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Project Change Management for Oil and Gas Projects in Alberta: Towards a Predictive Approach

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Project Change Management for Oil and Gas Projects in Alberta: Towards A Predictive Approach

By

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Abstract

Change is a common occurrence in construction projects. Irrespective of the magnitude or complexity of a project, changes normally occur due to different reasons. From contract award, through construction and commissioning phases of the project, there is constant occurrence of changes.

This research investigated the causes and sources of changes in oil and gas projects in Alberta. The objective is to determine the impact of change in an oil and gas projects and to propose a system for forecasting or estimating changes in a project. The focus of this project is the changes that occur in the execution phase of projects. In the oil and gas industry, different organizations have different names for the project delivery system known as gate process which is divided into phases. This research divided a project into phases also but the definition of phase differ slightly from the gate adaptation.

This research draws attention to the need to change allowance or scope allowance as some refers to it. Having established that change occur in every project, no provision is made in the project budget to accommodate these changes. Contingency reserve should not be confused with "change reserve". Contingency is the risk associated with the project within the control of the project team whereas change allowance is outside the control of the project team but with the owner such as scope change.

Data were collected from Inventory of Major Alberta Project (IMAP) and from questionnaires. Interview of questionnaire respondents was used to match the IMAP data to questionnaire responses. The data were analyzed using different statistical tools, SPSS and Microsoft Excel.

For detailed analysis, the projects were divided into cost and duration categories. Cost category consist of Large, Medium and Small cost projects while duration category includes Long, Medium and Short duration projects. Furthermore the projects were divided into four different phases namely: Bid, Preconstruction, Construction and Commissioning. The data analysis also included engineering percent complete for each of the categories and phases. This approach provided opportunity for detailed analysis of the data. The results of the analysis were used to plot model graphs that can be used to forecast changes in cost and duration for different phases of a project. Furthermore, an Excel tool was developed that could be used to forecast cost and duration changes in a project when the initial cost, initial duration and engineering percent complete are known.

The outcome of this research will be beneficial to all participants in oil and gas project (project owners, contractors and economy). By adopting the tool a lot of guess work will be removed on how to determine the amount of change that could be expected from any project. By so doing, incidences of dispute, claims and litigations will be substantially reduced. The research made some recommendations on how to improve change management in oil and gas projects in Alberta. The conclusion from the research is that change will occur in every project. Establishing a change management mechanism and planning for change starting from the planning stage of the project will assist in mitigating the adverse effect of change in a project. Organizations involved in projects should establish a fully staffed change management unit and procedure. This is currently lacking in most organizations according to survey responses. Change management should be represented at senior management level of organizations as a discipline of its own and should not hidden as a sub function under another disciplines.

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Dedication

This work is dedicated my dear wife Sandra Robert-Ezenta who has stood by me throughout all the challenges associated with this research. The dedication also goes to my children Kingsley and Anne for their support and encouragement. Lastly to my late father Robert Onwukwe Ezenta who taught me the values of education.

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Chapter 1 – Introduction

1.1 Introduction

Project change is a common occurrence in construction projects. No project has ever been executed exactly as planned and designed without the occurrence of one type of change or the other. According to Hao et al. (2008), project changes and/or adjustments are inevitable as they are a fact-of-life at all stages of design and construction. Oracle White Paper (2009) observes that, "Construction contracts differ from most legal agreements in that they expect and plan for changes". No matter the magnitude or complexity of a project, changes normally occur. From the moment a bid requested is issued to potential bidders, to contract award, through construction and commissioning, changes usually occur in any given project. In one of the projects the researcher participated in, the number of changes in the change management log was over 2,700. A lot of factors and causes are responsible for the occurrence of changes in a project. Major capital projects involve many decisions that have to be made based on incomplete information, assumptions and the personal experience of project professionals, (Coreworx, 2010). According to Cariappa (2000), construction contractors are required to build products efficiently and cost effectively, to satisfy customer requirements. Yet, these requirements generally change during the duration of the project due to advances in technology, change in focus, refinement of design, better understanding of what is needed, and economic factors. This makes it inevitable that some significant changes will be made before any construction project is completed. These changes impact the project through changes in initial cost and duration of the project. Project changes constitute extra work requiring additional cost and duration to execute. If not properly handled, project change may result in increased project cost and duration; disagreement, disputes, claims and even legal actions; none of these are advantageous to the contract parties or the economy as a whole.

If not resolved in a timely and amicable manner, disputes can be very expensive, sometimes and may costs fortunes and by so doing, erase any financial success the project may have achieved. The Construction Industry Institute (CII) (2012) stated that two things can be said about almost any engineering and construction project: (1) there will be changes made during the course of construction, and (2) the owner and the constructor will seldom initially agree on the total effect those changes have on the cost and schedule of the project. According to Coreworx (2010), making decisions with incomplete information often lead to changes which can interrupt the flow of work. Consequently, create delays, cause schedule slippage and inflate costs. CII identifies change management as having the highest cost impact to owners and contractors of all construction capital project practices (CII, 2003). Senaratne and Sexton (2004) noted that changes in construction projects are common and can lead to disruptive effects such as project delays, cost overruns and quality deviations. According to them, rework due to unplanned changes can cost 10-15% of contract value. Contributing, Hao et al (2008) noted that "Changes in construction projects are very common and likely to occur from different sources, by various causes at any stage of a project, and may have considerable negative impacts on items such as costs and schedule delays. A critical change may cause consecutive delays in project schedule, re-estimation of work statement, and extra demands of equipment, materials, labor, and overtime". Jergeas (2009) attributes cost overrun in the Alberta oil sand projects to poor management practices that lead to poor performance such as scope changes, design errors and omissions, lack of proper planning and scheduling, improper management of tools, equipment, material and labour among many other factors. McKenna & Wilczynski (2006), of Booz Allen Hamilton surveyed leaders from 20 companies from the United States, Europe and Asia with combined capital spending of more than $100 billion. In the survey, 80% of respondents said that they expect their companies to increase capital expenditures during the next five years. Despite this growth, more than half of the executives said that they are dissatisfied with their companies' over-all project performance, citing the costly budget and schedule overruns that plague 40 per cent of their projects.

Westney (2012), gave specific examples of cost overruns in some projects in the following statements:

> *A huge and complex oil and gas production project at Sakhalin Island (off the east coast of Siberia), the project was sanctioned in 2003 at $10 billion (a value that exceeded Shell's net income for the prior year).Two years later, with the project well into construction, Shell issued a 6K report announcing the cost had doubled to $20 billion (today it is over $22 billion). One does not have to look far for other examples. Many projects in the Canadian oil sands have experienced 50% to 100% cost overruns, as have numerous offshore developments, refineries, and pipelines.*

An extract from Halari (2010) shows in Table 1.1 a compilation on cost and schedule variation of major projects in Alberta oil and gas compiled by Condon (2006) as quoted by Halari (2010).

Table 1.1 Cost Overruns on Alberta Oil & Gas Projects (Source: Halari, 2010)

Projects	Company	Original Estate CAD$ billion	Final Cost CAD$ billion	% Cost Overrun	Original Finish Date	Actual Finish Date
Mildred Lake	Syncrude	1	2	100%	1977	1978
Millennium	Suncor	1.9	3.4	94%	2000	2001
AOSD – Phase 1	Shell	3.5	5.7	63%	2002	2003
UE-1	Syncrude	3.5	7.5	114%	2004	2006

Due to the reluctance of oil and gas companies to publish the final project cost of their projects, information on cost overrun of recent projects are not easily and publicly available.

Figure 1.1 shows an aerial view of a typical oil and gas project in Alberta. The complexity of the project is typical in the industry.

Figure 1.1 Oil and Gas Construction Project in Alberta, Canada
Source: http://www.albertaenergychallenge.com/#!__main/page-2

Rashid et al., ((2012) observed that the words “Change Order” conjure strong feelings of negativity for all involved in construction projects; owners do not like them because they generally feel they are paying for others’ mistakes; contractors believe that change disrupts workflow and require additional paperwork and time; engineers, contractors, and owners agree that projects would be better without change orders. All these notwithstanding, project change is inevitable in any project. The success of a project may be determined by the ability of all parties to the project to manage project change efficiently from inception to project completion.

1.2 Definition

A project change or deviation (as it is known in other parts of the world) is the difference between the contract value and requirements as set forth in the original agreement between the parties (often established at the time of bid) and the requirements imposed on the project subsequent to this agreement (usually recognized during the actual construction of the project). In construction projects, a project change refers to an alteration or a modification of pre-existing conditions, assumptions and basic information or requirements (project or client), Ming et al. (2004). Baca (2005) defines project change management as the proactive identification and management of modifications to a project. According to West Virginia Office of Technology (n.d.) “A change management process is a method by which changes to the project (e.g. to the scope, deliverables, timescales or resources) are formally defined, evaluated and approved prior to implementation”. Furthermore the report maintains that a change management process is used to ensure that every change identified is formally:

- Communicated
- Documented

- Reviewed
- Approved
- Implemented.

Ibbs et al. (2001) stated that any additions, deletions, or other revision to project goals and scope are considered to be changes, whether they increase or decrease the project cost or schedule. It is worth mentioning that changes to a project can be an increase or decrease to the overall project cost and duration. Park and Peña-Mora (2003) noted that construction changes refer to work state, processes, or methods that deviate from the original construction plan or specification. CII (2012), defines project change as any modification to the contractual guidance provided to the constructor by the owner, owner's agent, or design engineer. Thus, it encompasses changes in specifications, drawings, and other written or oral guidance. Rashid et al. (2012) noted that change is an event that results in any modification of the original scope.

Project change is any deviation from the original scope and concept of a project that was agreed to by all parties at the time of contract execution. Some changes may not have quantitative value but impact the ability to execute the project as was originally intended. For instance in a project, the original contract stated that the owner is responsible for providing transportation for all workers to the site. A change was proposed by the owner to shift the responsibility to the contractor. Contractor rejected the change, arguing that they do not have the logistical capacity to plan and manage staff and craft travel through air and land from different locations in North America. This led to a disagreement between the parties resulting in delays of workers to travel to site. This was eventually resolved as the owner took back that responsibility however, the project was delayed for more than three weeks as a result of the disruption caused by the proposed change. Project change management therefore is any deviation or variation between the original project cost and duration and cost or duration at any point in the project lifecycle. This project change occurs at all phases of the project. However, it may be more evident in one phase than the other. It is a common mistake to assume that project change will only be noticed at the end of the project.

1.3 Project Change Management vs. Traditional Change Management

Project change management is different from traditional change management. Traditional change management is concerned with process change or process reengineering meant to create efficiency in an organization's service or product delivery. Price and Chahal (2006) noted that the need to change is usually driven by external factors such as new legislation or increased competition, or internal factors such as the implementation of new technologies. According to Creasey (2007), change management is the process, tools and techniques to manage the people-side of change to achieve the required business outcome. Change management incorporates the organizational tools that can be utilized to help individuals make successful personal transitions resulting in the adoption and realization of change. Bocklund and Fraser (2009) state that change management is a structured process that rallies support for change at all levels of the organization while building the knowledge, skills and incentives to sustain it. It is the people side of change. This research is not on traditional change management rather on project change management which is the management of the variation between the original project scope, budget and schedule that was established at the time of contract award and the current scope of the project at any time in the project lifecycle. Project change management deals with the identification and processing of changes between the contract scope and final scope of any project. It is this definition of change management that is the focus of this study. For the remainder of this research, the term change management and project change management will be used interchangeably and will refer to variation in a project between the original scope and the current scope of the project. For the remaining part of this thesis, change management when used will be in the context of project change management and should not be interpreted to mean traditional change management.

1.4 **Problem Statement**

In the oil sands projects like every other construction project, owners and contractors know that change will occur in the project before completion, however, none of the parties have any idea of the magnitude and value of the change at the time of bid. According to Boukendour (2005) huge cost overruns are experienced by the mega projects such as:

i) Canadian Firearms Program

- Planned cost: $119 m Final cost: $1bn

ii) International Space Station

- Planned cost: $8bn Final cost: $26bn

iii) Channel Tunnel

- Planned cost: £4.9bn Final cost: £10bn

iv) Concorde

- Planned cost: £90m Final cost:1.1bn

Hardly in any project and the cost overrun in budgets even though project owners know that will it occur. The current practice is to assume that contingency will take care of any increase in cost. Contingency reserve is meant to cover items in the general scope of work whose extent is not fully known at the time of contract award. Usually contingency reserve runs from about 5% to 25% of the initial project cost. This reserve is not meant to take care of changes in the project that are outside the original scope of the project. When asked if the percentage they provided is the contingencies, they answered in the affirmative. This is common mistake in project delivery where contingency reserve is erroneously assumed to take care of any changes a project may experience. This misapplication of the contingency reserve and the need for change reserve is one of the reasons for this research. Currently, there is no defined tool for estimating or forecasting the magnitude of changes and its impact on cost and duration in oil and gas projects in Alberta. Four project managers were independently asked how they determine value of change in cost and duration in their projects. All the four gave different percentages they use for change.

In most Alberta oil sands projects engineering design is usually hardly completed before the bid process is initiated. This subjects the projects to a lot of unknowns, wild estimates which results in changes as the project is progresses. The result of this is that significant changes occur prior to the project completion and these changes cause most projects to overrun budget and schedule. If not properly managed, the relationship between owner and contractor may sour leading to disagreement, claims, dispute and may be legal action.

This research seeks to identify the major causes of changes in oil and gas projects in Alberta. Also intended to be accomplished is the determination of the sources of the change and the stage in the project when they occur. Finally the project will advocate for the establishment of change reserve for every project similar to contingency reserve since change will certainly occur in the project.

While changes add to project cost and schedule, failure to agree on the impacts and compensation for the changes can lead to dispute some of which may last for years long after the project is completed with resultant financial and reputational consequences. Change is often mentioned as the one of the major factors responsible for the project cost and schedule overrun. The construction industry believes this statement to be true (Senaratne and Sexton 2004; CII 2003; Jergeas 2009; Rashid et al. 2012). However, there has not been enough attempt to quantitatively determine the magnitude and impact of the change. The purpose of this research is therefore:

1) To identify the major causes of changes in oil and gas projects in Alberta.
2) Determine the factor most responsible for changes in the cost and schedule.
3) Identify the phases of the project where changes occur.
4) Determine if changes in a project is responsible for project cost and schedule overrun.
5) Develop a tool that can be used to forecast changes in different phases of a project.

1.5 Research Questions

This project will attempt to answer the following questions:

1) Does change occur in all projects?
2) Is change in project responsible for changes in project cost and duration? Alberta oil and gas project have been known to experience significant cost and schedule overrun. How much of these overrun are caused by changes in the project?

3) Does change in project cost and duration lead to cost and schedule overrun? How significant is the impact caused by change to cost and schedule? If it is established that change is responsible for cost and schedule overrun, how significant is the value of these overruns that are attributable to changes in the project cost and schedule?

4) Which factors are most responsible for changes in project cost and duration?

5) Which construction phase produces the largest change in cost and duration?

6) Can potential changes in a project be forecasted? If so how?

1.6 Research Goal

The goal of this research is to investigate causes of changes in a project and to determine a methodology for forecasting changes in project cost and duration in oil and gas projects in Alberta. The following factors have been identified as the major causes of cost and schedule overrun in projects. The impact of the following eleven factors will be investigated as part of this research.

1) Design Change
2) Site Condition
3) Scope Change
4) Regulations
5) Change in Technology
6) Market Condition
7) Management Decisions
8) Environmental Conditions
9) Materials and Equipment

10) Fast Tracking

11) Others

If it is determined that these change factors have significant impact, the research will develop a model that will assist in predicting the impacts of the factors on cost and schedule. Given that the cost of extracting Alberta oil is higher than the cost of extracting oil in other parts of the world (see section 2.5), any contribution on how to reduce production cost of Alberta oil will be a welcome development to make Alberta oil more competitive. This will have a direct impact on Albert and by extension, Canadian economy.

The objective is to provide a tool which project owners and contractors can use to forecast potential changes in cost and duration in a project. If there is a uniform tool that is mutually agreed to by all parties to forecast changes in project cost and duration, project change will be better managed, leading to efficient project delivery in the oil and gas industry in Alberta.

1.7 Limitations and Scope of the Research

The scope of this research is the causes of change in oil and gas projects in Alberta executed between year 2004 and 2012 which result from changes in a project. The study will not include causes of project change such as inflation which are not directly related to changes in the project. While these other causes may be equally important in a project, they are not considered because they do not result directly from changes in a project. Rather, the focus of the research will be limited to changes in project cost and schedule as well as the contribution of Engineering Percent

Complete[1] to the changes. Also only project with estimated initial cost from $5million and above and estimated initial duration of 6 months and above will be used for the analysis. It is intended that a model will be developed that will assist project owners and contractors to quantitatively estimate or forecast increase or decrease in project cost and schedule.

1.8 Summary

This chapter introduced the research, the definitions of change management, problem statement, research question, research goal including scope of the research and limitations. It laid out the purpose of the research and what the research aims to accomplish. The next chapter which is chapter 2 will review relevant literatures in change management and other related body of works.

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[1] The percentage of engineering design that was completed prior to bid request from contractors by project owner.

Chapter 2 – Literature Review

2.1 Introduction

Despite the awareness of project change management in project management practices, there is still a limited body of literature available on the subject. According to Stare (2010) an examination of the literature shows that the area of change management is poorly addressed. Continuing he said that “on average, this subject is covered by just a few pages in books, not even a whole chapter, and we could not find any books dedicated solely to the management of project changes”. Most of the available literature on project change management focused on infrastructure and building projects. It was challenging to find sufficient body of work on project change management dedicated to oil and gas projects in Alberta. Even in body of works that discussed change management in Alberta oil and gas sector, none of the works focused on the estimating cost and duration change in oil and gas projects in Alberta. It is this apparent void that this research seeks to fill. Oil and gas projects in Alberta are unique in terms of project execution strategy, size, environment, contract type, labour market, complexity and location. Chanmeka et al., (2012) noted that these projects are widely recognized as among the most challenging types of construction projects to delivery. This uniqueness, therefore, deserves a specialized approach for successful delivery of the project.

The review of some oil and gas project contracts shows that very few contract clauses are dedicated to change management. Given the importance of change management in the construction industry, one would have thought that there will be abundance of literature and books on the subject. According to CII (1995) although change management is a key factor in project success and although change is a root cause of much of the litigation plaguing the industry, little quantitative research has been done on the impacts of change on projects. According to them, most of what is understood about the impact of change in the industry today is based on anecdotal information and personal experience. Their research tested two hypotheses on the relationship between frequency of change and productivity and efficiency of timing of change. They concluded that projects cannot endure numerous changes that amount to a significant proportion of the original scope without suffering a significant decline in overall cost performance. They also concluded that projects have a significantly reduced ability to recover schedule losses or budget pressures as they approach completion. Change is very likely to occur in any construction project, therefore, planning and managing the change is of utmost important if the project is to be completed on time and budget. Most importantly, costly claims could be avoided if change process is put in place and planned throughout the project lifecycle.

2.2 Management of Change

2.3.1 Project Cost Overruns Values from Existing Body of Work

A review of most literature and others body of works show varying degrees of cost overruns in projects.

Diekmann and Nelson (1985) reviewed 22 federally funded and administered projects between 1979 – 1983 and concluded that the projects incurred 13% cost and 25% schedule overrun, caused by design errors, government initiated changes and differing site conditions, weather etc. Semple et al (1994) reviewed 24 projects in western Canada and concluded that more than one half experienced at least 30% increase in original project cost while more than one third experienced more than 60% increase in original project cost. According to Love and Li (2000) the major cost due to change is by the cost of rework and this can amount to 10 – 15% of contract value.

Semple (1996) analyzed construction change order impact. Her research sought to determine if the traditional 10% overhead and 10% profit markups are still acceptable to both the owners and contractors. Furthermore, the study attempted to determine the current value of markup in change orders. The study developed a method for determining change order markups. From the survey, the study determined that there is no significant agreement on a fair and reasonable value of markups for change order value. However, there is agreement that a 7 – 8 % markup is fair. These values does not align with the differences between original project cost and duration and final project cost and duration of oil and gas projects in Alberta reviewed in this research.

Vandenberg (1996) studied the impact of change orders in labour efficiency in construction. Using 43 projects, 27 of which were impacted by change, he developed a linear regression model to predict the impact on labour productivity. He calculated change by breaking the project schedule down into six periods (i.e., changes before construction start, 0 - 20%, 20 - 40%, 40 - 60%, 60 - 80%, and 80 - 100%), listing the percentage of change that occurred in each period, and calculating a weighted timing factor. The results according to him show that impacted projects have larger amounts of change, have a larger decrease in labor efficiency, and are more impacted by change that occurs later in the project schedule. He concluded that the results appear to be consistent with the intuitive judgment of industry professionals. His research is however, limited to the mechanical trade, but does include specific work in plumbing, HVAC, process piping, and fire protection.

Al-Dubaisi (2000) studied the causes, effects and control of change orders in a large building construction project in Saudi Arabia. His analysis indicates that cost overrun from change orders were in the magnitude of 6 – 10% of the original contract value while schedule overrun was less than 10% of the original project duration. In most project in other industry sectors, architectural and engineering design are 100% complete prior to bidding and tendering. In the oil and gas projects in Alberta, engineering design is hardly complete prior to start of the bidding process. In fact there are instances of projects that are bid based on the project 3D 'model' with limited engineering design. In situations like this, changes can be easily made to the project without a thought through consideration of the impact and consequences of such changes to the project cost and duration.

Ahmed (2001) studied the effect of change orders in combined sewer over flow projects in the city of Detroit. In the 12 sewer over flow projects studied, there were 208 change orders resulting in cost overruns. Additional scope due to the change orders resulted in 7% cost increase in the projects while there is a 1% reduction in cost due to the changes. According to him, average time extension on the projects was 30%.

Mechanda (2005) stated that preconstruction project contingencies are typically assigned at five to ten percent of the project budget and may be largely consumed by change orders on a given project. These change orders, according to him, result from unanticipated project conditions, document or process deficiencies, or by scope changes. The challenge is that these percentages are arbitrary and not data driven. They have become ‘the norm’ through traditional practices.

The value of changes in cost and duration in a project cannot be a one number fits all in every project. Every project is unique and brings its peculiarity to the table. The uniqueness of any project should be considered before arriving at a percentage (contingency) of anticipated change.

2.3.2 Other Existing Body of Work

This section will review existing body of work on project change management, scope change, project overrun and other related publications. Some authors use the term change order, project change management and scope change interchangeably to represent the same title, they actually have different meanings and use in a project. Scope change is any deviation from the original scope of the project. Change order on the other hand is the instrument that is used to mutually modify the contract of any project. The owner and contractor must agree to the change before a change order is issued to modify the contract. Without this mutual agreement, the contract cannot be modified by any one party to the contract. While scope change is one of the causes of change in a project, scope change and change management may be used interchangeably going forward.

Coutts (1997) in his research on change management in the construction industry introduced the concept of Form ‘X’ mechanism as the means of establishing effective project control. The Form 'X' mechanism requires the design team to quantify, in financial and program terms, the effect of design or construction changes, and to obtain the client's specific authority prior to revising the works. In doing so the project manager is able to determine the magnitude of all changes in terms of time, money and quality. He concluded that Form X is a highly successful change control mechanism that was used in Hong Kong Mass Transit Rail project and could be used in any project worldwide.

Cariappa (2000) focused his work on the ‘Effect of Contract Changes on Performance of Construction Project’. His work focused on determining the effect of contract changes on “design-build”, “traditional” and “partnering” types of contracts as he chose to describe them. His objectives were to estimate the costs associated with each change; identify the types of changes, group them accordingly and to develop a graphical user interface that will help monitor these changes. His work did not include the determination of a factor that can be used to represent the potential value of changes in a given contract.

Gunduz (2002) studied the productivity loss associated with change orders. He defined the term ‘Delta’ as the difference between the actual labor hours expended to complete the project and the estimated base hours (including the approved change order hours). According to him, the method needs to be able to represent the cumulative impact of change, including any ripple effects. He stated that Delta can be attributed to a contractor's incorrect estimate, a contractor's inefficiency or the impact of productivity related factors, such as change orders, weather conditions, work interruptions and rework among others. His study focused on small electrical and mechanical projects which are labour intensive.

CII (2004) project change management research team focused on determining the nature and origin of problems related to changes and established the relationship to timing of changes throughout the project life cycle. Their investigation provided three deliverables:

1) a comprehensive view of agreements and changes;

2) a set of recommended best practices for the effective management of change; and

3) a prototype change management system, reflecting the means of implementing the research.

They introduced five change management best practices which include:

1) promote a balanced change culture;

2) recognize change;

3) evaluate change;

4) implement change and;

5) continuously improve from lesson learned.

Their work have been widely adopted and quoted by many authors.

Zou and Lee (2002) discussed the impact of project change management on project cost and schedule performance. They reviewed over 469 projects from the CII database from 1997 to 2002. They employed “benchmarking” and “matrix” to quantitatively predict how well a project changes in cost during project execution in comparison to its initial estimate. The study revealed the relationships of project management best practice elements with project change cost performance.

Park and Peña-Mora (2003) developed a dynamic project model that can be used as a planning and control tool for construction projects, focusing on effective change management. The model uses different characteristics and behavior patterns of construction change and compares them to those of rework. Change impact on construction performance was analyzed according to change characteristics to discover status and time. They model was latter applied to a real project to test the efficacy with positive result according to them.

Hsieh et al. (2004) discussed a statistical analysis method to develop the cause-effect relationship of change orders. They are of the opinion that cost and time overrun are the consequences of mismanagement of changes. Their work investigated the change order process on 90 public works projects. According to their findings, most change orders arise from problems in planning and design. They concluded that improvement in efficiency and effectiveness can be gained with just a ‘small fraction’ of funding given to management of change orders at the earlier stages of a project.

In their study Ibbs et al. (2005) stated that project changes affect the cost, scheduling and the duration of the projects, both directly and indirectly. Their paper was based on the five change management principles introduced by CII: (1) promote a balanced change culture; (2) recognize change; (3) evaluate change; (4) implement change; and (5) continuously improve lessons learned. The study concluded that by applying these principles, project participants can minimize deleterious change and promote beneficial changes that are desirable. They suggested that development and implementation of a project change management system before the commencement of the project is a good, proactive step towards constructively managing the project. The research proposed a Change Management System (CMS) made up of two levels. A level of starting principles and a detailed level of management processes. They suggested that each of the five principles should interact with one another in order to maximize the function of the system.

Ibbs (2005) studied the impact of change management on labour productivity. Using data from 162 projects a statistical analysis was done which derived three graphs to show the impact of change management labour productivity. The study is of the opinion that late changes have more disruptive impact than changes made early in the project.

Lee et al. (2005) identified practices used in construction industry to include:

1) pre-project planning;

2) constructability;

3) project change management;

4) design/information technology;

5) team building and

6) zero accident techniques.

Their study examined how these practices affect cost and schedule project outcomes using Multivariate Descriptive Discriminant Functions Analysis (DFA). They concluded that pre-project planning, project change management and design/information technology are critical practices indicating important impacts on both cost and schedule.

According to Mrozowski (n.d) as quoted by Mechanda (2005), scope changes and change orders impact various players in any given project in different ways:

Impacts on contractors

- *Disruption of project flow.*
- *Reduction in productivity.*
- *Increased project management time.*
- *Uncompensated management time.*
- *Breakdown in project relationships.*
- *Insufficient compensation for indirect costs.*
- *Personnel, equipment and bond capacity tied up on project.*
- *Disruption of cash flow.*
- *Coordination difficulties.*

Impacts on design professionals

- *Increased contract administrative time.*
- *Concern for liabilities due to errors and omissions.*
- *Uncompensated processing time.*
- *Breakdown in project relationships.*
- *Disruption in project flow.*

Impacts on owners

- *Increased project costs.*
- *Project delays.*
- *Breakdown in project relationships.*
- *Disruption of project flow.*
- *Increased administrative costs.*

Mechanda maintained that change-order management on hard-bid contracts can actually start during the bid process. In this type of contract, the issue may often be that the bid documents did not express the owner's intent clearly.

Motawa et al. (2006) used fuzzy logic-based change prediction model and Dynamic Planning and Control Methodology (DPM) to study an integrated system for change management in construction. According to them, change management in construction is an important aspect of project management, as changes constitute a major cause of delay and disruption in a project. Change in construction projects are very common and likely to occur from different sources, by various causes, at any stage of the project and may have considerable impacts. The study focused on predicting the likelihood and the impact of a change in a project. They asserted that change depends on 'stability' of the given initial scope of the activity. The main purpose of their prediction system is to estimate the level of stability in a project and how the prediction will help in taking appropriate actions to minimize the disruptive effects of changes. They used the DPM approach to provide policy guidelines for unexpected events by supplementing network-based tools with mechanisms to represent the dynamics of a project.

Using the data from CII, Zou and Lee (2008) examined the relationship between project characteristics and the implementation of Project Change Management Best Practice (PCMBP). They stated that implementation of PCMBP is one of the most important best practices and has a bigger impact on project schedule and cost performance than any other best practices in the construction industry. The study focused on understanding how PCMBP is implemented in different projects with different characteristics. According to them, the study is exploratory rather than confirmative or predictive. Their two main objectives were (1) to explore the correlation between project characteristics and the implementation of individual PCMBP elements (for each single element, which types of projects are most likely to adopt PCMBP) and (2) to investigate the correlation between project characteristics and overall implementation of PCMBP elements (which types of project use most of these elements and use them to the utmost extent). The study concluded that a formal documented change management process is essential. A justification procedure for all changes and authorization before implementation can help prohibit unnecessary or overestimated changes. Also the more a project uses the procedure, the better change cost performance can be expected.

Zou and Lee (2009) examined the relationship between change management practices and project cost performance. They noted that construction projects that adopt change management practices generally incur lower change costs in comparison with project budgets. The study also utilized data from CII benchmarking and matrix database for the research. They concluded that individual change management practice elements have different levels of leverage in helping to positively control project change cost. Also that using change management practice is truly helpful in lowering the proportion of cost change in project actual cost. According to them, the absolute monetary value of project change is less meaningful to their research than the ratio of it to the baseline because of different project scales.

Senaratne and Sexton (2009) in their study examined the role of knowledge in management of construction project change. The aim of the research was to investigate how knowledge is captured, created and used during unplanned change situations in the construction phase within collaborative team settings. Their case study indicated that different forms of knowledge are captured and shared between project team members during problem-solving activities connected with change events. They found out that limited availability of codified documents and limited details in the available codified documents hinder transfer and dissemination of new knowledge, which is generated through reactive process.

The Construction Owners Association of Alberta (COAA) conducted benchmarking of major projects in Alberta in collaboration with CII. According to their benchmarking of major projects summary (2009), they stated that:

> *Given the expert opinions of members of the COAA Benchmarking Committee, the relationship uses a cubic polynomial pattern due to the fact that as more design is completed before construction begins, the project tends to have less construction phase cost growth. This trend holds true until, at a certain point, the cost growth curve flattens and subsequently increases. Thus, an optimum value is found at approximately 60% engineering complete.*

The report benchmarks engineering percentage complete across the entire phase of the project. However, this research will focus on the contribution of the level of engineering percent complete at bid time and their subsequence effect throughout all four phases of a project (bid, preconstruction, construction and commissioning). This research tends to agrees with the benchmark report that there is a direct correlation between engineering percent complete and amount of change a project experiences.

Halari (2010) attributed the design changes in Steam Assisted Gravity Drain (SAGD[2]) projects to three major causes: first, the design of SAGD plants are based on pilot reservoir data which are known to change over a period of time even when the wells have started producing bitumen. Therefore, the changing reservoir conditions coupled with simulations to achieve the optimum bitumen production create a significant impact on the size and capacity of the surface plant design (Edmunds & Suggett, 1995), as quoted by Halari. The second cause of changes he noted is process design. Therefore, changes made to the process design result in changes to the Process Flow Diagrams (PFDs) and Piping and Instrumentation Diagrams (P&IDs), which subsequently impact the other disciplines. The last cause of changes from engineering perspective according to him is the change in design technology which makes it easy to effect changes in modern times unlike in time past when drawings were manually done and changes very cumbersome and expensive.

[2] Steam Assisted Gravity Drainage (SAGD) is a method of bitumen (oil) extraction from the ground in oil and gas projects in Alberta whereby steam at very high temperature is injected through pipes into the ground to melt the bitumen. The melted bitumen is pumped through another pipe to the processing facility.

Zhao et al. (2010) examined a prediction system using activity based dependency structure matrix (DSM[3]) to facilitate change management. According to them, a project management team needs to predict change in a timely manner, thus, the study utilized DSM method to analyze the causes of change in construction projects based on the form of information flow. They stated that, DSM was developed by Steward in 1981 to achieve more efficient presentation of dependency relationships between activities by means of matrix.

Stare (2010), focused his study on how project changes can be eliminated and how to reduce their negative impact. Stare concluded that for the effective realization of changes, a formal change management system has to be established and implemented in the enterprise. The systems according to the study include the procedure of change approval, the documents generated in the process, and the information system support.

Hwang and Low (2011) discussed the status, importance and impact of change management implementation in the Singapore construction industry. Their study explored the benefits and barriers of change management implementation as well as the importance and impact of change management in terms of project performance. They analyzed data on 384 projects from 32 companies and concluded that there is a very low level of implementation of change management in Singapore.

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[3] Design Structure Matrix (DSM) is a simple tool to perform both the analysis and the management of complex systems. It enables the user to model, visualize, and analyze the dependencies among the entities of any system and derive suggestions for the improvement or synthesis of a system. Source: http://www.dsmweb.org/

Halari and Jergeas (2011) examined the lessons learned from execution of oilsands' SAGD projects and concluded that lack of complete scope definition is one of the lessons learned from their round 1 and round 2 interviews. According to their survey, participants felt strongly that the complete scope of the project should be defined up front in the engineering phase. The consequences of not doing so they concluded will result in time being wasted on the project due to rework.

Chanmeka et al. (2012) studied the factors impacting performance and productivity in the oil and gas projects in Alberta. They analyzed 37 oil and gas projects and found out that poor planning and inadequate project scope definition gave rise to project cost and schedule performance problems, while labour productivity is merely an approximate cause. According to them, high correlations are revealed between deficient project performance and factors such as low engineering percent competed before start of construction.

Alp and Stack (2012) in their research analyzed scope management and change control practices for large and complex projects on a fast track schedule. They determined from their survey data result that 1) 78% of projects have unauthorized scope creep resulting in project cost overruns, and 2) 62% of participants responded that between 41% and 100% of projects are executed at a fast-tracked pace for the engineering, construction, and architectural industries.

Moghaddam (2012) in his study advocated for the introduction of project change management process in Iranian construction industry. He argues that the existence of such a procedure is vital in order to determine the contractual obligations of time, cost and quality. According to him, leaders in managing construction projects in Iran believe that not implementing a proactive change management system leads to severe cost and time overruns and also there is no system available for applying change management procedure.

The literature highlighted the state of change management in the construction industry, causes of change, remedies and best practices for effective change management. From the review it was obvious that there is low level of change management practices in the construction industry. Also evident from the review is the factor that there are different values being used by the industry to account for changes in cost and duration. The lack of agreement is the one of the reasons for consistent disagreement between owner and contractors on the cost of change. The review also established that there is a relationship between engineering percent complete and level of change in projects in oil and gas industry.

2.3.3 Deficiencies to Existing Works

As evidenced by the number body of works reviewed, a considerable amount of research has been done on project change management, however very few exist on oil and gas projects in Alberta. From the reviews some facts are evident:

1) Changes should be anticipated in any project and should be planned for.
2) Change cannot be eliminated, therefore must be managed.
3) Impact of change varies according to the various causes
4) There is no tool to effectively predict the value of potential change in a project.
5) Organizations use different percentages to represent the impact of change.
6) As engineering design complete increases prior to the commencement of any project the amount of change decreases.

There is unanimity of opinion in the construction and oil and gas industry that project changes impact project by altering the preplanned cost and schedule expectations. However, lacking is the absence of a tool to consistently quantify the relative value of change in terms of cost and schedule in the industry.

2.3.4 Causes and Sources of Project Change

Many writers have advanced reasons and causes of project change. While some of the reasons are internal, others are external to the project and are the most challenging to control or manage.

Administration Manual (DND, 1992) of Defense Construction Canada (DCC) as quoted by Cariappa (2000) classified changes based on the nature and origin of the change. The classifications are:

a) *Changes resulting from unforeseen site conditions, but do not require redesign (Type 1C)*
b) *Errors and omissions (Type 2C)*

Design changes are classified as:

a) *Changes that are made due to the update of requirements within the original scope (Type 1D)*
b) *Changes of requirements not within the original scope (Type 2D)*
c) *Changes in design made necessary by unforeseen site conditions (Type 3D).*

Roachanakanan (2005) noted that change orders resulting from revising the building specifications in response to client requirement are the primary cause of cost deviation.

Oracle White Paper (2009) categorized changes into (1) directed changes – which are directed by the owner; (2) constructive changes – resulting from action or inaction of the owner; and (3) cardinal change – which has the potential of causing the work to be performed fundamentally differently from the work the parties agreed to when the contract was bid and signed.

Horine (2005), stated that to better manage project changes and project risks, and to minimize the number of scope changes, it is important to understand the leading causes for unplanned scope changes on a project. According to him, causes of unplanned scope changes include:

a*) Shift in business drivers*
b) Shift in project acceptance criteria
c) Shift in technology
d) Poor scope statement
e) Poor requirements definition

He recommended six key management principles for effective project change control:

1) *Plan for Changes*
2) Set up change control system
3) Educate stakeholders
4) Use the system
5) Minimize scope changes and
6) Over-communicate

Alp and Stack (2012) attributed the cause of changes in a project to the fact that many construction projects are notoriously performed on a fast-tracked design and implementation schedule.

There is a general consensus that some of the causes of change include decisions made based on assumption, incomplete information, general uncertainty, increased project complexity and experience (Ibbs et al. 2001; Ibbs et al. 2007 and Hao et al. 2008).

CII (2012) noted that, with advances being made in computerized design, the changing of designs has become a quick and simple process, requiring only a few clicks of the computer mouse or the tapping of a screen. Contrast this with the days of hand-produced drawings when a change required many designing and drafting hours. The content ease of change reduces the reluctance to make changes and carries with it the potential for more frequent change, some of those changes being optional.

The complexities, mega size nature, high overlap of the engineering and construction phases according to Chanmeka et al. (2012) are some of the factors responsible for changes.

Rashid et al. (2012) classified the causes of changes as follows:

A - Changes attributed to the owner

1- Additional client request during the course of the project.
2- Stopped, disrupted or interrupted work.
3- Owner Financial difficulties.
4- Accelerated performance requested by the owner.
5- Delays from the owner's acts.
6- Initiated value engineering change.

B - Changes attributed to the designer/consultant

1- Design revisions (change).
2- Design errors or omissions.
3- Design deficiency.
4- Unanticipated works.
5- Discrepancies in the contract drawings.
6- Unavailable specified products.
7- Incomplete scope definitions.
8- Over inspection.
9- Differing site conditions.
10- Work method restrictions.

C - Changes attributed to the contractor

1- Construction errors.

2- Construction omissions.
3- Remedial work.
4- Work out of sequence.
5- Material & equipment late delivery.
6- Following new or different schedule.
7- Contractor financial difficulties.
8- Lack of skilled labor.
9- Increased Risks.

D - Changes attributed to Project Management
1- Lack of coordination.
2- Difference in contract interpretation.
3- Errors in contract documents.

E - Changes attributed to Local Authorities
1- Third party permits.
2- Governmental actions.
3- Restrictions in site access.
4- Utility relocation.

F - Changes attributed to Stakeholders
1- Impact scope changes definitions

G - Changes attributed to Force Majeure
1- Unexpected Events.
2- Acts of God.

Causes of Change

For the purposes of this research, eleven major causes and sources have been identified as the major causes of change in oil and gas projects in Alberta. It should be noted that this is not an exhaustive list of causes rather the causes that are frequently identified by many literatures reviewed as well as from researchers experience in the oil and gas industry.

1) Design Change:

This is one of the major sources of project change in the oil and gas projects in Alberta according to (Awad 2001; Hsieh et al., 2004; Lu and Issa 2005; Arain 2011; Moghaddam 2012). The major reason is that in almost all the oil and gas mega projects in Alberta, the owners request for bid from contractor when the engineering design has not been completed. The result is that the bid submitted does not contain the entire estimate to complete the job due to the fact that only partial information on the project is available as at that time. The general assumption is that change orders will be generated as the project goes on. This situation often leads to most projects doubling or even tripling the initial cost and duration established at bid time.

2) Site Conditions:

The ground is one of the "black boxes" in construction in that no matter the level of geotechnical examination or evaluation done, the underlying ground condition may still present unanticipated situations. The distances between test holes for soil samples hardly tell the entire story of the soil condition of locations in between the trial holes. That is one of the reason the owner usually shifts the liability of site condition to the contractor requiring the contractor to perform their own geotechnical test to satisfy themselves of the soil condition. Site condition and scope change are the most litigated aspects of construction activities. A typical Inspection and Site Visit clause in a construction project from Construction Clause Digest (2006) states that:

> *The Contractor further acknowledges and declares that it has visited and examined the site (but only as to visible surface conditions or conditions ascertainable from the results of any subsurface tests required or provided in connection with this Project, or other reports and documents available to the Contractor) and reasonably examined the physical, legal and other conditions affecting the Work including, without limitation, all*

soil, subsurface, water, survey and engineering reports and studies delivered to or obtained by Contractor and the conditions described in this Section 3.2.1. in connection therewith, Contractor by execution of the Contract and the Amendment establishing the Contract Sum, Contract Time and Guaranteed Maximum Price will be representing and warranting to Owner that it has, by careful examination, satisfied itself as to the conditions and limitations under which the Work is to be performed, including, without limitation, (l) the location, layout and nature of the Project site and surrounding areas, (2) generally prevailing climatic and weather conditions, (3) anticipated labor supply and costs, (4) availability and cost of materials, tools and equipment and (5) other similar issues.

This situation is usually a source of legal tussle and the court has in most cases sided with the contractor. A change situation will arise if the contractor encounters a soil condition at the time of construction that is substantially different from the site condition understood at the time the bid was made submitted. The understanding of the soil condition at the time of bid informs the value of bid the contractor submits for the project. Most oil and gas construction contract contains a clause for "Deferring Site Condition" which specifies the procedure for processing changes resulting from changes in site condition.

3) Scope Change:

This is any deviation from the original scope of work that was agreed to at the time of bid and contract award. Scope change is the major cause of change in a project and has the greatest impact on the project (CII 1994; Horine 2005; Arain and Low 2006; Jergeas 2009; Oracle White Paper 2009 and Arain 2011). This stems from the fact that engineering is never 100% complete in majority of the projects before the owner calls for bid from contractors. In the period between contract award and commencement of construction, several changes usually occur in the project while engineering design is still taking place. This situation often lead to changes in the scope of work. The scope change could be an increase or decrease in the size, cost and duration of the project.

4) Regulations:

Oil and gas projects are governed by a lot of regulation from government, professional bodies, trade unions, codes, standard and even industry best practices. These policies have a way of introducing change in the project. If the regulation change occurs after the project has been awarded, it will most likely lead to changes in project cost and duration. For instance the criticism and push back from United States of America and Europe on Alberta oil on the ground that the method of extraction is environmentally unfriendly. This is forcing government to make regulations requiring oil producers to adopt processes that are environmentally friendly. This often leads to redesign and equipment changes.

5) Change in Technology:

Change is the only constant thing in life and nothing changes more often in modern world like technology. According to ERCB (2008), a collaborative research between government and University of Albert and Calgary are investing over $1billion in commercial research targeting new oil sands extraction method to:

i) Reduce greenhouse emission.

ii) Reduce natural gas use.

iii) Reduce water consumption.

iv) Improve the value of refined products derived from bitumen.

Businesses on their own part are constantly coming up with new equipment, instruments and processes that will simplify the existing method of oil extraction and processing. These developments lead to change in the project with impact especially if they occur after the contract has been awarded.

6) Market Condition:

Market is the major driver for any oil and gas project. If owners cannot sell their product, there will be no incentive to embark on a multi-billion dollar project. Sometimes a multi-year purchase agreement is reached between project owners and buyers of the product even before the project is initiated. In situations where no market has been securely, the price of oil in the international market sometimes determine the inducement of owners to embark on a project. Some oil and gas projects have been scaled down or up or out rightly cancelled dues to fluctuating oil price especially when the price of oil is below the breakeven point for Alberta oil. The challenge of transport mechanism to move oil into international market is yet another issue affecting the ability of oil and gas organizations to embark on new project or even expand existing ones. The issue of transport mechanism is causing some oil and gas companies to rethink their projects.

7) Management Decision:

Owners can change the direction of the project at any time due to factors such as new opportunities, technology, mergers or outright indecision. Project owners have the freedom to change the course of the project at any time. However, such freedom comes with some cost and duration consequences. If project owner constantly makes project change decisions without recourse to the contractor, such decision may have a negative impact on the project. It is important that management decision is thought through, their impact understood and the contractor involved early enough in the process. The contractor may provide a perspective that may inform a better decision by the owner. Proper planning on the part of the owner in collaboration with the contractor will assist in mitigating the adverse impact of such changes.

8) Environmental Conditions:

Environmental conditions in a project includes very cold weather, excessively hot weather, persistent rain, high wind factor, radiation and force majeure to mention but a few. One of the construction contracts reviewed in the course of this research defined *force majeure* as "*an occurrence or event that delays, hinders or prevents the affected party's performance of some or all of its obligations under the contract (other than the obligation to make payment of money due), and is beyond the reasonable control of the affect party notwithstanding the exercise of reasonable due diligence to prevent or avoid such occurrence or event*".

Lister (2005) described *force majeure* as "greater force" that excuse a party from liability if some unforeseen event beyond the control of that party prevents it from performing its obligations under the contract, and that party's failure to perform could not be avoided by the exercise of due care. Typically, *force majeure* includes natural disasters or other "Acts of God", war, riot, terrorism, and sabotage. Situations caused by weather for instance will constitute a *force majeure* and hence a change if the particular situation is abnormal from the normal environmental situation in the location or area. For instance a persistent temperature of -40^{o}C in an area known to have historical seasonal temperature not below -20^{o}C will constitute *force majeure* and will be a cause for change if it prevented the affected party from performing its obligation under the contract. It should be noted that the environmental condition must have disrupted planned work or changed the scope or pace of work for it to be considered a change.

9) Materials and Equipment:

In most oil and gas projects, owners usually assume the responsibility of providing key equipment and materials for the project. A change situation will arise if the originally designed equipment or material is changed. For instance if the original design calls for a 1/4 tonne motor or rotating equipment and the revised drawing require a 1/2 tonne equipment, the situation will requires different handling in terms of lifting, manpower skills etc. Similarly in a situation where a plastic pipe is to be replaced with a metal or stainless still pipe calls for change because of the different skill sets and handling of the two different materials.

10) Fast Track:

Fast tracking is the parallel or simultaneous execution of two activities in a construction project so that they overlap. This practice is most visible when engineering design and construction activities are taking place simultaneously in the project. While this practice is meant to shorten the project duration, it is however accompanied by multitude of challenges. Some of the challenges include the fact that a lot of changes and corrections are made to the design as owners most times do not have the complete picture of the project when the contract was awarded. These changes have cost and schedule consequences. During period of high oil price, most oil producer wants to get their product to the market as quick as possible in other to take advantage of the high oil price. For this reason, projects are started with little engineering design complete thereby setting up the project for fast tracking.

11) Others:

In addition to the causes of project changes outlined above, survey participant where given the opportunity to add any cause of change that is not listed in the questionnaire. The participant identified causes are listed under “Others”.

2.3.5 Impact of Change

Change has considerable impact on any project. Ming et al. (2004) noted that delays in completion, over spending and quality defects are common problems besetting the project delivery process in the construction industry. The impacts associated with changes in the project can be categorized as follows:

1) Quality: Change has the ability to dilute the quality of the project if a change is implemented when the cost and schedule are held constant. If the contractor is forced to effect a change without any consideration in terms of payment or schedule extension, a poor quality work will certainly occur. Arain and Low (2005) stated that contractors may tend to compensate for the losses by cutting corners due to the frequent changes by the owners. This will affect the quality of work negatively.

2) Rework: Is the repair, reconstruction, demolition etc. of a work already completed as a result of changes or error. Frequent rework has the tendency of leading to schedule creep which will elongate the duration of the project. Ming et al. (2004) noted that the major cost due to change is by the cost of rework or revision of work. Rework is the unnecessary effect of re-doing a process or activity that was incorrectly implemented in the first place. The cost of rework, according to them, may be as high as 10-15% of

contract value. The researcher recognizes the significant impact of rework on project but does not share the view that reworks is a major outcome of changes in a project. In some of the projects the researcher actively participated in the oil and gas sector, rework constituted a negligible fraction of extra cost of the project. In one of such projects, while increase in cost as a result of changes was over $700 million in a $400 million project, rework was less than $3 million. In another project of over $1 billion in project cost, the amount of rework was less than $7 million. For this reason, this research does not consider rework as having significant impact on changes in project cost or duration.

3) Productivity: When changes occur in a project, productivity suffers because effort is diverted to doing work that was not originally planned. The disruption of the work may impact the ability of the contractor to execute the project at the pace originally projected. Ming et al. (2004) noted that in cases whereby workers were expected to work for overtime over a prolonged period to compensate for the project schedule delays, productivity was greatly affected. Lee et al. (2005) stated that working overtime to catch up with extra work as a result of change could demoralize the morale of workers and deteriorate the productivity of workers.

4) Dispute and Claims: This can be the unintended consequences of changes in a project. Where the contractor and the owner fail to agree on the cost and schedule impact of a change and all arbitrations fails, the result may be a lengthy and costly court process. Diekmann and Nelson (1985) in their research found out that overall claim rate was 6% “(i.e. 6 cents on the dollar)” and that 46% of the claims were due to design errors, 26%

were either discretionary or mandatory and that 72% of all claims were outside the control of the contractor. Ibbs (2005) stated that change, especially when it resulted in protracted disputes and litigations, is a serious and expensive problem for the construction industry.

2.3.6 Project Change Management Process

Project change management is the process of identifying, documenting, processing, negotiating, executing and compensation for variation of work between the original contract value and any additional changes.

Ming el al. (2004) recommended process includes:

1) start up;
2) identify and evaluate;
3) approval and
4) implement and review.

Hao et al. (2008) suggests a generic change model which includes:

1) identify changes;
2) evaluate and process changes;
3) approve changes and
4) implement changes.

