- In what way can the changes in the ORG chart prevent schedule delays?

11- What was the process of setting landmark milestones in the PMH1 project? (Client obligations, Fish Window work, Materials, etc.)

12- What type of events can have effects on set milestones? (production delays, Supplier commitments, Subs, etc)

13- What types of actions are taken to prevent milestone changes? (Org Chart, Resources, Craft, etc.)

Appendix D – Second Interview Consent Form

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

The University of British Columbia
Faculty of Applied Science
School of Engineering
Okanagan Campus
3333 University Way
Kelowna, BC Canada
V1V 1V7
Phone 250 807 8723
Fax 250 807 9850
www.ubc.ca/okanagan/engineering

Consent Form

The Port Mann Highway 1 Project – A case study on linking organizational charts and schedule conflicts

Principal Investigator:
Name: Dr. Kasun Hewage, P.Eng.
Position: Assistant Professor, School of Engineering
Phone: 250-807-8176
Fax: 250-807-9850
Email: Kasun.Hewage@ubc.ca

Co-Investigator(s):
Names: Mohammad Amin Shamloo
Phone: 778-386-9119
E-mail: ashamloo@interchange.ubc.ca

Statistical data gathered in this research will be used for the research thesis of MASc degree of the co-investigator. The thesis is considered a public document. Total confidentiality and privacy of research participants will be protected in any publications and presentations. We have taken permission from the competent authority (project manager) of your company to conduct this research study.

Purpose:

The long-term goal of the proposed research program is to develop a methodology to optimize schedule conflicts for construction in Canada. This would facilitate the construction managers and clients to incorporate social and economical aspects in to the project schedule beyond the financial considerations. The initial research will review schedule conflicts in construction in global and local context for its developments and current trends. To achieve the research objective, the student will perform observations in active construction projects, and compile an extensive literature review to develop the framework. A comparison will then be made with what has been done in the past, what we are doing today and what should we do for future projects. You are being invited to take part in this research study to share your professional experiences in current status of construction management and scheduling techniques in the Port Mann Highway extension project. The research participants are construction managers and clients. The interview will focus on results that have been gathered through interviews with the segment 1 of the Port Mann Highway extension project. These results will be shared with you. A recommendation has been made to see if the solution proposed will help similar projects. The questions asked in this interview will be to see if senior management form similar projects validate the proposed solution.

Study Procedures:

The data will be collected through an interviews process. You will be given the opportunity to participate in the interview process. It will be up to you to decide whether to participate in the interviews of this study.

Interviews: An interview will be held of about 30-45 minutes in the event of further information required and we may contact the same professional twice for clarification purposes. Interview questions will be based on your field of experience, its level and familiarity with information and communication technologies.

Potential Risks:

There are no known risks for the participants by providing their opinions in this research project.

Potential Benefits:

Benefits of this research to the construction industry as whole are:

1. Construction companies can incorporate aspects of schedule conflicts and the process to avoid them, which would be a value addition to the project.

2. Applications of dealing with schedule conflicts for mega projects would significantly reduce current drawbacks in CS which will enhance project outcome.

Confidentiality:

All documents will be identified only by code number and kept in a locked filing cabinet with the principal investigator. Subjects will not be identified by name in any reports of the completed study. All computer files will be password protected and data will be stored and maintained in a UBC facility by the principal investigator for at least 5 years then will be deleted from the database.

Contact for information about the study:

If you have any questions or desire further information with respect to this study, you may contact Dr. Kasun Hewage or one of his associates at 1-250-807-8176.

Contact for concerns about the rights of research subjects:

If you have any concerns about your rights as a research participant and/or your experiences while participating in this study you may contact the Research Subject Information Line in the UBC Office of Research Services at 1-604-822-8598 or the UBC Okanagan Research Services Office at 250-807-8832. If these numbers are long-distance, email RSIL@ors.ubc.ca or call toll-free 1-877-822-8598.

Copy of the finding of this research:

If you like to receive a copy of the finding/results of the research please provide your email address below.

_____

Consent:

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason and without any negative consequences on your employment. The information provided by you in the interviews will not be shared with any competent authority.

Your signature below indicates you consent to participate in this study and that you have received a copy of this consent form for your own records.

_____

Participant's Signature Date

_____

Printed Name of the Participant

Appendix E – Second Interview Questions

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Influence of Hierarchy and other Variables on Schedule Delays in Mega Highway Projects in Urban Areas

Interview Script

Thank you for agreeing to participate in this interview. The purpose of the interview is to assess the current status of CS delays. The survey should take approximately 30 minutes to complete. All information received will be treated in strictest confidence and in accordance with the UBCO code of conduct.

The intent of the interviews will be to get an idea of how we can reduce schedule delays. This will help identify solutions that can be used by other construction and project management teams.

After all the interviews are completed a matrix will be made to identify all possible solutions.