Oracle White Paper (2009) proposed the following essential change management steps:

1) identify the contract requirements;
2) identify the potential change and create a potential change order file;
3) determine entitlement, measure the effect of the change, and calculate the cost of the change;

4) negotiate and execute the change order and

5) maintain complete records of the executed change.

Hwang and Low (2011) noted that the process of change management comprised of four basic principles:

1) to identify changes;

2) to evaluate changes;

3) to implement changes; and

4) to learn from past experiences.

These four principles work together to achieve the objective of an effective change management system they maintained.

The researcher recommends the process shown in Figure 2.1 which is based on the experience of the researcher on various projects. The process assumes that each project has a change management department as well as change management process. Numbers and captions in red are the key project change management focal points. They are further described in detail below.

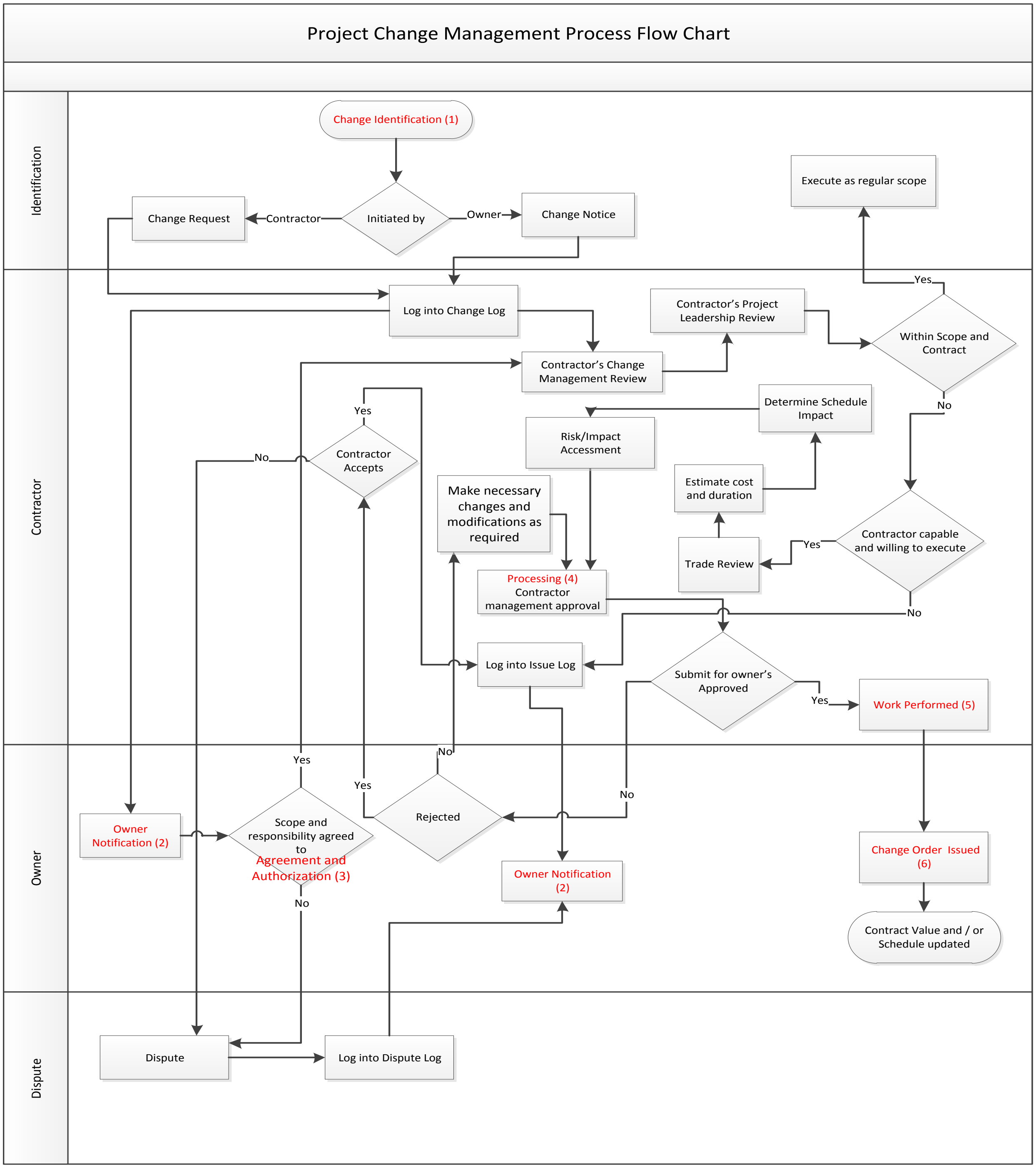

Figure 2.1 - Change Management Flow Chart

From the flow chart, a change management process should include the following:

1) Change Identification: Change management process starts with identification of any variations between the original contract and scope of the project at any point in time in the project lifecycle. For instance if the original contract scope is for the erection of two 50,000 gallon tanks and a revision in the drawings require the installation of three tanks, that is a change. In most contracts, while the owner has the right to change the scope at any given time, the contractor is entitled to compensation for the extra scope associated with the work. If there is a disagreement between the owner and the contractor and the change is within the general scope of the work, the contractor will perform the work and use the dispute mechanism to seek for payment and or extension of time. Sun et al. (2004) suggest that the aim of the project team is to actively seek to identify potential changes at the earliest opportunity. Identification is a crucial element of change in that without identifying and analyzing an issue, it may be impossible to determine if it is a change or not. Every change may not be as obvious as the addition of extra tank as mentioned above, however, every issue should be analyzed to determine if it qualifies as a change. The task for both the owner and the contractor is to review project documents on a regular basis, especially engineering drawings which in most cases are produced as project execution is taking place.

2) Owner Notification: The owner can add additional scope to the contract at any time. However, the owner has the obligation to notify the contractor in a timely manner to

enable the contractor respond appropriately. At the same time, contracts usually contain notification period during which the contractor must notify the owner through the contractual notification process of any identified changes. If the contractor fails to notify the owner within the contractual notification period and proceeds to perform the work, the owners may deny the contractor the opportunity for any compensation for the work done in relation to the change. The notification clause according to Oracle White Paper (2009) is important because it prevents the contractor from prejudicing the owner's rights to investigate, mitigate, and document the change while opportunity still exist before the work is carried out.

3) Agreement and Authorization: Following notification, the owner and contractor has to agree that the item identified constitutes a change. For owner initiated change, the owner and contractor must agree on the cost and schedule extension. Also for changes identified by the contractor, an agreement and authorization is required on the cost and schedule impact prior to commencement of work by contractor. If no agreement is reached, the issue may be resolved through the contractual dispute mechanism. If on the other hand agreement is reached the rest of the process is activated.

4) Processing: This involves logging the change item into a change log; estimating labour hours, material, equipment and financial cost; schedule impact analysis to determine any impact of the proposed change on the duration of the project especially the critical path; processing the change with the supporting documentation and obtaining owner's approval. Most contract states clearly that works related to changes cannot be performed without the owner's approval. It is not uncommon for the owner

and contractor to disagree on the cost of the change as well as the duration. This disagreement is resolved through the normal dispute resolution mechanism in the contract. Where the mechanism fails to resolve the issue, arbitration and or litigation may ensue.

5) Work Performed: Upon approval, the contractor executes the work according to the quality and standard specified for the job. The owner will inspect the work to make sure that it is executed as agreed prior to authorizing payment.

6) Change Order Issued: Is the consummation of the change process. The owner usually originates the change order and delivered to the contractor for execution. If the contractor agrees to all the information contained in the change order, the contractor signs the order. Upon signing by the contractor and owner the change order amends the contract.

2.3.7 Change Management Instruments

There are a lot of processes, procedures and instruments required to manage changes in any project. As stated above, the owner has contractual right to make changes to a project provided the cost and schedule impacts are agreed to by the contractor. The contractor can also initiate a change provided that the owner's approval is obtained prior to implementation of the change. It should be noted that cost and schedule are not the only impacts. Issues such as quality, productivity may also be impacted. For the purposes of this research, only the cost and schedule impacts are considered. Instruments for processing change management include the following:

1) Contract: This is an agreement entered into by the owner and the contractor at the time of contract award. The contract contains the scope of work, schedule, cost, duration, quality, and procedure for processing changes among other provisions. In a majority of the projects, the owner is responsible for preparing the contract. It is a common practice that parties that prepared the contract write it in a way to favour them. It is the responsibility of the other party to understand the content of the contract they entered into. Once signed the contract becomes binding on all parties. In the oil and gas projects in Alberta, the contract types can be fixed cost, lump sum, cost reimbursable, unit rate etc. or combination the different types. Each contract type has a different impact on how change is managed and processed in a project.

2) Change Notice: This is a notice from the owner to the contractor, specifying changes the owner intends to effect on the project. In the oil and gas projects in Alberta, most contracts require notice to be in a written form in order to avoid any ambiguity. According to Moghaddam (2012) change notice is a document issued by the client (or by contractor to subcontractor) notifying them of the possible and potential changes that may be encountered. The notice usually contains description, scope and instruction to the contractor. In response to the notice, the contractor will indicate acceptance or rejection of the notice. If the work requested is outside the scope and competence of the contractor, the contractor can reject the work if it is substantially different from the original scope of work or if it is a "cardinal[4]" change. According to Libor (n.d.) a cardinal change is a

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[4] A cardinal change is any change that substantially alters the original contract.

change or series of changes that are beyond the scope of the contract. Such changes need not be followed by the contractor, and a refusal to perform them would not constitute a breach of the contract. Continuing, he noted that the basic tests for determining if a change is cardinal are (a) whether the additional work was within the contemplation of the parties when they executed the contract; and (b) whether the project, as modified, is still the same basic project. If on the other hand the notice is accepted, the contractor will provide information on the proposed solution, cost and schedule impact (see Appendix D for sample change management forms).

3) Change Request: In some cases, a change may be initiated by the contractor. There are a lot of reason why a contractor may initiate a change including, but not limited to, design errors, scope change, extra work, incorrect revisions, difference between contract and drawings, incorrect materials and equipment, differing site conditions, weather factors, unsafe situations, environmental factor, to name but a few. In this case the contractor will raise a Change Request to the owner (Appendix D). The notice will give description of the requested change, impact on cost, schedule and associated risks. Moghaddam (2012) describes change request as a document issued by the contractor for initiating request for change notice due to some unforeseen factors such as differing site conditions, constructive events and changes.

4) Extra Work: The definition of extra work is usually very blurred and difficult to differential from scope change. Extra work is usually a source of contention between the owner and the contractor especially in situations where what constitutes extra work is not well defined in the contract. Extra Work is additional work within the existing scope of

work that will require additional effort, time and cost to accomplish. For instance, installation of pipe in a pipeline project is within the scope of work. However, if the contract stated quantity is 200m of pipe and during construction it was discovered that the actual length is 350m, the extra 150m is extra work. Oracle White Paper (2009) defines extra work as added work not provided for in the original contract, but found to be essential for the satisfactory completion of the project within its intended scope. Sample of extra work Form is show in Appendix D.

5) Change Order: Is most frequently misused and confused with change management. Change order is an instrument in the change management process, issued by the owner to the contactor and used to modify or change the original contract. Any agreement reached between the owner and the contractor relating to changing any aspect of the contract including cost, schedule, scope, quality etc. is routed through a change order. Prior to being incorporated into the contract, a change order must be signed by both the owner and the contractor following the procedure specified in the contract. Once incorporated into the contract, the change order modifies the section of the contract or adds to it. According to Cariappa (2000) a change order is a formal written document that specifies the alteration of part of the construction contract documents. Moghaddam (2012) stated that a change order describes the scope, price, schedule and method of payment for a change. Toronto Contractor's Association (n.d.) noted that a change order is used when the owner and contractor agree on a price and the changes in scope of work and schedule. American Institute of Architects (AIA) (n.d) described change order as a written

instrument prepared by the Architect and signed by the Owner, Contractor and Architect, stating their agreement upon all of the following:

i) change in the work;
ii) the amount of the adjustment, if any, in the contract sum; and
iii) the extent of the adjustment, if any, in the contract time.

To recover on a change order pursuant to this contractual provision, all parties must sign and agree to each of the essential elements of the change. Until all required parties sign the change order, a contractor or subcontractor may perform the changed work but is at risk that the party to be charged with responsibility for the changed work will not agree to the terms for its performance (see Appendix D).

7) Change Log: To track changes in the project, a change log is used to track and document all the changes that are occurring in the project. The change log enables the contractor and owner keep track of all identified, pending, approved and disputed changes in the project. Change logs at a minimum should contain the following information:

   a. Change Notice/Request No.
   b. Change Order No.
   c. Description
   d. Date of Identification
   e. Date of Notification
   f. Date of Submission
   g. Estimated Man Hours
   h. Estimated Material Cost
   i. Estimated Equipment Cost
   j. Total Hours
   k. Total Cost
   l. Date of Change Approval/Rejection/Resubmission
   m. Approved Amount

n. Approved Hours
o. Comment

See Appendix C for sample Change Log

8) Request for Information (RFI): This is a document mostly issued by the contractor to the owner requesting the owner to provide clarification; notification of missing information; request additional information on any aspect of the contract document, equipment, material or work process. The contract provides a notification period within which the contractor must notify the owner of any issue as soon as it is discovered and also a time period within which the owner must provide a response in order not to delay the project. According to Hess et al. (2008) RFI is a communication tool to facilitate resolution of or to clarify design documentation issues. In some cases, a response from the owner could be in the form of a Change Notice or Field Change Notice (FCN) depending on the nature of the issue involved. It is important to note that RFI on its own is not a change instrument but could result in the creation of other instruments that will lead to a change in the contract. Oracle White Paper (2009) stated that although RFIs are not in and of themselves indicative of a change, the process might identify the need for a change. Information requested through RFI are mostly engineering in nature that were not clearly defined at the time of bid. Given that engineering design is hardly completed prior to the bid process in most oil and gas project in Alberta, the number of RFI's raised in a typical project runs into the hundreds or even thousands depending on the scope and complexity of the project (see Appendix D).

9) Field Change Notice (FCN): Also known as Design Change Notice (DCN) is issued by the designer engineer or architect on behalf of the owner notifying the contractor of design changes to the project. FCN is an engineering project document and may not be used for changes that do not involve changes to design or engineering components. Upon issue of an FCN by the owner to the contractor, the contractor will respond with a Change Request (CR) estimating the cost and schedule impact (if any) of the proposed change (see Appendix D).

10) Field Change Request (FCR): FCR or Design Change Request (DCR) is originated by the contractor to the owner requesting a change in design or suggesting a better option to the existing design. Based on past experience, the contractor is in a vantage position to know if the design will work as originally intended. This knowledge is often volunteered to the owner in the form of suggestion of a better way of achieving owner's objective. The owner has a choice to accept or reject the recommendation or accept it with modification. If accepted, the normal change process is used to document and process the change, including any cost and schedule impacts (see Appendix D).

2.3 Project Delivery Systems

Project delivery system also known as gate process is a sequence of processes through which project lifecycle is implemented. Most of the major oil and gas companies have their unique project delivery systems. The systems are almost the same things with little variability from each company to differentiate them from other organizations. Figure 2.2 shows the project delivery system of an oil and gas company. The scope of this research is Phase 4 (Execution) of the project delivery system.

Phase 1 IDENTIFY and Assess Opportunities	Phase 2 SELECT from Alternatives	Phase 3 DEVELOP Preferred Alternative	Phase 4 EXECUTE Detailed (EPC)	Phase 5 OPERATE and Evaluate
Clearly Frame Determine Project Feasibility and Alignment with Business Strategy	**Select the Preferred Project Development Option**	**Finalize Project Scope, Cost and Schedule and Get the Project Funded**	**Produce an Operating Asset Consistent with Scope, Cost and Schedule**	**Evaluate Asset to Ensure Performance to Specifications and Maximum Return to the Shareholders**
-Feasibility	-DBM	- FEED - Long-Leads - Regulatory Approval - AFE	- Detailed Design - Procurement - Fabrication - Construction - Commissioning	-Start-Up - Performance Testing - De-bottleneck

Figure 2.2 Project Delivery System of a Typical Oil and Gas Company

This research divided phase four into five phases and used the word phase to describe each of those sub phases as shown in Figure 2.3. Changes that occur in phases 1, 2, 3 and 5 of typical project delivery system are outside the scope of this research.

2.4 Origin of Change

Change in a project can originate from any phase or stage of a project. The change that is critical to change management and this research are changes that occur after the bidding process has commenced and through to project completion. Prior to the bidding process, the owner is at liberty to effect any change without any implication to any third party. However, any change occurring after contractor have submitted their bid may have major impact on cost and duration. For the purposes of this research, changes that occur during the design stage prior a formal bid process is not recognized and hence outside the scope of this project. Figure 2.3 shows the potential points of origin of change in a typical project. This figure is authored by the researcher and based in part on the experience of the researcher on various projects as well as knowledge obtained from various bodies of work reviewed.

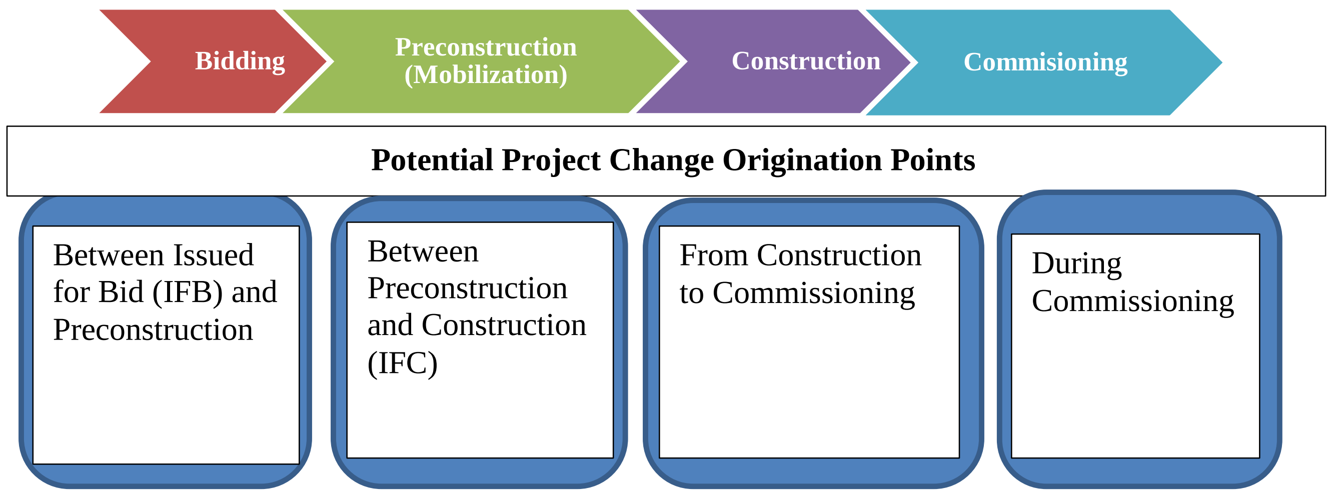

Figure 2.3 Potential Points of Origin of Change in a Project

This research has recognized four major points of origins of change in a typical project namely:

1) Bidding Phase: When the owner requests for bid from contractor, the owner provides bidding and project documents to the bidders. These documents are referred to as Issued for Bid (IFB) document. Contractors bid for the job based on the information contained in the bid documents. Most times engineering design is still taking place as the bid

process is in progress which may change information in the IFB documents. If the changes are not communicated to the bidders and discovered later in the project, this will constitute change as the contractor's bid did not take those changes into consideration in their bid response. The owner may communicate the changes to the contractor through an RFI if they are discovered prior to contract award. In this case, the contractor will modified their bid to include the changes. Depending on level of engineering percent complete before the commencement of the bid process, changes in this phase could be significant. The advantage to the owner is that change at this stage of the project is less expensive than changes that occurred in other phases of the project.

2) Preconstruction Phase: Given that engineering design is still taking place even after the contract is awarded and signed, changes still occur in the project even before the commencement of construction. When the contract is awarded, the owner issues the contractor documents and drawings titled Issued for Construction (IFC). The IFC are the only legal document that can be used for construction execution. However, even after the issue of the IFC drawing, the owner constantly issue revisions to the documents and drawings, leading to changes to the project. These revisions and changes are the major sources of change during this phase.

3) Construction Execution Phase: This is the phase that actual construction of the project takes place. It is in this phase that all the ideas on paper are actualized so that the project can be seen, touched and felt. With reality of the project becoming obvious, constant adjustments are being made to make sure that the concept meets the owner's

expectations. Substantial changes in the project take place in this phase of the project lifecycle. Changes at this phase of the project could be very expensive and disruptive to the entire construction process.

4) Commissioning Phase: With mechanical completion (construction and installation completion according to design), no one is sure that the project will work as expected. Testing is done prior to turning over the project to the owner. During testing changes still occur as systems are being twitched and revised in order to meet operational expectation of the project. One of the measures of success of the project is that the project operates as expected. If this is not the case, change is made to make that happen.

The points of origins of change identified above are common in most oil and gas projects in Alberta and are defined for the purposes of this research.

2.5 Project Risks

There are various risk categories associated with any project. The categories are shown below:

2.5.1 Operational Risks

Operational risks are those risks associated with uncertainties and unknowns within the existing scope of a project. This type of risk is within the operational control of the project team. According to Rolstadås et al. (2011) operational risks are threats with a potential impact on project objectives resulting from actions that are controlled by the project manager. Operational risks originate from uncertainties in estimates of time, resources and costs, previously referred to as volatility, and ambiguity as a consequence of missing pieces of information. Examples of operational risks include: errors and omissions, estimating errors etc.

2.5.2 Strategy Risks

Strategic risks are those risk which are caused by things like changes outside the original project scope of work. This risk is outside the control of the project team but within the control of the project owner. Rolstadås et al. (2011) define strategic risk as threats with a potential impact on project business objectives resulting from decisions made by corporate management. Examples of strategic risks are scope change, changes in design, incomplete engineering design, management decisions, deferring site conditions etc.

2.5.3 Global Risks

Global risks are those risks to a project caused by project external factors. These risks are outside the control of both the project team and owner. Rolstadås et al. (2011) describe this risk as contextual risk and states that contextual risks are threats with a potential impact on business and project objectives imposed by circumstances outside the project and beyond the control of project and corporate management. Examples of this type of risk include market factors, government regulations, environmental factors etc.

While operational risk is protected by contingency reserve, there are no reserves in most projects to accommodate strategic and global risks. Strategic and global risks are the focus of this research. This research is advocating for a change reserve in all projects that will be used to mitigate the impact of strategic and global risks. The tool developed from this research will serve as a useful tool to forecast the magnitude of this reserve.

2.6 Structure of Oil and Gas Projects in Alberta

Alberta ranks third, after Saudi Arabia and Venezuela, in terms of proven global crude oil reserves in the world according to Alberta Energy (2012) as shown in Figure 2.4.

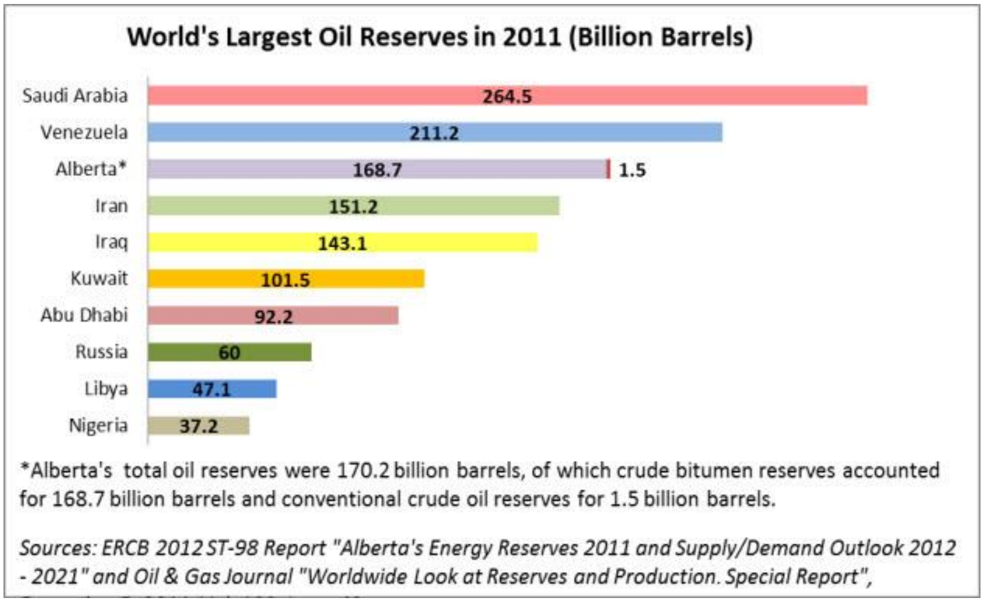

Figure 2.4: World's Largest Oil Reserves 2011 by Country

In 2011, Alberta's total proven oil reserves was 170.2 billion barrels, or about 11 percent of total global oil reserves (1,523 billion barrels). Almost all of Alberta's proven oil reserves are found in Alberta's oil sands area. Of Alberta's total oil reserves 168.7 billion barrels representing about 99 percent comes from the oil sands; and the remaining 1.5 billion barrels come from conventional crude oil. Notably, Alberta accounts for an overwhelming majority of Canada's oil reserves Alberta Energy AREPS (2012).

Alberta oil sands are located in three major areas of the Province as show in Figure 2.5. The locations are Athabasca sand in Fort McMurray, Peace River and Cold Lake.

Figure 2.5: Map of Alberta Oil Sands Locations
Source: Alberta Geological Survey

Alberta oil has two major methods of extraction, namely – mining and in-situ production. Mining is used when the oil deposit is located within than 75 m below the surface. Open pit mining involves the excavation of overburden (top soil) to expose the bitumen deposit. The deposit is excavated using shovels (Figure 2.6) and trucked to a facility where the deposit is crushed and the bitumen is separated from the ore. The bitumen is transported to an upgrader to refine the bitumen into a usable feed stock for refineries.

Figure 2.6: Alberta Oil Sands Mining Operation
Source: http://www.theogm.com/2010/08/11/suncor-energy-leading-the-way-in-alberta-oil-sands/ Photo Suncor

In-situ recovery is used for bitumen deposits buried too deeply – more than 75 m below the surface as shown in Figure 2.7. Approximately 80% of Alberta oil sands are recoverable through in-situ production, with only 20% recoverable by mining[5]. There is presently two commercial method of in-situ production, Steam Assisted Gravity Drain (SAGD) which is the dominant method and Cyclic Steam Stimulation (CSS) according to Alberta Oil Sands Industry Quarterly update (2013).

[5] Alberta Oil Sands Industry Quarterly

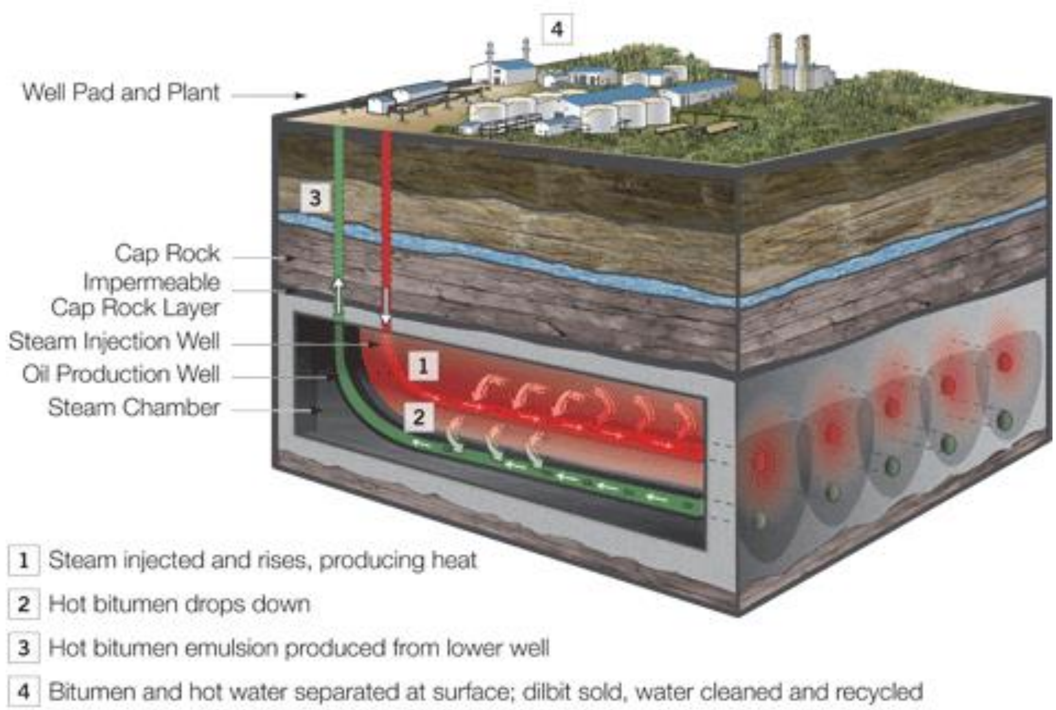

Figure 2.7 Steam Assisted Gravity Drain SAGD Process for Oil Extraction
http://www.connacheroil.com/index.php?page=great_divide_oil_sands

Alberta oil is classified as “heavy bitumen” because it is more difficult and costs more to process unlike light crude. This is one of the major reasons why most Alberta oil sand installations are mega projects running from hundreds of millions into billions of dollars in construction cost. Irrespective of the method of production (mining or in-situ), expensive facilities is required to process the oil into a form that can be used as a feedstock by refineries. Paes and Throckmorton (2008) noted that the development of the oil sand reserves requires significant investment in order to achieve the economic production of oil.

Table 2.1 shows the volume of bitumen being produced through mining and in-situ as well as established reserve that could be extracted by both methods of projection.

Table 2.1 Volumes and Established Reserves of Crude Bitumen in Alberta (millions of barrels)
Source: ERCB, "Alberta's Energy Reserves 2009 and Supply/Demand Outlook 2010---2019". 2010

Recovery Method	Initial Volume-In-Place	Initial Established Reserves	Cumulative Production	Remaining Established Reserves
Total	1,802.7	176.7	6.9	169.8
Mining	130.8	38.7	4.5	34.2
In situ	1,671.9	138.0	2.4	135.5

Honarvar et al. (2011) in their publication for Canadian Energy Research Institute (CERI) study estimated investments, reinvestments, and revenues from operation of new oil sands projects is approximately $2,077 billion during the period 2010 - 2035. Of the amount, $253 billion is considered strategic initial capital for construction and $1,824 billion for operation, maintenance and sustaining capital.

2.7 Bitumen Extraction Cost in Alberta Oil Sands

Oil price including Alberta oil is dictated by supply and demand. According to Alberta Government publication Alberta’s Heavy Oil Prices (2013) there are many different varieties and grades of crude oil. Alberta oil is referred to as heavy crude oil because it is thicker and more difficult to refine. The benchmark for Alberta oil is Western Canada Select (WCS) is priced at $58 USD per barrel. According to Wood Mackenzie as quoted by Oil Price (2013) and The Globe and Mail (2013) new oil sands mines require prices of around $80 USD per barrel to break even while in-situ projects require $65 - $70 USD per barrel to break even. This explains why there is a rush to start new oil sands projects when the price of oil in the international market hovers above $80 USD per barrel and up. This gives rise to starting projects when engineering design in incomplete in order to cash in on the upward swing of the oil price. As the price of oil drops below $70 per barrel, investment in Alberta oil sands slows down considerably.

2.8 Change Provisions in Construction Contracts

After reviewing 96 contract clauses from different projects, CII (2012) identified design change and construction change clauses as having large impact of utilization, subject to dispute and subject to major disputes in construction projects. Also change is among the nine most problematic clauses in 36 contracts reviewed by CII. According to Oracle White Paper (2009) the change clause could be the most important clause in a construction contract because it specifies that the owner can make changes in quantities or other alterations it deems necessary to complete the work (scope), which can affect the contract time (schedule) or cost (budget). The contractor, on the other hand, is obligated by the change clause to execute changes to the work according to the owner's instructions, provided that a mechanism exists for the contractor to be compensated for the cost and time. Arain (2011) noted that change clauses of project contract ensure that the contract price and time can be adjusted due to changes in field conditions, requested technological improvements, evolving environmental regulations and a host of other conditions both favourable and unfavourable.

Some of the challenges of contract change clauses are that the contract is drafted by the legal team of the owner and reviewed by the legal team of the contractor. The construction teams are usually more focused on executing the project and as such sufficient time is not spent to read and understand the contract.

In the course of this research, the researcher had access to change management provisions from different oil and gas construction contracts and observed that change management did not receive sufficient mention. Some of the contracts have only a clause that focused on change management while the most extensive has only a page devoted to change management. Given the importance of change management in a project, one would think that significant sections of the contract will be devoted to change management. Change is the only occurrence in a project that has the potential of changing the cost and duration course of the project. It could be a source of extra spending by the owner or additional revenue to the contractor.

2.9 Summary

This chapter reviewed previous researches and bodies of work on project change, change management, change order, structure of Alberta oil and gas projects and change contracts. From all the works reviewed, some major key observations include the following:

1) Change is a component of every project.
2) Neglecting change increases the risk on the project.
3) Though change management has been with us for some time now, there is limited number of literatures available on the subject.
4) While contingency reserve is meant to cover operational risks, there is currently no reserve for strategic and global risks.
5) There is the absence of a tool to forecast changes in cost and schedule as a result of change.

6) Alberta oil and gas project are started with incomplete engineering designs thereby giving rise to changes.

In the next chapter, analysis of data collected through questionnaires, interviews and Inventory of Major Alberta Projects (IMAP) will be done in order to further the objectives of this research.

Chapter 3 – Research Methodology and Data Collection

3.1 Introduction

This chapter will document the methodology used for this work. Research methodology is the various procedures, methods, experiments, observations, statistical approaches etc. used by a researcher to carry out a research.

According to Rajasekar, Philominathan & Chinnathamni (2013), research methods are the various procedures, schemes and algorithms used in research. They include theoretical procedures, experimental studies, numerical schemes, statistical approaches, etc. Research methods help us collect samples, data and find a solution to a problem.

This research is being conducted to understand the impact of changes in a project on project cost and duration. In the course of that, determine a system or approach for forecasting changes in cost and schedule in oil and gas projects in Alberta. The focus of this chapter is to describe the methodology to be used in this research.

Research data will be collected through secondary source (IMAP), questionnaires and interviews. Statistical analysis will be used to analyze the collected data. The choice of the research methodology is informed by the need to collect data, observe a trend and make a projection.

The research questions for this research as stated in chapter 1 are:

1) Does change occur in all projects?
2) Is change in project responsible for changes in project cost and duration? Alberta oil and gas project have been known to experience significant cost and schedule overrun. How much of these overrun are caused by changes in the project?

3) Does change in project cost and duration lead to cost and schedule overrun? How significant is the impact caused by change to cost and schedule? If it is established that change is responsible for cost and schedule overrun, how significant is the value of these overruns that are attributable to changes in the project cost and schedule?

4) Which factors are most responsible for changes in project cost and duration?

5) Which construction phase produces the largest change in cost and duration?

6) Can potential changes in a project be forecasted? If so how?

3.2 Research Methodology

Research methodology is the process through which the research objective is achieved in answering the research questions. According to Naoum (2007) research strategy can be defined as the way in which the research objectives can be questioned. He is of the opinion that there are two research strategies namely: qualitative and qualitative. Deciding on the type of strategy to use according to him depends on the purpose of the study and the type and availability of the information which is required.

Alburt (n.d.) stated that the qualitative method permits a flexible and iterative approach, while the quantitative research method permits specification of dependent and independent variables and allows for longitudinal measures of subsequent performance of the research subject.

Research methodology and approach for this research includes the following:

1) Data collection: Three primary sources were used for data collection (see Figure 3.1):

    a. Secondary Data: The foundation of the data used for this research is through data from Inventory of Major Alberta Projects (IMAP) published by Alberta Enterprise and Advanced Education of Alberta government (see appendix E). The data from this sources includes all the project executed in Alberta from 2004 to 2012. Out of the list, 264 project from oil and gas were filtered from the list and used as base data. The projects and organizations were used as the basis for selecting participant for the questionnaire.

b. Questionnaire: A total of 380 questionnaires were distributed online to participants from organizations identified in the IMAP data. From the questionnaire 253 responses representing 66.57% were received (details are contained in subsequent sections).

c. Interview: Based on the responses from the questionnaire, 240 respondents from organizations in the IMAP data agreed to participate in an interview. From the interview, 223 responses were matched to projects in the IMAP data and used for analysis.

2) Statistical Analysis: The research used various statistical tools for analysis which includes correlation analysis, ANOVA test, scatter plots using SPSS; and bar charts, line graphs, frequency distribution using Microsoft Excel.

3) Model: The results of the analysis were used to develop models graphs (see Appendix L) for forecasting changes in cost and duration in different phases of an oil and gas project.

4) Change Management Tool: Equations of the graphs were used to develop a tool for forecasting changes in the cost and duration in a project where the graphs prove inadequate (see section 4.9).

3.3 Sample Size

According to Veal (1997) questionnaire surveys usually involve only a proportion, or sample of the population in which the researcher is interested. There are different methods governing the determination of the size of a sample for a research. The choice of method depends on the size of the population and type of research being undertaken.

From the data collected from IMAP, 264 projects were identified with potentials of meeting the requirement for the research. Additionally, 380 online questionnaires were sent to participants using Fluid Survey. Participants were selected from organization with projects in the IMAP data. Out of the responses, 253 responses were selected representing 66.57% response rate. According to Krejcie and Morgan (1970) sample size for small sample can be determined using the following formula:

$$s = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)}$$

s = Sample size

X^2 = Table value of Chi-Square @ *d.f.* = 1 for desired confidence level

0.10=2.71; **0.05=3.841**; 0.01=6.64; 0.001=10.83

N = Population size

P = Proportion of population targeted (assumed to be 0.50)

d = Degree of accuracy (expressed as a proportion)

d.f.= Degree if Freedom

Given a population size N =380, X^2= the table value of Chi-Square for 1 degree of freedom at the desired confidence level (3.841), P=0.50 (proportion of population targeted and d=0.05 (degree of accuracy), the sample size will be:

$$s = \frac{3.841*380*0.5(1-0.5)}{0.05^2(380-1) + 3.841*0.5(1-0.5)}$$

$$=191$$

As started earlier, a total of 380 questionnaires were distributed out of which 253 responses were received. This is greater than 191 hence the sample size for the research is adequate.

Respondents from the questionnaire were requested to participant in interview in order to match the survey data with the IMAP data. Out of the 253 questionnaire respondents, 240 agreed to participant in the interview. At the end of the interview and matching with IMAP data, 223 projects with complete information were obtained to be used in the research analysis. This number is greater than 191 which is the minimum number of required statistical sample according to the equation above. Figure 3.1 below show the relationship between the IMAP data, questionnaire response and interview.

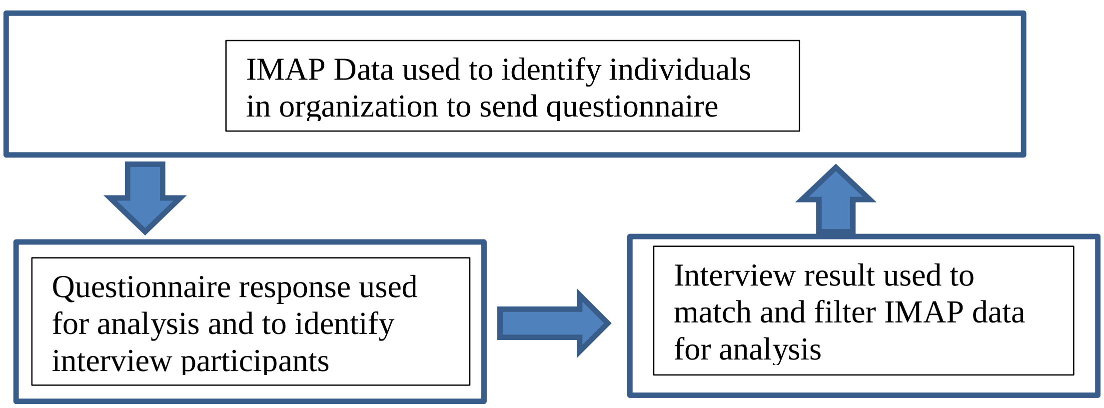

Figure 3.1 Questionnaire Interview and IMAP data relationships

3.4 Data Collection

The researcher designed and administered questionnaire containing 40 questions (see Appendix B) to participants. The questionnaire was accompanied by an introductory letter (see Appendix A) and approval certificate from Conjoint Faculties Research Ethics Board of the University of Calgary (see Appendix A). Respondents were assured of their anonymity and the confidentiality of any information provided including their personal information, organization they work for and their projects. With that assurance, participants freely volunteered information. The questionnaire was divided into seven sections namely: A, B, C, D, E, F and G.

Section A – Participants' Profile – The purpose of this section is to obtain information about participant's background, experience and involvement in projects in the oil and gas sector in Alberta. No identifying person information about the participants were collected.

Section B – Organizations' Project Involvement - The purpose of this section is to obtain information on the role of the participant's organization in the oil and gas projects in Alberta. The three major roles of organizations in oil and gas projects for the purposes of this study are owner organization; design and engineering organization and construction contractor organization. These are the three major participants in any project. Whereas there are so many other organizational types that are involved in oil and gas projects, the other organizations derive their involvement from the major three specified earlier. The subsector of this section include:

Section B1 – Project Involvement

Section C – General - The purpose of this section is to obtain information on the phase of the project the participants and their organization participated in. The project phases for the purposes of this research as illustrated in Figure 3.2.

Section C includes the following subsections:

Section C1 - Contract Type

Section C2 – Overall Change in the Project

Section C3 – Engineering Percent Complete

Section D – Change Management Organization and Knowledge - The purpose of this section is to determine the level of practice of project change management in organizations, including the existence of project change management unit, leadership of change management as well as participants' experience in project change management.

Section D1 – Existence of Change Management Unit in Organization

Section D2 – Location of Change Management Function in Organization

Section D3 – Management of Change Management Unit

Section D4 – Presence of Change Management Processes and Procedures

Section D5 – Knowledge of Change Management

Section E – Project Cost - The purpose of this section is to obtain information about the changes in the project, initial cost and changes in cost at different phases of the project the participants were actively involved in. Section D includes the following subsections:

Section E1 – Cost – Project Budget

Section E2 – Changes in Project Cost – Bid Phase

Section E3 – Changes in Project Cost – Pre-Construction Phase

Section E4 – Changes in Project Cost – Construction Phase

Section E5 – Changes in Project Cost – Construction Phase

Section F – Project Duration The purpose of this section is to obtain information about the changes in the project, initial duration and changes in duration at different phases of the project the participants were actively involved in. Section F includes the following subsections:

Section F1 – Change in Project Duration

Section F2 – Change in Project Duration – Bid Phase

Section F3 – Change in Project Duration - Pre-Construction Phase

Section F4 – Change in Project Duration - Construction Phase

Section F5 – Change in Project Duration – Commissioning Phase

Section G – Ranking - The purpose of this section is to collection information on the opinion and experience of the participant on the impact of change on project cost and schedule. Participants were asked to ranking causes of change in order of importance.

The questionnaires were designed to collect data on four phases of the project where changes are likely to originate namely: bid, preconstruction, construction and commissioning. The phases of projects as shown in Figure 3.2 is authored by the researcher for the purposes of this study.

The questionnaire data was summarized using data keys developed for this research (see Appendix F).

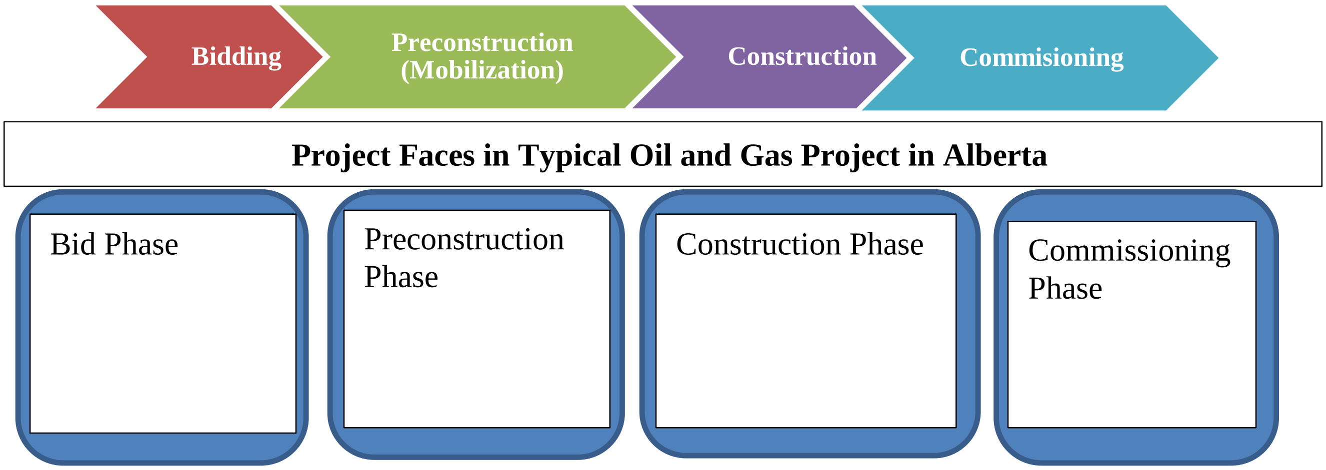

Figure 3.2 – Phase in Oil and Gas Project in Alberta

3.5 Nature of Collected Data

Due to the sensitive nature of the data required for this research and the promise of confidentiality made to participants to protect their identity, the organization names, project names and project location will not be disclosed. Without this promise of anonymity, data for the research would not have been collected as the IMAP data was not sufficient to identity changes in cost in different phases of the project which was made possible from the interviews.

3.6 Summary

This chapter described the methodology adopted in this research. The methodology includes data collection, statistical analysis and presentation of results. Initial statistical analysis was done to determine the sample size of the data to be collected. The data was split into phases to enable in-depth study of the nature of changes that occurred in each phase.

The next chapter will focus on analysis of data collected from efforts in this chapter.

Chapter 4 – Analysis and Discussion of Result

4.1 Introduction

In this chapter, the analysis of data collected in the course of this research will be done to determine if the research questions will be answered or supported by the data. One of the objectives of this research is to develop a tool that will assist oil and gas organizations to effectively estimate and plan for potential changes in a project, so as to reduce avoidable changes in project cost and duration. Without proper planning, management and monitoring of the project, changes will cause cost and duration overruns. The situation may also result in disagreement leading to disputes, claims and counter claims and legal actions which could be expensive to the owner, contractors and economy as a whole. This chapter will be divided into the following sections: Research Questionnaire, Characteristics of the Data, Analysis, Hypothesis Testing, Model and Change Management Tool (Change Manager 1.0) developed in the course of this research.

Existing bodies of works have suggested different values for costs and schedule overruns: Semple et al. (1974) 30% - 80 %, Love and Li (2000) 10% - 15%, Flyvbjerg et al. (2003) 80% - 200%, Senaratne and Sexton (2004) 10% -15%. None of the studies reviewed focused on oil and gas projects in Alberta, hence the reason for this research.

4.2 Research Data Questionnaire and Interview

Following ethics board approval of the research, questionnaire and interviews were conducted. A total of 380 questionnaires requests were sent to participants. The participants were identified through personal contacts, social media contacts and referrals from friends, co-worker and acquaintances. Due to the sensitive nature of the data required for the research, participants were assured of their anonymity including the identity of their organizations and projects. Consequently codes were assigned to represent the project and organizations' names.

Secondary data was obtained from the Inventory of Major Alberta Projects (IMAP 2012)[6], published quarterly by Albert government through the Alberta Enterprise and Advanced Education. This data source is publicly available for each of the preceding quarter. A request was made to Alberta Enterprise and Advanced Education and they provided the researcher with data from 2004 to 2012. In order to avoid potential cross matching that could reveal the identity of the organizations and participants, the names of the organization and project description has been stripped from the IMAP data (see Appendix E for partial list of the projects). The research used IMAP data on oil and gas projects executed in Alberta from year 2004 to 2012. The choice of the period is based on when structured data started to be kept by Alberta Enterprise and Advanced Education. As stated in section 3.3 and illustrated in Figure 3.1, 253 out of 380 questionnaires responses were received. Out of this number, 240 participants agreed to participant in personal interviews. At the end of the exercise, a total of 223 projects meeting the requirement for the research was selected as the sample size.

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[6] Quarterly data is publicly available at http://albertacanada.com/business/statistics/inventory-of-major-projects.aspx. A request was made to Alberta Innovation and Advanced Education who provided data from 2004 – 2012.

4.3 Characteristics of the Data

The IMAP data includes all project in Alberta from both the public and private sectors. The initial filtering was done to select projects identified as chemicals & petrochemicals, oil & gas, oilsands and pipelines projects. Company name and project descriptions were removed from the data. Finally, projects with estimated initial cost of $5 million and above and estimated initial duration of 6 months and above were selected. There were no upper limit for cost and duration. This resulted in data with estimated initial cost range of $6 million to $15,200 million and estimated initial duration range of 6 months to 9 years. The reason for this data boundary is because of the huge dispersion in data creating outliers which is capable of affecting the result of the analysis. Furthermore survey and interview respondents indicated that most oil and gas projects have estimated initial cost in excess of $5 million and durations of six months and above. The details and character of the data are discussed in the sections below.

4.3.1 IMAP Data

Secondary data from Inventory of Major Alberta Projects (IMAP) used for this research were collected from Alberta Innovation and Advanced Education. The data contains information on all projects executed in Alberta by both public and private sectors from 2004 to 2012. A summary of partial list of the data is available in Appendix E. To protect the identity of participants (because of the sensitive nature of the data provided), the company names, project names and project description in the IMAP data were removed and replace with codes to avoid possible cross referencing of the data. This is in fulfilment of the promise made to survey participants in compliance with the requirement of University of Calgary Ethics Board. The projects were matched with information obtained from participants through the interview as part of the survey (see figure 3.1).

4.3.2 Survey Questionnaire

The questionnaire (see Appendix B) was subdivided into seven sections namely:

a. Section A – Participant's Profile.
b. Section B – Organization's Project Involvement.
c. Section C – General.
d. Section D – Change Management Organization and Knowledge
e. Section E – Project Cost.
f. Section F – Project Duration.
g. Section G – Ranking.