Background

Currently the research done on the Port Mann Highway Extension Project specifically on the first segment has presented some key issues that can cause delay on the CS. The two main elements identified by professionals working on this project have been Communication and LF experience. The focus on the proposed solution provided below is to help the flow of information from the field to the office and from the office to the field. The proposed solution is to help with communication only. Later on research will help identify solutions for LF experience.

Proposed solution

The procedure in estimating for a job is mostly based on previous jobs completed by any given contractor. These estimates are derived from data such as: MHRS spent, equipment, permanent materials, permits, training, learning curves, and resources available. From these inputs the preliminary schedule can be made and roughly the time line for the project can be set.

During the job, engineers continuously change data as the job goes forward to identify schedule delays and issues. Schedule is forecasted and is compared to the original CS which identifies areas that need more focus and concentration.

Using software that can utilize, process and analyze inputs such as: MHRS spent on each scheduled task, supplier delivery times, costs, resources available at the start and finish of each task, tracking completed works and work in process, the comparison of actual work completed to scheduled work, time of obtaining permits, and quality can be very helpful. This software then can process them in a way that schedule and cost can be forecasted. The figure 1 below represents what can be inputted in to the software daily and processed. It also presents what kind of data can be outputted.

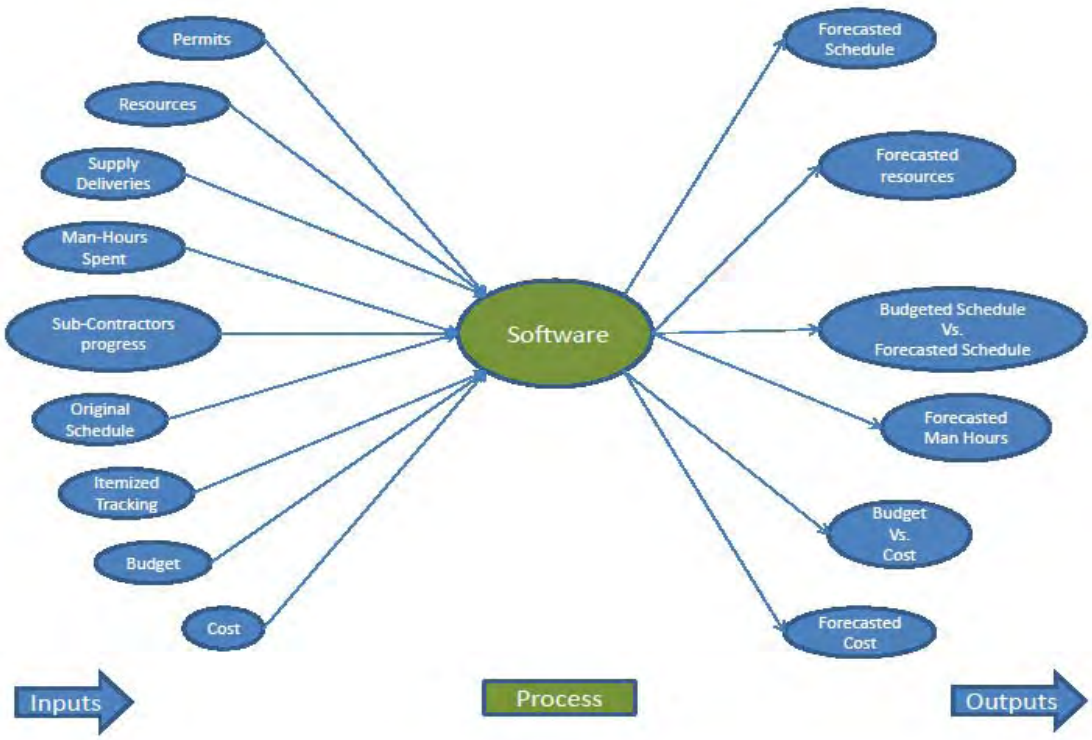

Figure 1: Inputs and outputs

Questions:

1- What are your thoughts on having the construction schedule updated daily?

   a. Would it have any impact on the production schedule?

   b. Would it have any affect in helping to identify schedule delay and conflicts?

2- What are your thoughts on having superintendents using tablets to update the completed works in the field?

3- Is it beneficial to see the difference between the original schedule and the forecasted schedule daily?

4- Would it be helpful to see the difference in costs when over resourcing tasks in the schedule to gain lost time?

5- How much importance will allowing changes to the schedule have by adding approval times for permits based on job to date?

6- Does inputting supplier delivery times in to the schedule affect forecasting the schedule? If so how important is it?

7- In terms of communication the main aspect brought up in the Port Mann project was the communication between departments and production conflicts which have significant effects on the construction schedule. Do you think the proposed solution would help resolve many of these problems?

8- What solutions can you propose to help with communication in mega infrastructure projects?