The questionnaire responses were analyzed using Microsoft Excel and SPSS statistical tools. Detailed results of the analysis is available in Appendix G. A summary of the results are shown in tables 4.1 – 4.15 and Figure 4.1 – 4.16. Most of the raw data collected through questionnaire were reformatted in a form that could be analyzed using SPSS and Microsoft Excel. Codes were assigned to the data for this purpose. All the codes used in analyses are available in Appendix F.

4.3.3 Demographics of Respondents

Analysis was done to understand the demography of the survey participants. Table 4.1 shows the category of professionals in the oil and gas industry that participated in the survey. The mix of participants in the table represents the major professionals that are present in any given project. Depending on the size and complexity of the project, other professionals not listed in the table may be present. In general, the list can be said to be representative of a typical oil and gas project. As evident in the table, project managers, project engineer and construction manager are the dominant professions in oil and gas projects in Alberta accounting for 67.8% of project participants according to survey responses. For the purposes of this study, craft and trades manpower were not included in the survey as they are not part of management in any project.

Table 4.1 - Participant's Role Distribution of their Organization

Roles	Frequency	Percent
Project Manager	59	26.5%
Project Engineer	41	18.4%
Construction Manager	51	22.9%
Contract Manager	16	7.2%
Project Control Manager	16	7.2%
Change Manager	9	4.0%
Estimating Manager	12	5.4%
Scheduling Manager	9	4.0%
Others: Specify	10	4.5%
Total	223	100.0%

To provide representative opinion across the industry, participants were chosen from all the major organizations in a typical project. As shown in Table 4.2, majority of survey participants' work for construction contractor organizations, followed by owner organizations and Engineering, Procurement & Construction (EPC) organizations. The three groups accounting for 79% of survey responses represent the major organizational participants in any oil and gas project in Alberta. The owner organization owns the project. The EPC organization does the engineering design while construction contractor organization is responsible for building the project. There are other organizations like Construction Management, Specialist Subcontractors, Prime Contractor, and Suppliers etc. who provide one service or the other. Each of these organizations play one role or the other in any project. In some projects, an organization may fill more than one role. For instance, an EPC organization can also be the construction contractor organization and even the Prime contractor. The construction contractor organization can also act as a supplier; provide additional subcontract services or even construction management functions. The owner on its part could also be the prime contractor. It is for this reason that while the total number of responses is 223, the total in Table 4.2 is 273 as some organizations play more than one role.

Table 4.2 Role of Organization Distribution of Project

Role of Organization in Project	Responses N	Responses Percent
Owner Organization	61	22.3%
Construction Management Organization	12	4.4%
Construction Contractor Organization	98	35.9%
EPC Organization	57	20.9%
Subcontractor Organization	11	4.0%
Prime Contractor	26	9.5%
Suppliers	6	2.2%
Others: Specify	2	0.7%
Total	273	100.0%

4.3.4 Participants' Experience

The years of experience of survey participants in oil and gas industry; in their organizations and in their current role are shown in Table 4.3. From the table, participants with less than 5 years of experience dominate each of the factors (experience in oil and gas industry, experience in organization and experience in their present role). The years of experience for participants with less than 5 years of experience range average 26% of responses. Given that 5 years of experience has the highest percentage in each of the categories that raises a question on the impact or relationship between years of experience and quality of change management in the projects. Viewed from another perspective, an average of 70% of participants have up to 19 year of experience in the oil and gas industry, in their organization and present role. Given this number of years of experience of 70% of participants, this research will consider the opinion expressed in survey as expert opinion that could be relied upon for the purposes of this research.

Table 4.3 – Participants Experience

Years	Experience in Oil and Gas Industry		Year of Experience in Organization		Years of Experience in Present Role	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
< 5 Years	45	20.2	63	28.3	62	27.8
5 - 9	43	19.3	60	26.9	58	26
10 -14	29	13.0	44	19.7	13	5.8
15 – 19	44	19.7	17	7.6	18	8.1
20 – 24	33	14.8	22	9.9	22	9.9
25 – 29	20	9.0	13	5.8	26	11.7
30 +	9	4.0	4	1.8	24	10.8
Total	223	100.0	223	100.0	223	100.0

4.3.5 Degree of Engineering Percent Complete

One of the issues the research investigated is the relationship between the level of engineering percent complete and the changes in cost and schedule in different phases of the project. The general notion in the industry is that the lower the level of engineering percent complete prior to contract award, the higher the number of changes in cost and duration that will occur in the project. Table 4.4 shows the responses of survey participants on the engineering percentage complete prior to bid. As can be seen in the table, 60% of the projects have 54.3% engineering percent complete prior to contract award. This is an indication of low level of engineering percent complete in oil and gas projects and could be reason for most changes in projects.

Table 4.4 - Percentage of Engineering Complete

Engineering Complete	Frequency	Percent (%)	Cumulative %
0-20	20	9.0	9.0%
21-40	58	26.0	35.0%
41-60	43	19.3	54.3%
61-80	43	19.3	73.6%
81-100	59	26.4	100.0%
Total	223	100.0	

4.3.6 Cost and Duration

Responses from survey participants show an overwhelming agreement that changes occurred in their projects and that these changes were responsible for changes in cost and duration as shown in Table 4.5. An average of 85.65% of survey participants stated that cost and schedule changes occurred in their projects and that the changes where caused by changes in the project. These project changes include design change, site condition, scope change, changes in regulations, changes in technology, market conditions, management decisions, changes in environmental conditions, material and equipment, fast tracking and other causes. This is not unexpected as it is common knowledge in the industry that no project is executed exactly as designed. Given the magnitude and complexities of oil and gas projects, change is sure to occur. The challenge has been the magnitude of the change that can be expected in term of the financial cost as well as project duration. Anticipating, planning and managing the change process is a sure way to avoid project overrun as well as costly claims and counter claims.

Table 4.5 – Cost and Schedule change occurrence in Projects

Item	Yes		No	
	Response	Percent	Response	Percent
Where there cost changes in project	192	86.1%	31	13.9%
Where cost changes related to changes in the project	187	83.9%	36	16.1%
Where there schedule change in the project	190	85.2%	33	14.8%
Where schedule change related to changes in the project	195	87.4%	28	12.6%

It should be noted that there are other factors, such as inflation, delays, productivity etc. that can cause changes in project costs and duration. These other causes were not considered as causes of changes in project cost and duration for the purposes of this study. Only causes of project cost resulting from changes in the project are considered in this research. The sources of these changes are discussed further in this research.

Table 4.6 shows the response from participants on the causes of change in each phase of the project lifecycle. The causes were chosen based on information from literature review, interaction with professional in the oil and gas industry as well as experience of the researcher having worked as Manager Change Management in major oil and gas projects in Alberta. Participants were given the option to identify other causes of change not listed in the table through the "Others: Please specify" option in the questionnaire. The causes of change were surveyed for each of the four phases of a project lifecycle (Bid, Preconstruction, Construction and Commissioning). The table shows the number and percentage contribution from each of the factors to changes in cost and duration in a project. The bolded numbers represent causes that survey and interview respondents ranked highly in their responses. In the table, it could be noticed that while the total number of projects used for analysis is 223, the total number of responses in each of the phases were more than 223. The reason is because the participants were given the option in choosing more than one factor and rank them in their order of importance.

Table 4.6 – Summary of Major Causes of Cost and Schedule Changes in Different Phase of a Project

Phases	**Causes**	**Cost**		**Schedule**	
		N	**Percent**	**N**	**Percent**
Bid Phase	Design Changes	129	**35.5%**	83	**24.5%**
	Site Condition	4	1.1%	13	3.8%
	Scope Change	112	**30.9%**	104	**30.7%**
	Changes in Regulations	3	0.8%	9	2.7%
	Change in Technology	4	1.1%	11	3.2%
	Market Conditions	13	3.6%	9	2.7%
	Management Decisions	87	**24.0%**	69	**20.4%**
	Environmental	2	0.6%	5	1.5%
	Materials and Equipment	4	1.1%	34	**10.0%**
	Fast Tracking	1	0.3%	2	0.6%
	Others: Specify	4	1.1%	-	-
	Total	363	100.0%	339	100.0%
Preconstruction Phase	Design Changes	123	**23.9%**	99	**29.4%**
	Site Condition	89	**17.3%**	53	**15.7%**
	Scope Change	130	**25.3%**	105	**31.2%**
	Regulations	1	0.2%	3	0.9%
	Change in Technology	1	0.2%	4	1.2%
	Market Conditions	11	2.1%	12	3.6%
	Management Decisions	102	**19.8%**	49	**14.5%**
	Environmental	47	9.1%	2	0.6%
	Materials and Equipment	5	1.0%	5	1.5%
	Fast Tracking	1	0.2%	1	0.3%
	Others: Specify	4	0.8%	4	1.2%
	Total	514	100.0%	337	100.0%

Table 4.6 (Cont'd)

Phases	**Causes**	**Cost**		**Schedule**	
		N	**Percent**	**N**	**Percent**
Construction Phase	Design Changes	73	**11.7%**	58	**12.5%**
	Site Condition	143	**23.0%**	89	**19.2%**
	Scope Change	104	**16.7%**	78	**16.8%**
	Regulations	4	0.6%	4	0.9%
	Change in Technology	-	-	-	-
	Market Conditions	2	0.3%	5	1.1%
	Management Decisions	81	**13.0%**	72	**15.5%**
	Environmental	77	**12.4%**	59	**12.7%**
	Materials and Equipment	117	**18.8%**	88	**19.0%**
	Fast Tracking	16	2.6%	6	1.3%
	Others: Specify	5	0.8%	5	1.1%
	Total	622	100.0%	464	100.0%
Commissioning Phase	Design Changes	10	3.3%	27	6.6%
	Site Condition	13	4.2%	39	9.5%
	Scope Change	38	**12.4%**	57	**13.8%**
	Regulations	3	1.0%	4	1.0%
	Change in Technology	4	1.3%	2	0.5%
	Market Conditions	10	3.3%	9	2.2%
	Management Decisions	75	**24.5%**	59	**14.3%**
	Environmental	7	2.3%	53	**12.9%**
	Materials and Equipment	127	**41.5%**	147	**35.7%**
	Fast Tracking	9	2.9%	5	1.2%
	Others: Specify	10	3.3%	10	2.4%
	Total	306	100.0%	412	100.0%

From the table, it could be seen that design change is a major cause of cost and schedule change in all phases of the project except commissioning phase. This is not unexpected as projects freeze design at some point in time of the project execution prior to project completion. It is a common knowledge in the industry that design changes at the early phases of the project is less expensive to implement than changes in the latter part of a project. Unexpectedly, site condition is ranked highly only in the preconstruction and construction phases (Preconstruction 17.3% and 15.71% and Construction 23% 19.2%) of projects for both cost and schedule respectively. This is contrary to popular opinion in the industry that site condition is the major cause of change in any project. Scope change is one of the factors that was ranked highly (30.9% & 30.7%, 25.3% & 31.2%, 23.0% & 16.7 & 16.8& and 12.4% &12.7 for Bid, Preconstruction, Construction and Commissioning phases respectively) in all phases of the project for cost and schedule respectively. Scope change has a high cost response from the survey in the bid phase and declines in other phases. For changes in schedule, the percentage contribution of scope changes is the same for bid and preconstruction phase but declines from construction through to commissioning phases. Management decision is another factor that runs through all the phases of the project for both cost and schedule. This is an area that requires serious consideration. Management decision has high impact on project changes, according to survey responses. Ability of management to freeze changes to the project, proper planning and management of change, will assist in controlling project cost as well as duration overruns. Other factors that were ranked highly according to the survey responses include environmental condition and materials & equipment especially in the construction and commissioning phases of the project.

With proper planning, monitoring and control, the impact of these causes can be significantly reduced which will lead to cost efficient and timely completion of any project.

From Table 4.7, over 80% of respondents agree that changes in a project are responsible for project cost and schedule overruns. This is consistent with Table 4.4 which show that about 85% of survey responses say that changes occurred in the projects they participated in and that the changes in project costs and durations were caused by changes in the project.

Table 4.7 – Ranking of Impact of Cost and Schedule Overrun

Options	Changes in projects are responsible for project cost overrun		Changes in projects are responsible for project schedule overrun	
	Frequency	Percent (%)	Frequency	Percent (%)
Strongly Disagree	15	6.7	11	4.9
Disagree	13	5.8	12	5.4
No Opinion	7	3.1	20	9.0
Agree	77	34.5	91	40.8
Strongly Agree	111	49.8	89	39.9
Total	223	100.0	223	100.0

All the results of the survey are available in Appendix G.

4.4 Analysis

The research data were analysed using correlation analysis, scatter plot, t-test and ANOVA from SPSS statistical tool; box and whisker plots, frequency distribution, and line graphs from Microsoft Excel. Results of the analysis are presented in tables, figures and graphs in subsequent sections.

Due to the wide range of cost and duration data ($6 million to $15,200million and 6 months to 9 years respectively), the data were divided into categories for the purposes of this study as shown the Table 4.8. The reason for this division is because the range of the data varied widely and analysing them as one group of data will introduce undue skewness in the result. Furthermore, categorizing the data enabled a better understanding of the character of each of the projects. Analyzing the data in this manner has the added advantage of detailed analysis of each category. The research categorized cost into Large, Medium and Small costs and duration into Long, Medium and Short duration. These classifications are the creation of this research for the purposes of better analysis of the research data after understanding the level of dispersion in the collected data.

Table 4.8 – Cost and Schedule Categories

Estimated Initial Cost		Estimated Initial Duration	
Categories	Amount ($million)	Categories	Duration
Large	> =$1,000	Long	> 2 years
Medium	>$100 - $999	Medium	>1 year - 2 years
Small	$5 - $100	Short	0.5 – 1 year

For the purposes of this study and analysis, large category projects range in estimated initial cost from $1billion and above, medium category projects starts from $100 million to under $1billion in estimated initial cost while small projects $100 million to $5million in estimated initial costs shown in Table 4.8. Similarly, Long duration category are projects with over 2 years in estimated initial duration; medium duration projects have estimated initial duration of over 1 year to 2 years and short projects are from 6 months to 1 year in duration.

To analyze the data, the estimated initial cost, engineering percent complete, changes in cost and duration in different phases were used.

Central tendencies of min, median, standard deviation and max were used to understand the variability in the data. The central tendency of the data is shown in Table 4.9 for cost and duration categories for different phases of the project. Also included are engineering percent complete and estimated initial duration for each of the projects.

Table 4.9 – Summary of Central Tendencies of Research Data

Categories	Central Tendency	Engr Percent Complete	Estimated Initial Cost & Duration	Different Project Phases			
				Increase Bid	Increase Preconstruction	Increase Construction	Increase Commissioning
Large Cost	Min	10%	$1000m	$28m	$40m	$348m	$27m
	Median	40%	$2000m	$154m	$325m	$1284m	$140m
	Std Dev	13.03	3220.18	233.45	423.35	2382.46	185.21
	Max	70%	$15200m	$1090m	$1972m	$12900m	$853m
	Count	46	46	-	-	-	-
Medium Cost	Min	10%	$110m	$3m	$2m	$7m	$0.5m
	Median	52.71%	$321.32	$21m	$39m	$129m	$15m
	Std Dev	24.85	119.61	21.51	47.93	174.91	25.64
	Max	100%	$900m	$140m	$290m	$850m	$150m
	Count	90	90	-	-	-	-
Small Cost	Min	7%	$6m	$0.5m	$0.5m	$1.5m	$0.5m
	Median	55%	$36m	$3.66m	$7.93m	$19m	$3.65m
	Std Dev	27.02	27.24	4.01	14.11	20.86	3.82
	Max	100%	$100m	$29m	$43m	$98m	$17m
	Count	87	87	-	-	-	-
Long Duration	Min	10%	2.1(yr)	0.1(yr)	0.1(yr)	0.2(yr)	0.1(yr)
	Median	45%	4.52(yr)	0.2(yr)	0.3(yr)	0.6(yr)	0.2(yr)
	Std Dev	19.77	1.59	0.11	0.17	0.24	0.11
	Max	90%	9(yr)	0.5(yr)	1.08(yr)	1.44(yr)	0.6(yr)
	Count	99	99	-	-	-	-
Medium Duration	Min	10%	1.1(yr)	0.1(yr)	0.1(yr)	0.1(yr)	0.1(yr)
	Median	54.6%	1.51(yr)	0.1(yr)	0.2(yr)	0.4(yr)	0.1(yr)
	Std Dev	26.52	0.23	0.07	0.13	0.21	0.06(yr)
	Max	100%	2(yr)	0.4(yr)	0.8(yr)	1.6(yr)	0.4(yr)
	Count	75	75	-	-	-	-
Short Duration	Min	9%	0.5(yr)	0.1(yr)	0.1(yr)	0.1(yr)	0.1(yr)
	Median	56.92%	0.72(yr)	0.1(yr)	0.2(yr)	0.3(yr)	0.1(yr)
	Std Dev	27.44%	0.12(yr)	0.04(yr)	0.08(yr)	0.17(yr)	0.07(yr)
	Max	96%	1(yr)	0.2(yr)	0.4(yr)	0.9(yr)	0.3(yr)
	Count	49	49	-	-	-	-

Additional details of the summary information in Table 4.9 are available in Appendix H.

From the data, frequency distribution bars, and graphs were plotted see sample in Figures 4.1 and 4.2. Additional charts and graphs are available in Appendix I.

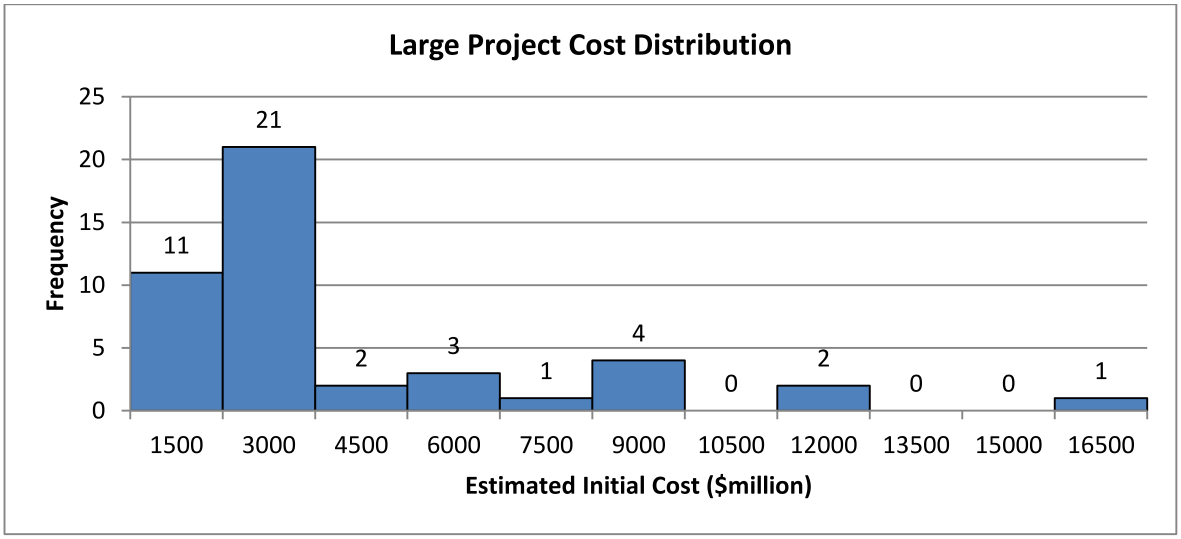


Figure 4.1 Large Cost Frequency Distribution Bar

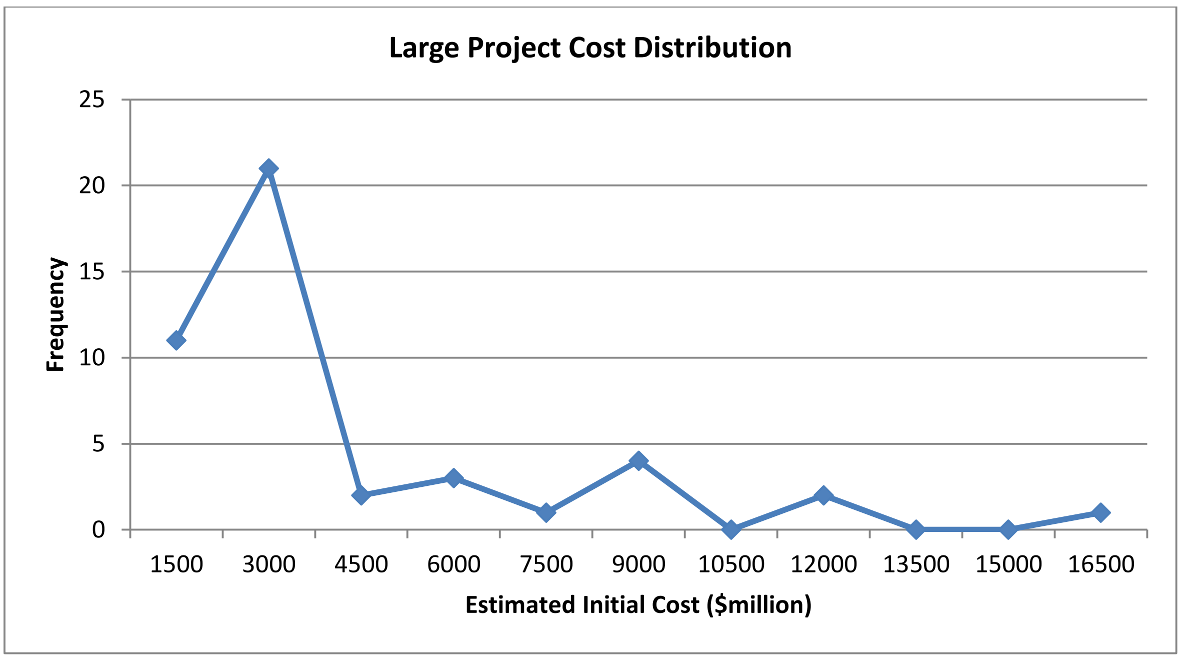


Figure 4.2 Large Cost Frequency Distribution Graph

Additional information is available in Appendix I.

From the frequency tables it could be seen that the shape of the large cost project curve is skew to the left with a long drawn out tail. This indicates that there is a cluster of values within the lower part of the large projects and a few data points with very large values spaced out. Medium cost projects show identical shape for the frequency curve similar to the large cost project but skewed to the left with a long right tail. Small project cost however, has a near bell shaped curve (see Appendix I).

Long, medium and short duration projects have nearly bell shaped curves which indicates that most of the data points are clustered near the middle of the curve (see Appendix I).

Engineering percent complete has an almost bell shaped curve (see Appendix I).

4.5 Costs

To visually depict the profile of the data in different phases of the project, box and whisker plots were used. The box and whisker plots for different categories are discussed in the sections below. Additional box and whisker plot are available in Appendix J.

4.5.1 Large Cost Projects: Changes in Cost over Project Lifecycle

Large cost projects are projects from $1billion dollars and above in estimated initial cost. Estimated initial cost of large projects used for this research range from $1,060 million to $15,200 million. The estimated initial cost was plotted against changes in cost in different phases – bid, preconstruction, construction and commissioning as shown in Figure 4.3.

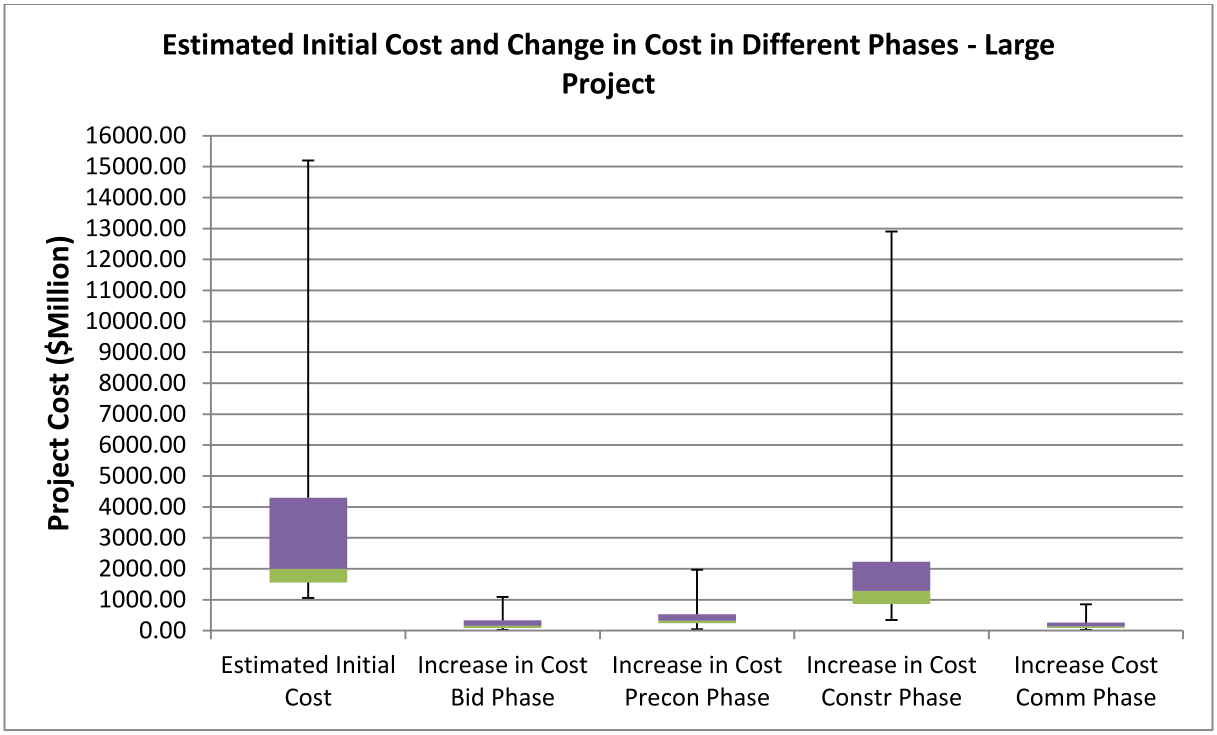


Figure 4.3 - Estimated Initial Cost and Change in Cost in Different Phase - Large Project

Figure 4.4 shows the box and whisker plot for changes in cost in different phases without the estimated initial cost. As shown in Figures 4.3 and 4.4, most of the changes in cost occur in the construction phase of the project. This is not unexpected as construction phase is when ideas in drawings and specifications are actualized. If the design and specifications does not meet owner's expectation as construction progresses, changes are made to the project in order to realize owner's expectation. Even when the drawings are exactly as intended, the reality may also create a change of mind on the part of the owner as the project begins to take shape and evolve. As projects execution progresses from bid to construction phase, the cost of change increases at different rates. A change could be made in the bid or preconstruction phase without a significant cost implication. If the same change is made at the construction or commissioning phase, the cost implication will be considerably high.

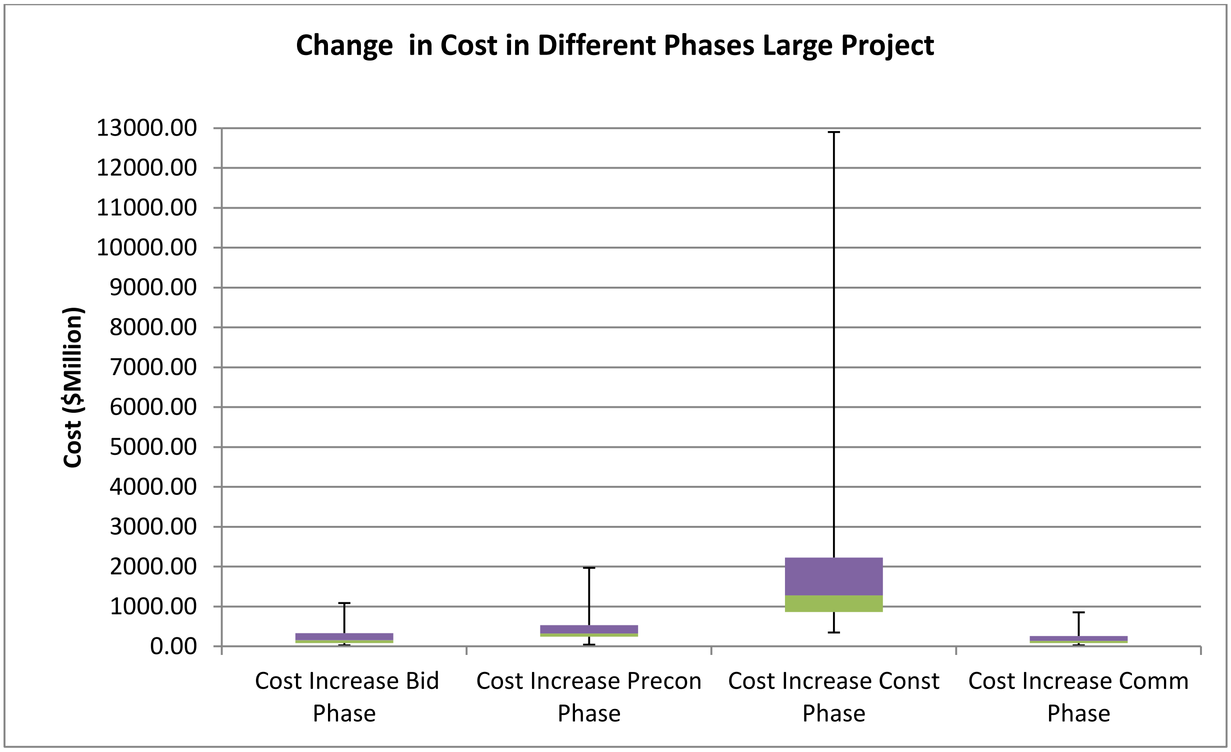


Figure 4.4 - Change in Cost in Different Phases Large Project

4.5.2 Medium Cost Projects: Changes in Cost over Project Lifecycle

Projects with estimated initial cost ranging from above $100 million to less than $1billion are classified as medium project for the purposes of this study. Medium cost project data for this study range from $110 million to less than $900 million. Figure 4.5 is a box and whisker plot showing change in cost in different phases in a medium project. It could be seen from the chart that changes in cost in the construction phase is the dominant location of cost increase in medium projects. This is consistent with the result of large projects where the largest increase in cost occurred in the construction phase as well.

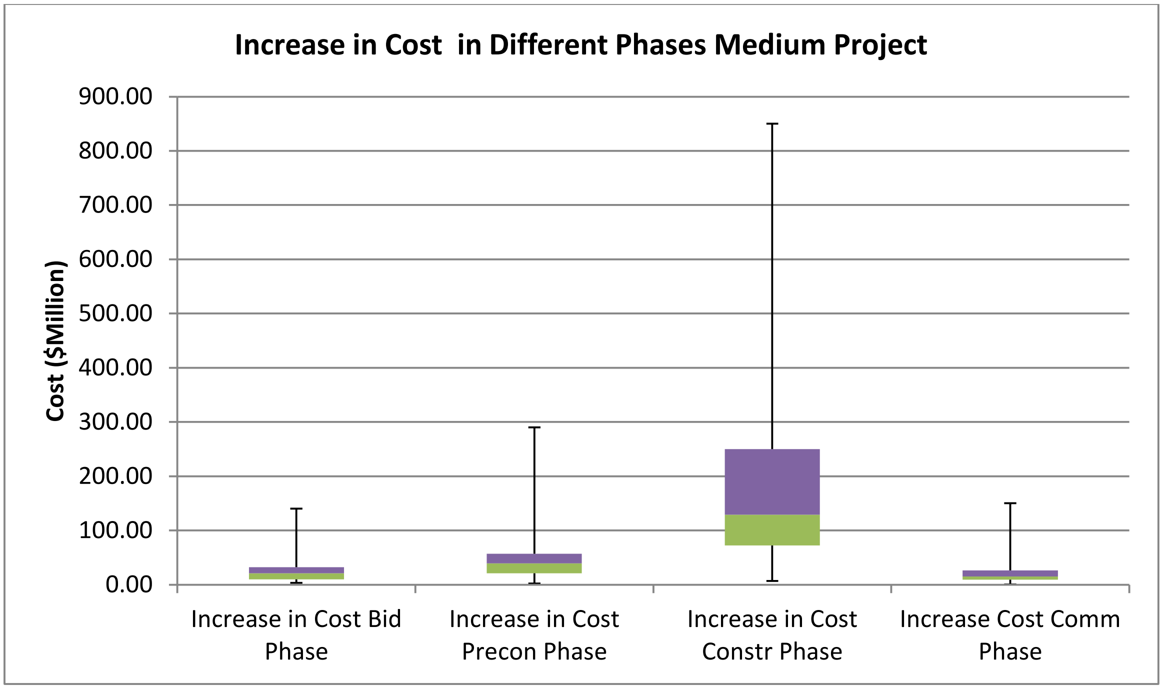


Figure 4.5 - Increase in Cost in Different Phases Medium Project

4.5.3 Small Cost Projects: Changes in Cost over Project Lifecycle

Small cost project range in cost from $5 million to $100 million in estimated initial cost. For this research small project data ranges from $6 million to $99 million in estimated initial cost (see Appendix J). Like large and medium project, the biggest change in cost in small projects occurred in the construction phase as shown in Figure 4.6.

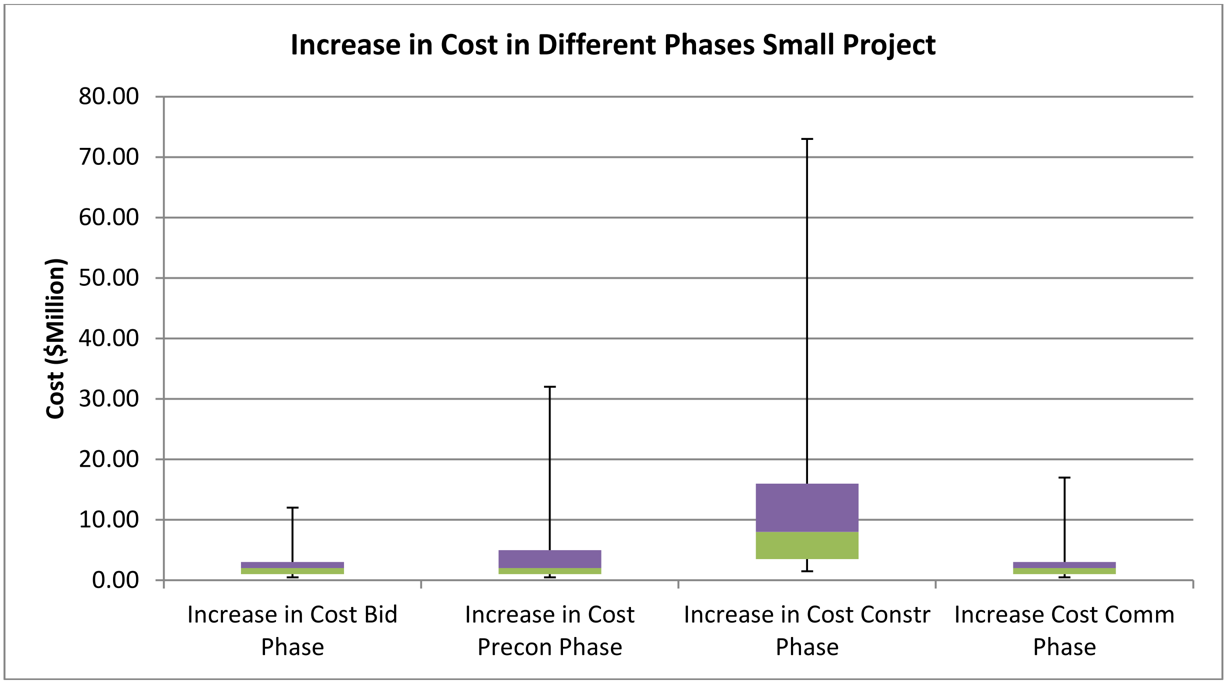


Figure 4.6 - Increase in Cost in Different Phases Small Project

Obvious question from the box and whisker plot could be what can be done to control the amount of changes especially in the construction phase. If this phase is responsible for the largest cost increase in any project, controlling changes in this phase will have an obvious impact on the amount of project cost overruns. The consequences of not doing so may be the different between a successful or failed project.

4.6 Duration

Data collected for the project vary in duration from 6 months to 9 years in estimated initial duration. To manage the data effectively, the duration was divided into categories; long, medium and short durations as stated earlier. Long duration projects are projects with estimated initial duration of more than 2 years. Medium duration projects range from estimated initial duration of over 1 year to 2 years, while short duration project have estimated initial duration of 6 months to 1 year. These categories are adopted for the purposes of this study.

4.6.1 Long Duration Projects: Changes in Duration over Project Lifecycle

Projects that qualify as long duration project from the data collect range from 2.1 years to 9 years in estimated initial duration with a standard deviation of 1.59 and median of 4 years. Like cost category, construction phase has the biggest changes in duration. This is not unexpected as increase in cost results from increase in the volume of work and time will be required to execute them. While changes in duration in the construction phase is the dominant cause of change in long projects, changes in duration in the bid and preconstruction phase are equally large as shown in Figure 4.7. One important observation here is that the changes in cost and duration are not linearly related. This mean that a 10% change in cost does not necessarily lead to a 10% change in duration.

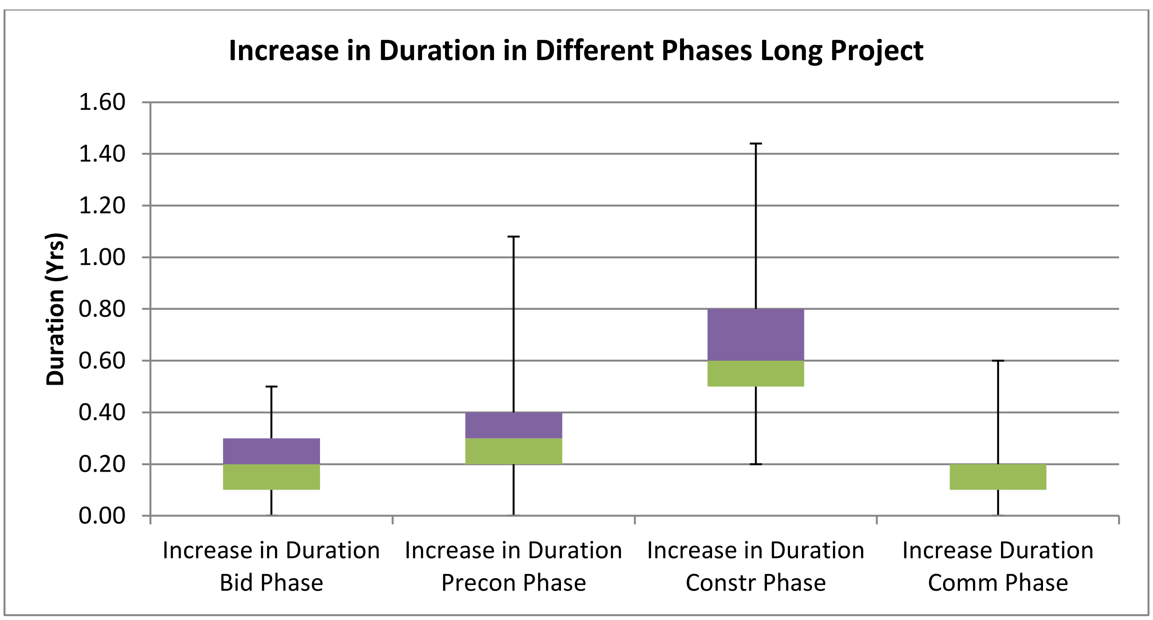


Figure 4.7 - Increase in Duration in Different Phases Long Project

4.6.2 Medium Duration Projects: Changes in Duration over Project Lifecycle

Medium duration projects range in estimated initial duration from over one year to 2 years. As shown in Figure 4.8, the biggest duration change occurred in the construction phase. The reason all the quartiles did not appear in the box and whisker plots for bid, preconstruction and commissioning phases is because the minimum values in the 25th percentile, median and 75th percentiles are the same in each of the phases, thus creating a zero value. This means that the rate at which the duration change for each of the projects in the phases noted above is very gradual. This is a bit of a surprise as one would have expected a radical rate of change for the projects in each of these phases.

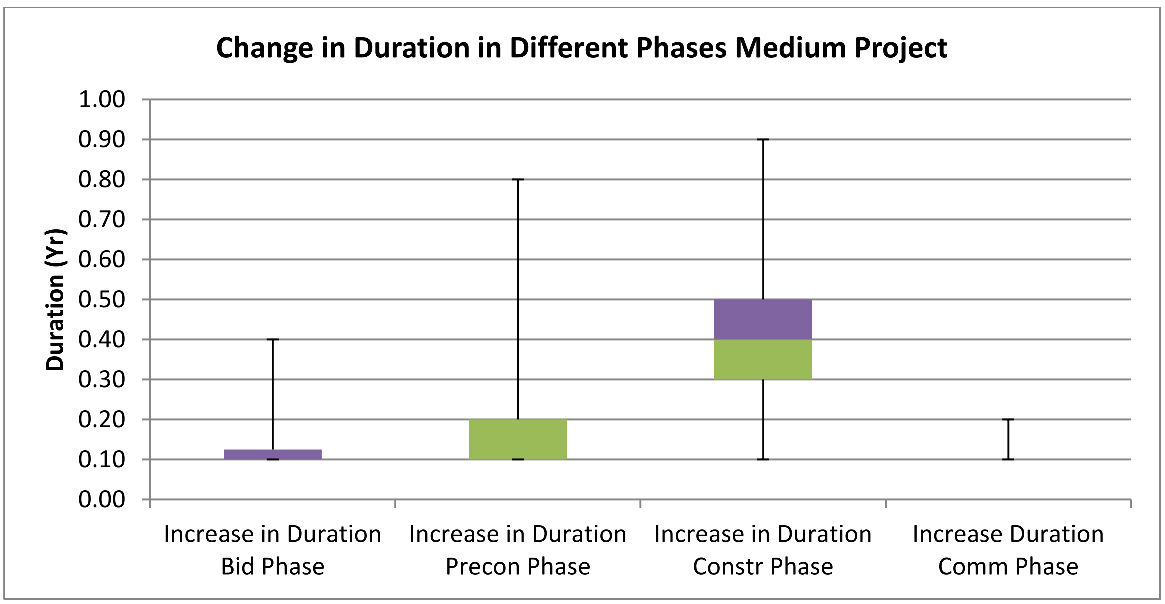


Figure 4.8 - Change in Duration in Different Phases Medium Project

4.6.3 Short Duration Projects: Changes in Duration over Project Lifecycle

Short projects range in duration from 6 months to one year in estimated initial duration. Like large and medium duration projects, small duration project experienced biggest change in duration in the construction phase. Also like medium duration projects, most of the percentiles are the same for each of the phases thereby creating a zero value for plotting purposes as shown in Figure 4.9.

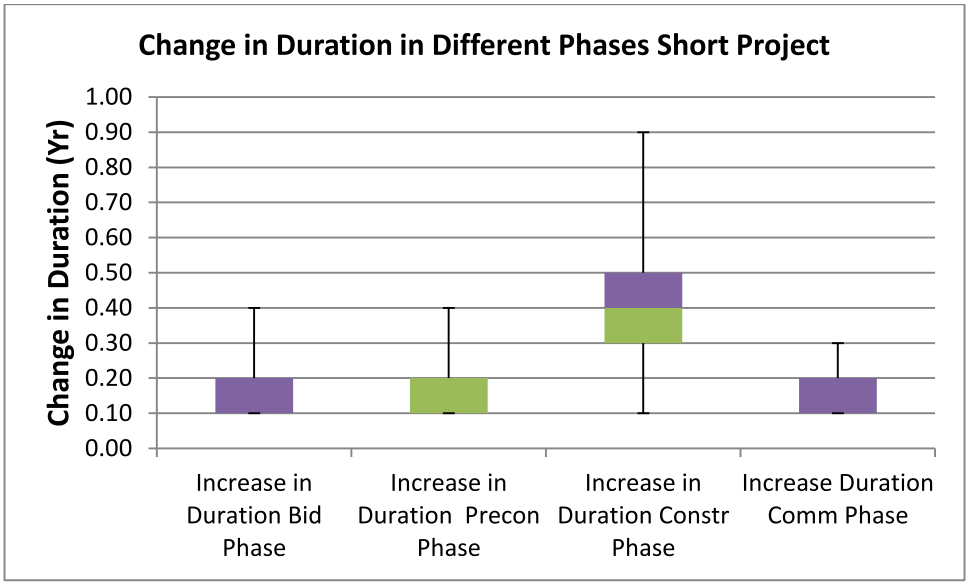


Figure 4.9 - Change in Duration in Different Phases Short Project

4.7 Hypothesis Testing

Project change management in this research focuses on the impact of changes in a project on cost and schedule overrun including the contribution of engineering percent complete to such changes. To undertake this exercise, data were collected using questionnaires, interviews and secondary data from Inventory of Major Alberta Projects (IMAP) in Alberta from 2004 to 2012. A number of statistical tools including scatter plots, correlation, ANOVA, frequency tables, graphs, box and whisker plot were used to analyze the data. Research hypotheses were proposed and tested in this section to determine if the research questions were supported by available data.

Correlation Coefficient:

Correlation is the determination of the degree of linear relationship between two variables. This relationship can be negative where the nature of the relationship is such that an increase in one variable leads to decrease in the other. It could be positive where increase in one variable leads to increase in the other. The degree of correlation vary from -1 to + 1, where -1 or +1 indicates a perfect correlation. As the number tends towards 0, the strength of the relationship decreases. A value of zero does not mean that there is no relationship rather it signifies that the relationship is not linear. According to Stockwell (2008) correlation exists when two variables have a linear relationship beyond what is expected by chance alone.

> *Continuing he said that a value of -1 represents a "perfect negative correlation", while a value of 1 represents a "perfect positive correlation". The closer a correlation measure is to these extremes, the "stronger" the correlation between the two variables. A value of zero means that no correlation is observed. It is important to note that a correlation measure of zero does not necessarily mean that there is no relationship between the two variables, just that there is no linear relationship present in the data that is being analyzed.*

Hypothesis testing will assist in determining the relationship between the dependent and independent variables. According to Weisstein (2014),

> *Hypothesis testing is the use of statistics to determine the probability that a given hypothesis is true. The usual process of hypothesis testing consists of four steps.*

1. Formulate the null hypothesis Ho (commonly, that the observations are the result of pure chance) and the alternative hypothesis Ha (commonly, that the observations show a real effect combined with a component of chance variation).

2. Identify a test statistic that can be used to assess the truth of the null hypothesis.

3. Compute the p-value, which is the probability that a test statistic at least as significant as the one observed would be obtained assuming that the null hypothesis were true. The smaller the P-value, the stronger the evidence against the null hypothesis.

4. Compare the p-value to an acceptable significance value α (sometimes called an alpha value). If $p \leq \alpha$, that the observed effect is statistically significant, the null hypothesis is ruled out, and the alternative hypothesis is valid.

For the purposes of this study, the dependent variable is the total project cost (estimated initial cost and changes in cost) while the independent variables include: changes in cost, project duration, change in project duration and engineering percent complete.

Hypothesis Tests

1) **Engineering Percent Complete and Total Cost:**

The first hypothesis that will be tested is the relationship between engineering percent complete and the total cost of the project.

Null Hypothesis $H_o: \mu$

Low percentage of engineering percent complete is not responsible for increase in total cost of projects

Alternative Hypothesis $H_1: \mu$

Low percentage of engineering percent complete is responsible for increase in total cost of the projects

For each of the hypothesis, we have data for the engineering percent complete, initial project cost, changes to the project cost and final project cost. The hypothesis is investigating the research question whether the percentage of engineering percent complete has a direct relationship with changes in cost in a project. The first test is a correlation analysis between engineering percent complete and total project cost.

Table 4.10 shows the correlation between engineering percent complete and total cost of the project. From the table, there is a negative correlation of -0.157 between engineering percent complete and total project cost. The value of 0.157 shows that the relationship is weak as it is well lower than 1. The negative value shows that as the engineering percent complete increases, total cost decreases and vice versa. It should be understood that total cost is estimated initial cost plus changes in cost in different phases of the project.

Table 4.10 Correlation Analysis between Engineering Percent Complete and Total Project Cost

		Engineering Percent Complete	Total Cost Project Cost
Engineering Percent Complete	Pearson Correlation	1	-0.157*
	Sig. (2-tailed)		0.019
	N	223	223
Total Cost from all Phases	Pearson Correlation	-0.157*	1
	Sig. (2-tailed)	0.019	
	N	223	223

*. Correlation is significant at the 0.05 level (2-tailed).

The table also shows a Sig. (p value) of 0.019. As this value is less than 0.05, the null hypothesis which states that *low percentage of engineering percent complete is not responsible for increase* *in total cost of the project* is rejected. The alternative hypothesis which states that *low percentage of engineering percent complete is responsible for changes in project* is accepted. This therefore, confirms that percentage of engineering percent complete is responsible for changes in project cost.

Figure 4.10 shows the scatter plot of the relationship between engineering percent complete and total project cost. The weakness in the correlation is shown in the scatter plot as there are many data points falling widely outside the line of best fit. The 0.025 R^2 value shows data weakly fits the regression line. This means that only 2.5% variability in the data is explained by the model.

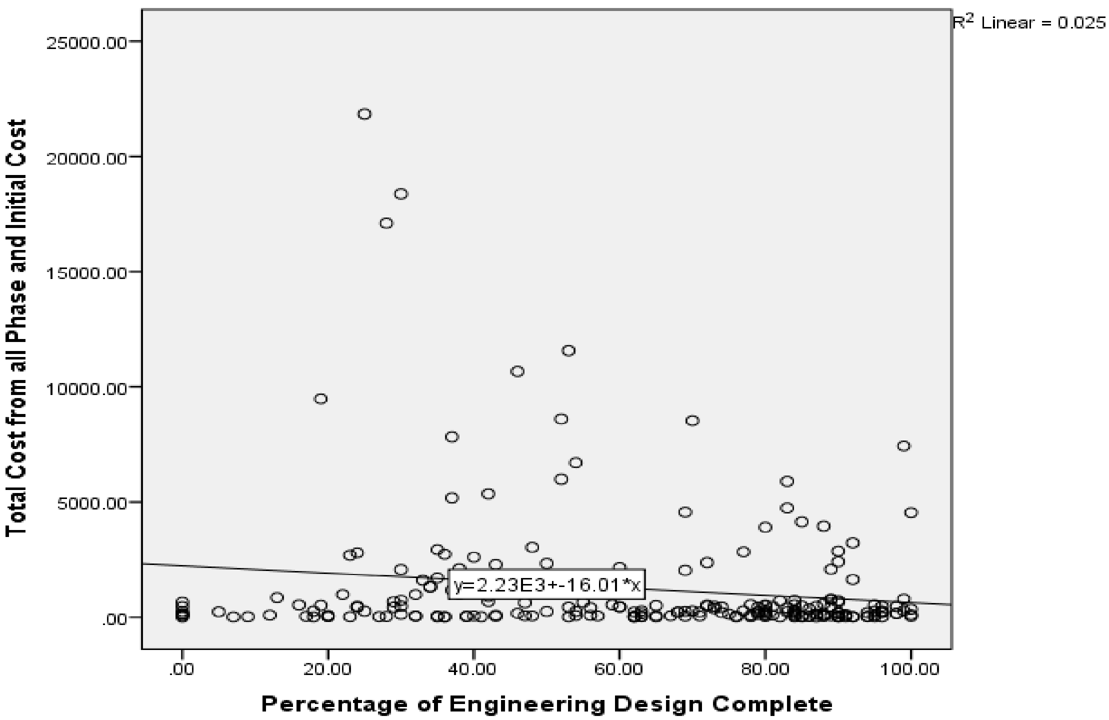


Figure 4.10 Scatter Plot between Percentage Engineering Complete and Total Project Cost

Other analysis results are available in Appendix K.

2) Total Cost and Changes in Project

The next test investigates the relationship between changes in the project cost and total cost of the project. Change in the project cost is represented by changes in various phases (bid, preconstruction, construction and commissioning) of the project. The hypothesis to investigate this is stated below.

Null Hypothesis $H_o{:}\mu$

Changes in a project do not lead to increase in project cost.

Alternative Hypothesis $H_1{:}\mu$

Changes in a project lead to increase in project cost.

Table 4.11 shows the correlation analysis between changes in a project and increase in project cost. The correlation result shows a value of 0.935 which indicates a very strong relationship between changes in a project and increase in project cost. The table also shows a Sig. (p value) of 0.000 which is less than 0.05. Therefore, the null hypothesis that *changes in a project do not lead to increase in project cost* is rejected. The alternative hypothesis which states that *changes in a project lead to increase in project cost* is accepted.

Table 4.11 Correlations between Total Project Cost and Change in Project Cost

		Total Cost from all Phase and Initial Cost	Change in Total Cost
Total Cost from all Phase and Initial Cost	Pearson Correlation	1	0.935**
	Sig. (2-tailed)		0.000
	N	223	223
Change in Total Cost	Pearson Correlation	0.935**	1
	Sig. (2-tailed)	0.000	
	N	223	223

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.11 is the scatter plot showing the relationship between changes in a project and the total project cost. The diagram shows a linear positive relationship indicating that as changes increase total project cost also increases. Also a 0.874 R^2 value indicates that the data fits very well with the regression line. This means 87.4% of the variability in the data is explained by the model.

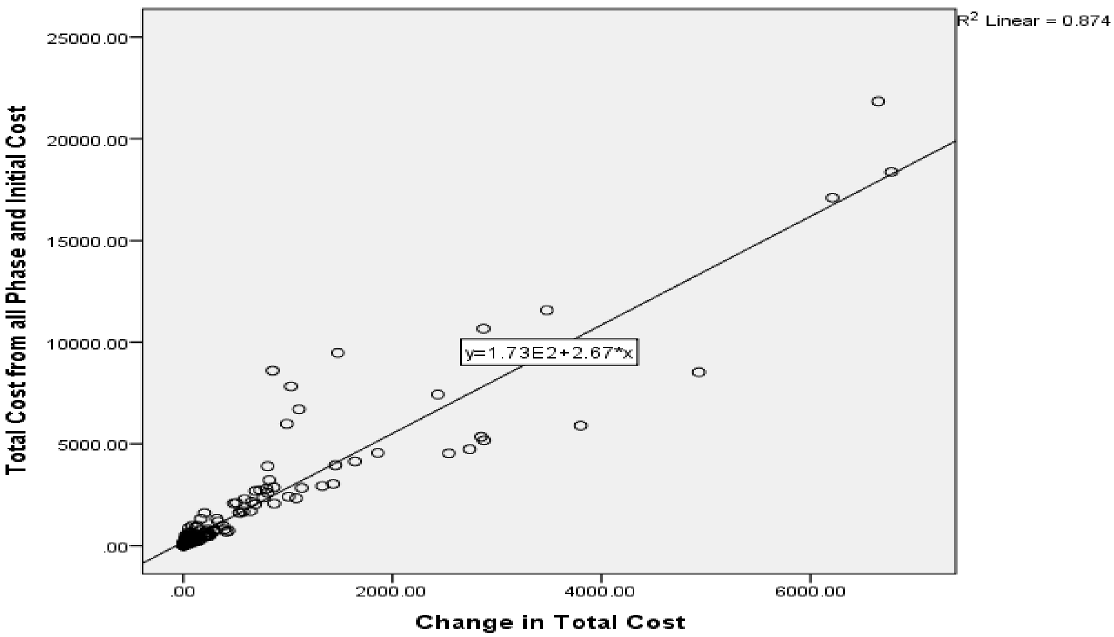


Figure 4.11 Changes in Project Cost and Total Project Cost

3) Total Cost and Change in Duration

Null Hypothesis $H_o:\mu$

Changes in a project do not lead to increase in project duration.

Alternative Hypothesis $H_1:\mu$

Changes in a project lead to increase in project duration.

From Table 4.12, the correlation between total project cost and total duration is 0.586. This shows that there is a good relationship between both variables. With a Sig p-value of 0.000

which is less than 0.05, the null hypothesis which states that *Changes in a project do not lead to increase in project duration* is rejected in favour of the alternative hypothesis which states that *changes in a project lead to increase in project duration* is accepted. Thus it can, therefore, be concluded that changes in a project leads to increases in project duration.

Table 4.12 Correlations between Total Project Cost and Project Duration

		Total Project Cost	Total Duration
Total Project Cost	Pearson Correlation	1	0.586**
	Sig. (2-tailed)		0.000
	N	223	223
Total Duration	Pearson Correlation	0.586**	1
	Sig. (2-tailed)	0.000	
	N	223	223

**. Correlation is significant at the 0.01 level (2-tailed).

The scatter plot in Figure 4.12 shows the relationship between changes in the project and project duration. It can be seen that as the changes increase, project duration also increases. Also a 0.344 R^2 value indicates that the data fits very well with the regression line. This means 34.4% of the variability in the data is explained by the model.

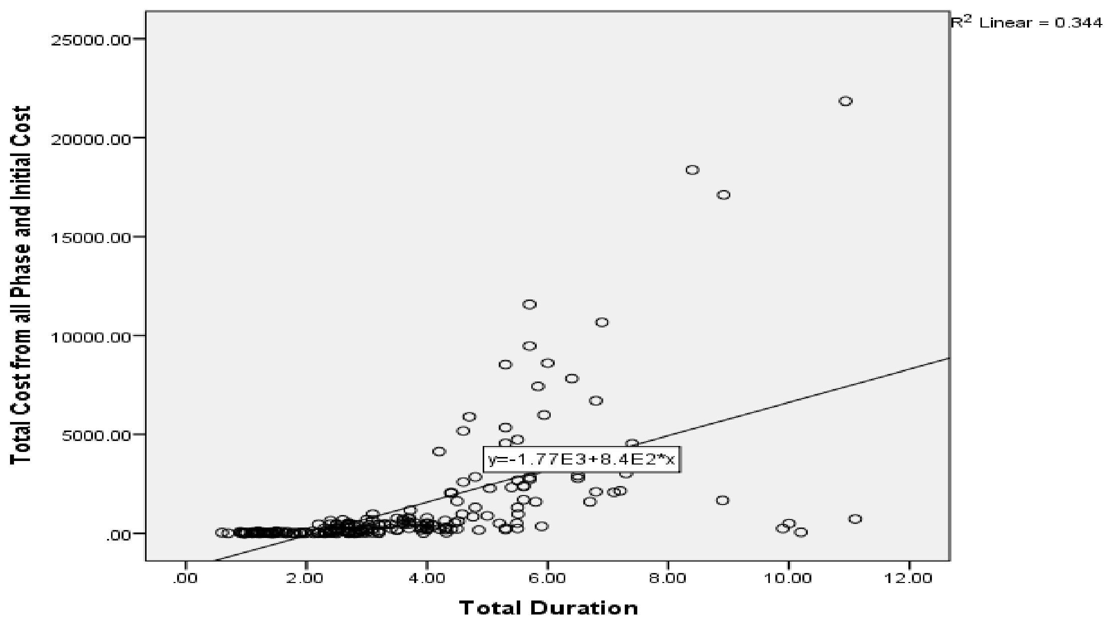


Figure 4.12 Scatter Plot of Changes in Project and Project Duration

4) Changes in a Project, Total Project Cost and Project Duration

This test focuses on the combined impact of changes in project cost and duration at various phases of the project. The total project cost, changes in cost and changes in duration in different phases of the project is used for this purpose. A hypothesis was proposed to assist in determining this relationship.

Null Hypothesis H_o:μ

Changes in a project does not cause changes in project cost and project duration.

Alternative Hypothesis H_1:μ

Changes in a project cause changes in project cost and project duration.

The result of the correlation is shown in Table 4.13 and 4.14. As shown in the Table 4.13, all the project phases have correlation values of between 0.550 to 0.931. This indicates strong to very strong linear relationship between total project cost and the change in cost in different phases of the project. Each of the phases has Sig. (p-value) of 0.000 which lead to rejection of the null hypothesis which states that *changes in project does not cause changes in project cost.* Instead the alternative hypothesis stating that *changes in project causes changes in project cost* is accepted.

Table 4.13 Correlations between Total Project Cost and Changes in Cost in Different Phases of a Project

		Total Project Cost	Change in Duration Bid Phase	Change in Duration Constr	Change in Duration Comm	Change in Duration Precon
Pearson Correlation	Total Cost Project Cost	1.000	-	-	-	-
	Change in Cost Bid Phase ($mil)	0.749	1.000	-	-	-
	Change in Cost PreCon Phase ($mil)	0.851	0.812	1.000	-	-
	Change in Cost Contr Phase ($mil)	0.911	0.550	0.704	1.000	-
	Change in Cost Com Phase ($mil)	0.826	0.931	0.823	0.627	1.000
Sig. (1-tailed)	All Phases	0.000	0.000	0.000	0.000	0.000
N	Total	223	223	223	223	223

Similarly in Table 4.14, all the phases have correlation value of between 0.512 to 0.706. This indicates a strong correlation between changes in project and change in project duration in different phases of the project. In all cases, the Sig (p-value) was 0.000 which means that correlation is significant and leads to the rejection of the null hypothesis which states that *changes in a project does not lead to changes in project duration.* The alternative hypothesis which states that *changes in project leads to changes in project duration* is accepted.

Table 4.14 Correlations between Total Project Cost and Changes in Duration in Different Phases of a Project

		Total Project Cost	Change in Duration Bid Phase	Change in Duration Constr	Change in Duration Comm	Change in Duration Precon
Pearson Correlation	Total Cost Project Cost	1.000	-	-	-	-
	Change in Duration Bid Phase	0.526	1.000	-	-	-
	Change in Duration Constr	0.690	0.584	1.000	-	-
	Change in Duration Comm	0.546	0.614	0.592	1.000	-
	Change in Duration Precon	0.512	0.706	0.648	0.630	1.000
Sig. (1-tailed)	All Phases	0.000	0.000	0.000	0.000	0.000
N	Total	223	223	223	223	223

Detailed data of the analysis are contained in Appendix K.

4.8 Model

The data were used to plot graphs for each category of cost (large, medium and small) and duration (long, medium and short) with engineering percent complete. The purpose of the graph is to estimate changes in cost and duration in different phases of the project when the initial cost, initial duration and engineering percent complete are known. In the project cost plots, estimated initial cost was plotted in the x-axis while changes in different phases of the project is plotted on the y-axis. For project duration, estimated initial duration was plotted on the x-axis while changes in duration in different phases were plotted on the y-axis. Similarly, engineering percent complete was plotted on the x-axis against changes in cost and changes in duration in different phases of the project. An example of the model in shown in Figure 4.13. The rest of the results are available in Appendix L. Two graphical options were explored in the course of choosing a graph and equation that best fit for the data. The options are, exponential and linear. The result from linear equation was well outside the realms of reality of the data. The result from exponential equation closed fits the data. For that reason, exponential equation was used throughout the model because the result from the model closely reflect the actual data when tested.

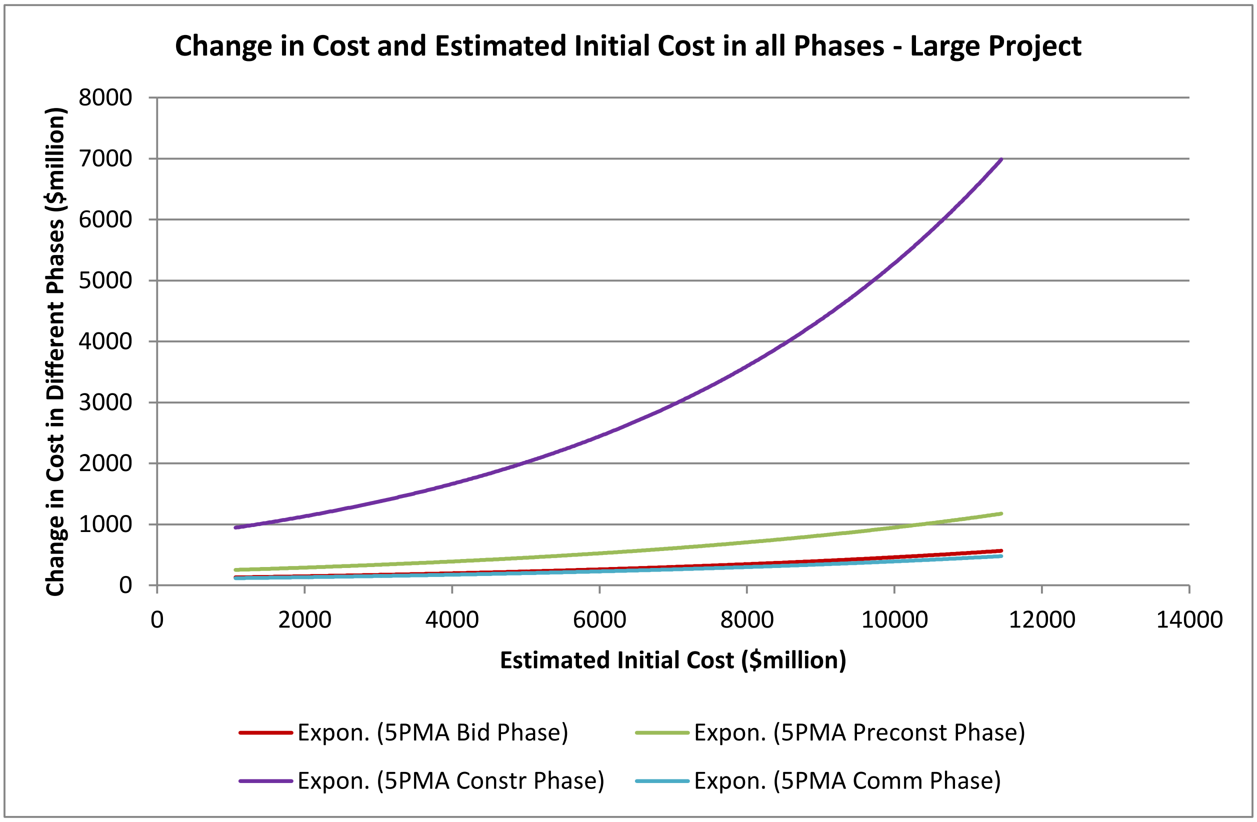


Figure 4.13 - Change in Cost and Estimated Initial Cost in all Phases - Large Project

For each of the categories, four line graphs were plotted representing each of the different phases of the project for cost and duration (bid, preconstruction, construction, and commissioning). The equation of the graphs are obtained and used in the formula for the change management tool (Change Manager 1.0) developed from this study. The graphical model is limited to estimating changes in cost in different phase when estimated initial cost or duration is within the graph's scale. The limitation of the graph is that it can only be used for deriving changes in cost and duration when the estimated initial cost and duration are within the scale of the graph. If the estimated initial cost and duration are outside the scale of the graph, the model cannot be used to estimate changes in cost and duration in each of the phases. It is for this reason that a tool (Change Manager) was developed to estimate changes in cost and duration for any value of estimated initial cost or duration (see section 4.9).

How to use the graph:

1) Determine estimated initial cost and duration of the project. This information should be available from project estimate or budget.
2) Determine engineering percent complete at the time of bid and contract award. This information should be available from the design or EPC organization.
3) From the project definition Table 4.15 below, determine the cost and duration categories.

Table 4.15 Project Definition Table

Estimated Initial Cost		Estimated Initial Duration	
Category	Amount ($million)	Category	Duration
Large	> =$1,000	Long	> 2 years
Medium	>$100 - $999	Medium	>1 year - 2 years
Small	$5 - $100	Short	0.5 – 1 year

4) Identify the relevant graph in Appendix L that corresponds to the project cost and duration definitions.

5) Identify the estimated initial cost and duration on the horizontal axis of the graph while change in cost and duration are on the vertical axis.

6) Similarly engineering percent complete is plotted on the horizontal axis while changes in cost and duration as result of engineering percent complete are on the vertical axis.

7) On the horizontal axis of the graph, determine the number that matches the estimated initial cost or duration or any number closest to it.

8) Draw a vertical line from the value determined in #7 and read the value corresponding to it for each of the phases and engineering percent complete.

9) The values for cost and duration for each phases and category represent the change in cost or duration for the project.

10) Determine the engineering percent complete and read vertically to determine the change in cost and duration as a result of engineering percent complete.

11) Add the values obtained in step #10 to the number obtained in steps #7 to #9 to obtain the total change in cost or duration for each of the phases.

12) Summation of the values from step #11 gives the total change in cost and duration for the project.

4.9 Change Management Tool

To assist organizations in estimating potential change in cost and duration in a project as well changes in different phases of a project, a Microsoft Excel tool – Change Manager 1.0 has been developed in the course of this research. Figures 4.14 to 4.21 show screenshots of the tool. To use the tool, click on the 'Add New Project' button to launch the tool.

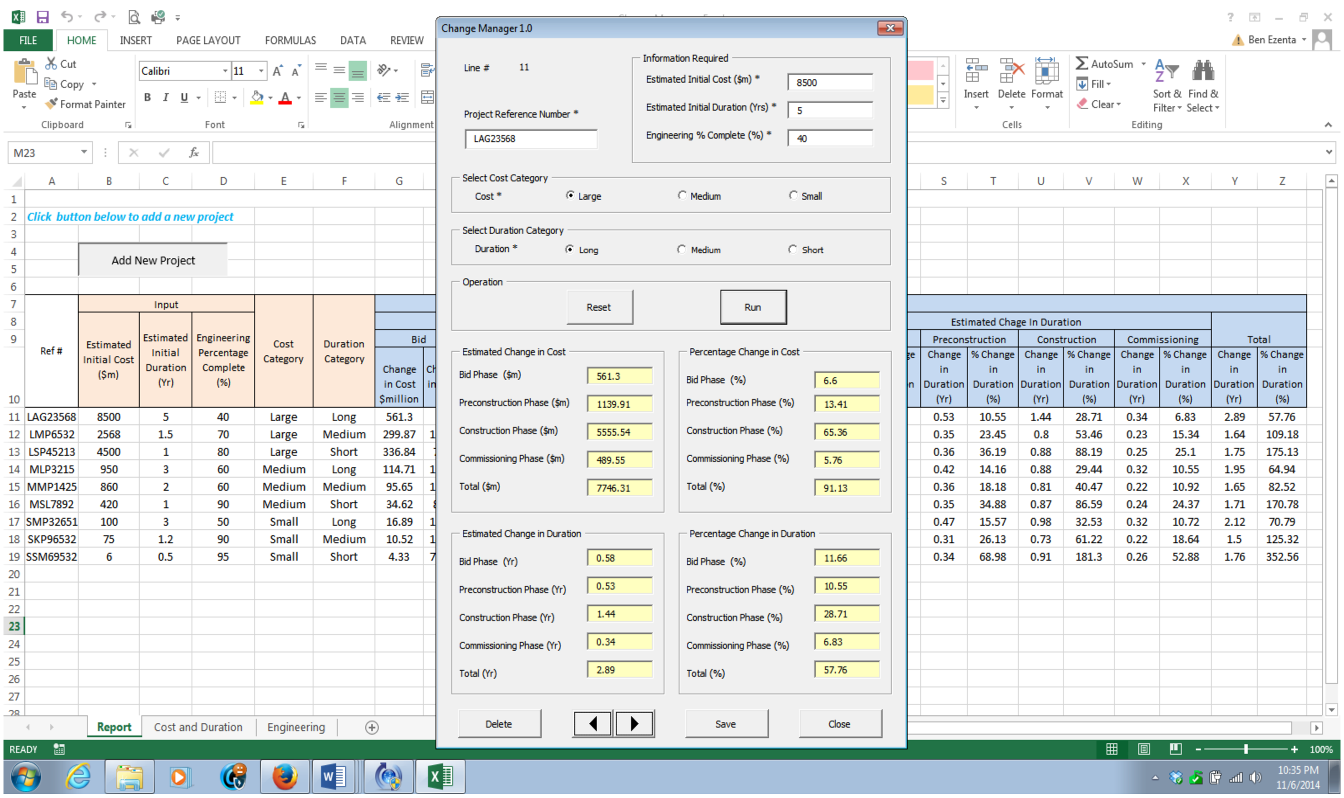


Figure 4.14 – Change Manager 1.0

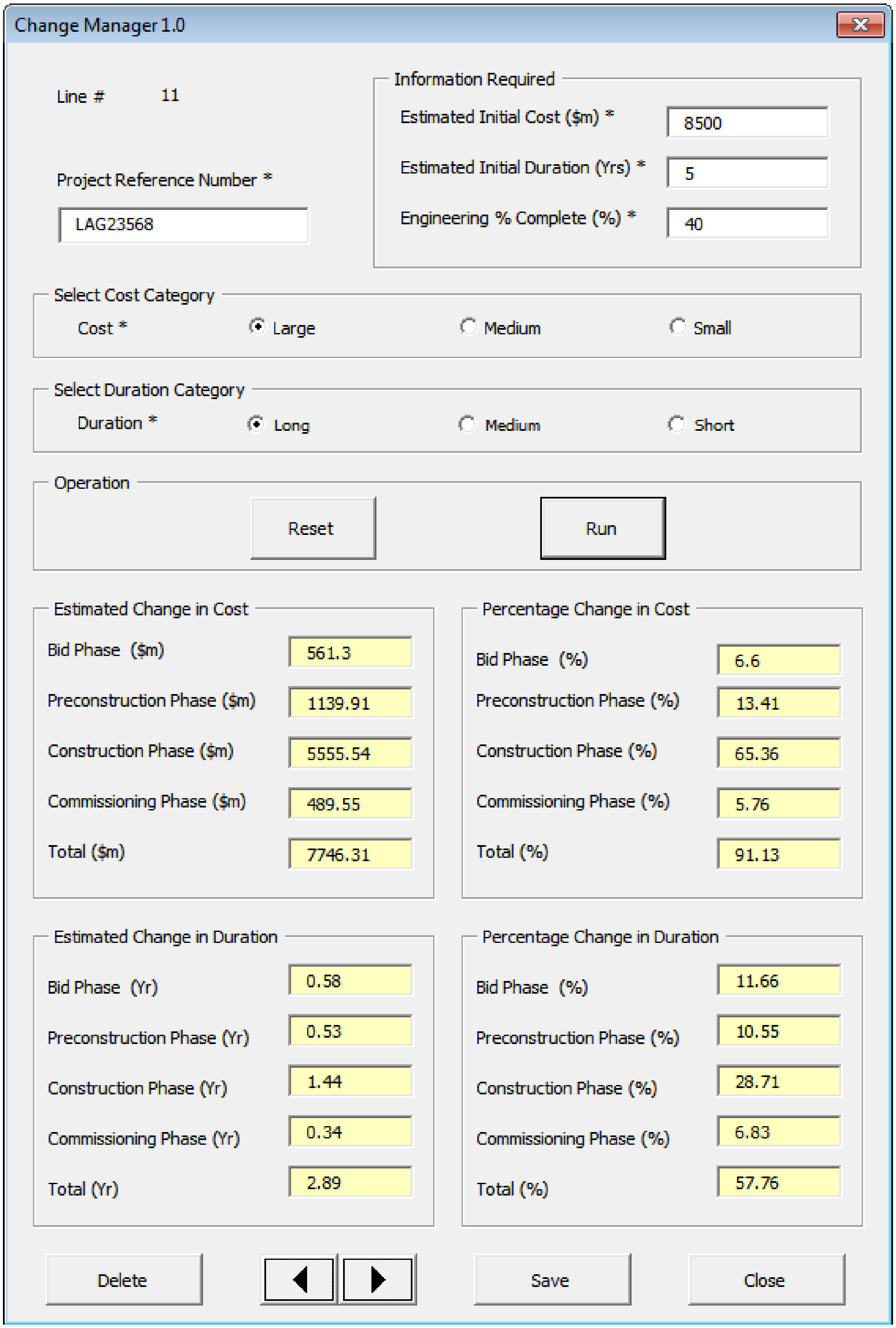


Figure 4.15 – Screenshot of Change Manager 1.0

The tool consists of six different sections:

1) Input: This section is used to input the initial values of cost, duration and engineering percent complete. Also in this section is the project reference number which identifies each project.

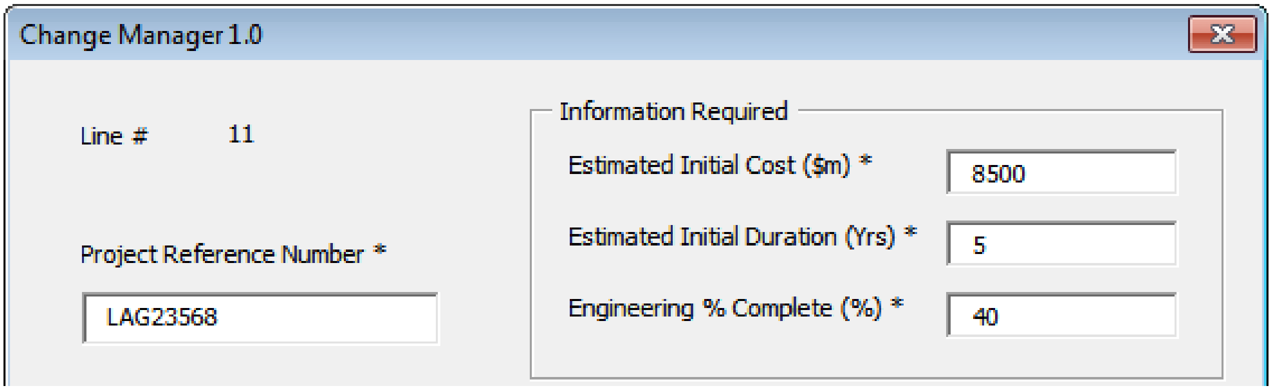


Figure 4.16 - Information Required

2) Category: The user selects the category in the cost and duration section. Each category has equation (see Appendix M) running in the background which is derived from the line graph obtained in the modeling section of this research. The category section contains radio buttons indicting that only one option can be selected for cost and one option for duration.

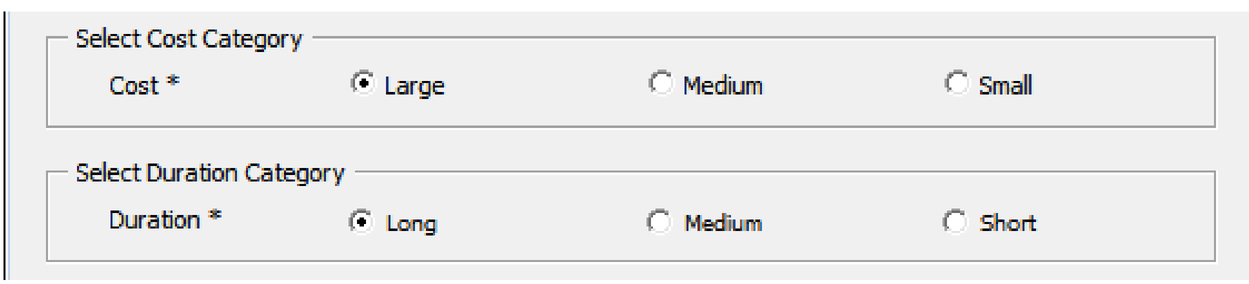


Figure 4.17 – Cost and Duration Category

3) Operation: If an error is made in the input or selection of the categories, the Reset button can be used to erase all the data and start over. After entering the inputs and selecting the categories, clicking on the Run button will execute the program for the calculation.

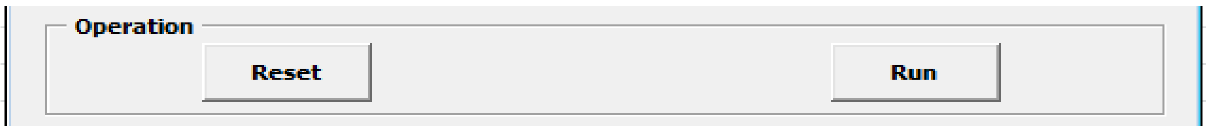


Figure 4.18 - Operation

4) Output: The result of the calculation is display in the output section. The estimated change in cost for each of the phases (bid, preconstruction, construction and commissioning), is displayed in the Estimated Change in Cost section. Their equivalent percentage is displayed in the Percentage Change in Cost section. Similarly, the change in duration is displayed in the Estimated Change in Duration section with the corresponding percentage in the Percentage Change in Duration section. The result can be saved, using the Save button to add the project to the database using the forward button. The Delete button can be used to delete entry from the database or report.

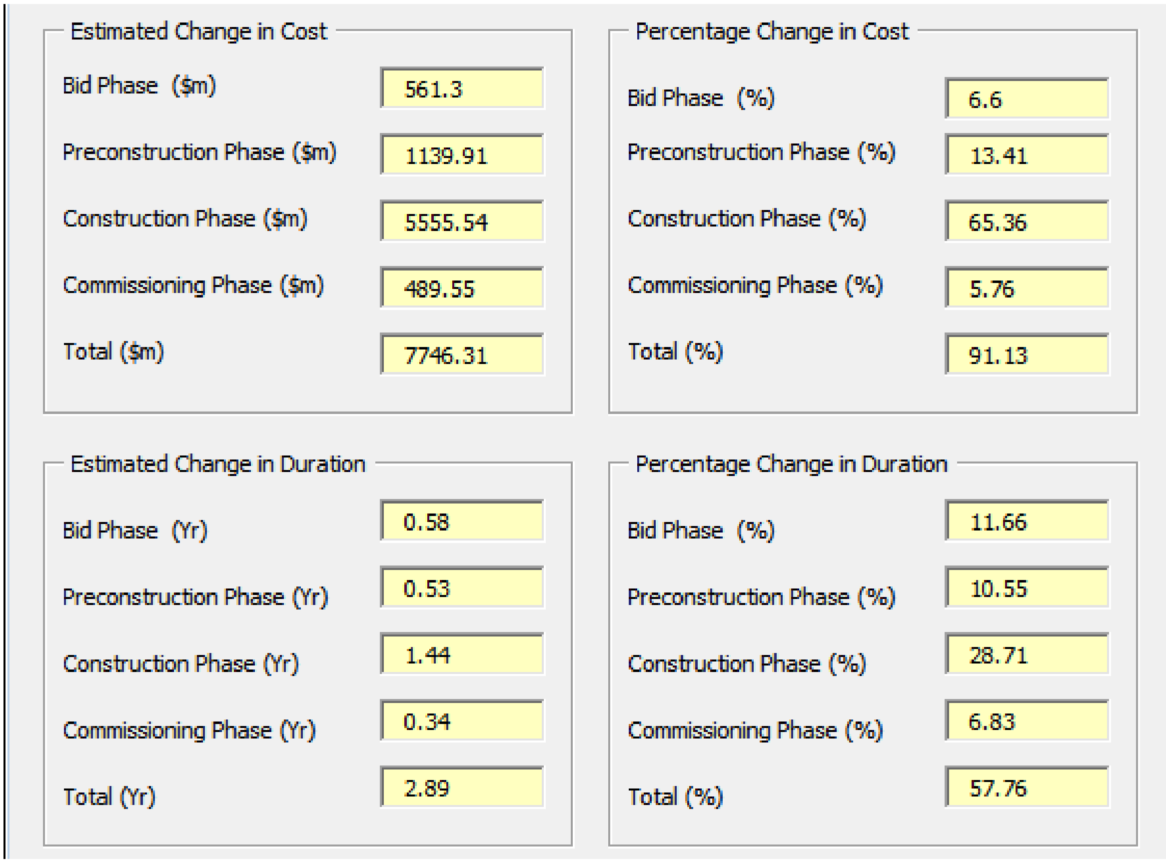


Figure 4.19 - Results

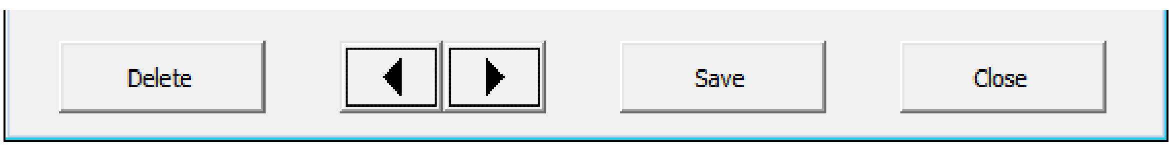
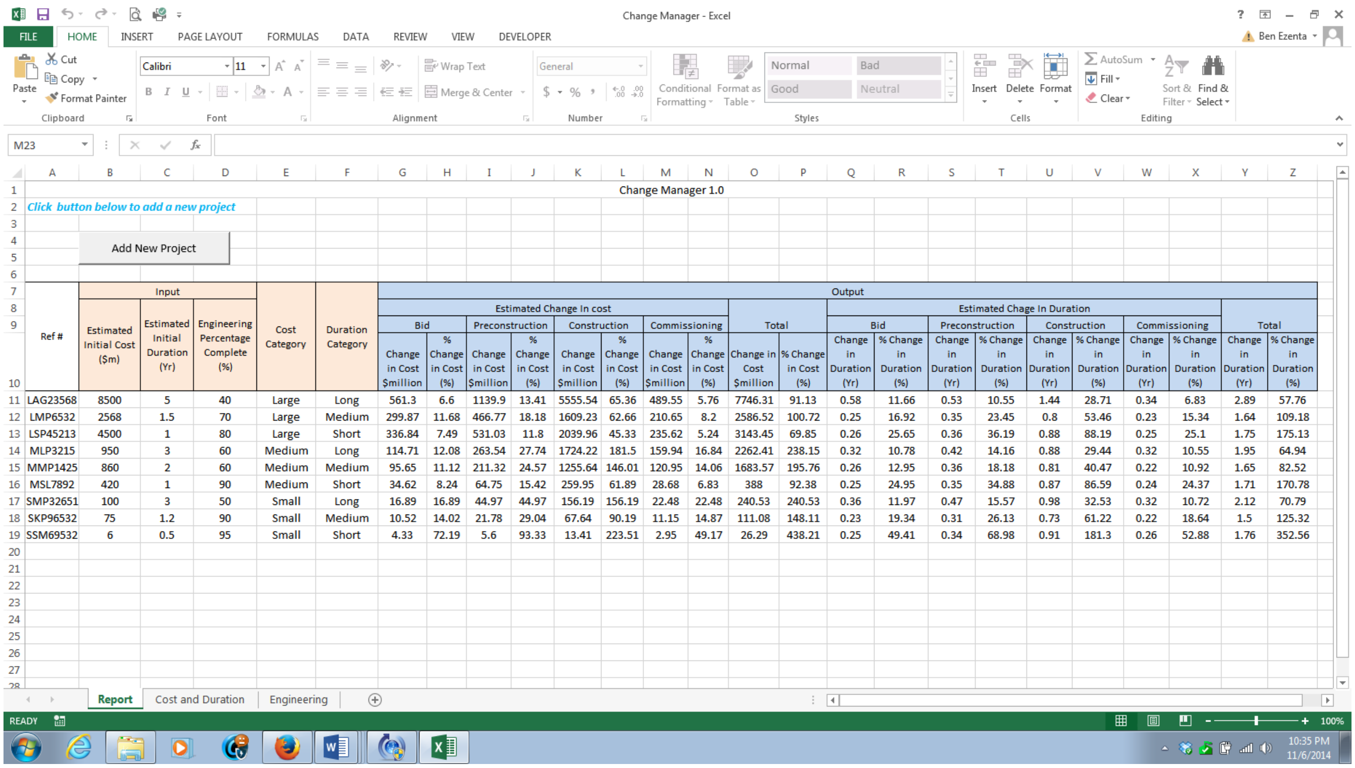


Figure 4.20 – Other Operations

5) Report: The report of the calculation is stored in the spreadsheet for future reference and reporting.



Ref #	Input: Estimated Initial Cost ($m)	Input: Estimated Initial Duration (Yr)	Input: Engineering Percentage Complete (%)	Cost Category	Duration Category	Bid: Change in Cost $million	Bid: % Change in Cost (%)	Preconstruction: Change in Cost $million	Preconstruction: % Change in Cost (%)	Construction: Change in Cost $million	Construction: % Change in Cost (%)	Commissioning: Change in Cost $million	Commissioning: % Change in Cost (%)	Total: Change in Cost $million	Total: % Change in Cost (%)
LAG23568	8500	5	40	Large	Long	561.3	6.6	1139.9	13.41	5555.54	65.36	489.55	5.76	7746.31	91.13
LMP6532	2568	1.5	70	Large	Medium	299.87	11.68	466.77	18.18	1609.23	62.66	210.65	8.2	2586.52	100.72
LSP45213	4500	1	80	Large	Short	336.84	7.49	531.03	11.8	2039.96	45.33	235.62	5.24	3143.45	69.85
MLP3215	950	3	60	Medium	Long	114.71	12.08	263.54	27.74	1724.22	181.5	159.94	16.84	2262.41	238.15
MMP1425	860	2	60	Medium	Medium	95.65	11.12	211.32	24.57	1255.64	146.01	120.95	14.06	1683.57	195.76
MSL7892	420	1	90	Medium	Short	34.62	8.24	64.75	15.42	259.95	61.89	28.68	6.83	388	92.38
SMP32651	100	3	50	Small	Long	16.89	16.89	44.97	44.97	156.19	156.19	22.48	22.48	240.53	240.53
SKP96532	75	1.2	90	Small	Medium	10.52	14.02	21.78	29.04	67.64	90.19	11.15	14.87	111.08	148.11
SSM69532	6	0.5	95	Small	Short	4.33	72.19	5.6	93.33	13.41	223.51	2.95	49.17	26.29	438.21

Ref #	Bid: Change in Duration (Yr)	Bid: % Change in Duration (%)	Preconstruction: Change in Duration (Yr)	Preconstruction: % Change in Duration (%)	Construction: Change in Duration (Yr)	Construction: % Change in Duration (%)	Commissioning: Change in Duration (Yr)	Commissioning: % Change in Duration (%)	Total: Change in Duration (Yr)	Total: % Change in Duration (%)
LAG23568	0.58	11.66	0.53	10.55	1.44	28.71	0.34	6.83	2.89	57.76
LMP6532	0.25	16.92	0.35	23.45	0.8	53.46	0.23	15.34	1.64	109.18
LSP45213	0.26	25.65	0.36	36.19	0.88	88.19	0.25	25.1	1.75	175.13
MLP3215	0.32	10.78	0.42	14.16	0.88	29.44	0.32	10.55	1.95	64.94
MMP1425	0.26	12.95	0.36	18.18	0.81	40.47	0.22	10.92	1.65	82.52
MSL7892	0.25	24.95	0.35	34.88	0.87	86.59	0.24	24.37	1.71	170.78
SMP32651	0.36	11.97	0.47	15.57	0.98	32.53	0.32	10.72	2.12	70.79
SKP96532	0.23	19.34	0.31	26.13	0.73	61.22	0.22	18.64	1.5	125.32
SSM69532	0.25	49.41	0.34	68.98	0.91	181.3	0.26	52.88	1.76	352.56

Figure 4.21 – Cost and Duration Change Report

The tool can be used for a "what if analysis" of different possible scenarios for changes in cost and duration.

4.10 Summary

The research obtained data through questionnaires, interviews as well as data from IMAP. These data were summarized and analyzed and used for analysis. Different statistical and data analysis tools were used including T-Test, correlation test of significance, ANOVA test, scatter plots, Box and Whisker plots, frequency distribution and line graphs. Detail results of these tests and analysis are contained in the Appendices.

The result of the analysis was used to answer the research questions which were established in chapter 1 of this study. Hypothesis were proposed and tested. The test result assisted in answering the research questions as well.

The result of the analysis assisted in developing Excel models and tool that could be used to estimate changes in project cost and duration when the estimated initial cost, duration and engineering percent complete are known. A screenshot of the tool and how to use it is included in the chapter.

The next chapter will detail the benefit of the research; limitations and areas of further research work; recommendations and conclusion.

Chapter 5 – Summary Recommendations and Conclusions

5.1 Introduction

Project change management is primarily concerned with the management of the variations between initial cost and duration of a project and the cost and duration of the project at any point in time in the life cycle of the project. The variation could be an increase or decrease. But most of the time, it is an increase in the project cost and duration. There is hardly any project that was completed exactly as originally planned in terms of cost and duration. A lot of factors and causes are responsible for this variation in cost and duration. If project change is not properly managed, it could be a source of increase in cost, increase in duration, disagreement, dispute, claims or even legal action between the owner and the contractor.

While owners and contractor know that changes will occur in a project, enough is not currently being done to plan for these changes and their potential impact. The most common practice is to assume that once there is contingency reserve in the project that will take care of all the risks associated with the project. This is a misconception as contingency reserve is designed to mitigate operational risks to the project hence, the value of contingency is low compared to the value of changes in a project. To hedge against overruns associated with strategic and operational risks, this research is advocating for the creation of change reserve which will be used to mitigate against changes in cost and duration in a project. Given that engineering design in not always complete before contract award, this introduces an added layer of complexity which is often overlooked with severe consequences.

This research examined project change management from the point of view of causative and impact factors in order to assist project owners and contractors effectively forecast for changes in project cost and duration. Questionnaires and interviews were administered to collect data. Secondary data was collected from IMAP. The information were analyzed and used to develop a tool that could assist in estimating potential changes in cost and duration indifferent phases of a project.

5.2 Summary of Chapters

This research is divided into five chapters to enable thorough examination and investigation of the research topic.

Chapter 1 is an introduction to the study and includes problem statement, research questions, research goal and limitation of the study. The chapter gave background information on the need for the study. As stated in the chapter, one of the reasons for undertaking this study is to contribute to the existing body of knowledge in the area of project change management especially in the oil and gas projects in Alberta which has paucity of information at present.

Chapter 2 focused on review of relevant literatures and previous works on project change management. Some of the issues covered in the chapter includes the difference between traditional change management and project change management. Traditional change management deals with process reengineering or process change to improve the efficiency of product and service delivery in an organization. Project change management on the other hand is the management of variations between original project cost and duration and cost and duration at any point in a project lifecycle. Also included in the chapter are deficiencies in existing body of works; causes and source of change in a project; impact of change on a project; contingency; project delivery systems; project risks; project change management process as well as change management instruments. The chapter also includes the structure of oil and gas projects in Alberta, and change management contract provisions.

Chapter 3 provide details of the research methodology. This involves the methodology used in the research, method of data collection and how the data will be analyzed to answer the research questions.

Chapter 4 contains analysis of the research data collected through IMAP, questionnaire and interview. Statistical tools including t-test, correlation analysis, scatter plot, ANOVA, frequency bar, box and whisker plots and line graphs were used for the analysis. Hypothesis that helped to answer the research questions were proposed and in all cases, the null hypotheses were rejected while the alternative hypotheses were accepted. Which answered the research questions. The results of the analysis were used to develop a tool called Change Manager which could be used to estimate changes in project cost and duration for different phases of a project.

Chapter 5 is the summary of the entire research work. Information in the chapter includes summary of chapters, benefit of the research, discussion of research findings, area for further works, recommendations and conclusion.

5.3 Benefit of the this Research Work

This research work provided a lot of personal benefit to the researcher. Most importantly oil and gas owner organization and contractor organizations will benefit from the outcome of this research through better understanding of the role of contingency reserve and the need to create change reserve. Alberta economy as a whole will benefit from the result of this study through efficient management of oil and gas projects. The project broadened the scope of knowledge and information available to the researcher prior to starting the study. This has assisted the researcher in gaining new knowledge and skills in the area of change management. One of the major revelations from the research is that while all parties to an oil and gas project knows that changes in cost and duration will occur in the project, enough effort is not put at planning, monitoring and management of these changes. If this trend is reversed, it will tremendously benefit organizations that are involved in oil and gas projects. As was evidence from most of the literatures reviewed, change management is treated as an afterthought in most projects. The lukewarm treatment of change management manifest in cost and schedule overruns which could lead to disagreements, claims and legal actions.

Project owners could save a lot of money and time by having robust project change management program early on in the project prior to contract award and maintained throughout the project. The change management tool developed from this research could be used by the owner to forecast potential change in cost and duration in different phases of the project with engineering percentage complete prior to contract award in order to avoid any surprises. Contractor organization could also use the tool to properly inform themselves of the potential changes that may arise in the course of the project. If the project owner and contractor use the same tool to estimate for change (contingency), both parties will be well aware of what is to come and avoid surprises. Planning for project change and including the information in the bid response will enable all parties to be aware of potential changes before they occur.

The economy as a whole will be better for it when unnecessary legal actions is avoided. Money spent on avoidable changes can be used for more productive activities. Given the amount of money invested annually in oil and gas projects in Alberta, managing change will save the economy billions of dollars.

5.4 Research Findings

This research discovered a couple of things which were not obvious to the researcher at the beginning of the project. Other information which were known before the research were confirmed by the research data. Some of the findings from the research include the following:

1) Change occurs in almost every project. While this is a known fact, the questionnaire result overwhelmingly confirmed it.

2) Change is responsible for project cost and schedule overruns. This assertion was also confirmed from the result of the questionnaire. While there are other factors such as delays, inflation etc. that may contribute to project overrun, overwhelmingly survey participants agreed that changes in projects are responsible for cost and schedule overruns.

3) Engineering percentage complete is negatively correlated with changes in cost and duration in a project. The lower the engineering percent complete, the higher the possibility of changes in cost and duration occurring in the project. This impact of engineering percent complete was surprisingly not uniform in all project cost categories (Large, Medium and Small). It was discovered that the impact of engineering percent complete on small projects is minimal when compared to large and medium cost projects.

4) The largest change in cost and duration occurred in the construction phase.

5) Dividing projects into different phases (bid, preconstruction, construction and commissioning) and categories (Large, Medium and Small- cost; Long, Medium and Short - duration) provided a better understanding of where change is more likely to happen as well as the magnitude.

6) There is little or no change management planning in most projects by both owner organization and contractor organization before the contract award. This leads to reactive approach to project changes management.

7) Establishment of change reserve is required to mitigate against strategic and global project risks. At present, this is lacking in most projects.

5.5 Areas for Further Research

This research barely scratched the surface of change management in the oil and gas industry in Alberta. The study focused on cost and duration coupled with the impact of engineering percent complete. The effect of productivity, delays, labour and other related factors were not considered in the research. The tool developed from this study is still in the basic form. The following topics could be areas for further research in change management in the oil and industry in Alberta:

1) This research used a deterministic approach for analysis, it will be beneficial to use a probabilistic approach and compare the results.

2) Data used for the research was collected from secondary source, questionnaires and interview. It will be useful to conduct the same research with data directly provided by organizations in the industry.

3) The developed tool ‘Change Manager’ may need refinement as more data becomes available.

4) Need for Management reserve to hedge against global risks in a project.

5.6 Recommendations

Based on the literature review, analysis and findings in this research, the following recommendations are being proposed:

1) Change management process and procedures should be initiated at the commencement of project Front End Planning of any oil and gas project in Alberta. The process should be maintained throughout project execution and commissioning. Doing this will reduce the occurrence and impact of changes in a project.

2) One of the biggest challenges in most projects is that while the contract is usually put together by the legal and contract teams, the construction execution team hardly spend time to study and understand the contract. The construction execution team is usually concerned with execution strategy of the project thereby abdicating contract issues to the contract team. The construction contractor organization staff on their own part in most projects hardly paid attention to contract provision especially relating to project scope definition, change management provisions, dispute procedures etc. These are the views

expressed by participants in the interview. It is recommended that each party to a project should "Read and Know Your Contract" (RKYC). Without this knowledge, disagreements are bound to occur which may lead to disputes, claims and legal actions.

3) Traditionally, change management function is usually buried deep inside Project Control functions. This is one of the major setbacks to effective change management system. With little attention and resources deployed to change management, the result is that project changes are not well managed. Change management should be a full functional unit in any project, staffed with senior and intermediate project staff with adequate knowledge of the construction process as well as authority to make change management decision. Most project control staffs are not technically equipped in constructability and part of construction to understand the complexities of changes in different activities or systems in the project. This situation normally creates challenges in understanding when a change has occurred in the project.

4) Change can be the reason for the success or failure of a project. For the owner, it is the source of additional cost or savings. For the contractor, it is a source of additional profit or loss on a project. For that reason change management should be recognized as a discipline of its own with reporting structure in senior management.

5) Organizations should be encouraged to volunteer project data before, during and after project completion to an independent body for the purposes of research. The Construction Industry Institute (CII) collects data from organization similar to what is advocated above. Very few oil and gas organizations in Alberta subscribe to CII benchmarking

project. A similar program should be set up with Construction Owners Association of Alberta (COAA). Most importantly, the data provided should include cost and duration changes at various stages of the projects. It is understood that organizations are mindful of their information and will not want to disclose it to the public. This could be overcome by coding the data to strip out all identifying information. If this process is established, researcher will have adequate and accurate data that will assist in improving change management process in the industry which will benefit the organizations and society at large.

5.7 Conclusion

It is undisputable that change occurs in almost every construction project in the oil and gas industry in Alberta. These changes occur in all phases of the projects (bid, preconstruction, construction and commissioning). The causes of these changes include: Design Change, Site Condition, Scope Change, Regulations, Change in Technology, Market Conditions, Management Decisions, Environmental Factors, Materials & Equipment, Fast Tracking and Others. The change in project causes changes in cost and duration. For cost change, the rate of change varies for different project costs category (large, medium and small) and duration category (long, medium and short).

This research identified sources and causes of change in oil and gas projects in Alberta as well as their impact. The research also highlighted the misconception of the use of contingency reserve and provided an insight into the types of the risk contingency reserve is design to mitigate while advocating for the establishment of change reserve to the mitigate of strategic and global project risks. In the cause of the research, a tool was developed that could be used to estimate potential change in cost and duration in different phases of the project. With this knowledge, participants in the industry could focus on the phase of the project where most changes are likely to occur and take corrective actions to mitigate their impacts.

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Appendices

Appendix A – Research Approval

Conjoint Faculties Research Ethics Board
Research Services Office
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Calgary AB T2N 1N4
Telephone: (403) 220-3782
Fax: (403) 289-0693
cfreb@ucalgary.ca

CERTIFICATION OF INSTITUTIONAL ETHICS REVIEW

This is to certify that the Conjoint Faculties Research Ethics Board at the University of Calgary has examined the following research proposal and found the proposed research involving human subjects to be in accordance with University of Calgary Guidelines and the Tri-Council Policy Statement (TCPS2) on "*Ethical Conduct for Research involving Humans Subjects*". This form and accompanying letter constitute the Certification of Institutional Ethics Review.

File No:	REB13-0670
Principal Investigator:	Lynne Cowe Falls
Co-Investigator(s):	There are no items to display
Student Co-Investigator(s):	Ben Ezenta
Study Title:	Project Change Management in Oil and Gas Projects: a Risk Based Approach

Effective: October 24, 2013 **Expires:** October 31, 2014

Restrictions:

This Certification is subject to the following conditions:

1. Approval is granted only for the project and purposes described in the application.
2. Any modification to the authorized study must be submitted to the Chair, Conjoint Faculties Research Ethics Board for approval.
3. An annual report must be submitted within 30 days from expiry date of this Certification, and should provide the expected completion date for the study.
4. A final report must be sent to the Board when the project is complete or terminated.

Approved By: **Date:**

Christopher R. Sears, PhD, Chair , CFREB October 24, 2013

Conjoint Faculties Research Ethics Board
Research Services Office
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October 24, 2013

Lynne Cowe Falls

Civil Engineering

Dear Lynne Cowe Falls :

RE: Project Change Management in Oil and Gas Projects: a Risk Based Approach

Ethics ID: REB13-0670

The above named research protocol has been granted ethical approval by the Conjoint Faculties Research Ethics Board for the University of Calgary. Please make a note of the conditions stated on the Certification. In the event the research is funded, you should notify the sponsor of the research and provide them with a copy for their records. The Conjoint Faculties Research Ethics Board will retain a copy of the clearance on your file.

Please note, a renewal or final report must be filed with the CFREB within 30 days prior to expiry date on your certification. You can complete your renewal or closure request in IRISS.

In closing let me take this opportunity to wish you the best of luck in your research endeavor.

Sincerely,	**Date:**
Christopher R. Sears, PhD, Chair , CFREB	October 24, 2013

Appendix B – Research Questionnaire

Project Change Management for Oil and Gas Projects in Alberta: Towards a Predictive Approach

Questionnaire

Introduction

Scope change has been identified as the major cause of cost and budget overrun in the oil and gas projects in Alberta. The situation may be worsened by potential disputes and litigations that could arise as a result of incorrectly managed scope changes. While projects owners and contractors know that scope changes will occur, there is absence quantitative approach to forecast the magnitude and hence cost and schedule impact of the change. This research will collect data on major Alberta oil sand projects executed from year 2000 to 2012. The set of data expected to be collected will be the original contract cost and final cost. Any change in cost due to scope change will be analyzed. A model will be developed to provide a guide that will be used to provision for scope changes in any bid. The result will be used to forecast the value of scope change on any project irrespective of the magnitude, complexity and industry.

The questionnaire is divided into six sections A, B, C, D, E, F and G.

Section A

The purpose of this section is to obtain information about your background, experience and involvement projects in the oil and gas sector.

Choose one item from the drop down list

Section A1 – Participant's Profile		
1	What is your role in your organization?	<u>Choose an Item</u> Project Manager Project Engineer Construction Manager Contract Manager Project Control Manager Change Manager Estimating Manager Scheduling Manager Others: Specify
2	Do you have personal experience working in an oil and gas project in Alberta from 2000 – 2012?	Yes No
3	How long have you been working in the oil and gas industry?	<u>Choose an Item</u> Less than 5 years 5 – 10 years 10 – 15 years 15 – 20 years 20 – 30 years 30 years and above
4	How long have you been working with your organization?	<u>Choose an Item</u> Less than 5 years 5 – 10 years 10 – 15 years 15 – 20 years 20 – 30 years 30 years and above
5	How long have you been working in your present role?	<u>Choose an Item</u> Less than 5 years 5 – 10 years 10 – 15 years 15 – 20 years 20 – 30 years 30 years and above

Section B

The purpose of this section is to obtain information on the role of your organization in the oil and gas project you participated in. We are aware of the sensitivity of the questions in this section. You and your organization will not be directly identified in the result of the research or any publication arising from the research. The information will allow us to determine the impact of changes and better forecast their magnitude and causative categories. Once again, we assure you that you, your response and organization will remain anonymous.

Choose one project and answer the questions following. If you have been involved in more than one project, you can complete a separate questionnaire for each project

Section B1 – Project Involvement		
6	What is the role of the company you worked for or are working for in the project?	Choose all that apply ☐ Owner Organization ☐ Construction Management Organization ☐ Construction Contractor Organization ☐ EPC Organization ☐ Subcontractor Organization ☐ Prime Contractor ☐ Suppliers ☐ Others: Specify
7	What type of project did you participate in?	Choose an Item Oil – SAGD Project Oil – Tar sand – Mining Project Oil – Conventional Drilling Project Oil – Others Gas Others – Specify
8	Is the project located in Alberta?	Yes No
9	If answer to question #9 is 'No', please specify location.	

Section C

The purpose of this section is to obtain information on the contract type, occurrence and impact of change in project as well as the engineering percent complete the participant or organization participated or is participating in.

Section C1 – Contract Type		
10	What was the contract type used for the project	Choose all that apply ☐ Lump Sum ☐ Fixed Cost ☐ Reimbursable ☐ Turnkey ☐ Unit Rate ☐ Design and Build ☐ Others: Specify

Section C2 – Overall Changes in the Project		
11	Were there any change(s) to the project cost of the project that you participated in	☐ Yes ☐ No
12	If "Yes", was / is the cost change(s) related to changes in the project.	☐ Yes ☐ No
13	Were there any change(s) in the schedule of the project you participated in	☐ Yes ☐ No
14	If "Yes", was / is the changes in schedule related to changes in the project	☐ Yes ☐ No

Section C3 – Engineering Percent Complete		
15	What was the percentage of Engineering design completion prior to contract award	Choose an Item Less than 20%s 20 – 40% 40 – 60%s 60 – 80% 80 – 100%

Section D – Change Management Organization and Knowledge

The purpose of this section is to determine the level of practice of project change management in organizations, including the existence of project change management unit, leadership of change management as well as responders experience in project change management.

Section D1 – Existence of Change Management Unit in Organization		
16	Does your organization have a Change Management unit	☐ Yes ☐ No

Section D2 – Location of Change Management Function in Organization		
17	Where is change management function located in your organization	Choose only one Standalone unit Project Control unit Supply Chain Management unit Project Management unit Construction unit Others: Specify ☐

Section D3 – Management of Change Management Unit		
18	Who heads the Project Change Management unit in your organization or project	Choose only one Manager Supervisor Staff Director Design and Build Others: Specify ☐

Section D4 – Presence of Change Management Processes and Procedures		
19	Does your organization have a documented Change Management process and / or procedure	☐ Yes ☐ No

Section D5 – Knowledge of Change Management		
20	Who heads the Project Change Management unit in your organization or project	Choose only one Novice Entry Level Proficient Advanced Expert

Section E – Changes in Project Cost

The purpose of this section is to obtain information about the changes in project cost in order to determine changes that are attributable to changes. Although we are aware of the sensitivity of the questions in this section, the information will allow us to better determine the impact of scope changes and better forecast the magnitude of the changes in different situations. Once again, we assure you that you, your response and organization will remain anonymous

Section E1 – Cost – Project Budget		
21	What is the original budget of the project	Amount Specify ☐ I do not wish to answer

Section E2– Changes in Project Cost - Bid Stage		
22	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others: Specify
23	What was the total amount of change in this phase	Amount Specify ☐ I do not wish to answer

Section E3 – Changes in Project Cost - Pre-Construction Phase		
24	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions

		☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others: Specify
25	What was the total amount of change in this phase	Amount Specify ☐ I do not wish to answer

Section E4 – Changes in Project Cost - Construction Phase		
26	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others: Specify
27	What was the total amount of change in this phase	Amount Specify ☐ I do not wish to answer

Section E5 – Changes in Project Cost - Commissioning Phase		
28	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others: Specify
29	What was the total amount of change in this phase	Amount Specify ☐ I do not wish to answer

Section F

The purpose of this section is to obtain information about the changes in project schedule in order to determine changes that are attributable to changes. Although we are aware of the sensitivity of the questions in this section, the information will allow us to better determine the impact of scope changes and better forecast the magnitude of the changes in different situations. Once again, we assure you that you, your response and organization will remain anonymous

Section F1 – Changes in Project Duration		
30	What was the original duration estimate for the project	Duration in Years and Months ☐ I do not wish to answer

Section F2 – Changes in Project Duration - Bid Phase		
31	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others:
32	What was the total amount of change in this phase	Duration Specify ☐ I do not wish to answer

Section F3 – Changes in Project Duration - Pre-Construction Phase		
33	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others:
34	What was the total amount of change in this phase	Duration Specify ☐ I do not wish to answer

Section F4 – Changes in Project Duration – Construction Phase		
35	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others:
36	What was the total amount of change in this phase	Duration Specify ☐ I do not wish to answer

Section F5 – Changes in Project Duration – Commissioning Phase		
37	If "Yes", what was/were the cause(s)	Choose all that apply ☐ Design Changes ☐ Site Condition ☐ Scope Change ☐ Change in Regulations ☐ Change in Technology ☐ Market Conditions ☐ Management Decisions ☐ Environmental ☐ Materials and Equipment ☐ Fast Tracking ☐ Others:
38	What was the total amount of change in this phase	Duration Specify ☐ I do not wish to answer

Section G

The purpose of this section is to collection information on the opinion and experience about the impact of scope change on project cost and schedule.

Please circle only one option

Section G1 – Ranking						
	1= Strongly Disagree (SD) 2= Disagree (DI) 3= No Opinion (NO) 4= Agree (AG) 5= Strongly Agree (SA)	1	2	3	4	5
39	Would you agree that change has a significant impact in project cost overrun?	1	2	3	4	5
40	Would you agree that change has a significant impact in project schedule overrun?	1	2	3	4	5

Appendix C – Sample Change Log

1	Sample Change Management Log													
2	S/N	Ref #	Description	Work Area	Originator	Received Date	Submission Date	Date Approved	Impact on Cost	Impact on Schedule	Quantities	Hours	Estimated Total Cost	Estimated Total Duration	Comments
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
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20															
21															
22															
23															
24															
25															
26															
27															
28															

<Project Name> Change Notice			
Owner	*<Owner's Name>*	Contractor	*<Contractor's Name>*
Address	*<Address>*	Address	*<Address>*
Contract Number	*<Number>*	Date	*<Date>*
Reference Number	*<Number>*	Change Notice Number	*<Number>*
Description of Change: Location: Scope: Cost: Schedule:			
Pricing Method	☐Unit Cost ☐ Cost Reimbursable ☐Lump Sum ☐ Others ☐ N/A		
Authorized Owner's Rep	*<Name Title Signature>*	Date	*<Date>*
To: Owner ☐Accepted ☐ Acknowledge with Exceptions			
☐We are proceeding with the requested change ☐We are not proceeding with the requested change ☐We will proceed with the requested change with modifications			
Contractor's Rep	*<Name Title Signature>*	Date	*<Date>*

<Project Name>
Change Request

Owner	*<Owner's Name>*	Contractor	*<Contractor's Name>*
Address	*<Address>*	Address	*<Address>*
Contract Number	*<Number>*	Date	*<Date>*
Reference Number	*<Number>*	Change Request Number	*<Number>*

Description of Change:

Impact:

Proposed Solution:

Location:

Scope:

Labour Cost	Material Cost	Equipment Cost	Subcontractor Cost	Hours	Total Cost
<$>	*<$>*	*<$>*	*<$>*	*<Hr.>*	*<$>*

Schedule Impact	Critical Path	☐Yes ☐No	Number of Days	*<Days>*
	Total Float	☐Yes ☐No	Number of Days	*<Days>*
	Free Float	☐Yes ☐No	Number of Days	*<Days>*
	None Critical			

Contractor's Approval	*<Name* *Title* *Signature>*	Date	*<Date>*

To: Owner
☐Accepted ☐ Modification Required ☐ Suspend ☐ Rejected

Owner's Rep	*<Name* *Title* *Signature>*	Date	*<Date>*

<Project Name> Extra Work Request Form				
Contractor	*< Contractor's Name >*		Owner	*< Owner's Name >*
Contract #	*<Number>*		Date	*<Date>*
Reference #	*<Number>*		Extra Work Request #	*<Number>*
Location	*<Description of location of work to be done>*			
Description of work to be done: Scope of work:				
Labour	Duration______ Crew Size______ Craft _____ Supervision ________			
Equipment	Duration______ Equipment Qty______ Equipment Types________________			
Subcontractor	Name________________________________ Duration ________________			
Schedule Impact	Critical Path	☐Yes ☐No	Number of Days	*<Days>*
	Total Float	☐Yes ☐No	Number of Days	*<Days>*
	Free Float	☐Yes ☐No	Number of Days	*<Days>*
	None Critical			
Labour Cost	Equipment Cost	Subcontractor Cost	Hours	Total Cost
<$>	*<$>*	*<$>*	*<Hr.>*	*<$>*
Contractor's Rep	*<Name Title Signature>*		Date	*<Date>*
Owner ☐Accepted ☐ Rejected ☐ Resubmit				
Authorized Owner's Rep	*<Name Title Signature>*		Date	*<Date>*

CONTRACT CHANGE ORDER	
Owner	*<Address>*
Contractor	*<Address>*
Project No.	Change Order No.
Date Issued	Effective Date
DESCRIPTION OF CHANGE ORDER The contract is herein modified to incorporate the following changes: Description of Change Order: Reasons for Change Order Attachments *(List documents supporting change order)*	
Original Contract Value: Total of Previous Change Orders: Value of Current Change Order: Revised Contract Value	$ $ $ $ $
Original Contract Duration: Total of Previous Schedule Changes: Schedule Change in this Change Order: Revised Contract Duration:	
Comments:	
Owner's Authorized Rep	Contractor's Authorized Rep
Name: Title: Signature: Date:	Name: Title: Signature: Date:

Request for Information (RFI)

Contractor	*<Contractor's Name>*	Owner	*<Owner's Name>*		
RFI #	*<RFI Number>*	Reference #	*<Reference Number>*	Date	*<Date>*
Title					
Prepared By	*<Name>*	Area	*<Area Location>*	Discipline	*<Subject Matter>*

Description:

Supporting Documents:

Impacts:

☐Cost ☐ Schedule

Owner's Response:

Owner's Disposition	☐No Change Required ☐Field Change Notice (FCN) ☐Field Change Request (FCR) ☐Change Notice (CN) ☐Change Request (CR)

Disposition Date	*<Date>*		
Contractor	*<Name of Contractor>*	Owner	*<Name of Owner>*
Name	*<Name of Contractor's Rep>*	Name	*<Name of Owner's Rep>*
Title	*<Title>*	Title	*<Title>*
Signature	*<Signature>*	Signature	*<Signature>*
Date	*<Date>*	Date	*<Date>*

Field Change Notice (FCN)

Contractor	*<Contractor’s Name>*	Owner	*<Owner’s Name>*

FCN #	*<FCN Number>*	Reference #	*<Reference Number>*	Date	*<Date>*

Title	

Prepared By	*<Name>*	Area	*<Area Location>*	Discipline	*<Subject Matter>*

Description of Change:

Existing Condition:

Proposed Change:

Supporting Documents:

Directive to Contractor:

Impacts:
☐Cost ☐ Schedule ☐No Cost ☐No Schedule

Contractor to :

☐ Do Nothing ☐Receive Change Notice ☐Submit Change Request

Category:
☐Design ☐Construction ☐Equipment ☐Process

For Engineering Only

Reviewed By:	Name	Signature	Date
Field Engineer			
Design Engineer			
Approved By:			
Project Engineer			
Principal Engineer			

Field Change Request (FCR)

Contractor	*<Contractor’s Name>*	Owner	*<Owner’s Name>*		
FCR #	*<FCR Number>*	Reference #	*<Reference Number>*	Date	*<Date>*
Title					
Requested By	*<Name>*	Area	*<Area Location>*	Discipline	*<Subject Matter>*

Description of Change:

Existing Condition:

Proposed Solution:

Supporting Documents:

Impacts:
☐Cost ☐ Schedule ☐No Cost ☐No Schedule

Category:
☐Design ☐Construction ☐Equipment ☐Process

Reviewed By:	Name	Signature	Date
Field Engineer			
Construction Mgr.			
Approved By:			
Project Manager			

Owner Engineer’s Disposition:

Approval: ☐Approved ☐Not Approved ☐Approved with changes.

For Engineering Only			
Reviewed By:	Name	Signature	Date
Field Engineer			
Design Engineer			
Approved By:			
Project Engineer			
Principal Engineer			

Appendix E – Inventory of Major Alberta Projects

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
OH73	1CACA14C	Oil & Gas	Wheatland	$90.0	2004
JK42	4232231B	Oil & Gas	Wheatland	$130.0	2002-2005
QS36	2BA2BDDA	Oil & Gas	Greenview	$9.5	2004
QO30	DC2141D3	Oilsands	Wood Buffalo	$37.0	2005
QA34	3CD4AC2B	Oil & Gas	Greenview	$6.0	2004
MY99	44114D4B	Oilsand	Wood Buffalo	$1,100.0	2004-2013
QR94	3BADC4D4	Oilsand	Wood Buffalo	$270.0	2004-2006
DM68	DCAD434A	Oilsand	Wood Buffalo	$400.0	2000-2009
TR52	4441443C	Oilsands	Wood Buffalo	$10.0	2007
SK82	22A2DA22	Pipelines	central Alberta	$6.0	2011-2012
KL41	D32421BC	Oil & Gas	Redwater	$50.0	2005-2006
KP84	11BDB343	Pipelines	Yellowhead	$10.0	2004-2005
HJ13	13C2CA3C	Oil & Gas	Rocky View	$15.0	2004-2005
FY67	1443BD4B	Pipelines	Greenview	$17.5	2006-2007
ZA77	2DDC3A3D	Oilsand	Wood Buffalo	$30.0	2004-2005
II30	224341AB	Chemical & Petrochemical	Grande Prairie	$12.0	2004-2005
FD79	1AB3CA4C	Chemical & Petrochemical	Lacombe	$16.0	2004-2005
SN99	31C422CC	Pipeline	Athabasca	$90.0	2003-2004
AL18	4D423AB1	Pipeline	Opportunity	$19.3	2004
SP51	42BCAD13	Pipeline	Fort Saskatchewan	$50.0	2004-2005
NF84	23AD1432	Chemicals & Petrochemicals	Wheatland	$40.0	2005-2006
LK56	4221A314	Oil & Gas	Strathcona	$160.0	2005-2006
YA19	43C1CD41	Oil & Gas	Newell	$14.0	2005
FS52	D4A2A1AC	Oil & Gas	Clear Hills	$6.0	2005
MH14	DB14213C	Oil & Gas	Greenview	$13.0	2005
IA14	442DA14B	Oil & Gas	Greenview	$9.0	2005
SD74	242C2ABD	Oil & Gas	Greenview	$12.0	2005-2006
MS68	D1CDDDDD	Oil & Gas	Newell	$10.0	2005
VP11	14CD113A	Oil & Gas	Spirit River	$11.0	2005-2006
TU38	D3A3D442	Oil & Gas	east central Alberta	$40.0	2004-2005
KF73	2D2B4223	Oil & Gas	Strathcona	$250.0	2004-2006
EV71	1B3D111C	Oil Sands	Wood Buffalo	$50.0	2011-2012
KR19	24AB43CB	Oil Sands	Big Lakes	$150.0	2010-2011

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
MN13	22C3CAB4	Oil & Gas	Pincher Creek	$70.0	2005-2006
LS28	DC2BABCB	Oil & Gas	Yellowhead	$7.0	2005
MF22	1CDAB2BA	Oil & Gas	Yellowhead	$85.0	2005
AV82	3B13134D	Oilsands	Strathcona	$800.0	2005-2007
IA76	43D1ADB3	Oilsands	Bonnyville	$340.0	2005-2010
UU23	D2BC4BCD	Oilsands	Wood Buffalo	$450.0	2005-2007
BM14	24CA2DD1	Oilsands	Bonnyville	$100.0	1997-2005
UC68	44DACDAD	Oilsands	Bonnyville	$500.0	2005-2006
IQ54	22A1234A	Pipelines	central Alberta	$11.0	2011-2012
AW52	D2CDC423	Oil & Gas	Strathcona	$250.0	2004-2006
FP72	1242CC31	Oilsands	Wood Buffalo	$177.0	2007-2009
ZN22	14CC44D4	Oil & Gas	Strathcona	$200.0	2004-2006
UQ23	DA411DBA	Oilsands	Wood Buffalo	$216.0	2007-2009
BA74	34A411AC	Oilsands	Wood Buffalo	$178.0	2004-2006
PR63	31CA4C1B	Oilsands	Wood Buffalo	$44.7	2004-2005
MG17	24ABB3DB	Pipelines	Yellowhead	$8.0	2005
IB54	3CC23DB2	Pipelines	Greenview	$28.0	2005-2006
JF89	D13C2313	Oilsands	near Peace River	$25.0	2008
CE35	DBABB42C	Oil & Gas	Bowden	$21.0	2011-2012
QW13	DAA4BACB	Oil & Gas	Edmonton	$200.0	2006-2008
FT12	DCC41AC4	Oil & Gas	Northern Sunrise	$25.0	2006-2007
HC45	1DB4344D	Oil & Gas	Greenview	$6.0	2006
FQ55	2A14CB1B	Oil & Gas	Hardisty	$250.0	2006-2008
YH98	43DB4C42	Oil & Gas	Greenview	$9.0	2006-2007
OU70	4223B222	Oil & Gas	central Alberta	$100.0	2006
WO16	12C42DC3	Oil & Gas	Yellowhead Cty	$200.0	2005-2006
MF89	1D134CBB	Oilsands	Strathcona	$900.0	2006-2008
BA51	212112B3	Oilsands	Lakeland	$250.0	2004-2007
II58	3ABD1133	Oilsands	Wood Buffalo	$6,800.0	2005-2008
GH74	2A1B32A4	Oilsands	Wood Buffalo	$1,400.0	2004-2013
TP22	DAD13312	Oilsands	Wood Buffalo	$550.0	2005-2007
DO33	132DCBCA	Oilsands	Lakeland	$440.0	2005-2006
XR10	11B22A3C	Oilsands	Bonnyville	$350.0	2005-2006
YJ79	14B34241	Pipelines	Wood Buffalo	$34.0	2005-2006
TW51	112C2CD3	Oilsand	Wood Buffalo	$460.0	2009-2011
ZV78	134CACBA	Oilsand	Wood Buffalo	$234.0	2007-2010

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
IA99	3CB123A1	Pipelines	Wood Buffalo	$400.0	2005-2006
TY60	1D2BB13A	Pipeline	across Alberta	$35.0	2010
KI76	24212DC3	Pipelines	Clearwater	$40.0	2011-2012
DM23	341DC3BC	Pipelines	Wood Buffalo	$37.0	2005-2006
VF24	3BAAD2BC	Chemicals & Petrochemicals	Strathcona	$20.0	2007-2008
KL50	1D1B3B32	Oil and Gas	Fort Saskatchewan	$18.0	2008-2010
MR92	2C4A31BB	Oil & Gas	Strathcona	$1,150.0	2006-2009
WI21	411BDADD	Oilsands	Wood Buffalo	$7,750.0	2005-2008
VP40	1B2B43D4	Oilsands	Strathcona	$71.0	2007-2008
XA19	2A13ACA3	Oilsands	Wood Buffalo	$15,200.0	2007-2012
SN10	1C143D32	Pipeline	northeast Alberta	$22.0	2009
OQ40	1BBA44CB	Pipelines	Opportunity	$25.3	2005-2006
WO36	334CCA43	Pipelines	Wood Buffalo	$42.0	2006
GZ69	1B21C41B	Oilsand	Lindbergh	$1,200.0	2000-2010
LY12	D1C33234	Oilsand	Bonnyville	$340.0	2005-2010
VJ53	3D3D4AD1	Oil Sands	Wood Buffalo	$385.0	2012-2013
GS65	2D3DDD14	Oil Sands	Wood Buffalo	$415.0	2011-2012
VO96	2413C14A	Oil Sands	Wood Buffalo	$480.0	2012-2013
DL16	32C232A1	Oilsands	Wood Buffalo	$772.0	2005-2011
QU63	23DB23BC	Oilsands	Wood Buffalo	$1,000.0	2006-2008
HG44	4AB31CDC	Chemicals and Petrochemicals	Medicine Hat	$30.0	2012-2013
PI35	44CDAA4B	Pipeline	across Alberta	$46.0	2010
SH64	43B12D2B	Oilsands	Wood Buffalo	$50.0	2008-2009
XO50	4A42311A	Pipeline	Wood Buffalo	$355.0	2007-2008
OQ31	1DBCB322	Pipeline	Canada	$135.0	2005-2009
RO95	331CDDCA	Pipeline	Wood Buffalo	$200.0	2007-2008
OC92	41C4CC42	Oil & Gas	Ponoka	$28.0	2008-2009
MT33	1DCA1333	Oil & Gas	Special Area	$36.0	2007-2009
KX43	334C4CBD	Chemical & Petrochemical	Medicine Hat	$40.0	2010-2011
CQ68	32C4CAB4	Pipeline	Wood Buffalo	$51.7	2007-2008
TF28	1ADBBCCC	Chemicals & Petrochemicals	Fort Saskatchewan	$100.0	2007-2012
CA15	2A33AC13	Oil & Gas	Hardisty	$400.0	2006-2009
AE85	1CDC41C2	Oilsand	Lloydminster	$60.0	2004-2005
LX63	1241D411	Pipelines	Cold Lake	$60.0	2008
GI84	D333CA12	Oilsands	Wood Buffalo	$2,000.0	2007-2009

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
KY65	3A232133	Oilsands	Wood Buffalo	$5,000.0	2007-2010
FD95	3C44313B	Oilsands	Lakeland	$600.0	2007-2008
MS78	2DDBA2DD	Oilsands	Wood Buffalo	$3,100.0	2007-2013
FI71	1CBAD2CD	Oilsands	Wood Buffalo	$1,060.0	2008-2011
PQ22	2B4CD23D	Oilsands	Lakeland	$844.0	2007-2008
XQ22	D2DAAA3C	Oilsands	Lloydminster	$75.0	2008
HN82	24A32CAC	Oilsands	Wood Buffalo	$1,100.0	2003-2005
QY17	D4AA2AD2	Oil Sands	Fort Saskatchewan	$1,350.0	2012-2015
RX60	DD1DBB13	Oilsands	Wood Buffalo	$1,500.0	1997-2007
NF74	D14B42CA	Pipelines	Mountain View	$55.0	2008
GX48	2C213C43	Pipelines	Strathcona	$100.0	2007-2009
BS85	23A33DC2	Pipelines	Canada	$2,000.0	2008-2010
XZ20	4AB423D1	Pipelines	Edmonton	$300.0	2008-2009
IV98	34A1B21D	Pipelines	Hardisty	$300.0	2005-2009
YB43	D4BD4BB2	Pipeline	Lloydminster	$100.0	2006-2007
KZ98	DBD1D1B4	Oil & Gas	Strathcona	$133.0	2007-2008
JU35	32C3AAA4	Pipelines	Edmonton area	$135.0	2010-2012
KE15	D234C1D1	Oil and Gas	Hardisty	$600.0	2007-2009
FQ96	1143C4D3	Oilsand	Strathcona	$5,600.0	2006-2010
EY43	311BDC43	Oilsand	Wood Buffalo	$363.0	2008-2010
SX15	4D2AB21A	Oilsand	Wood Buffalo	$575.0	2000-2009
QE66	42A4B2D1	Pipeline	Wood Buffalo	$149.9	2007-2008
YP97	2BB123A2	Oil Sands	Wood Buffalo	$175.0	2008-2011
DM84	24DA1D3A	Oil Sands	Wood Buffalo	$1,600.0	2005-2011
NA48	4121ADA3	Oil Sands	Wood Buffalo	$1,700.0	2011-2013
CC44	1142B421	Oil Sands	Fort McMurray	$1,800.0	2011-2013
II32	4D2BC424	Oilsand	Lethbridge	$213.0	2009-2010
NL70	4AC4C3A3	Oilsand	Mackenzie	$77.5	2009-2011
LZ87	132B1A4D	Oilsand	NW Alberta	$190.0	2009-2010
NO10	3CB2CCAC	Oilsand	Peace River	$210.0	2007-2010
DV90	D443421D	Oilsand	Calgary	$100.0	2008-2009
VL52	D1CC4B33	Oilsand	Rocky View	$130.0	2008-2009
FC66	3B442B2D	Oilsand	Edmonton	$245.0	2007-2011
FT79	13C33DDD	Pipelines	Rainbow Lake	$324.0	2012-2013
BK84	42234C12	Oilsand	Pincher Creek	$123.0	2009-2010
DB53	1C2114AD	Oilsand	Willow Creek	$115.0	2009

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
SL39	444D2222	Oilsand	Parkland	$1,600.0	2007-2011
CX24	D314A311	Oilsand	Pincher Creek	$115.0	2009-2010
KW57	1DAD43AD	Pipeline	Canada	$2,400.0	2008-2009
RR27	413AC12B	Oilsand	Wood Buffalo	$850.0	2008-2010
DT68	DBDBBD1D	Oil & Gas	Grande Prairie	$30.0	2009-2010
XI58	2B2D2443	Oilsand	Wood Buffalo	$10.0	2010
TK11	4BDB3A42	Oilsand	Wood Buffalo	$2,000.0	2010-2014
GA26	D24CB433	Oilsand	Wood Buffalo	$1,060.0	2008-2011
XQ99	1BBABCAC	Oilsand	Wood Buffalo	$8,000.0	2009-2012
WY52	1D24BA13	Oilsands	Strathcona	$1,600.0	2004-2008
SK79	1ADABCBC	Oilsand	Wood Buffalo	$2,000.0	2007-2010
HS95	DC42B4B4	Pipeline	Wood Buffalo	$10.0	2010
AZ77	23B4D1BC	Oil and Gas	Hinton	$200.0	2012-2013
BP81	44441B1C	Oil and Gas	Grande Cache	$230.0	2012-2013
YM46	42424213	Oilsands	Wood Buffalo	$2,100.0	2006-2008
RA15	1D4C33C1	Oil Sands	Wood Buffalo	$110.0	2011-2012
JW40	3C23224C	Oil Sands	Wood Buffalo	$20.0	2011
UJ98	14D14B43	Pipelines	Strathcona	$150.0	2011-2013
UE22	341BC3AC	Oil Sands	Opportunity	$250.0	2011-2013
PM84	1A3D444D	Pipeline	Wood Buffalo	$300.0	2006-2008
YK49	3322BBA2	Oilsands	Strathcona	$2,000.0	2005-2008
BI31	134CC34C	Oilsands	Strathcona	$2,500.0	2005-2008
GC23	33441DDC	Oilsands	Wood Buffalo	$2,300.0	2006-2008
EK54	1333121C	Oil Sands	Wood Buffalo	$3,600.0	2012-2014
KG38	41DC14B2	Pipelines	Athabasca	$29.2	2011-2012
RG89	D1D411B3	Pipelines	Edmonton	$400.0	2011-2012
HX64	3B234433	Pipelines	Wood Buffalo	$250.0	2010-2011
TB42	232D211D	Oil Sands	Athabasca	$435.0	2011-2013
AU99	14CBC2CA	Pipelines	Wood Buffalo	$338.0	2006-2008
JD21	12ABAC1D	Pipelines	Fort McMurray	$283.0	2010-2012
BT88	33B3B1D1	Oil & Gas	Saddle Hills	$235.0	2011-2012
SB17	231BA21C	Oil & Gas	Bowden	$21.0	2011-2012
BC65	1314A31D	Oil & Gas	Pincher Creek	$40.0	2011-2012
LW87	424AD14A	Oil Sands	Wood Buffalo	$1,250.0	2010-2013
PU23	DCD21CBD	Oil Sands	Wood Buffalo	$2,000.0	2010-2015
BQ44	D434B234	Oil Sands	Wood Buffalo	$110.0	2011-2012

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
CO45	D33313CD	Oil Sands	Wood Buffalo	$220.0	2012-2013
QV11	1B223C33	Oil Sands	Wood Buffalo	$300.0	2011-2012
LQ39	1D322ADD	Oil Sands	Wood Buffalo	$20.0	2011
NB67	32241341	Oil Sands	Wood Buffalo	$2,500.0	2011-2013
AS99	3D4BCBBB	Oil Sands	Wood Buffalo	$10,900.0	2009-2012
OB75	12A1D2B1	Oil Sands	Opportunity	$250.0	2011-2013
EV39	DBCC2BDC	Oil Sands	Strathcona	$150.0	2011-2013
VJ92	D42C22B2	Oil Sands	Wood Buffalo	$1,400.0	2011-2014
QR98	1DBC1DBB	Oil Sands	Wood Buffalo	$175.0	2008-2011
MI52	44112C4C	Oil Sands	Wood Buffalo	$50.0	2011-2012
HR38	1C3BB221	Oil Sands	Big Lakes	$150.0	2010-2011
QX33	423CDAD3	Oil Sands	Wood Buffalo	$415.0	2011-2012
AM46	43B3DDCA	Oil Sands	Wood Buffalo	$1,700.0	2011-2013
NA45	413AB11B	Oil Sands	Wood Buffalo	$11,600.0	2011-2016
NE55	DBB443D3	Oil Sands	Wood Buffalo	$1,600.0	2005-2011
HE59	2DDBA3CD	Pipelines	Athabasca	$29.2	2011-2012
SF56	2C2A4ABC	Pipelines	Edmonton	$400.0	2011-2012
RF55	4A33AA4B	Pipelines	Wood Buffalo	$475.0	2011-2013
EN86	1CBBBD4C	Pipelines	Wood Buffalo	$250.0	2010-2011
SV57	234A324C	Pipelines	Edmonton area	$135.0	2010-2012
ZF58	11D23DBB	Pipelines	Kneehill	$8.7	2011-2012
QX65	422C4BDC	Pipelines	Innisfail	$34.0	2010-
VD75	DB4DABAB	Pipelines	Northern Sunrise	$9.0	2011-2012
OF87	3BC33CD2	Pipelines	central Alberta	$6.0	2011-2012
XQ90	3DD4C214	Pipelines	central Alberta	$11.0	2011-2012
CZ61	4D4AD134	Pipelines	across Alberta	$40.0	2011-2012
BB17	3CD2A44D	Pipelines	Fort McMurray	$283.0	2010-2012
QE63	21C44DA1	Chemicals and Petrochemicals	Lacombe	$41.0	2011-2012
GY27	13A3D32B	Oil and Gas	Saddle Hills	$235.0	2011-2012
UG42	2B1B2B1A	Oil and Gas	M.D. of Fairview	$66.0	2012-2012
WR54	DACCABAC	Pipeline	Wood Buffalo	$350.0	2006-2008
AD57	13B1214C	Pipeline	Slave Lake	$440.0	2010-2011
PG12	3D4AADDA	Oilsands	Wood Buffalo	$550.0	2007-2008
XK30	434A1C4C	Oil Sands	Wood Buffalo	$2,700.0	2012-2016
UT75	3C3B14BA	Oil Sands	Wood Buffalo	$1,600.0	2012-2017
NW38	3C2B2AA2	Oil Sands	Wood Buffalo	$300.0	2011-2012

Inventory of Major Albert Projects from 2000 to 2012					
Company Ref. No.	**Project Code**	**Project Sector**	**Project Location**	**Cost ($ Millions)**	**Construction Schedule**
QO82	3CC32422	Oil Sands	Fort McMurray	$2,500.0	2011-2013
TA44	2B33DC41	Pipeline	Mt Robson Prov Pk	$443.0	2007-2008
BD59	3434D23A	Pipelines	Mt Robson Prov Pk	$460.0	2007-2008
PG23	141CB33D	Oilsand	Wood Buffalo	$5,000.0	2007-2010
NU67	D3BD4CCD	Oilsand	Wood Buffalo	$7,800.0	2001-2006
GF28	32CDA3B4	Oilsands	Wood Buffalo	$8,100.0	2001-2005
VO33	DDD34144	Pipelines	Wood Buffalo	$400.0	2011-2012
ZI94	22D244C4	Pipelines	Fort McMurray	$370.0	2011-2013
VO33	DDD34144	Pipelines	Wood Buffalo	$400.0	2011-2012
ZI94	22D244C4	Pipelines	Fort McMurray	$370.0	2011-2013
VO33	DDD34144	Pipelines	Wood Buffalo	$400.0	2011-2012
ZI94	22D244C4	Pipelines	Fort McMurray	$370.0	2011-2013
VO33	DDD34144	Pipelines	Wood Buffalo	$400.0	2011-2012
ZI94	22D244C4	Pipelines	Fort McMurray	$370.0	2011-2013
VO33	DDD34144	Pipelines	Wood Buffalo	$400.0	2011-2012
ZI94	22D244C4	Pipelines	Fort McMurray	$370.0	2011-2013

Appendix F – Questionnaire Code Key

Question 1	
Project Manager	1
Project Engineer	2
Construction Manager	3
Contract Manager	4
Project Control Manager	5
Change Manager	6
Estimating Manager	7
Scheduling Manager	8
Others: Specify	9

Question 3	
Less than 5 years	1
5 – 9 years	2
10 – 14 years	3
15 – 24 years	4
25 – 29 years	5
30 years and above	6

Question 4	
Less than 5 years	1
5 – 9 years	2
10 – 14 years	3
15 – 24 years	4
25 – 29 years	5
30 years and above	6

Question 6	
Owner Organization	1
Construction Management Organization	2
Construction Contractor Organization	3
EPC Organization	4
Subcontractor Organization	5
Prime Contractor	6
Suppliers	7
Others: Specify	8

Question 7	
Oil and Gas	1
Oilsands	2
Pipeline	3
Chemical & Petrochemical	4

Question 10	
Lump Sum	1
Fixed Cost	2
Reimbursable	3
Turnkey	4
Unit Rate	5
Design and Build	6
Others: Specify	7

Question 15 Engineering Percentage Complete	
0-20	1
21-40	2
41-60	3
61-80	4
81-100	5

Questions 17, 19, 21, 23, 26, 28, 30, 32	
Design Changes	1
Site Condition	2
Scope Change	3
Regulations	4
Change in Technology	5
Market Conditions	6
Management Decisions	7
Environmental	8
Materials and Equipment	9
Fast Tracking	10
Others: Specify	11

Appendix G – Questionnaire Result Summary

Participant's Role in their Organization

Roles	Frequency	Percent
Project Manager	59	26.5%
Project Engineer	41	18.4%
Construction Manager	51	22.9%
Contract Manager	16	7.2%
Project Control Manager	16	7.2%
Change Manager	9	4.0%
Estimating Manager	12	5.4%
Scheduling Manager	9	4.0%
Others: Specify	10	4.5%
Total	223	100.0%

Participants Worked in Alberta

Responses	Frequency	Percent
No	2	0.01%
Yes	223	99.99%
Total	225	100.0%

Years of Experience in the Oil and Gas Industry

	Frequency	Percent	Cumulative Percentage
Less than 5 years	45	20.2%	20.2%
5 – 9 years	43	19.3%	39.5%
10 – 14 years	29	13.0%	52.5%
15 – 19 years	44	19.7%	72.2%
20 – 24 years	33	14.8%	87.0%
25 - 29 year	20	9.0%	96.0%
30 years and above	9	4.0%	100.0%
Total	223	100.0%	

Years of Experience in Organization

	Frequency	Percent	Cumulative Percentage
Less than 5 years	63	28.3%	28.3%
5 – 9 years	60	26.9%	55.2%
10 – 14 years	44	19.7%	74.9%
15 – 19 years	17	7.6%	82.5%
20 – 24 years	22	9.9%	92.4%
25 - 29 year	13	5.8%	98.2%
30 years and above	4	1.8%	100.0%
Total	223	100.0%	

Years of Experience in Present Role

	Frequency	Percent	Cumulative Percentage
Less than 5 years	62	27.8%	27.8%
5 – 9 years	58	26%	53.8%
10 – 14 years	13	5.8%	59.6%
15 – 19 years	18	8.1%	67.7%
20 – 24 years	22	9.9%	77.6%
25 - 29 year	26	11.7%	89.3%
30 years and above	24	10.7%	100.0%
Total	223	100.0%	

Role of Organization in Project

		Responses	
		N	Percent
Role of Organization in Project	Owner Organization	61	22.3%
	Construction Management Organization	12	4.4%
	Construction Contractor Organization	98	35.9%
	EPC Organization	57	20.9%
	Subcontractor Organization	11	4.0%
	Prime Contractor	26	9.5%
	Suppliers	6	2.2%
	Others: Specify	2	0.7%
Total		273	100.0%

Project Types

		Responses	
		N	Percent
Project Types	Oil and Gas	60	23.5%
	Oil sands	107	42.0%
	Pipelines	72	28.2%
	Chemical & Petrochemical	16	6.3%
Total		255	100.0%

Engineering Percent Complete

	Frequency	Percent
0-20	20	9.0%
21-40	58	26.0%
41-60	43	19.3%
61-80	43	19.3%
81-100	59	26.4%
Total	223	100.0%

Project Located in Alberta

	Frequency	Percent
No	2	0.01%
Yes	223	99.99%
Total	225	100.0%

Existence of Change Management Unit in Organization

	Frequency	Percent
No	142	63.68%
Yes	81	36.32%
Total	223	100.0%

Location of Change Management Function in Organizations

	Frequency	Percent
Standalone unit	3	1.35%
Under Project Control unit	112	50.22%
Under Supply Chain Management unit	38	17.04%
Under Project Management unit	13	5.83%
Under Construction unit	16	7.17%
Under Contract Management unit	30	13.45
Others	11	4.48%
Total	223	100.0%

Leadership of Change Management Unit

	Frequency	Percent
Manager	13	5.83%
Supervisor	25	11.21%
Staff	172	77.13%
Director	3	1.35%
Others	10	4.48%
Total	223	100.0%

Presence of Change Management Procedure

	Frequency	Percent
No	120	46.19%
Yes	103	53.81%
Total	223	100.0%

Experience with Change Management

	Frequency	Percent
Novice	5	2.24%
Entry Level	12	5.38%
Proficient	114	51.12%
Advanced	45	20.18%
Expert	47	21.08%
Total	223	100.0%

Contract Types

		Responses	
		N	Percent
Contract Type	Fixed Cost	49	14.7%
	Reimbursable	141	42.3%
	Turnkey	5	1.5%
	Unit Rate	130	39.0%
	Lump Sum	8	2.4%
Total		333	100.0%

Cost and Schedule Changes in Projects

	Yes		No	
	Response	Percent	Response	Percent
Where there cost changes in project	192	86.1%	31	13.9%
Where cost changes related to changes in the project	187	83.9%	36	16.1%
Where there schedule change in the project	190	85.2%	33	14.8%
Where schedule change related to changes in the project	195	87.4%	28	12.6%

Cost Change in Project

	Frequency	Percent
No	31	13.9%
Yes	192	86.1%
Total	223	100.0%

Cost Change Related to Changes in Project

	Frequency	Percent
No	36	16.1%
Yes	187	83.9%
Total	223	100.0%

Schedule Change in Project

	Frequency	Percent
No	33	14.8%
Yes	190	85.2%
Total	223	100.0%

Schedule Change Related to Changes in Project

	Frequency	Percentage
No	28	12.56%
Yes	195	87.44%
Total	223	100.00%

Causes of Change in Project Cost in Bid Phase

		Responses	
		N	Percent
Causes of Change in Cost in Bid Phase	Design Changes	129	35.5%
	Site Condition	4	1.1%
	Scope Change	112	30.9%
	Regulations	3	0.8%
	Change in Technology	4	1.1%
	Market Conditions	13	3.6%
	Management Decisions	87	24.0%
	Environmental	2	0.6%
	Materials and Equipment	4	1.1%
	Fast Tracking	1	0.3%
	Others: Specify	4	1.1%
	Total	363	100.0%

Causes of Change in Project Cost in Preconstruction Phase

		Responses	
		N	Percent
Causes of Change in Cost in Preconstruction Phase	Design Changes	123	23.9%
	Site Condition	89	17.3%
	Scope Change	130	25.3%
	Regulations	1	0.2%
	Change in Technology	1	0.2%
	Market Conditions	11	2.1%
	Management Decisions	102	19.8%
	Environmental	47	9.1%
	Materials and Equipment	5	1.0%
	Fast Tracking	1	0.2%
	Others: Specify	4	0.8%
	Total	514	100.0%

Causes of Change in Project Cost in Construction Phase

		Responses	
		N	Percent
Causes of Change in Cost in Construction Phase	Design Changes	73	11.7%
	Site Condition	143	23.0%
	Scope Change	104	16.7%
	Regulations	4	0.6%
	Market Conditions	2	0.3%
	Management Decisions	81	13.0%
	Environmental	77	12.4%
	Materials and Equipment	117	18.8%
	Fast Tracking	16	2.6%
	Others: Specify	5	0.8%
	Total	622	100.0%

Causes of Change in Project Cost in Commissioning Phase

		Responses	
		N	Percent
Causes of Change in Cost in Commissioning Phase	Design Changes	10	3.3%
	Site Condition	13	4.2%
	Scope Change	38	12.4%
	Regulations	3	1.0%
	Change in Technology	4	1.3%
	Market Conditions	10	3.3%
	Management Decisions	75	24.5%
	Environmental	7	2.3%
	Materials and Equipment	127	41.5%
	Fast Tracking	9	2.9%
	Others: Specify	10	3.3%
Total		306	100.0%

Causes of Change in Project Schedule in Bid Phase

		Responses N	Responses Percent
Causes of Changes in Schedule in Bid Phase	Design Changes	83	24.5%
	Site Condition	13	3.8%
	Scope Change	104	30.7%
	Regulations	9	2.7%
	Change in Technology	11	3.2%
	Market Conditions	9	2.7%
	Management Decisions	69	20.4%
	Environmental	5	1.5%
	Materials and Equipment	34	10.0%
	Fast Tracking	2	0.6%
Total		339	100.0%

Causes of Change in Project Schedule in Preconstruction Phase

		Responses N	Responses Percent
Causes of Change in Schedule in Preconstruction Phase	Design Changes	99	29.4%
	Site Condition	53	15.7%
	Scope Change	105	31.2%
	Regulations	3	0.9%
	Change in Technology	4	1.2%
	Market Conditions	12	3.6%
	Management Decisions	49	14.5%
	Environmental	2	0.6%
	Materials and Equipment	5	1.5%
	Fast Tracking	1	0.3%
	Others: Specify	4	1.2%
	Total	337	100.0%

Causes of Change in Project Schedule in Construction Phase

Causes of Change in Schedule in Construction Phase	Responses	
	N	Percent
Design Changes	58	12.5%
Site Condition	89	19.2%
Scope Change	78	16.8%
Regulations	4	0.9%
Market Conditions	5	1.1%
Management Decisions	72	15.5%
Environmental	59	12.7%
Materials and Equipment	88	19.0%
Fast Tracking	6	1.3%
Others: Specify	5	1.1%
Total	464	100.0%

Causes of Change in Project Schedule in Commissioning Phase

Causes of Change in Schedule in Commissioning Phase	Responses	
	N	Percent
Design Changes	27	6.6%
Site Condition	39	9.5%
Scope Change	57	13.8%
Regulations	4	1.0%
Change in Technology	2	0.5%
Market Conditions	9	2.2%
Management Decisions	59	14.3%
Environmental	53	12.9%
Materials and Equipment	147	35.7%
Fast Tracking	5	1.2%
Others: Specify	10	2.4%
Total	412	100.0%

Summary of Cost and Schedule Causes in Different Phases

Phases	**Causes**	**Cost**		**Schedule**	
		N	**Percent**	**N**	**Percent**
Bid Phase	Design Changes	129	35.5%	83	24.5%
	Site Condition	4	1.1%	13	3.8%
	Scope Change	112	30.9%	104	30.7%
	Regulations	3	0.8%	9	2.7%
	Change in Technology	4	1.1%	11	3.2%
	Market Conditions	13	3.6%	9	2.7%
	Management Decisions	87	24.0%	69	20.4%
	Environmental	2	0.6%	5	1.5%
	Materials and Equipment	4	1.1%	34	10.0%
	Fast Tracking	1	0.3%	2	0.6%
	Others: Specify	4	1.1%	-	-
	Total	363	100.0%	339	100.0%
Preconstruction Phase	Design Changes	123	23.9%	99	29.4%
	Site Condition	89	17.3%	53	15.7%
	Scope Change	130	25.3%	105	31.2%
	Regulations	1	0.2%	3	0.9%
	Change in Technology	1	0.2%	4	1.2%
	Market Conditions	11	2.1%	12	3.6%
	Management Decisions	102	19.8%	49	14.5%
	Environmental	47	9.1%	2	0.6%
	Materials and Equipment	5	1.0%	5	1.5%
	Fast Tracking	1	0.2%	1	0.3%
	Others: Specify	4	0.8%	4	1.2%
	Total	514	100.0%	337	100.0%
Construction Phase	Design Changes	73	11.7%	58	12.5%
	Site Condition	143	23.0%	89	19.2%
	Scope Change	104	16.7%	78	16.8%
	Regulations	4	0.6%	4	0.9%
	Change in Technology	2	0.3%	5	1.1%
	Market Conditions	81	13.0%	72	15.5%
	Management Decisions	77	12.4%	59	12.7%
	Environmental	117	18.8%	88	19.0%
	Materials and Equipment	16	2.6%	6	1.3%
	Fast Tracking	5	0.8%	5	1.1%

	Others: Specify	622	100.0%	464	100.0%
	Total	73	11.7%	58	12.5%
Commissioning Phase	Design Changes	10	3.3%	27	6.6%
	Site Condition	13	4.2%	39	9.5%
	Scope Change	38	12.4%	57	13.8%
	Regulations	3	1.0%	4	1.0%
	Change in Technology	4	1.3%	2	0.5%
	Market Conditions	10	3.3%	9	2.2%
	Management Decisions	75	24.5%	59	14.3%
	Environmental	7	2.3%	53	12.9%
	Materials and Equipment	127	41.5%	147	35.7%
	Fast Tracking	9	2.9%	5	1.2%
	Others: Specify	10	3.3%	10	2.4%
	Total	306	100.0%	412	100.0%

Changes in Project Responsible for Project Cost Overrun

		Frequency	Percent
	Strongly Disagree	15	6.7%
	Disagree	13	5.8%
	No Opinion	7	3.1%
	Agree	77	34.5%
	Strongly Agree	111	49.8%
	Total	223	100.0%

Change in Project Responsible for Project Schedule Overrun

		Frequency	Percent
Valid	Strongly Disagree	11	4.9%
	Disagree	12	5.4%
	No Opinion	20	9.0%
	Agree	91	40.8%
	Strongly Agree	89	39.9%
	Total	223	100.0%

Appendix H – Central Tendencies

Large Cost

	Engr Percent Complete	Estimated Initial Cost	Cost Increase Bid Phase	Cost Increase Precon Phase	Cost Increase Constr Phase	Cost Increase Comm Phase	Total Increase in Cost	Total Cost
Min	10%	$1000m	$28m	$40m	$348m	$27m	$574m	$1674m
Median	40	2000	154	325	1284	140	2212	4236
Std Dev	13.03	3220.18	233.45	423.35	2382.46	185.21	2969.76	6045.83
Max	70%	$15200m	$1090m	$1972m	$12900m	$853m	$15899m	$31099m

Medium Cost

	Engr Percent Complete	Estimated Initial Cost	Cost Increase Bid Phase	Cost Increase Precon Phase	Cost Increase Constr Phase	Cost Increase Comm Phase	Total Increase in Cost	Total Cost
Min	10%	$110m	$3m	$2m	$7m	$0.5m	$13.5m	$155m
Median	50	276.5	21	39	129	15	223	480
Std Dev	24.83	177.61	21.51	47.93	174.91	25.64	252.78	426.92
Max	100%	$900m	$140m	$290m	$850m	$150m	$1380m	$2315m

Small Cost

	Engr Percent Complete	Estimated Initial Cost	Cost Increase Bid Phase	Cost Increase Precon Phase	Cost Increase Constr Phase	Cost Increase Comm Phase	Total Increase in Cost	Total Cost
Min	7%	$6m	$0.5m	$0.5m	$1.5m	$0.5m	$4m	$10m
Median	55.03%	$20m	$2m	$2m	$8m	$2m	$12m	$37.5m
Std Dev	27.02	27.24	4.01	14.10	20.85	3.82	19.88	36.85
Max	100%	$100m	$29m	$43m	$98m	$17m	$108m	$183m

Long Duration

	Engr Percent Complete	Estimated Initial Duration	Duration Increase Bid Phase	Duration Increase Precon Phase	Duration Increase Constr Phase	Duration Increase Comm Phase	Total Increase in Duration	Total Duration
Min	10%	2.1(yr)	0.1(yr)	0.1(yr)	0.2(yr)	0.1(yr)	0.2(yr)	3.2(yr)
Median	40	4	0.2	0.3	0.6	0.2	1.31	4.8
Std Dev	19.77	1.59	0.11	0.17	0.24	0.11	0.55	1.71
Max	90%	9(yr)	0.5(yr)	1.08(yr)	1.44(yr)	0.6(yr)	2.94(yr)	11.1(yr)

Medium Duration

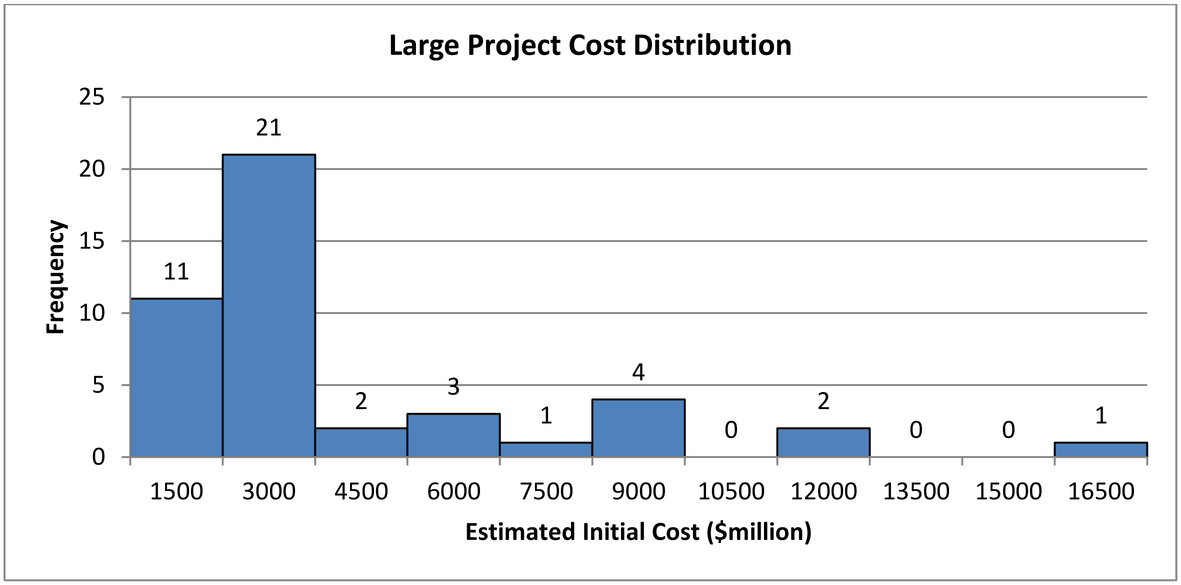
	Engr Percent Complete	Estimate d Initial Duration	Duration Increase Bid Phase	Duration Increase Precon Phase	Duration Increase Constr Phase	Duration Increase Comm Phase	Total Increase in Duration	Total Duration
Min	10%	1.1(yr)	0.1(yr)	0.1(yr)	0.1(yr)	0.1(yr)	0.4(yr)	1.7(yr)
Median	60	1.5	0.1	0.2	0.4	0.1	0.8	2.4
Std Dev	26.52	0.23	0.07	0.13	0.21	0.06	0.41	0.46
Max	100%	2(yr)	0.4(yr)	0.8(yr)	1.6(yr)	0.4(yr)	2.9(yr)	4.3(yr)

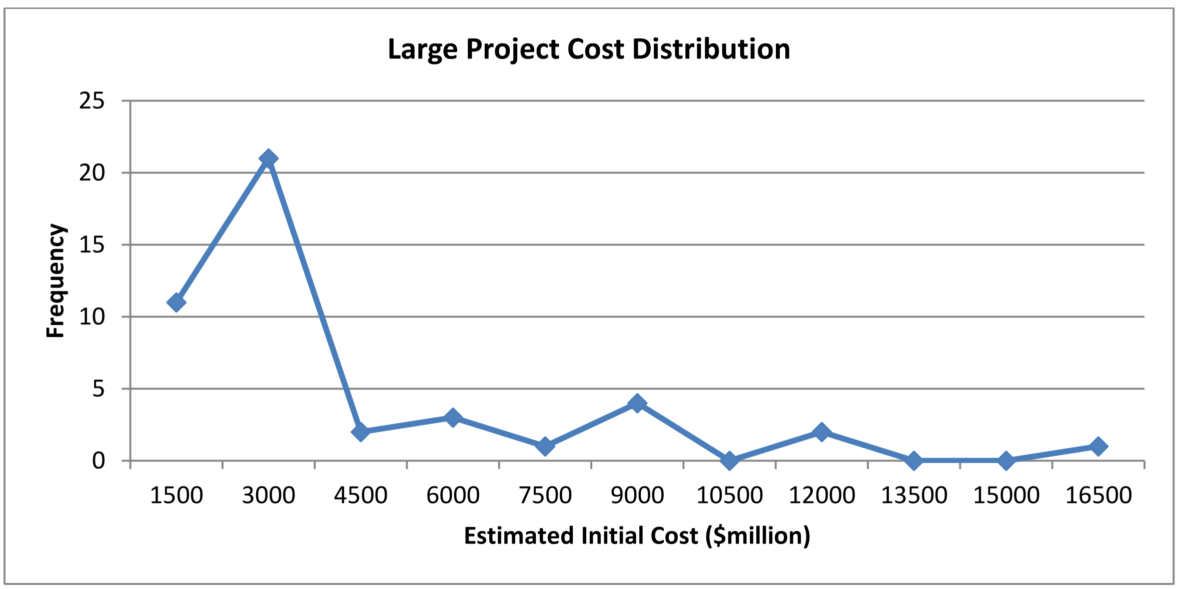
Short Duration

	Engr Percent Complete	Estimated Initial Duration	Duration Increase Bid Phase	Duration Increase Precon Phase	Duration Increase Constr Phase	Duration Increase Comm Phase	Total Increase in Duration	Total Duration
Min	9%	0.5(yr)	0.1(yr)	0.1(yr)	0.1(yr)	0.1(yr)	0.5(yr)	1.2(yr)
Median	56.92(yr)	0.72(yr)	0.11(yr)	0.17(yr)	0.37(yr)	0.16(yr)	0.7(yr)	1.5(yr)
Std Dev	27.44	0.12	0.04	0.08	0.17	0.07	0.25	0.26
Max	96%	1(yr)	0.2(yr)	0.4(yr)	0.9(yr)	0.3(yr)	1.6(yr)	2.2(yr)

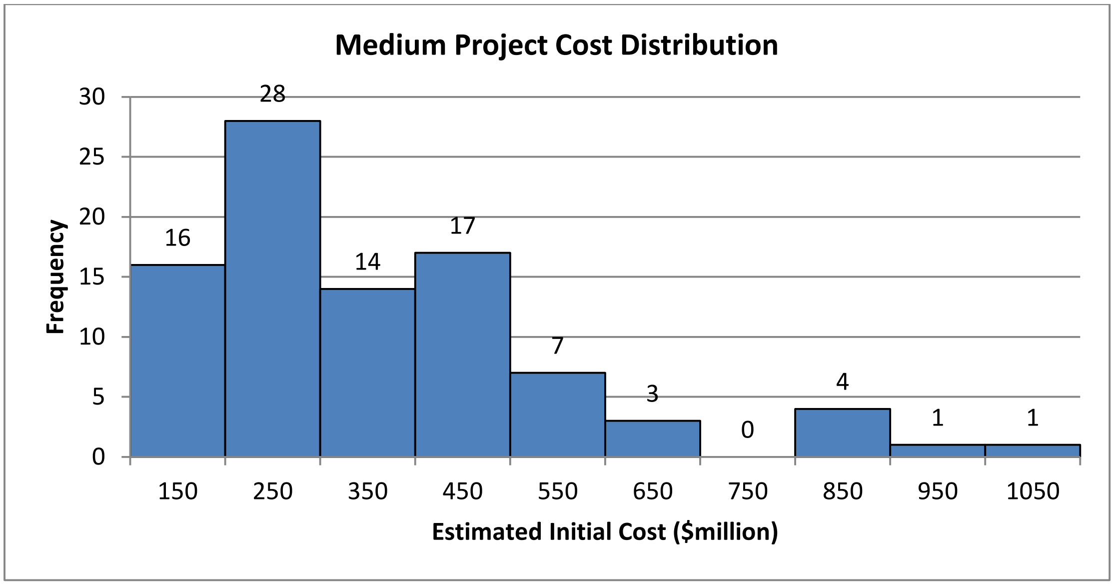
Appendix I – Frequency Distribution

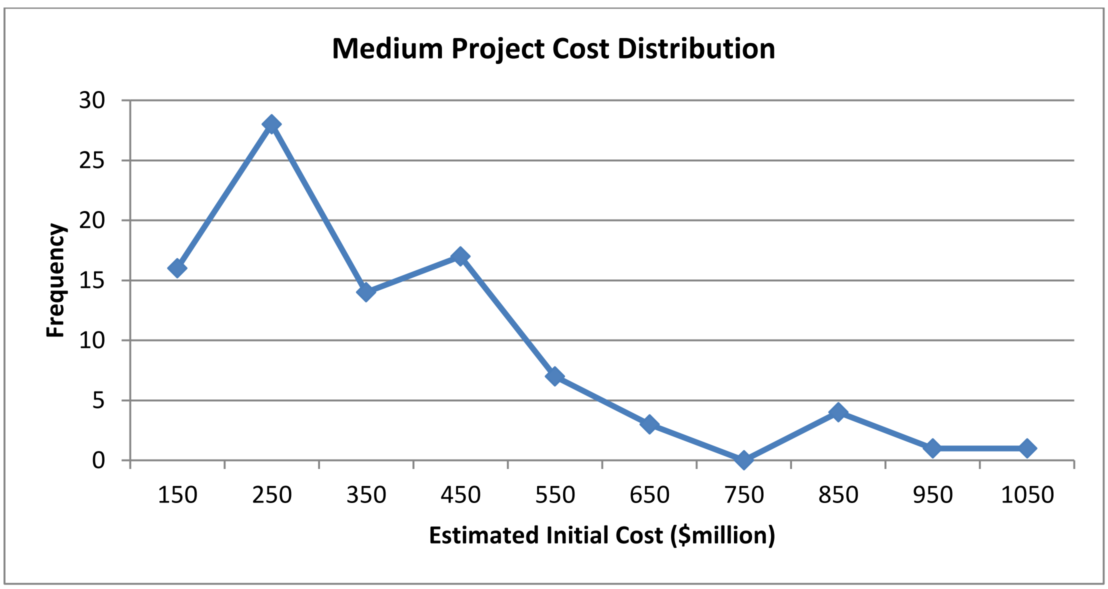
Large Project Costs



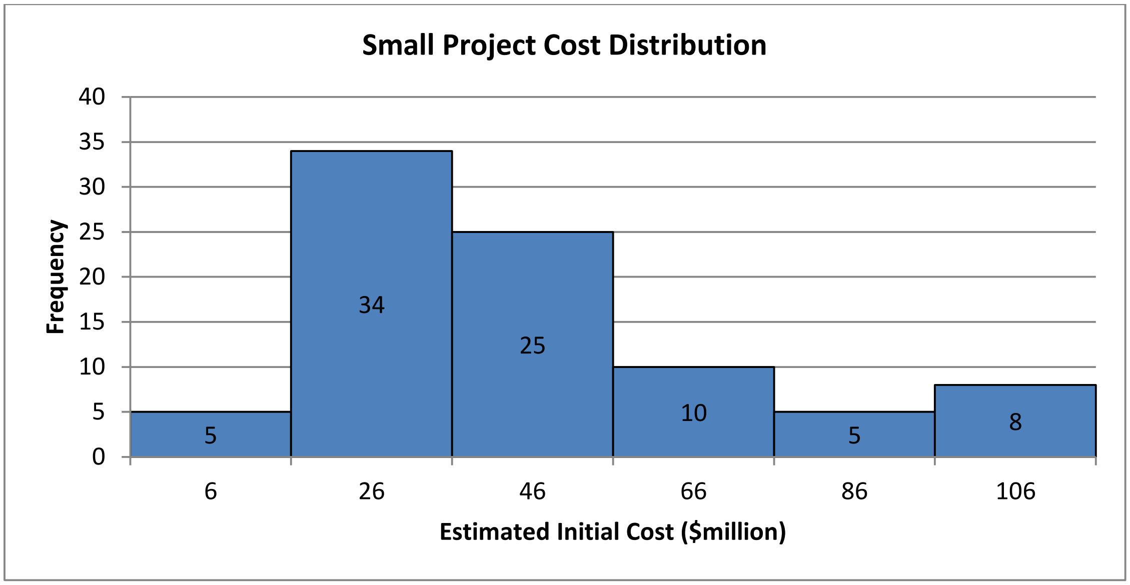


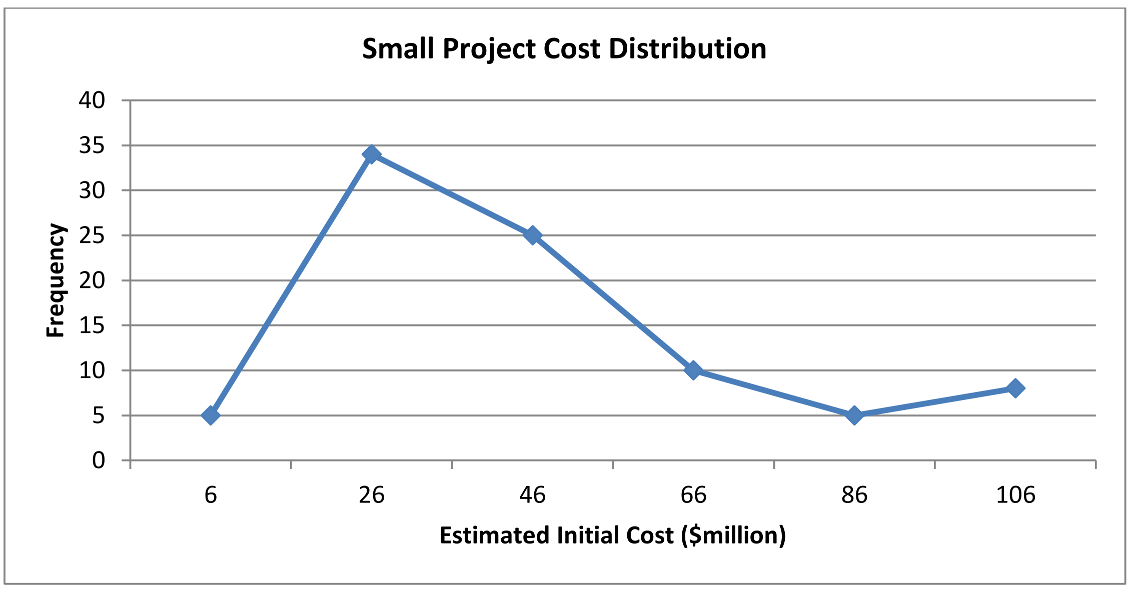
Medium Project Costs



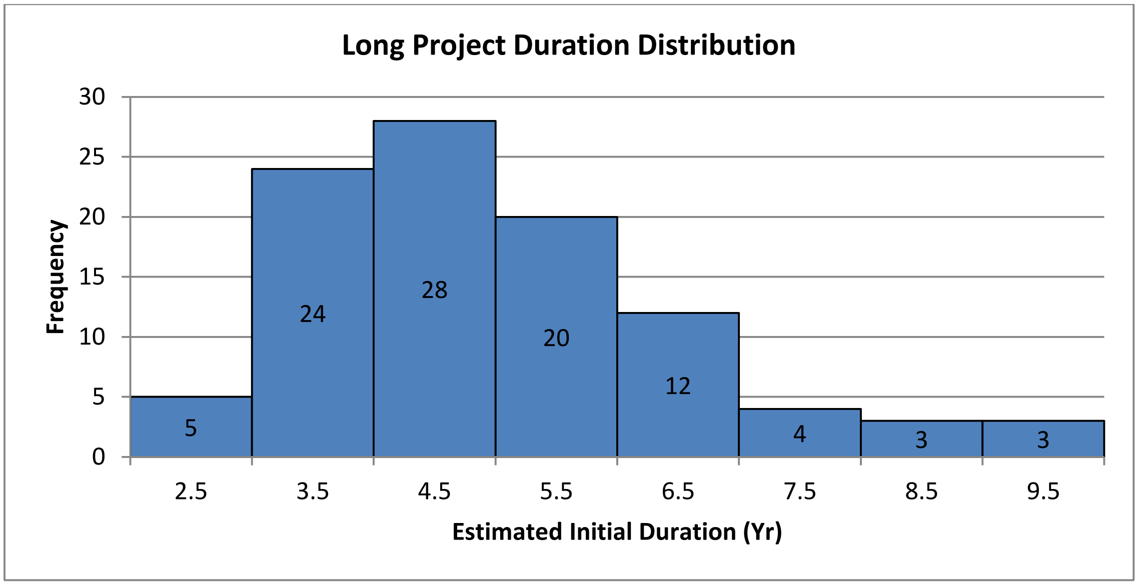


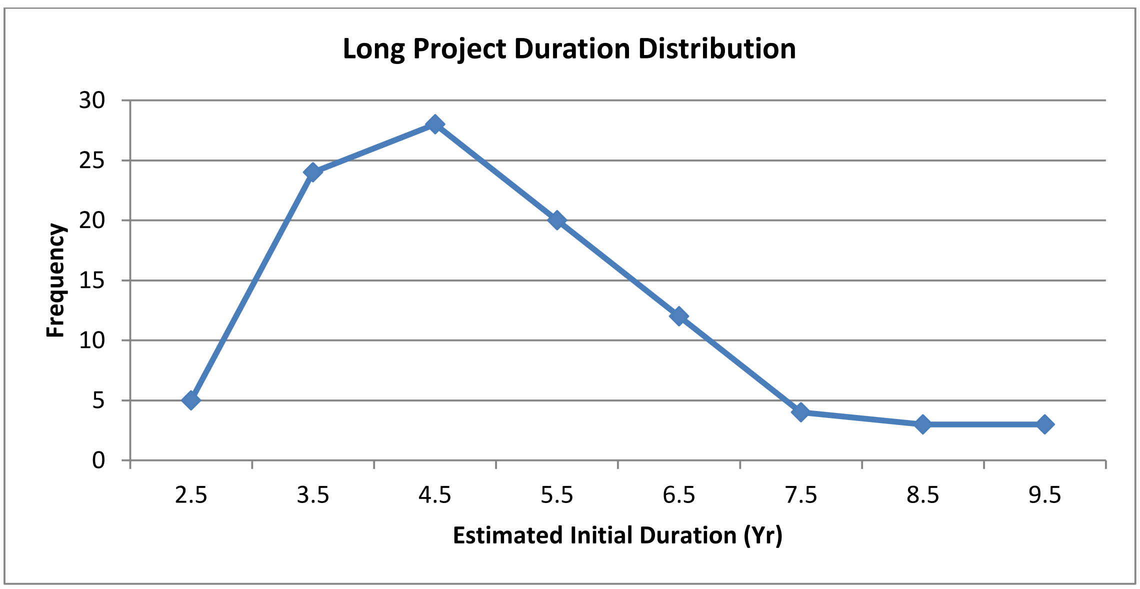
Small Project Costs



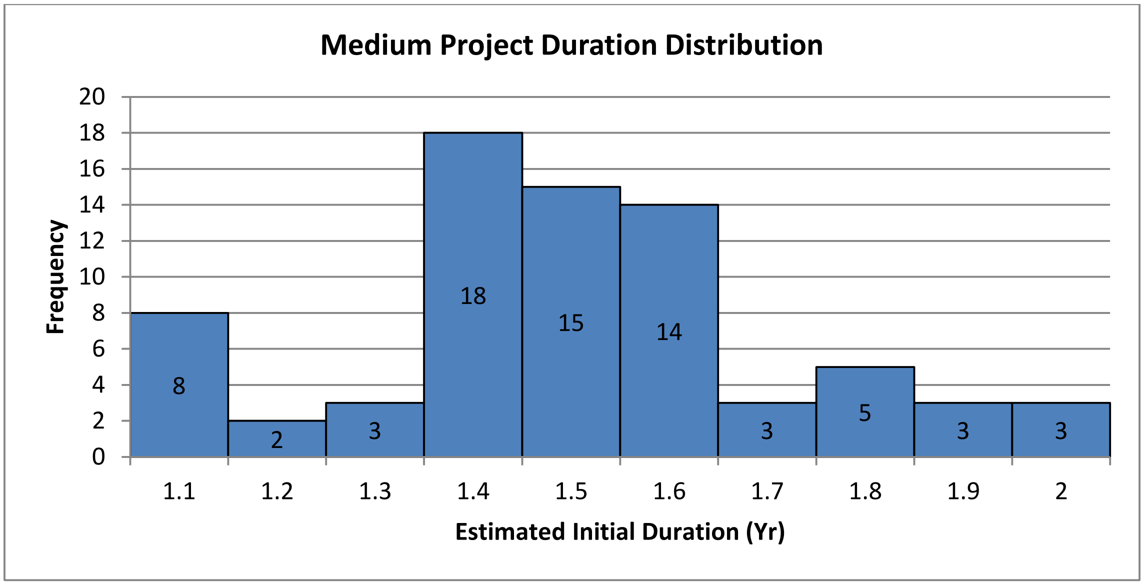


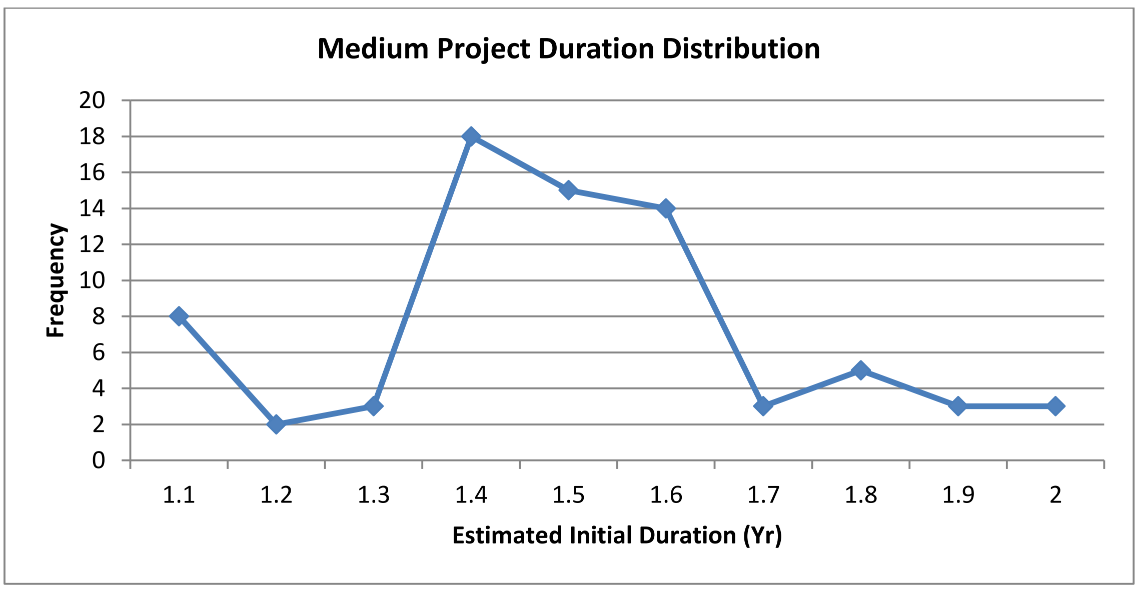
Long Duration Projects



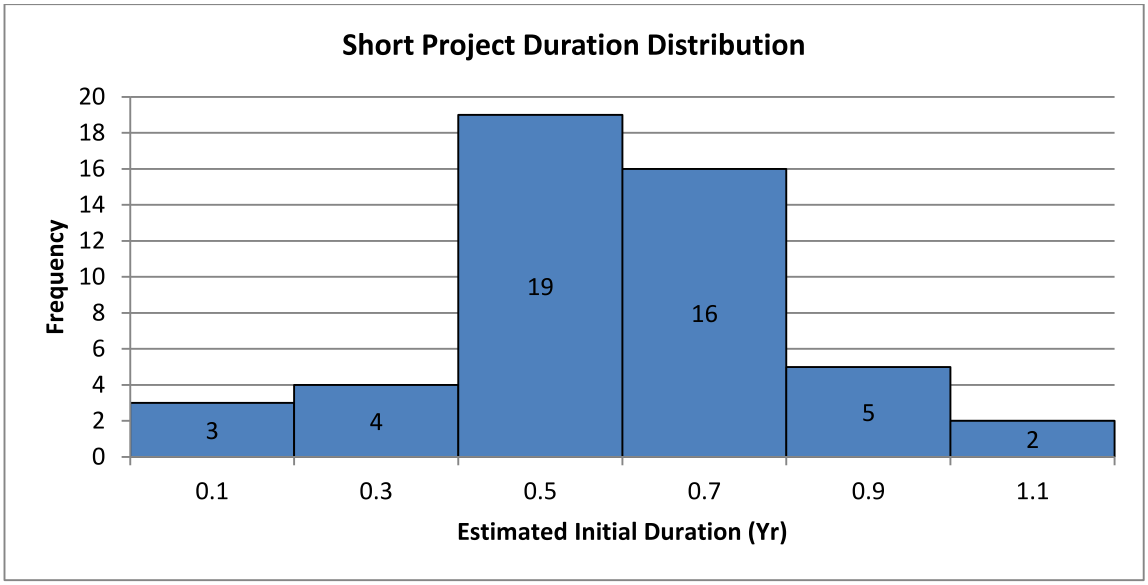


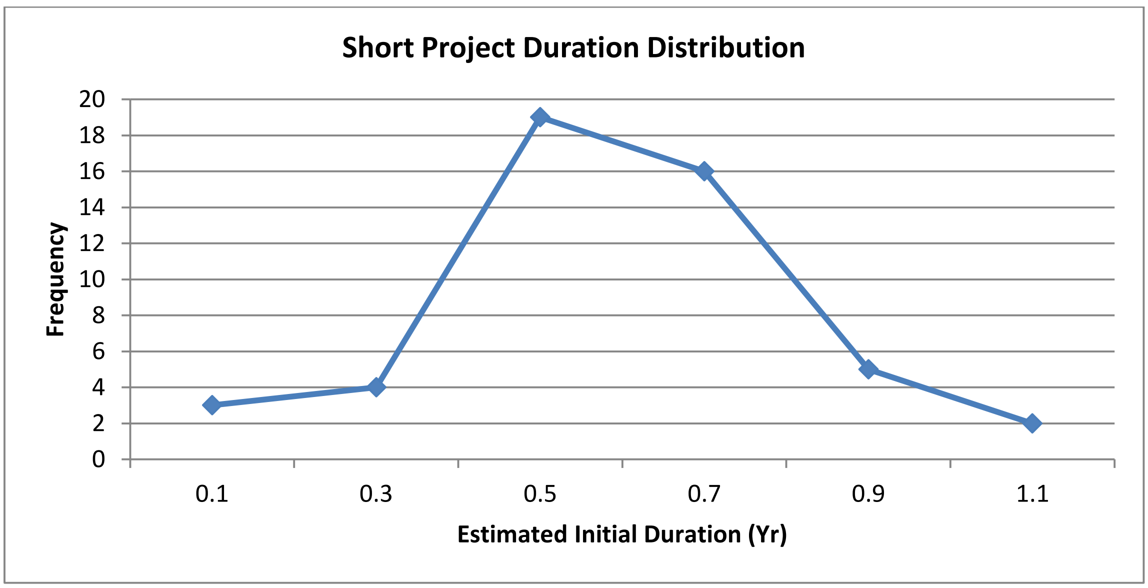
Medium Duration Projects



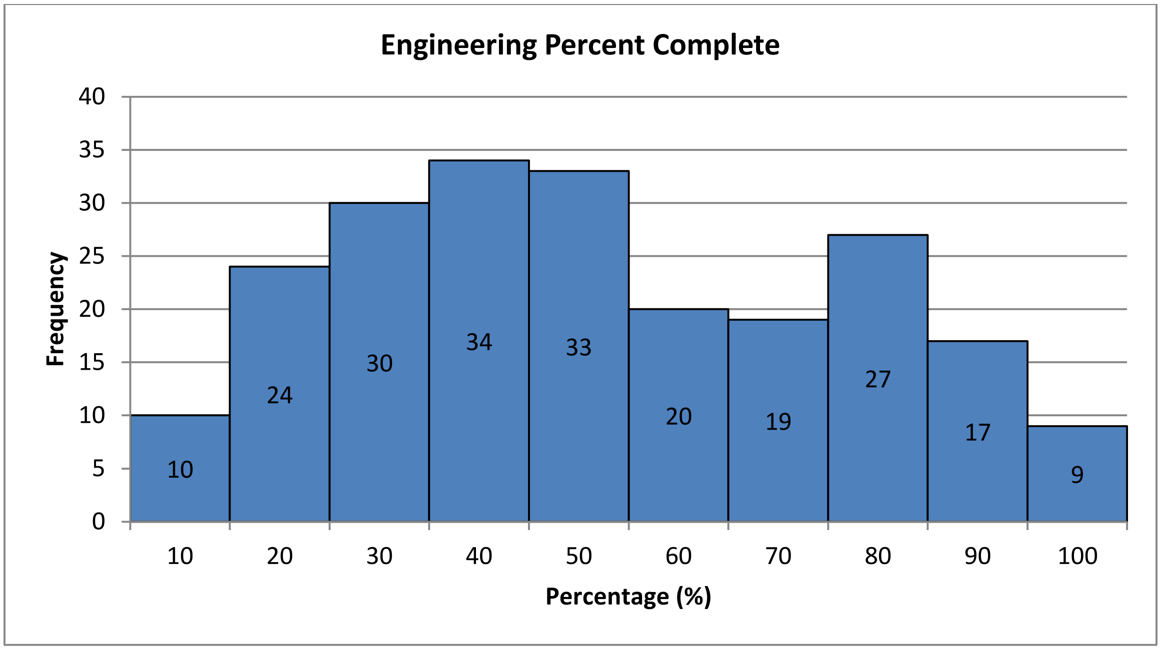


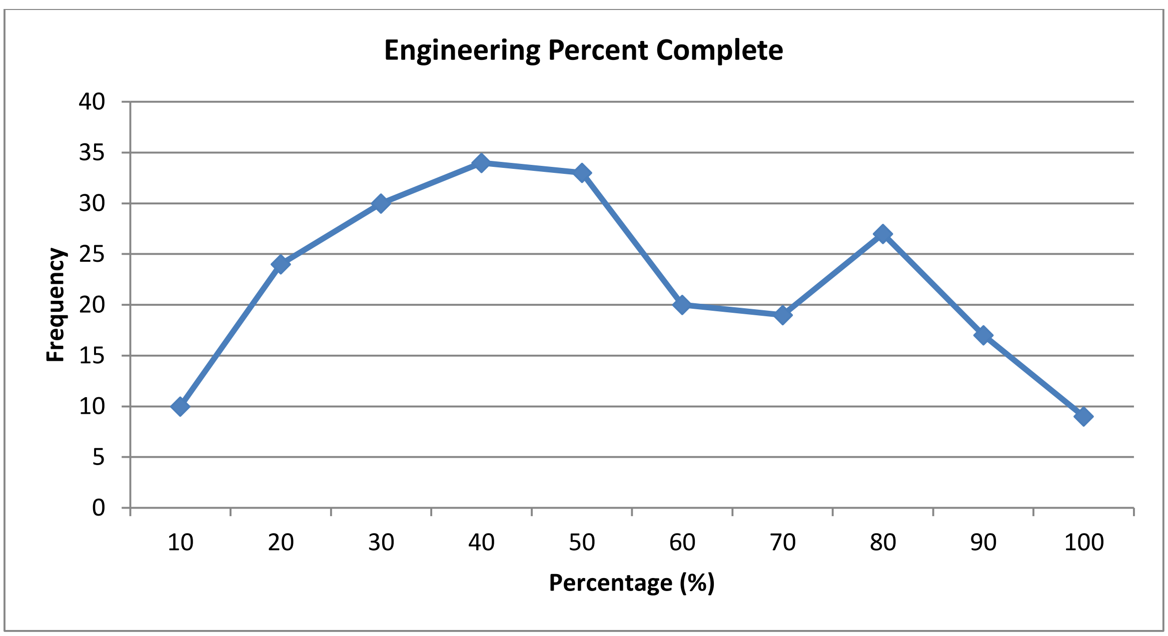
Short Duration Projects





Engineering Percent Complete

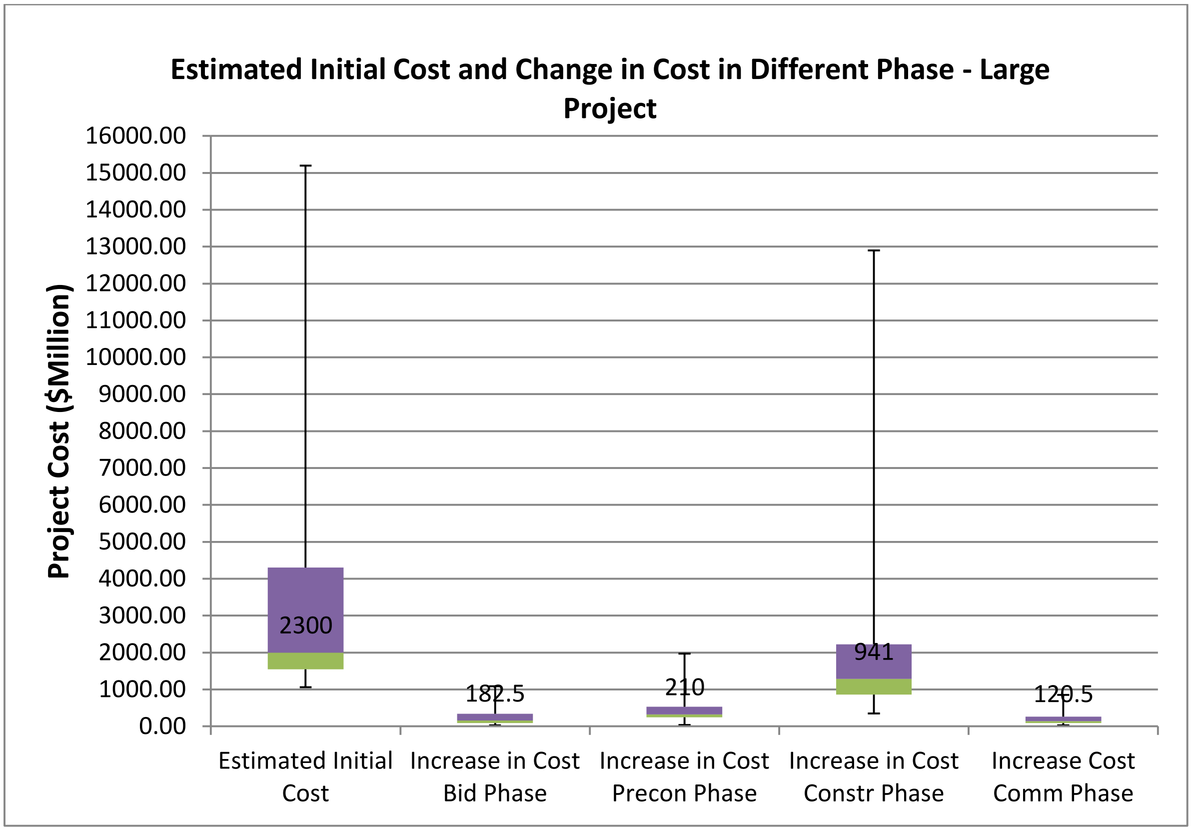


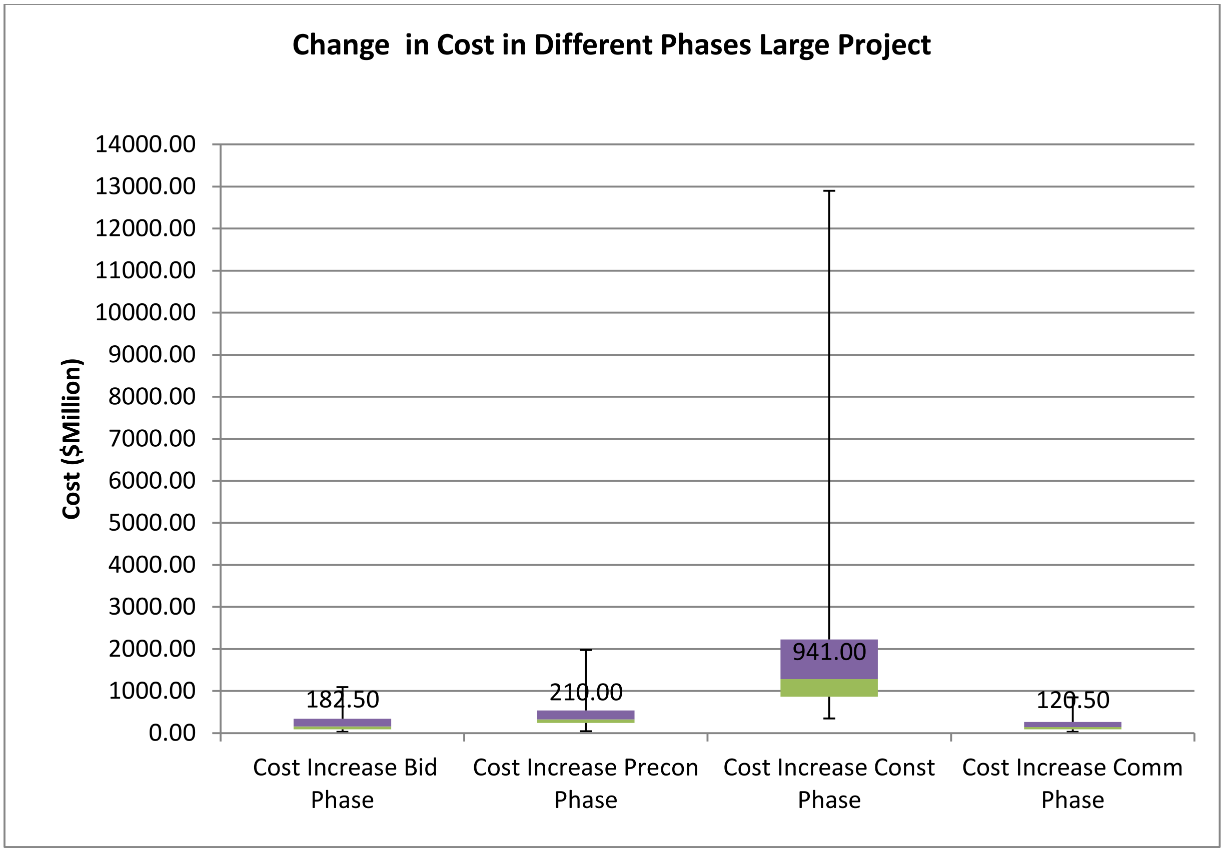


Appendix J – Box and Whisker Plots

Cost

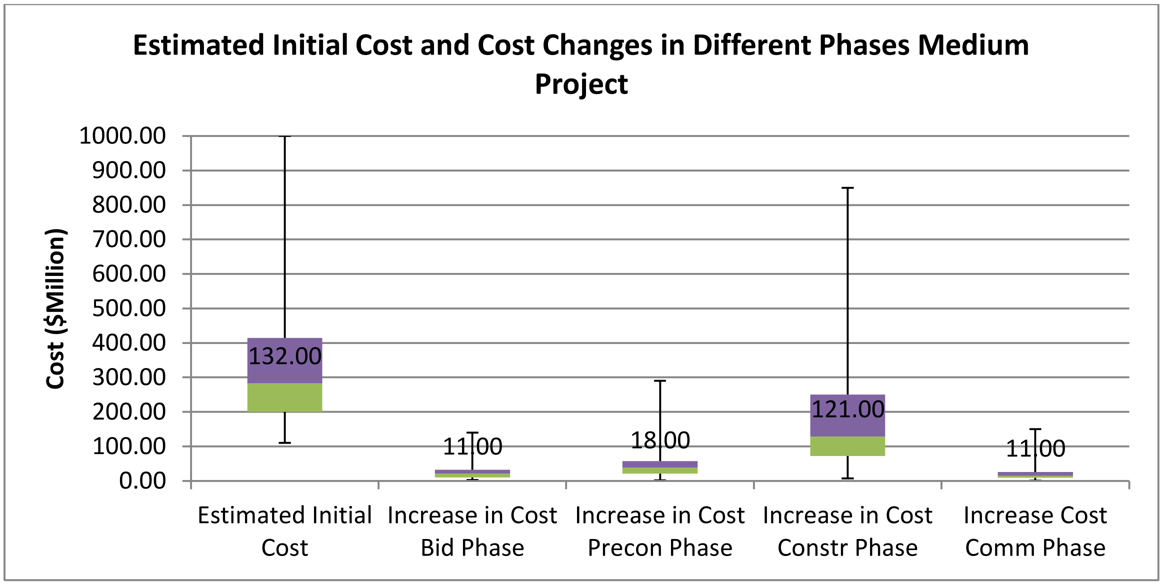
Large Cost



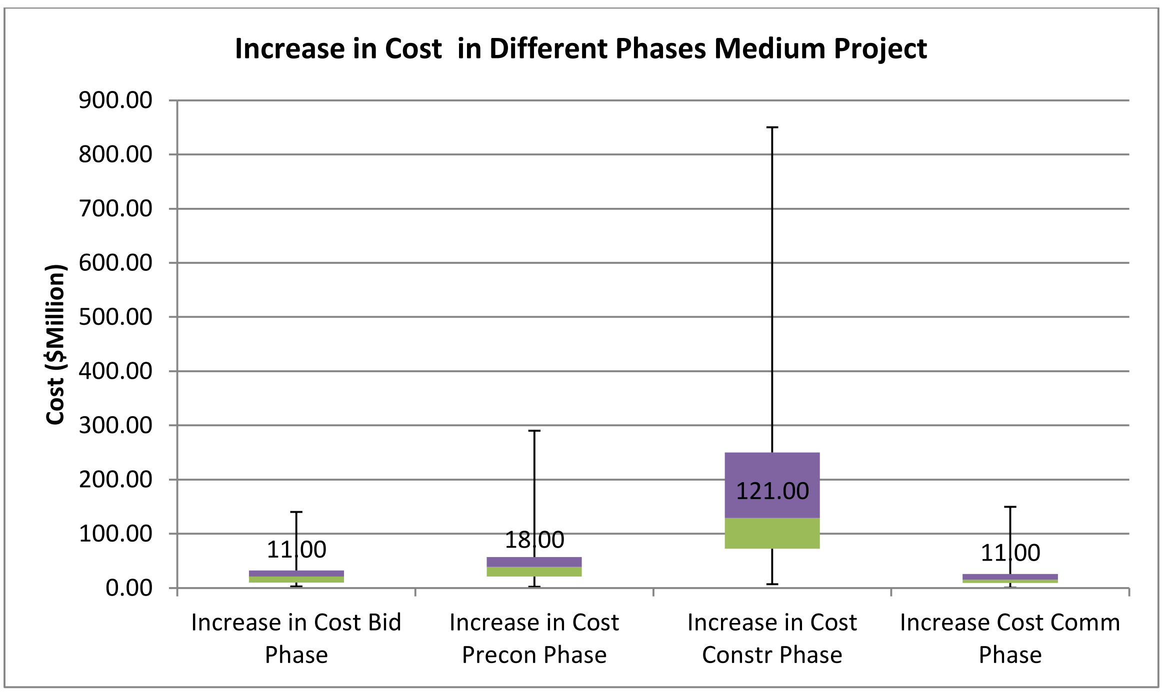


Change in Cost in Different Phases Large Project
Cost ($Million)
14000.00
13000.00
12000.00
11000.00
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
182.50
210.00
941.00
120.50
Cost Increase Bid Phase
Cost Increase Precon Phase
Cost Increase Const Phase
Cost Increase Comm Phase

Medium Cost

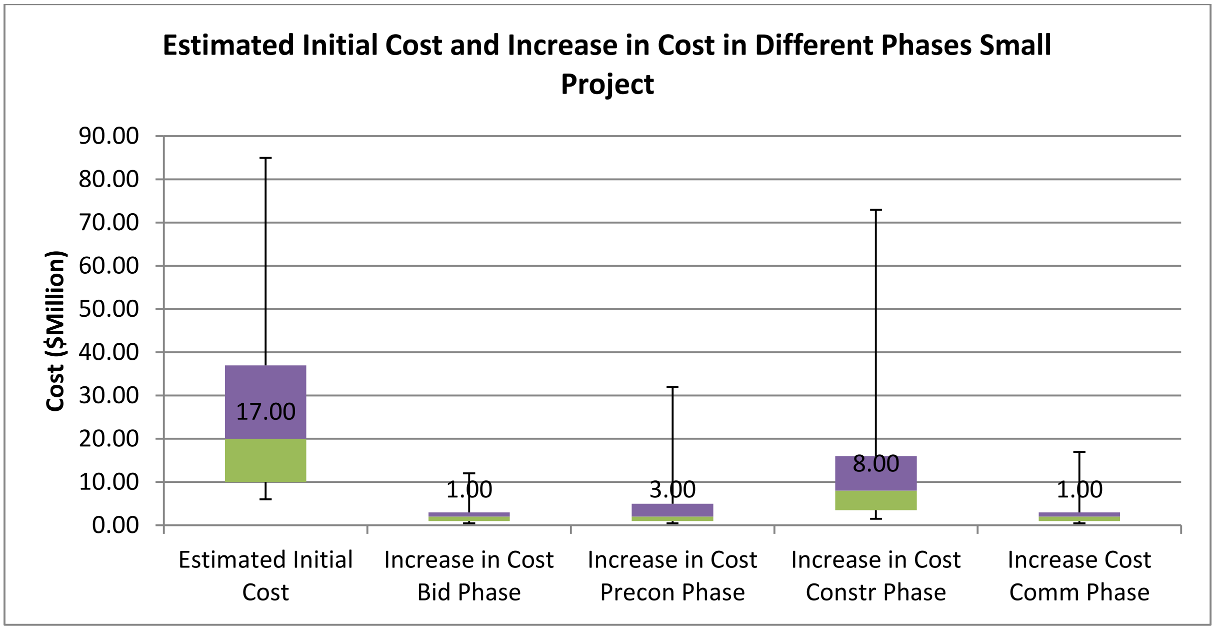


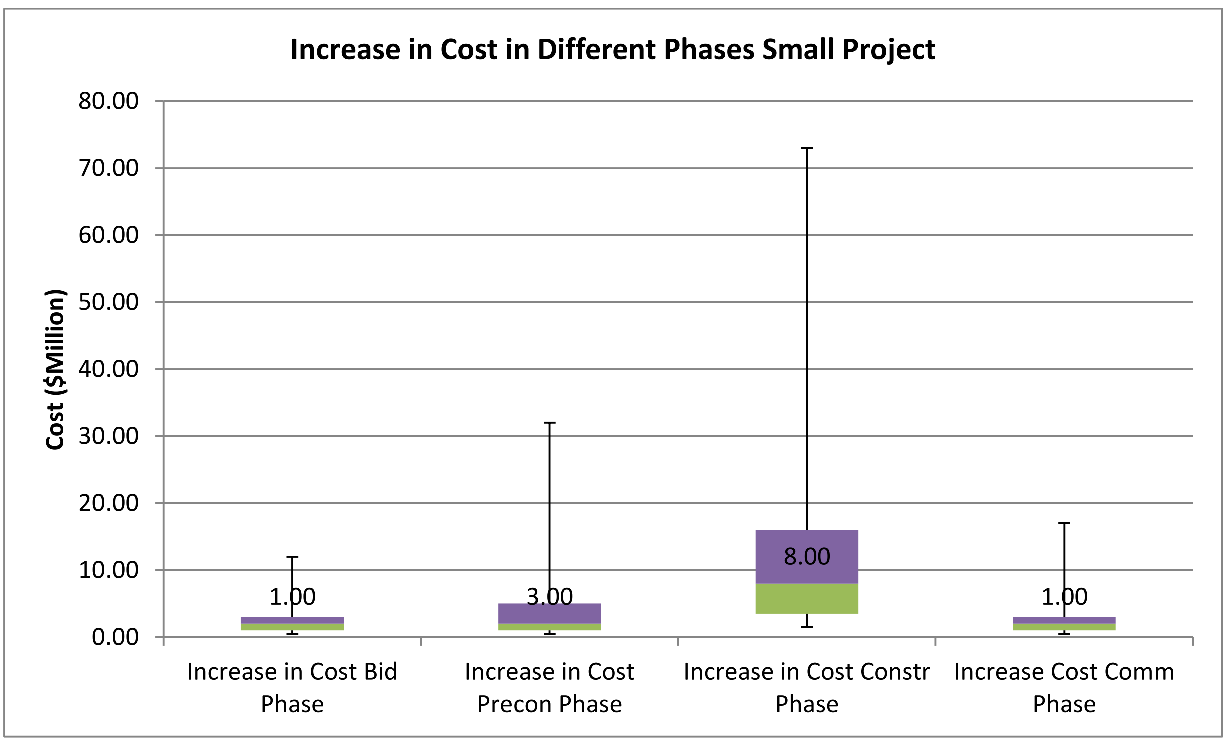
Estimated Initial Cost and Cost Changes in Different Phases Medium Project
Cost ($Million)
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
132.00
11.00
18.00
121.00
11.00
Estimated Initial Cost
Increase in Cost Bid Phase
Increase in Cost Precon Phase
Increase in Cost Constr Phase
Increase Cost Comm Phase



Increase in Cost in Different Phases Medium Project
Cost ($Million)
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
11.00
18.00
121.00
11.00
Increase in Cost Bid Phase
Increase in Cost Precon Phase
Increase in Cost Constr Phase
Increase Cost Comm Phase

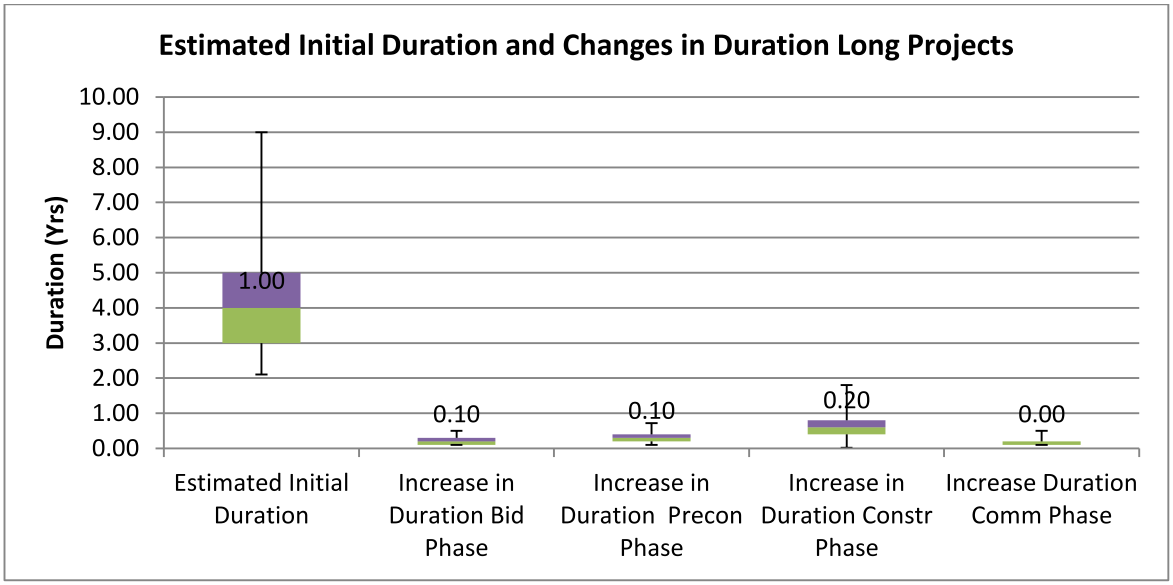
Small Cost

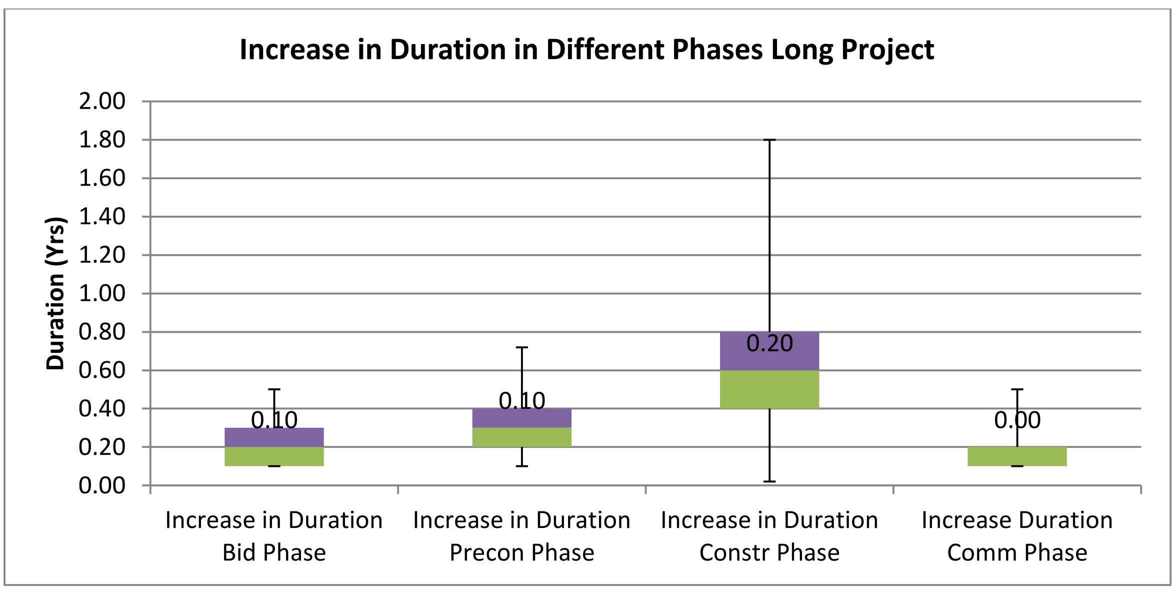

Estimated Initial Cost and Increase in Cost in Different Phases Small Project
Cost ($Million)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
17.00
1.00
3.00
8.00
1.00
Estimated Initial Cost
Increase in Cost Bid Phase
Increase in Cost Precon Phase
Increase in Cost Constr Phase
Increase Cost Comm Phase


Increase in Cost in Different Phases Small Project
Cost ($Million)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
3.00
8.00
1.00
Increase in Cost Bid Phase
Increase in Cost Precon Phase
Increase in Cost Constr Phase
Increase Cost Comm Phase

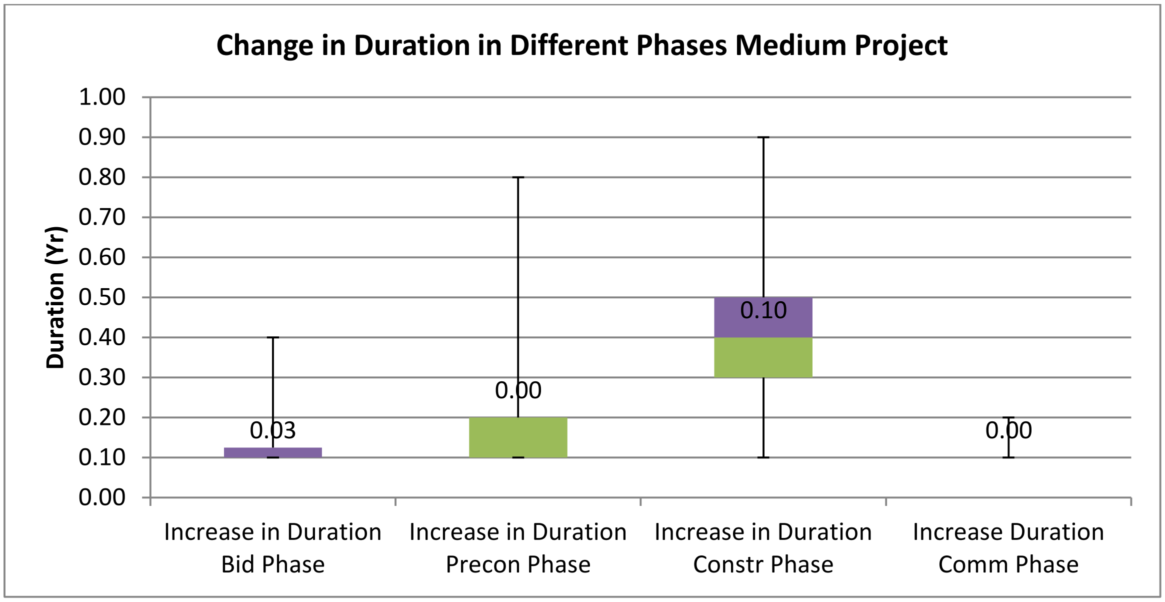
Duration

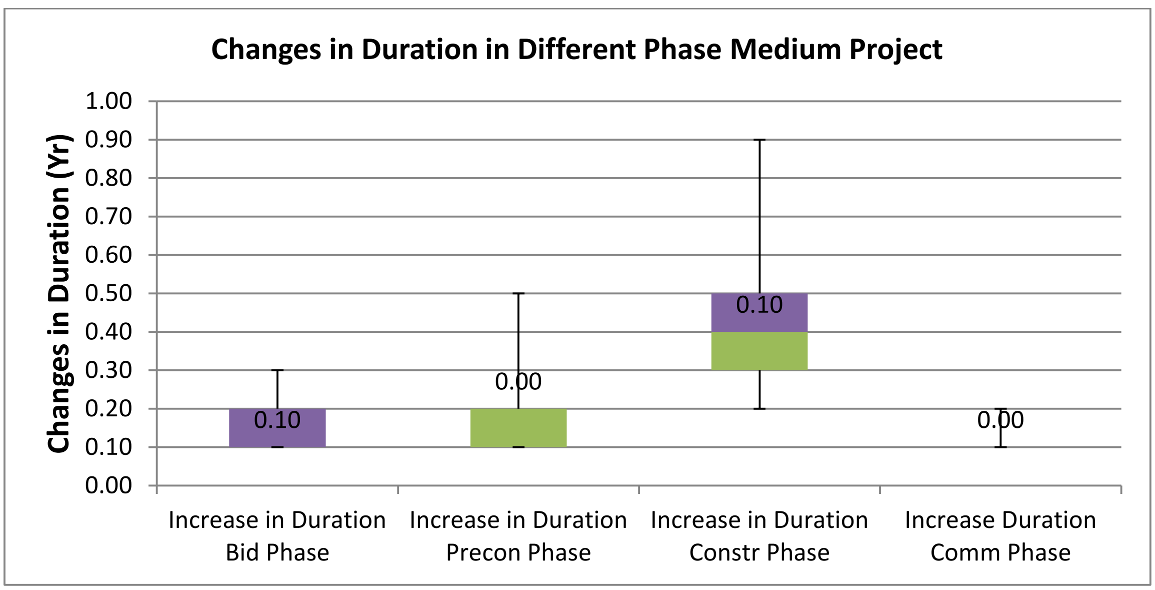
Long Duration



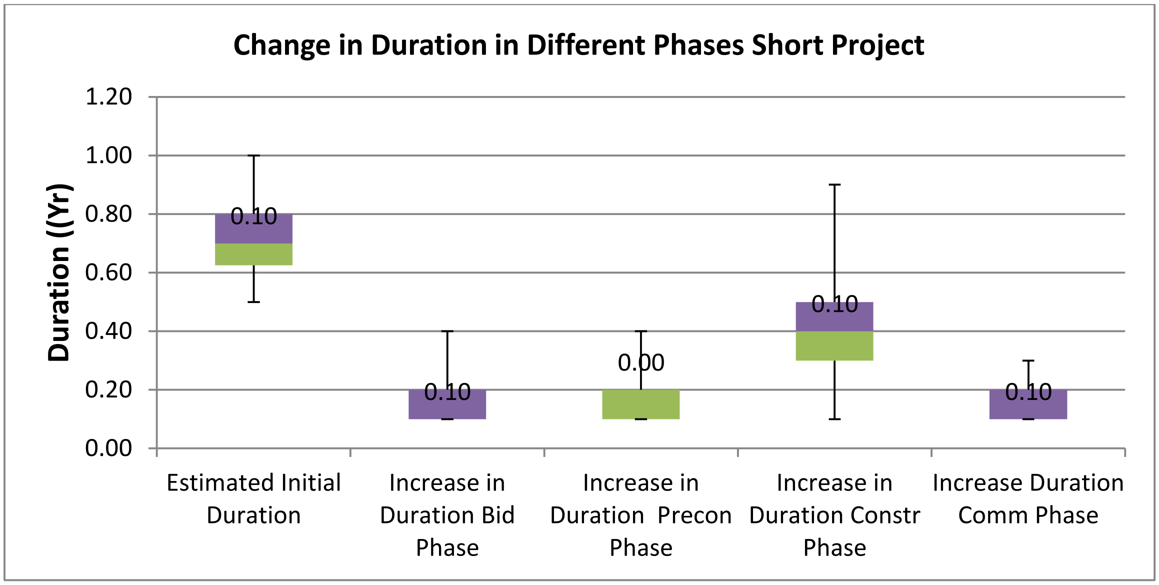


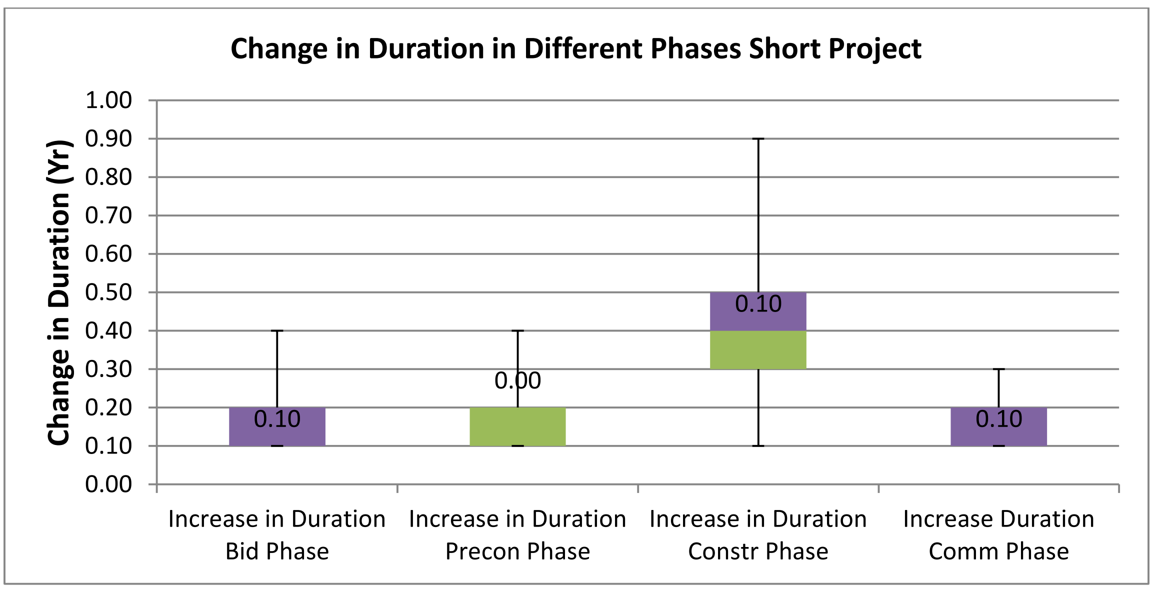
Medium Duration





Short Duration



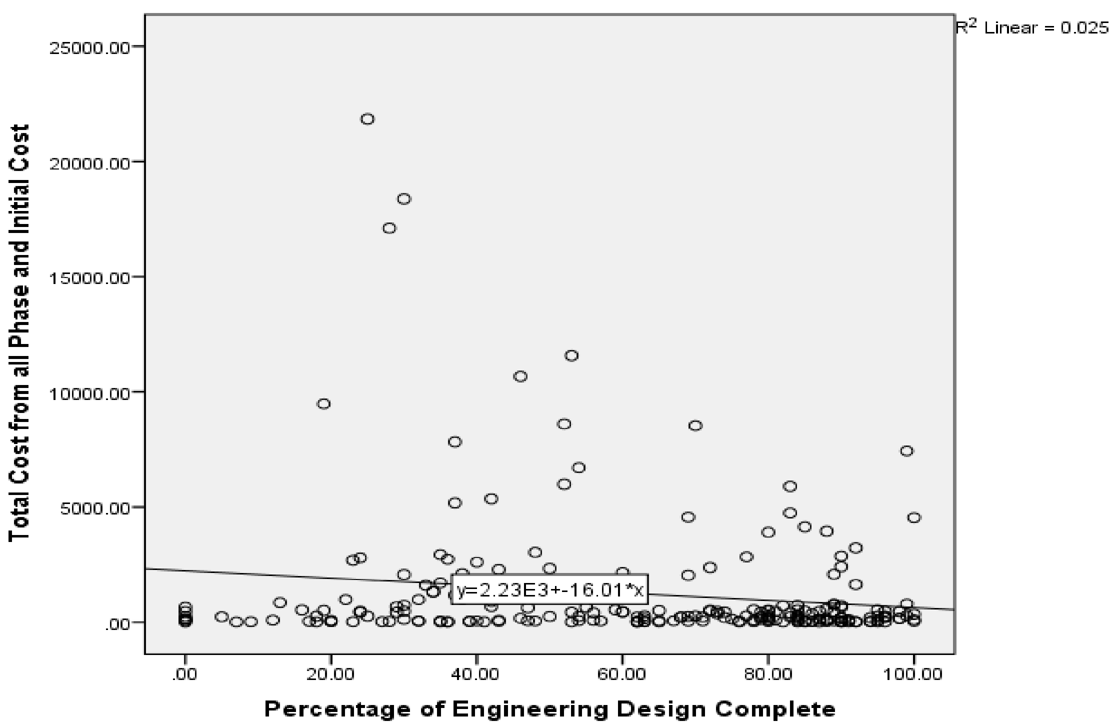


Appendix K – SPSS Result

Table 4.8 Correlation Analysis between Engineering Percent Complete and Total Project Cost

		Engineering Percentage Complete	Total Cost Project Cost
Engineering Percentage Complete	Pearson Correlation	1	-.157*
	Sig. (2-tailed)		.019
	N	223	223
Total Cost from all Phases	Pearson Correlation	-.157*	1
	Sig. (2-tailed)	.019	
	N	223	223

*. Correlation is significant at the 0.05 level (2-tailed).



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.157[a]	.025	.020	2823.37848

a. Predictors: (Constant), Percentage of Engineering Design Complete

ANOVA[a] of Total Cost and Percentage Engineering Complete

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	44276262.212	1	44276262.212	5.554	.019[b]
	Residual	1761693989.388	221	7971466.015		
	Total	1805970251.600	222			

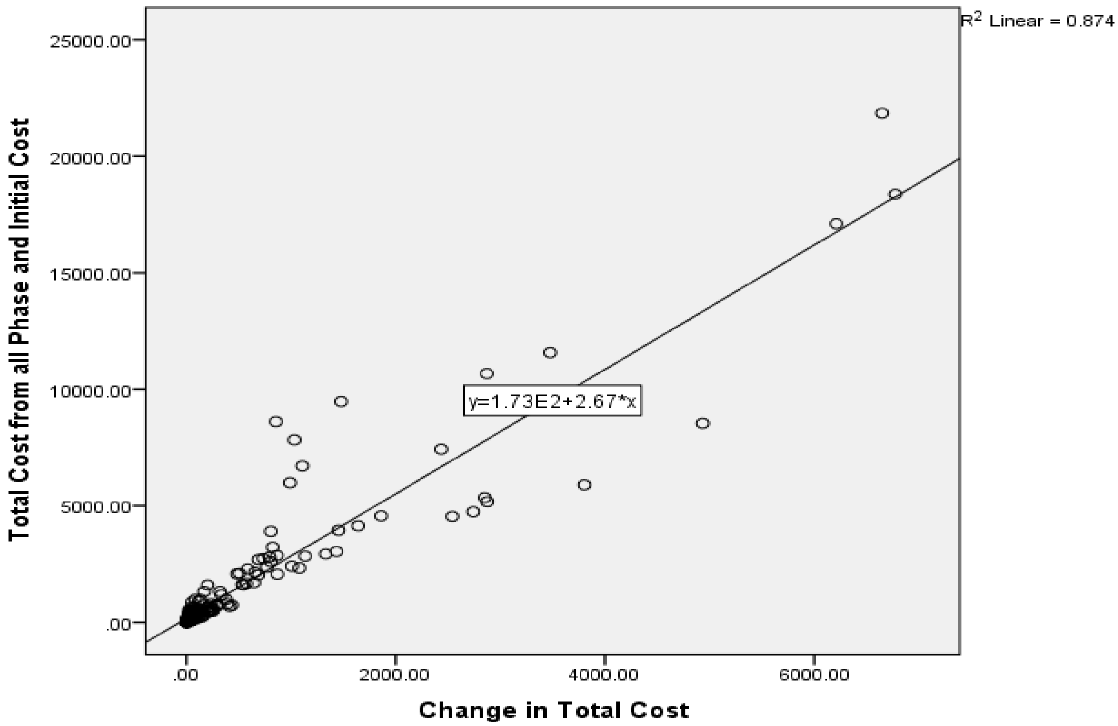
a. Dependent Variable: Total Project Cost

b. Predictors: (Constant), Percentage of Engineering Design Complete

Correlations between Total Project Cost and Change in Project Cost

		Total Cost from all Phase and Initial Cost	Change in Total Cost
Total Cost from all Phase and Initial Cost	Pearson Correlation	1	.935**
	Sig. (2-tailed)		.000
	N	223	223
Change in Total Cost	Pearson Correlation	.935**	1
	Sig. (2-tailed)	.000	
	N	223	223

**. Correlation is significant at the 0.01 level (2-tailed).



Model Summary of Changes in the Project and Total Project Cost

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.935[a]	.874	.873	1015.58103

a. Predictors: (Constant), Change in Project Cost

ANOVA[a] of Changes in Project Cost and Total Project Cost

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1578029785.551	1	1578029785.551	1529.981	.000[b]
	Residual	227940466.048	221	1031404.824		
	Total	1805970251.600	222			

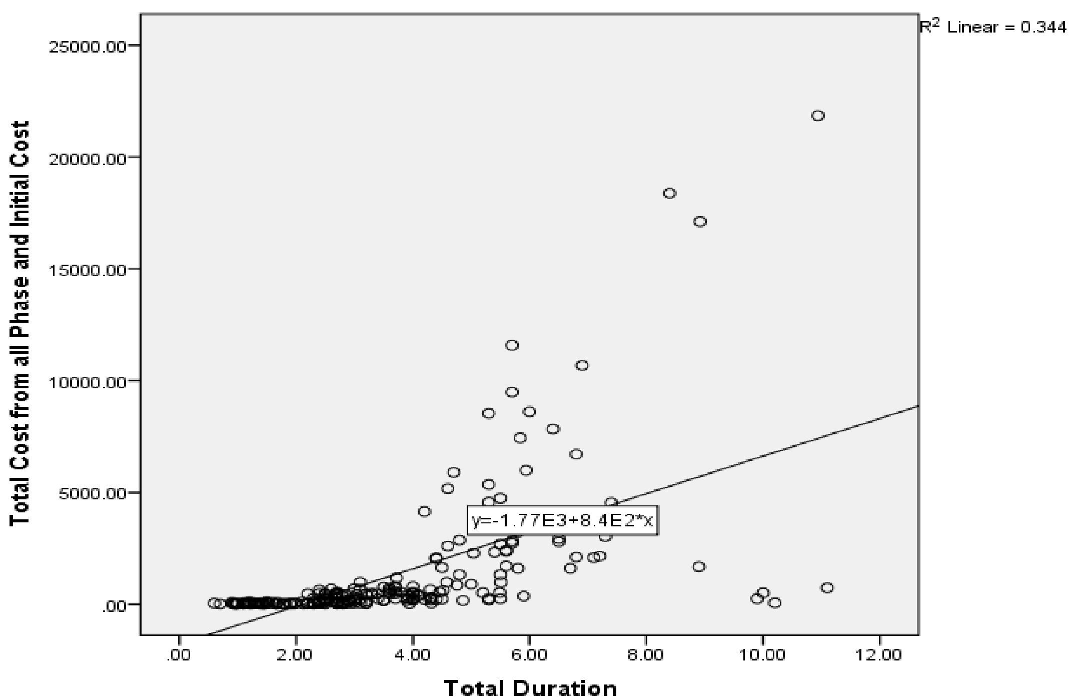
a. Dependent Variable: Total Project Cost

b. Predictors: (Constant), Changes in Cost

Correlations between Total Project Cost and Project Duration

		Total Project Cost	Total Duration
Total Project Cost	Pearson Correlation	1	.586**
	Sig. (2-tailed)		.000
	N	223	223
Total Duration	Pearson Correlation	.586**	1
	Sig. (2-tailed)	.000	
	N	223	223

**. Correlation is significant at the 0.01 level (2-tailed).



Scatter Plot of Changes in Project and Project Duration

Correlations

		Total Cost Project Cost	Cost Change in Bid Phase	Cost Change in PreCon Phase ($mil)	Change in Cost Contr Phase ($mil)	Change in Cost Com Phase ($mil)
Pearson Correlation	Total Cost Project Cost	1.000	.749	.851	.911	.826
	Cost Change in Bid Phase	.749	1.000	.812	.550	.931
	Cost Change in PreCon Phase ($mil)	.851	.812	1.000	.704	.823
	Change in Cost Contr Phase ($mil)	.911	.550	.704	1.000	.627
	Change in Cost Com Phase ($mil)	.826	.931	.823	.627	1.000
Sig. (1-tailed)	Total Cost Project Cost	.	.000	.000	.000	.000
	Cost Change in Bid Phase	.000	.	.000	.000	.000
	Cost Change in PreCon Phase ($mil)	.000	.000	.	.000	.000
	Change in Cost Contr Phase ($mil)	.000	.000	.000	.	.000
	Change in Cost Com Phase ($mil)	.000	.000	.000	.000	.
N	Total Cost Project Cost	223	223	223	223	223
	Cost Change in Bid Phase	223	223	223	223	223
	Cost Change in PreCon Phase ($mil)	223	223	223	223	223
	Change in Cost Contr Phase ($mil)	223	223	223	223	223
	Change in Cost Com Phase ($mil)	223	223	223	223	223

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	694843035.986	4	173710758.996	667.636	.000[b]
	Residual	39028193.313	150	260187.955		
	Total	733871229.299	154			

a. Dependent Variable: Total Cost Project Cost

b. Predictors: (Constant), Change in Cost Com Phase ($mil), Change in Cost Contr Phase ($mil), Cost Change in PreCon Phase ($mil), Cost Change in Bid Phase

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.558[a]	.311	.307	1817.57462

a. Predictors: (Constant), Original Project Schedule (Yr)

Correlations

		Total Cost Project Cost	Change in Duration Bid Phase	Change in Duration Constr	Change in Duration Comm	Change in Duration Precon
Pearson Correlation	Total Cost Project Cost	1.000	.526	.690	.546	.512
	Schedule Change in Bid Phase	.526	1.000	.584	.614	.706
	Schedule Change Constr	.690	.584	1.000	.592	.648
	Schedule Change Comm	.546	.614	.592	1.000	.630
	Schedule Change in Precon New Value	.512	.706	.648	.630	1.000
Sig. (1-tailed)	Total Cost Project Cost	.	.000	.000	.000	.000
	Schedule Change in Bid Phase	.000	.	.000	.000	.000
	Schedule Change Constr	.000	.000	.	.000	.000
	Schedule Change Comm	.000	.000	.000	.	.000
	Schedule Change in Precon New Value	.000	.000	.000	.000	.
N	Total Cost Project Cost	223	223	223	223	223
	Schedule Change in Bid Phase	223	223	223	223	223
	Schedule Change Constr	223	223	223	223	223
	Schedule Change Comm	223	223	223	223	223
	Schedule Change in Precon New Value	223	223	223	223	223

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	433555475.640	4	108388868.910	54.137	.000[b]
	Residual	300315753.660	150	2002105.024		
	Total	733871229.299	154			

a. Dependent Variable: Total Cost Project Cost

b. Predictors: (Constant), Schedule Change in Com Phase (Yrs), Schedule Change in PreCon Phase (Yrs), Schedule Change in Bid Phase (Yrs), Schedule Change in Constr Phase (Yrs)

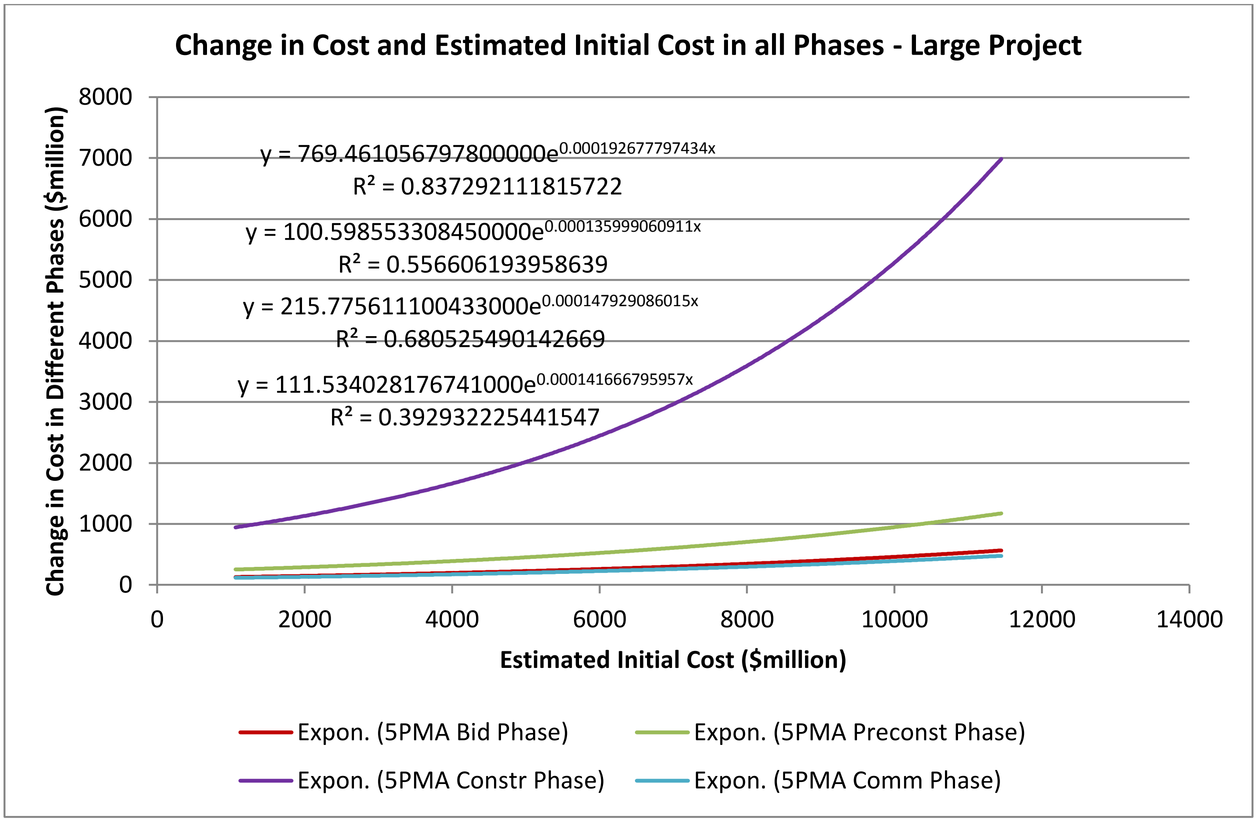
Model Summary

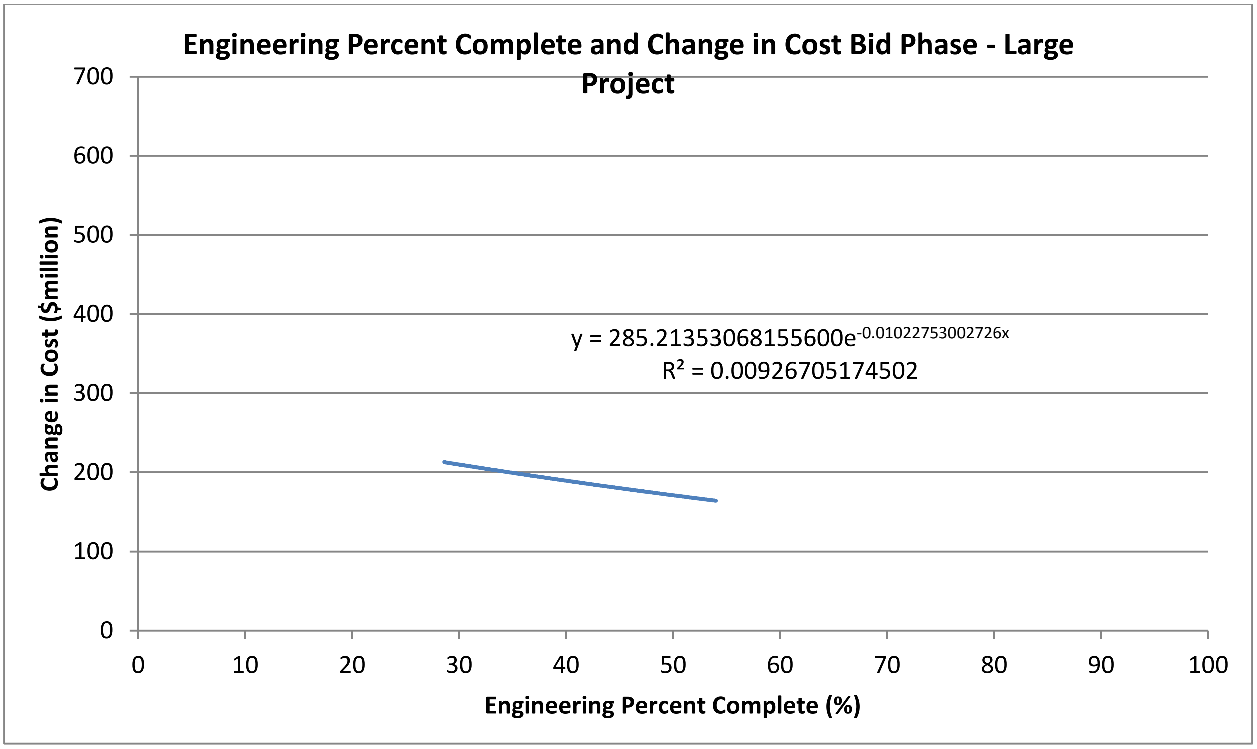
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.769[a]	.591	.580	1414.95761

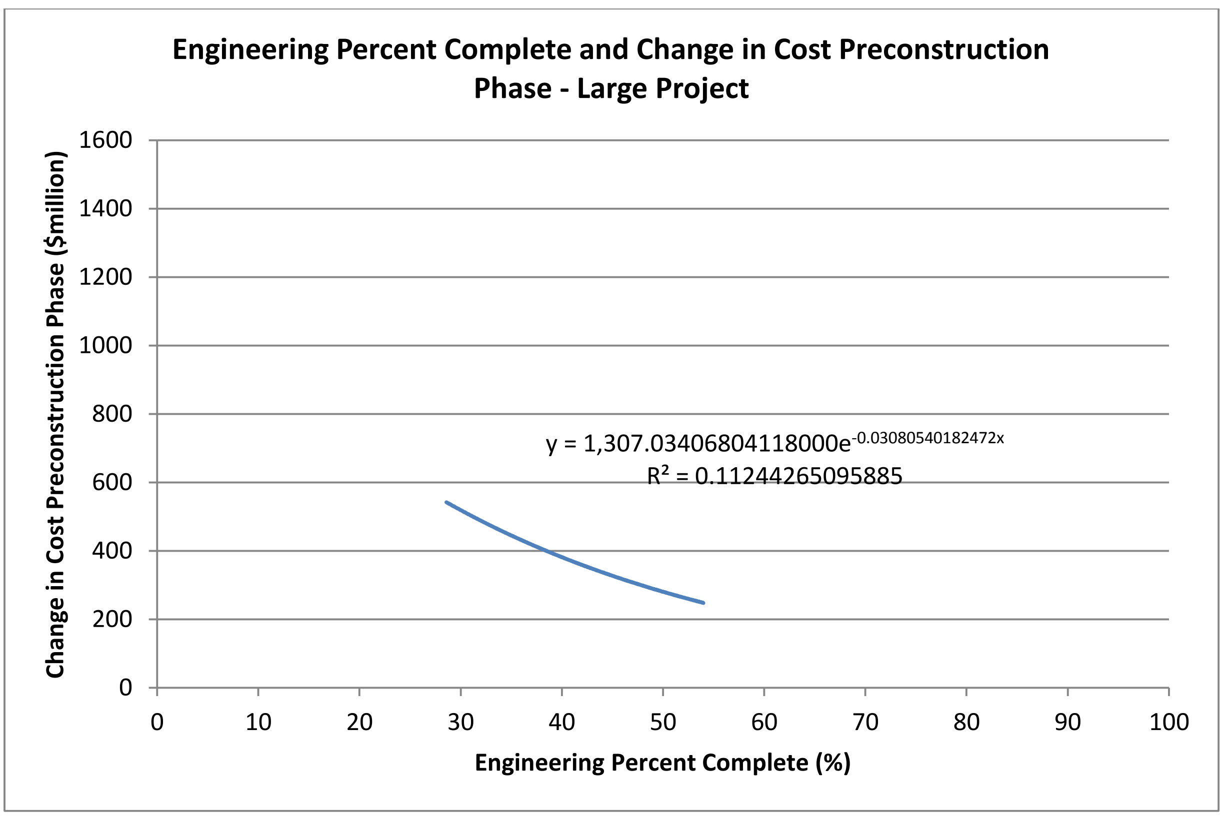
a. Predictors: (Constant), Schedule Change in Com Phase (Yrs), Schedule Change in PreCon Phase (Yrs), Schedule Change in Bid Phase (Yrs), Schedule Change in Constr Phase (Yrs)

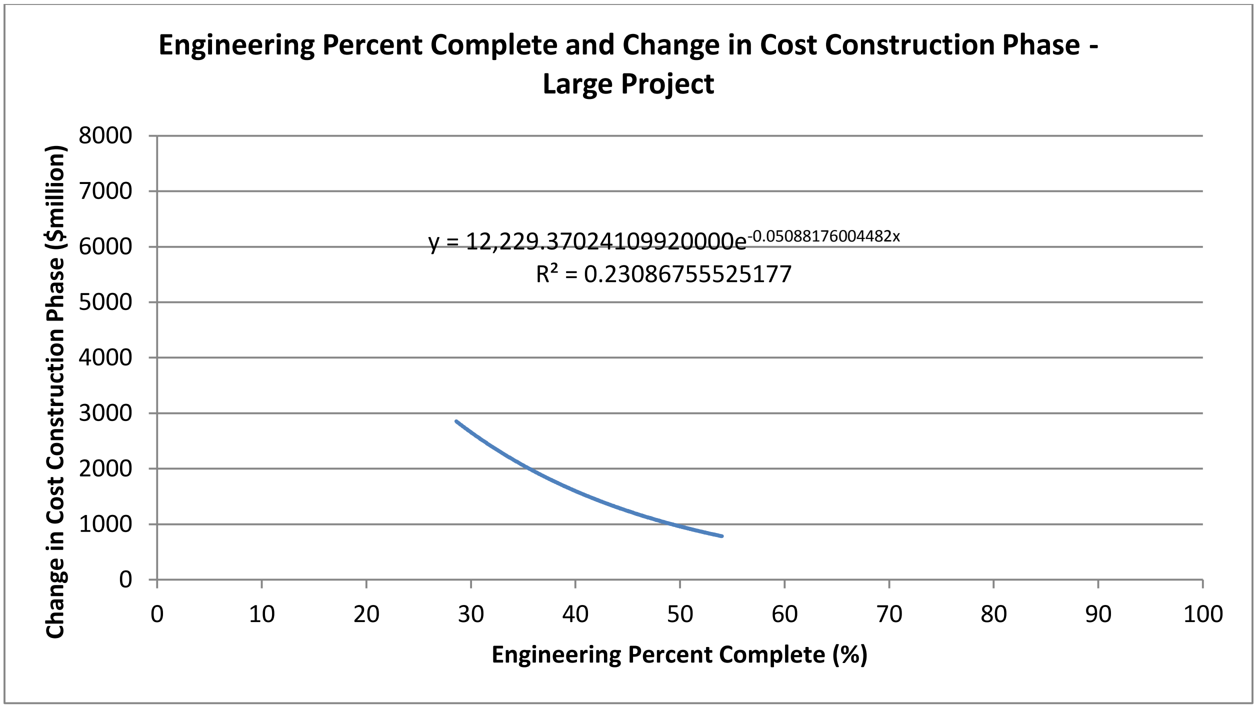
Appendix L - Graphs

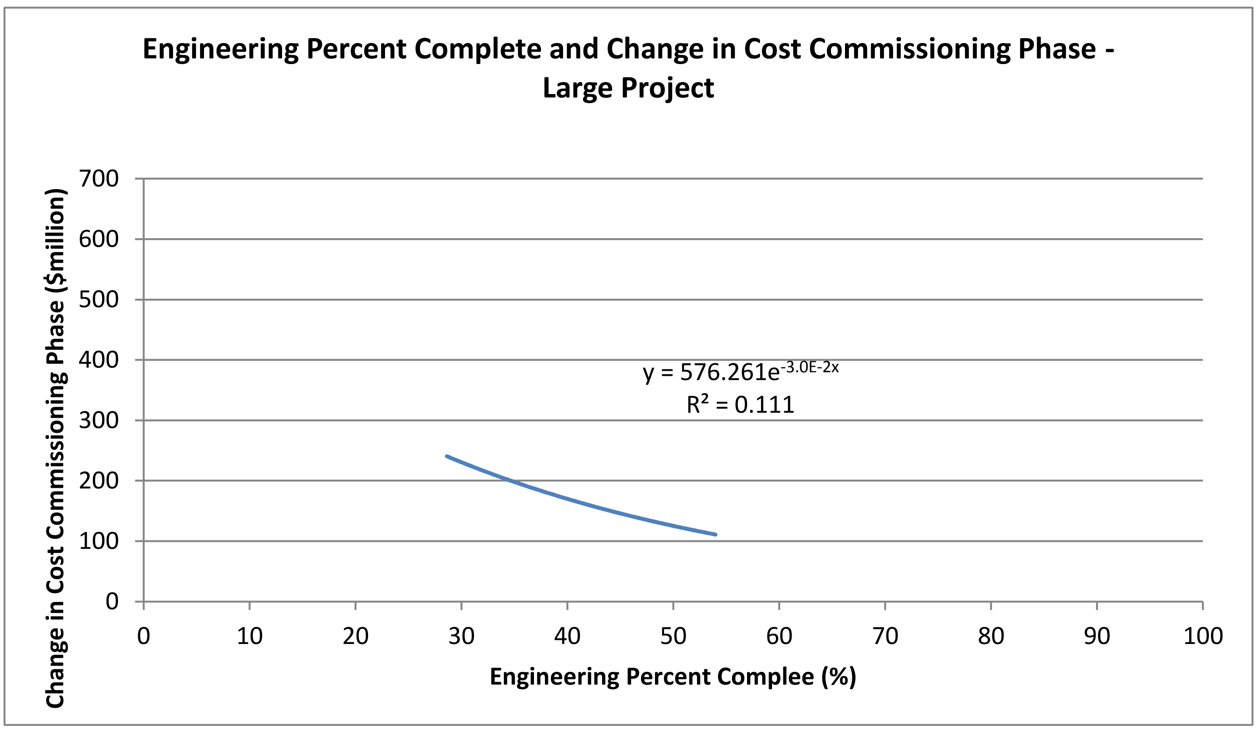
Large Cost



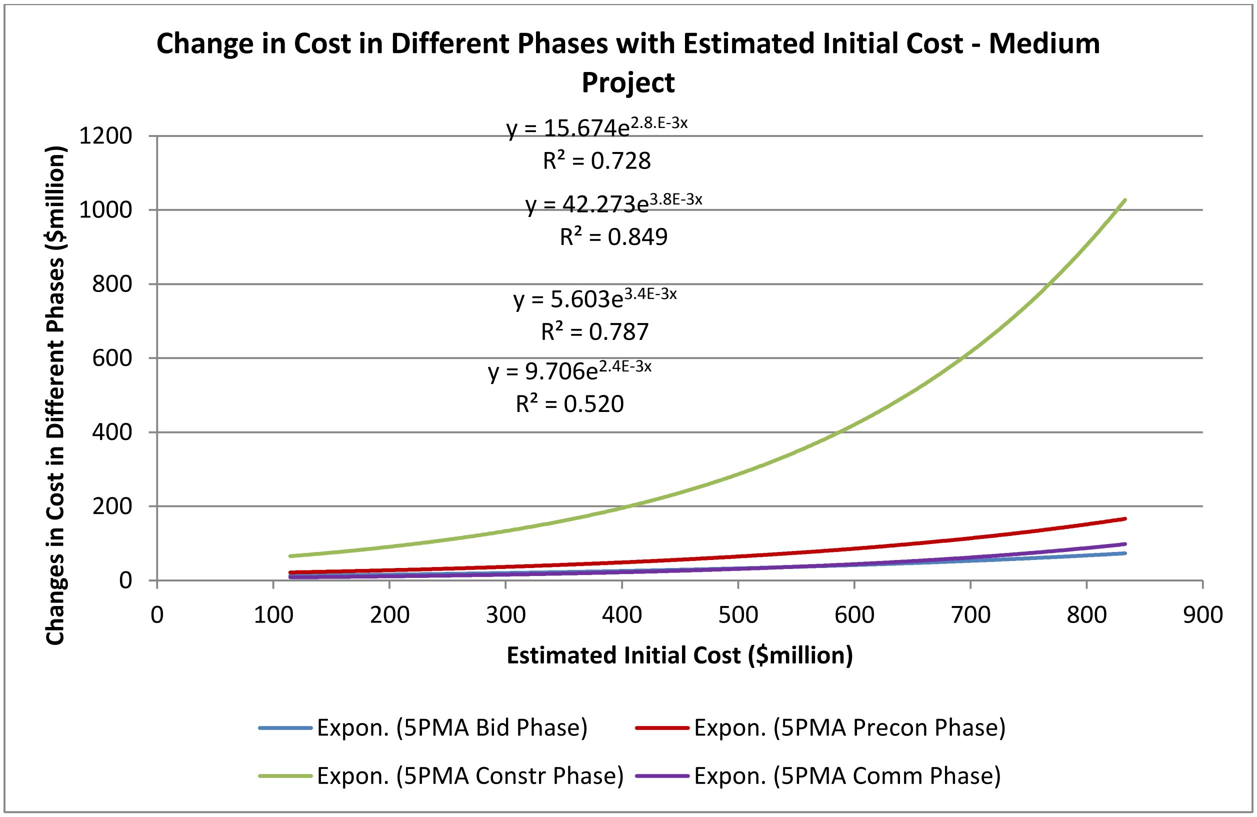

Engineering Percent Complete and Change in Cost Bid Phase - Large Project
y = 285.21353068155600e-0.01022753002726x
R² = 0.00926705174502
Change in Cost ($million)
Engineering Percent Complete (%)
0
100
200
300
400
500
600
700
0
10
20
30
40
50
60
70
80
90
100


Engineering Percent Complete and Change in Cost Preconstruction Phase - Large Project
y = 1,307.03406804118000e-0.03080540182472x
R² = 0.11244265095885
Change in Cost Preconstruction Phase ($million)
Engineering Percent Complete (%)
0
200
400
600
800
1000
1200
1400
1600
0
10
20
30
40
50
60
70
80
90
100

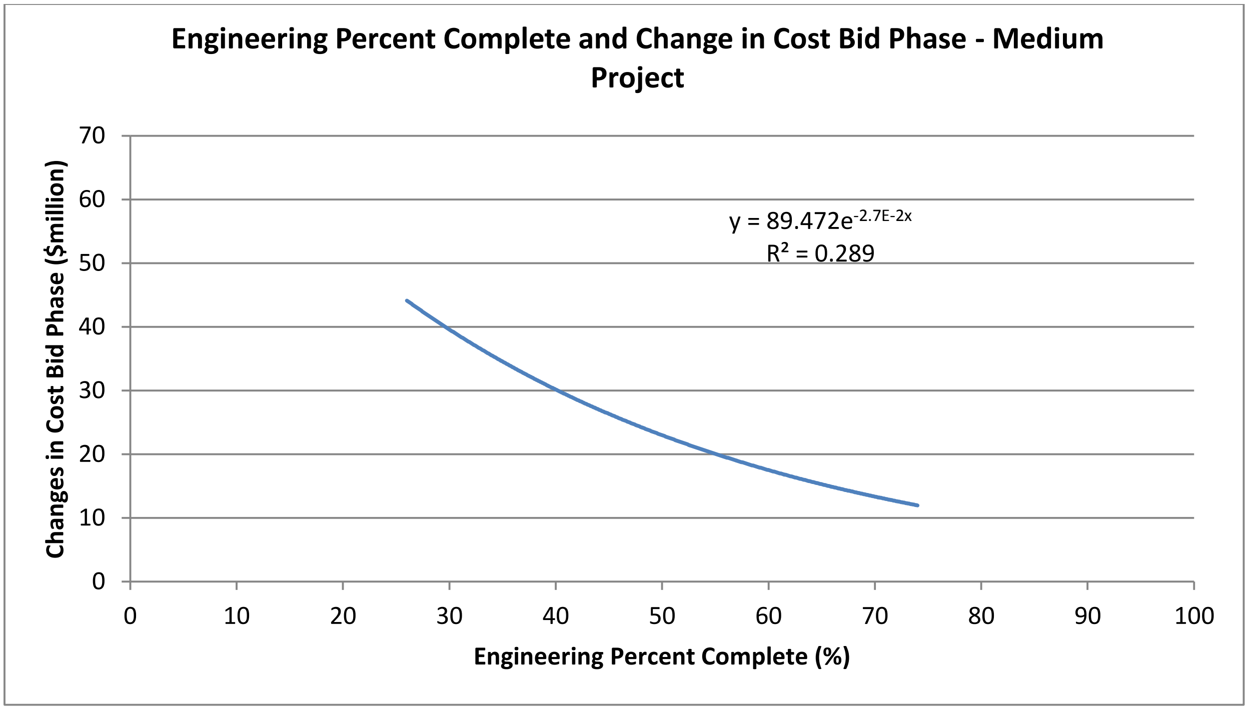

Engineering Percent Complete and Change in Cost Construction Phase - Large Project
y = 12,229.37024109920000e^-0.05088176004482x
R² = 0.23086755525177
Change in Cost Construction Phase ($million)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

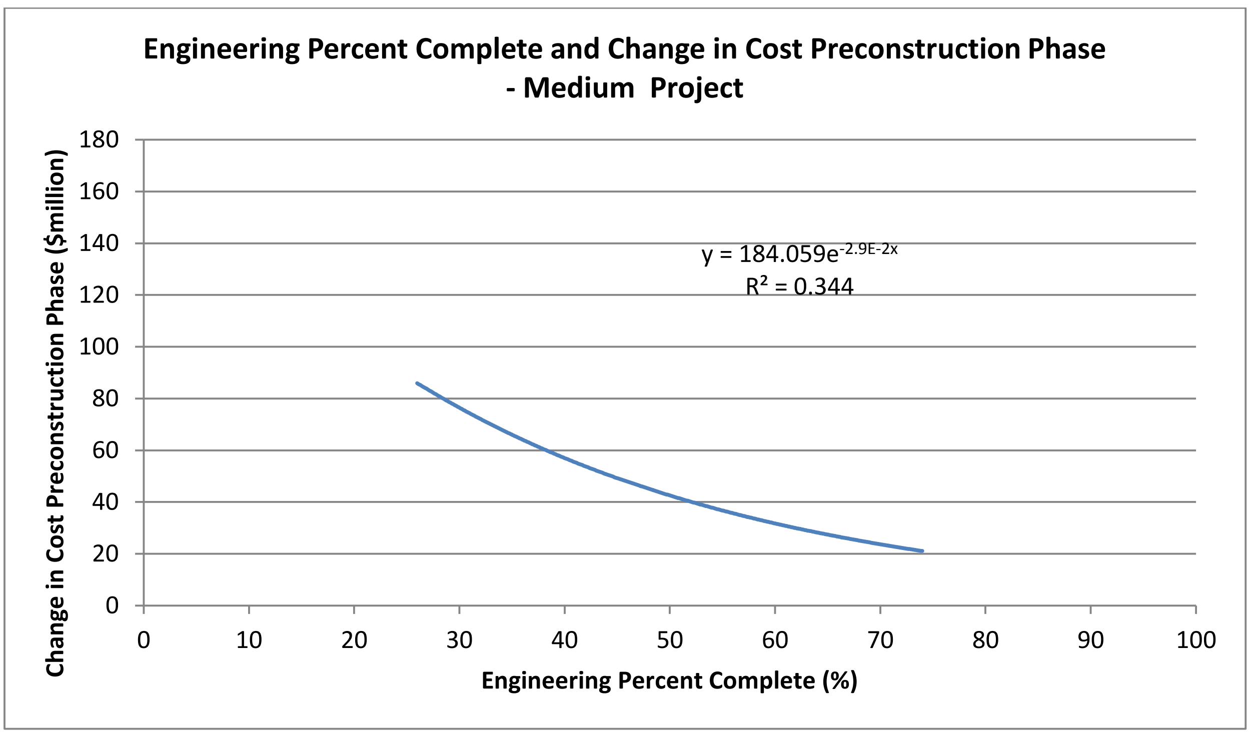

Engineering Percent Complete and Change in Cost Commissioning Phase - Large Project
y = 576.261e^-3.0E-2x
R² = 0.111
Change in Cost Commissioning Phase ($million)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complee (%)

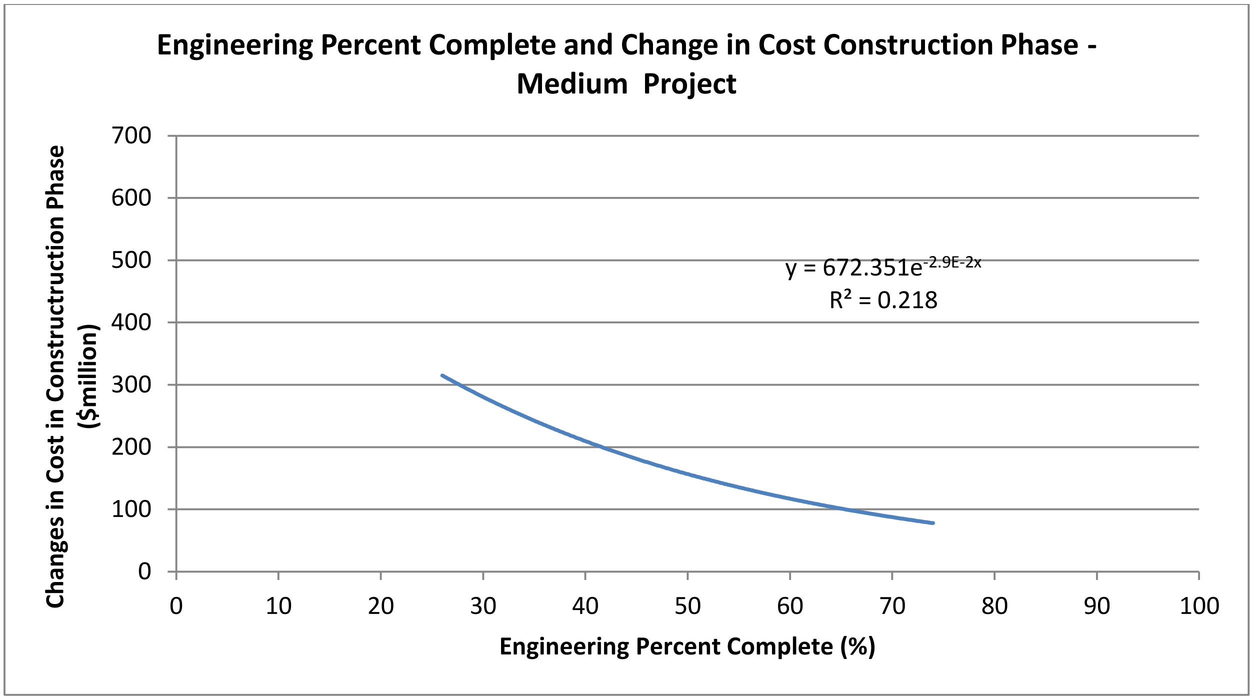
Medium Cost

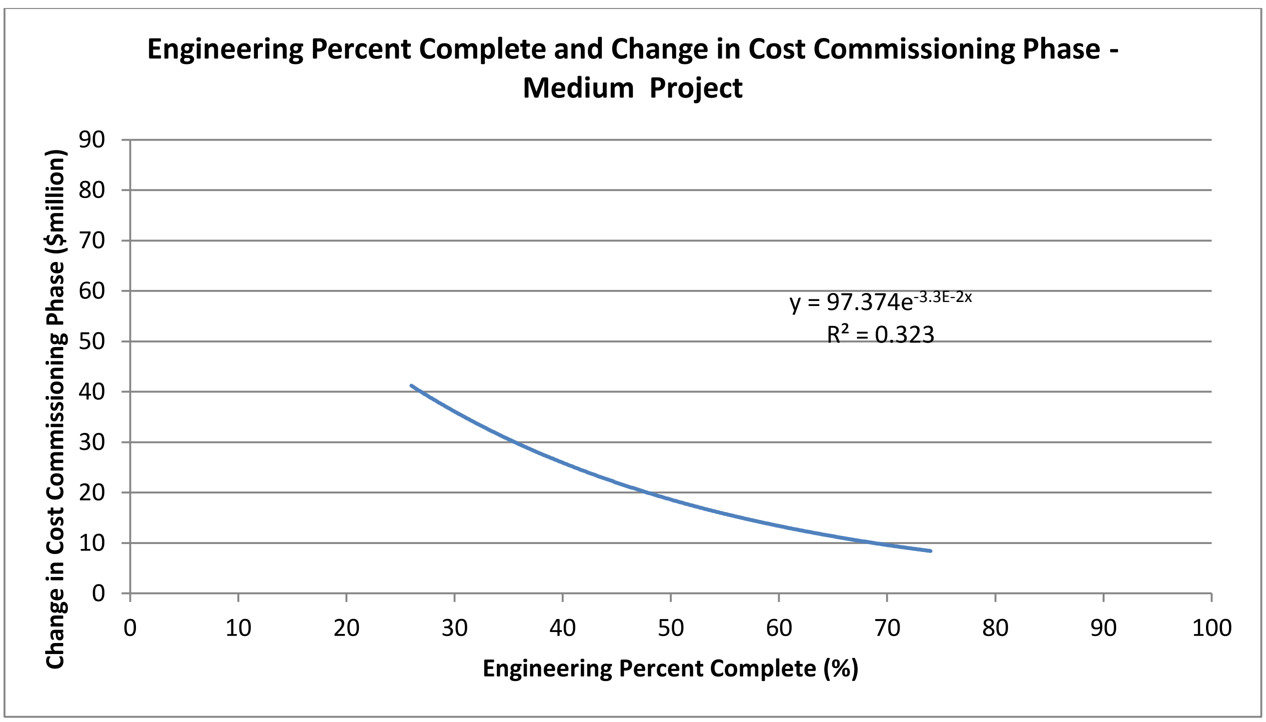


Change in Cost in Different Phases with Estimated Initial Cost - Medium Project
y = 15.674e^2.8.E-3x
R² = 0.728
y = 42.273e^3.8E-3x
R² = 0.849
y = 5.603e^3.4E-3x
R² = 0.787
y = 9.706e^2.4E-3x
R² = 0.520
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900
Changes in Cost in Different Phases ($million)
Estimated Initial Cost ($million)
Expon. (5PMA Bid Phase)
Expon. (5PMA Precon Phase)
Expon. (5PMA Constr Phase)
Expon. (5PMA Comm Phase)

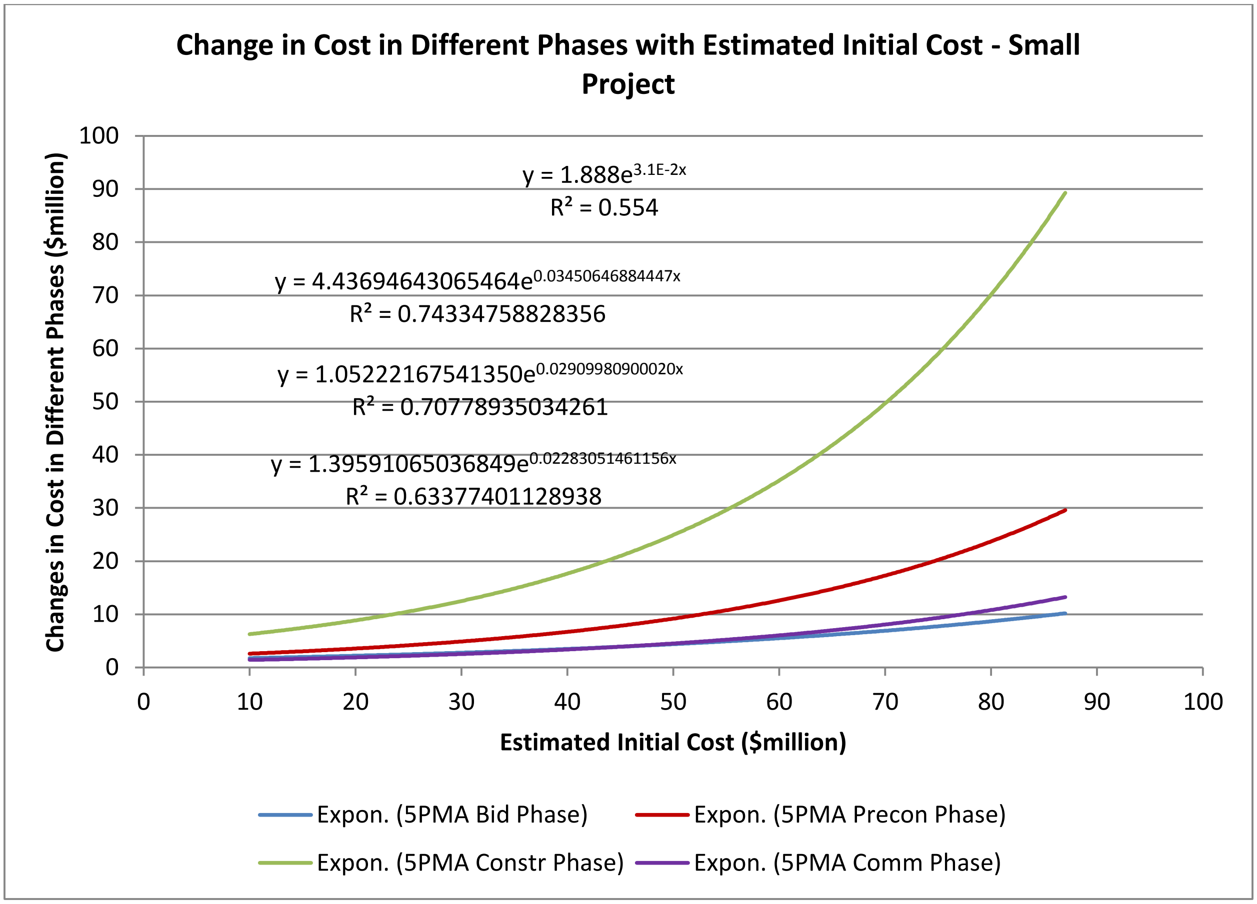

Engineering Percent Complete and Change in Cost Bid Phase - Medium Project
y = 89.472e^-2.7E-2x
R² = 0.289
Changes in Cost Bid Phase ($million)
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)


Engineering Percent Complete and Change in Cost Preconstruction Phase - Medium Project
y = 184.059e^-2.9E-2x
R² = 0.344
Change in Cost Preconstruction Phase ($million)
0
20
40
60
80
100
120
140
160
180
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

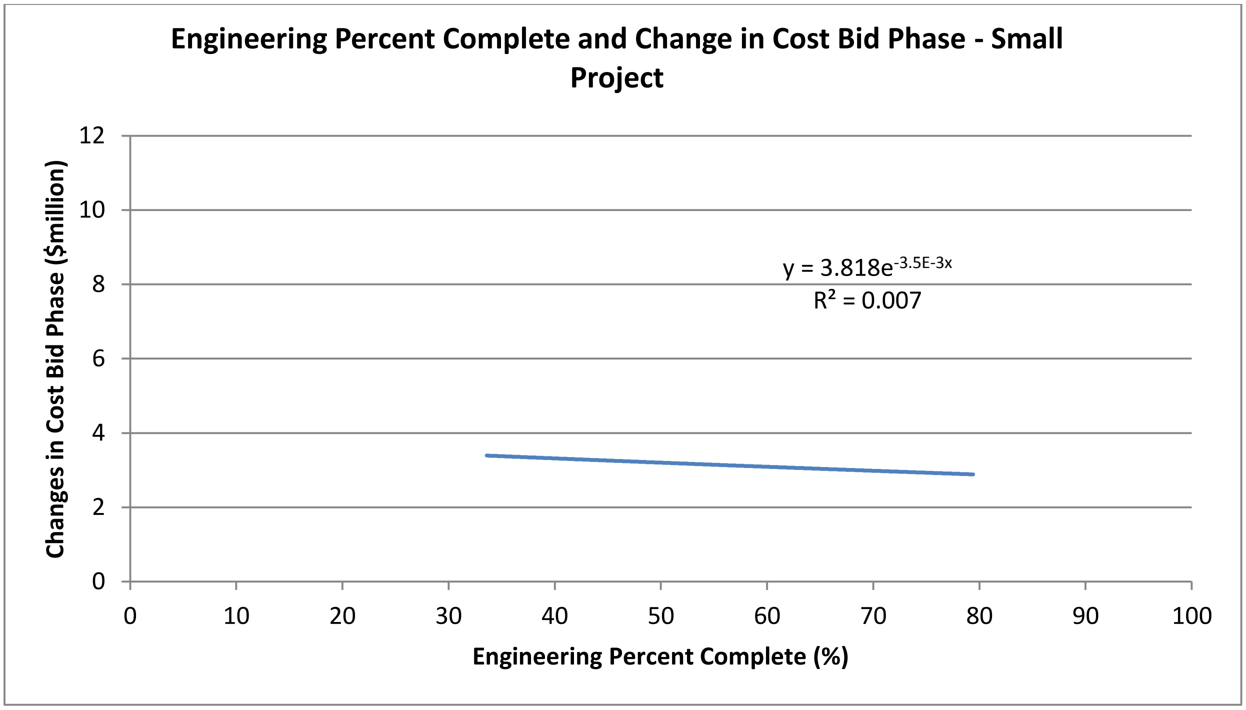

Engineering Percent Complete and Change in Cost Construction Phase - Medium Project
Changes in Cost in Constructruction Phase ($million)
700
600
500
400
300
200
100
0
y = 672.351e-2.9E-2x
R² = 0.218
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

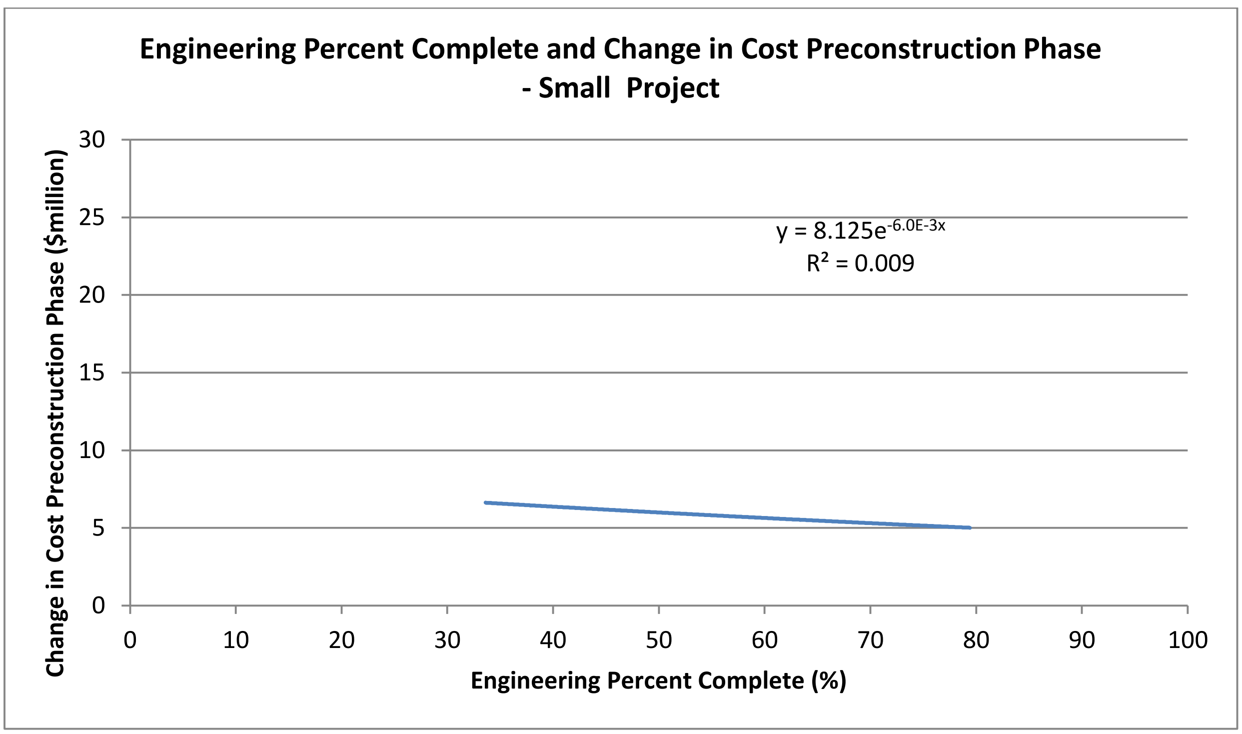

Engineering Percent Complete and Change in Cost Commissioning Phase - Medium Project
Change in Cost Commissioning Phase ($million)
90
80
70
60
50
40
30
20
10
0
y = 97.374e-3.3E-2x
R² = 0.323
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

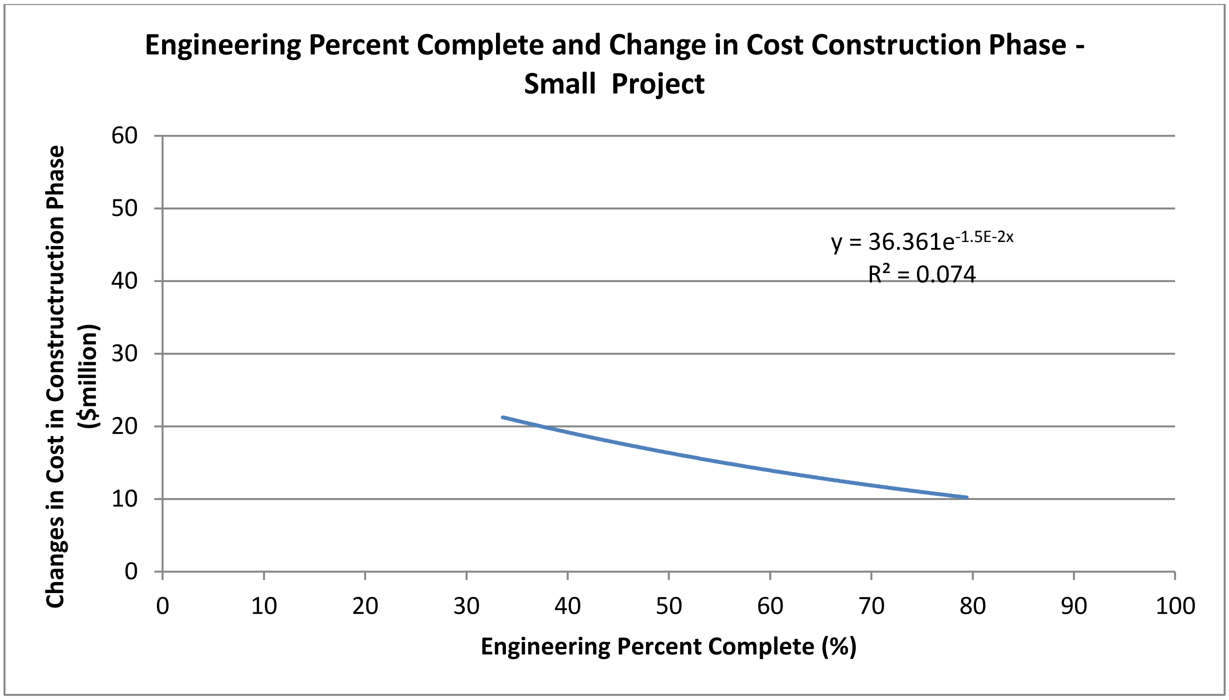
Small Cost

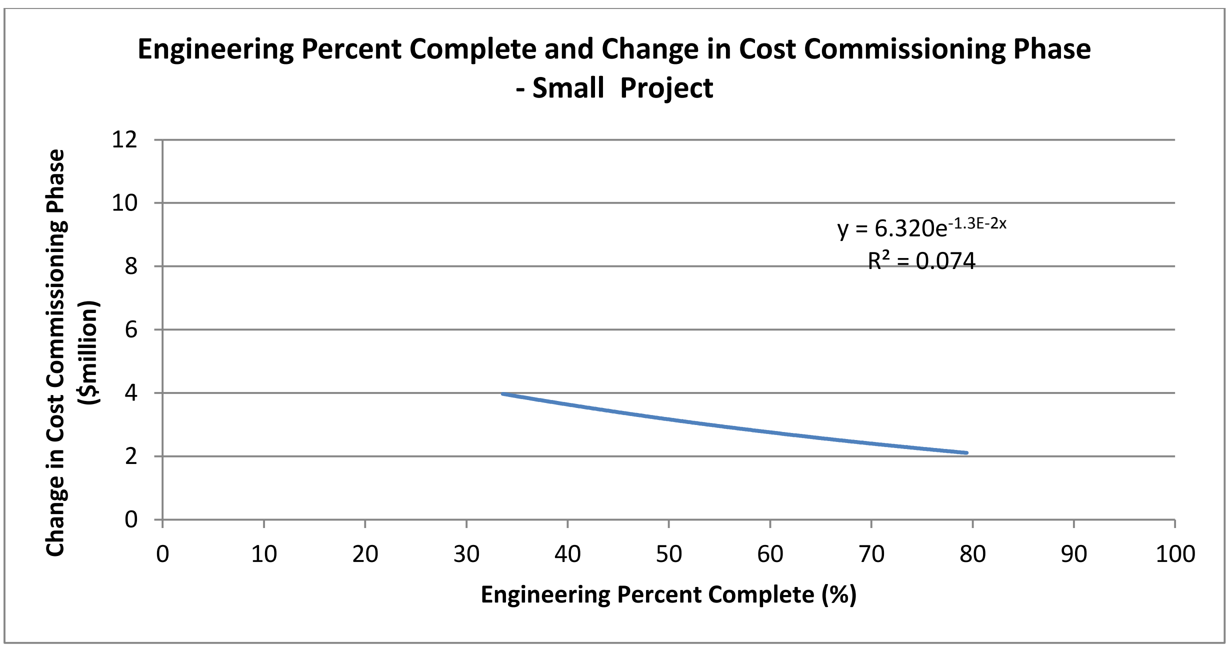


Change in Cost in Different Phases with Estimated Initial Cost - Small Project
y = 1.888e3.1E-2x
R² = 0.554
y = 4.43694643065464e0.03450646884447x
R² = 0.74334758828356
y = 1.05222167541350e0.02909980900020x
R² = 0.70778935034261
y = 1.39591065036849e0.02283051461156x
R² = 0.63377401128938
Changes in Cost in Different Phases ($million)
Estimated Initial Cost ($million)
0
10
20
30
40
50
60
70
80
90
100
Expon. (5PMA Bid Phase)
Expon. (5PMA Precon Phase)
Expon. (5PMA Constr Phase)
Expon. (5PMA Comm Phase)


Engineering Percent Complete and Change in Cost Bid Phase - Small Project
y = 3.818e-3.5E-3x
R² = 0.007
Changes in Cost Bid Phase ($million)
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

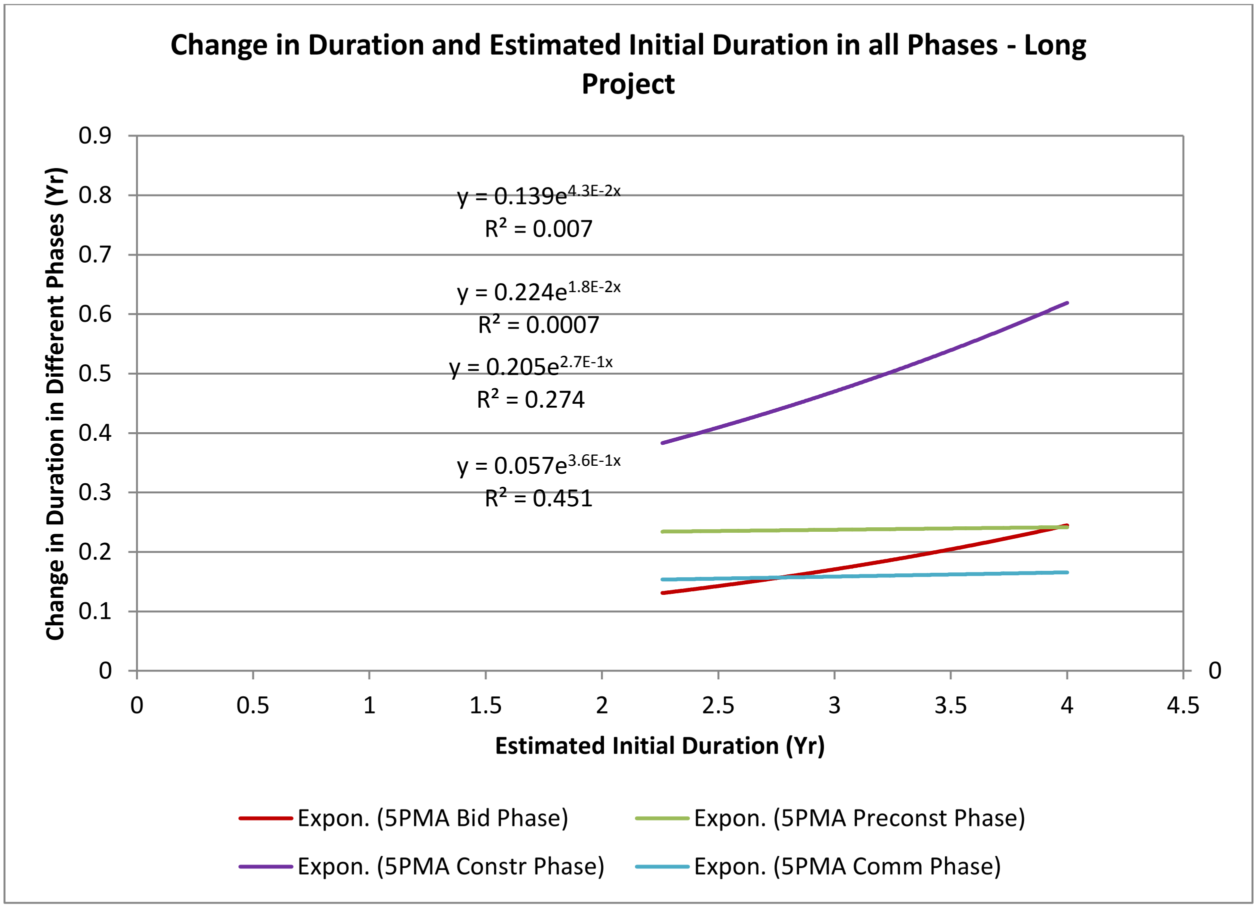

Engineering Percent Complete and Change in Cost Preconstruction Phase - Small Project
y = 8.125e-6.0E-3x
R² = 0.009
Change in Cost Preconstruction Phase ($million)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

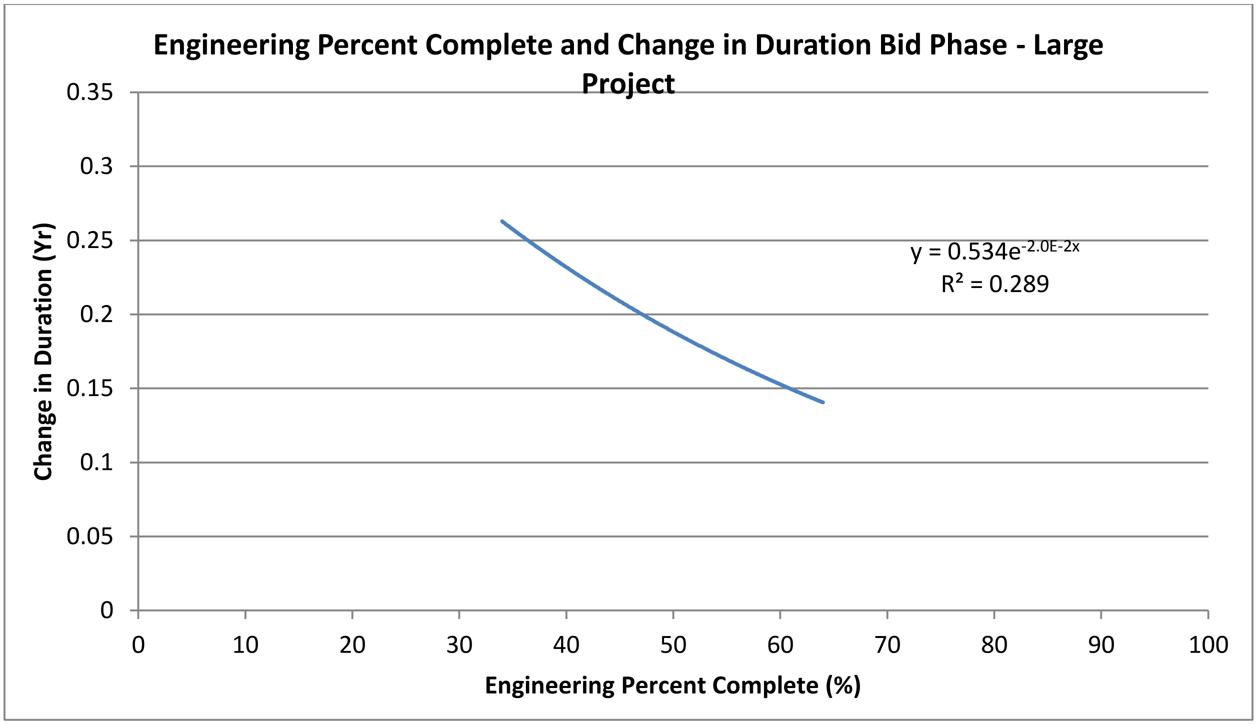

Engineering Percent Complete and Change in Cost Construction Phase - Small Project
60
50
40
30
20
10
0
Changes in Cost in Constructruction Phase ($million)
y = 36.361e^-1.5E-2x
R² = 0.074
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)


Engineering Percent Complete and Change in Cost Commissioning Phase - Small Project
12
10
8
6
4
2
0
Change in Cost Commissioning Phase ($million)
y = 6.320e^-1.3E-2x
R² = 0.074
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

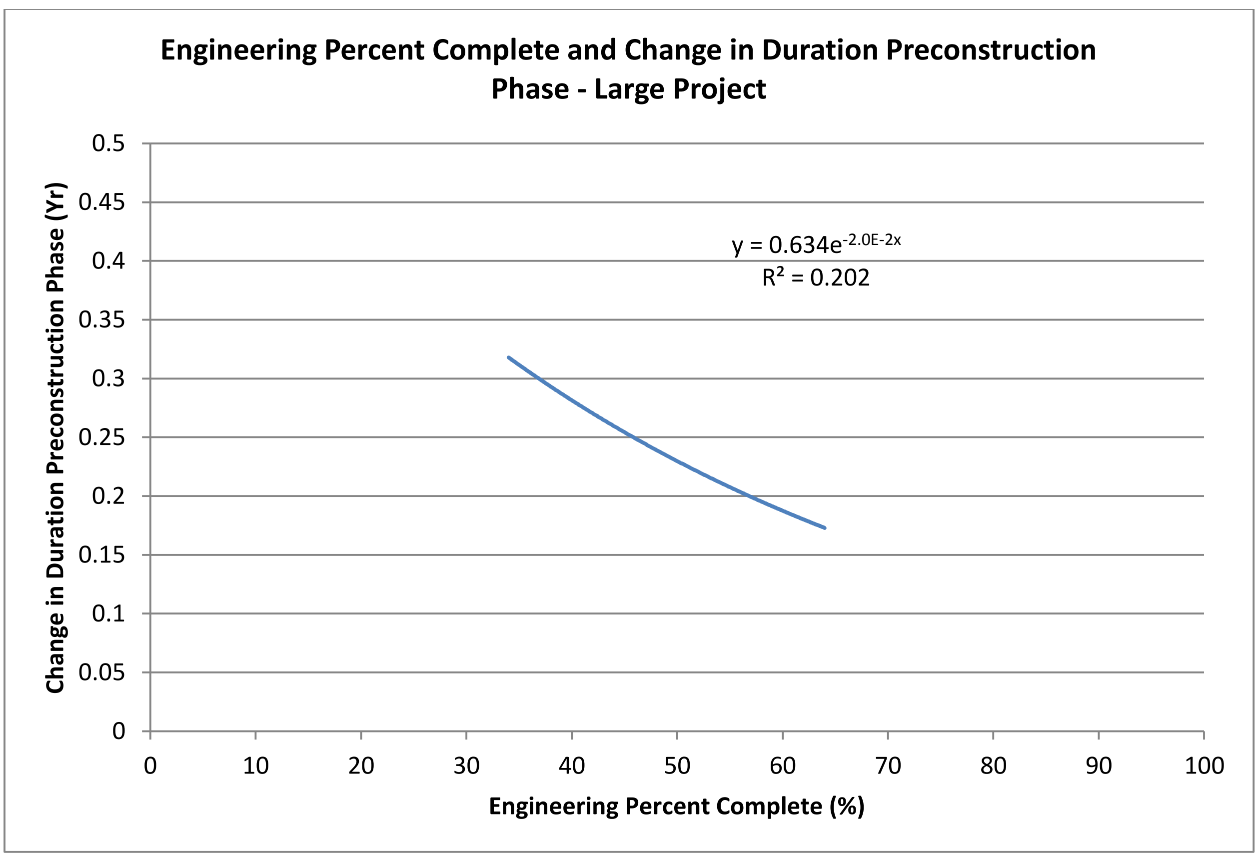
Duration

Long Duration

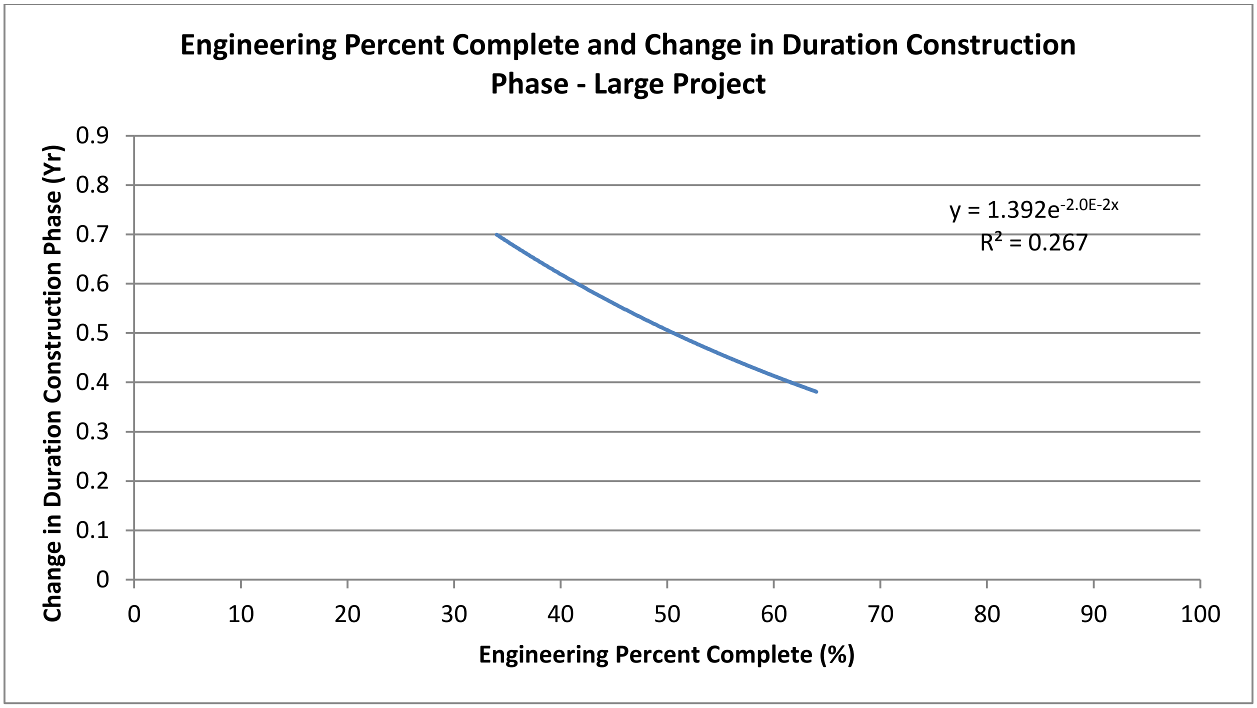


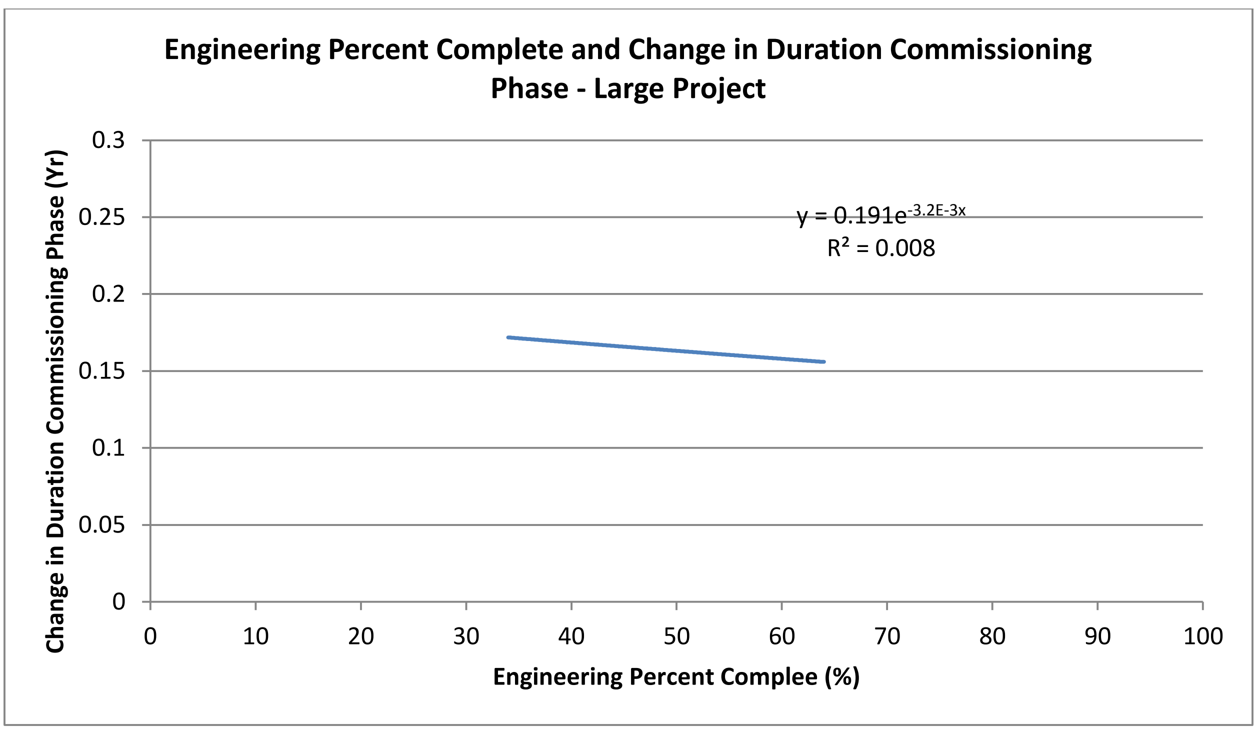


Engineering Percent Complete and Change in Duration Bid Phase - Large Project
Change in Duration (Yr)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
y = 0.534e^-2.0E-2x
R² = 0.289
0 10 20 30 40 50 60 70 80 90 100
Engineering Percent Complete (%)

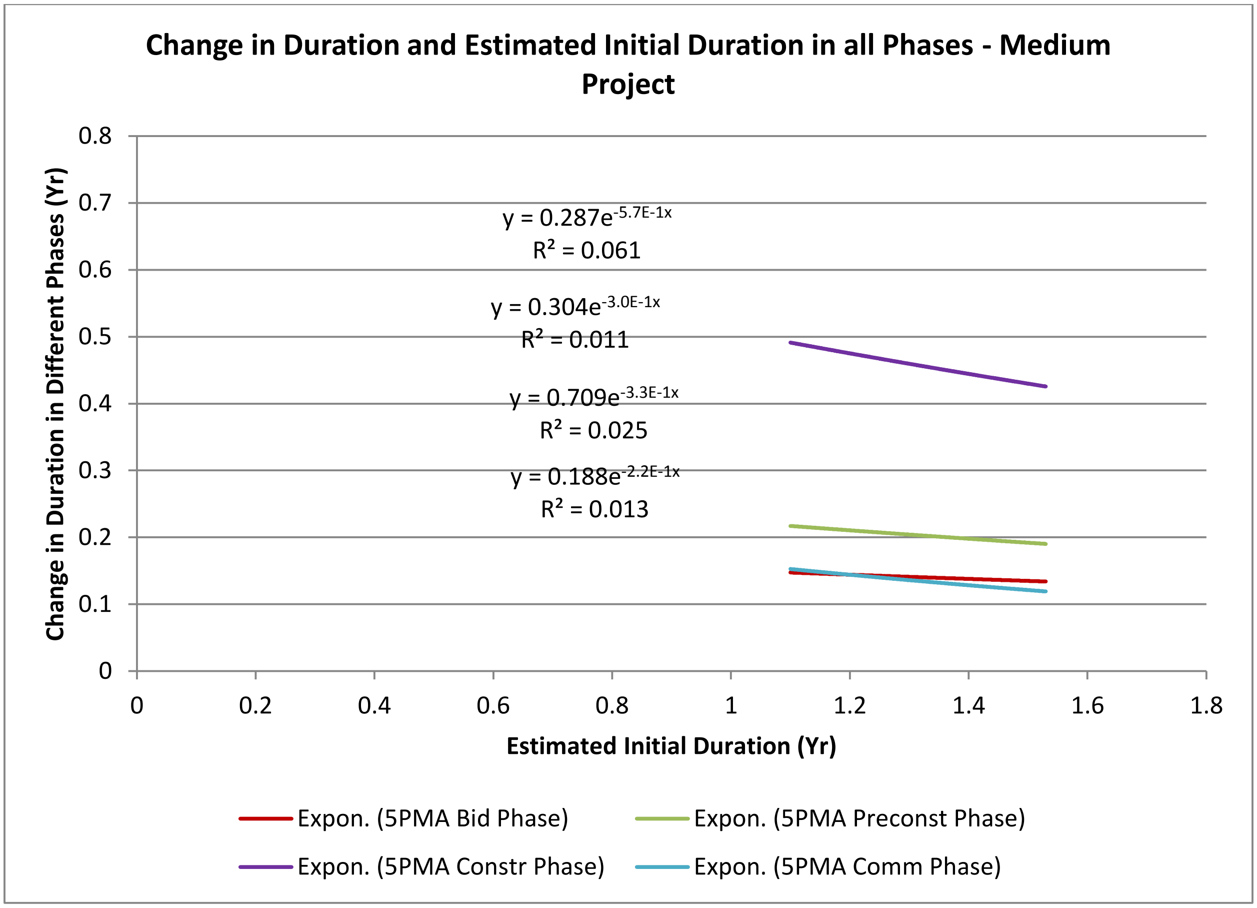


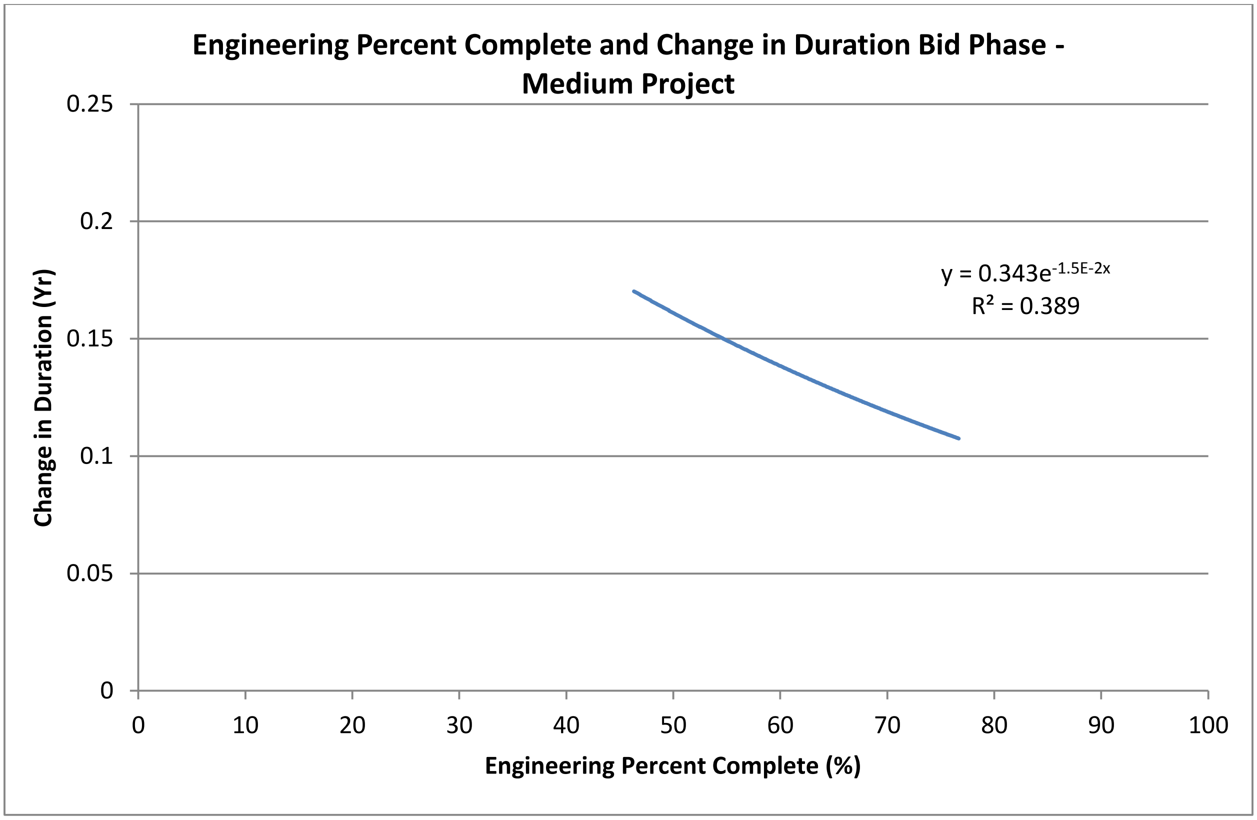
Engineering Percent Complete and Change in Duration Preconstruction Phase - Large Project
Change in Duration Preconstruction Phase (Yr)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
y = 0.634e^-2.0E-2x
R² = 0.202
0 10 20 30 40 50 60 70 80 90 100
Engineering Percent Complete (%)

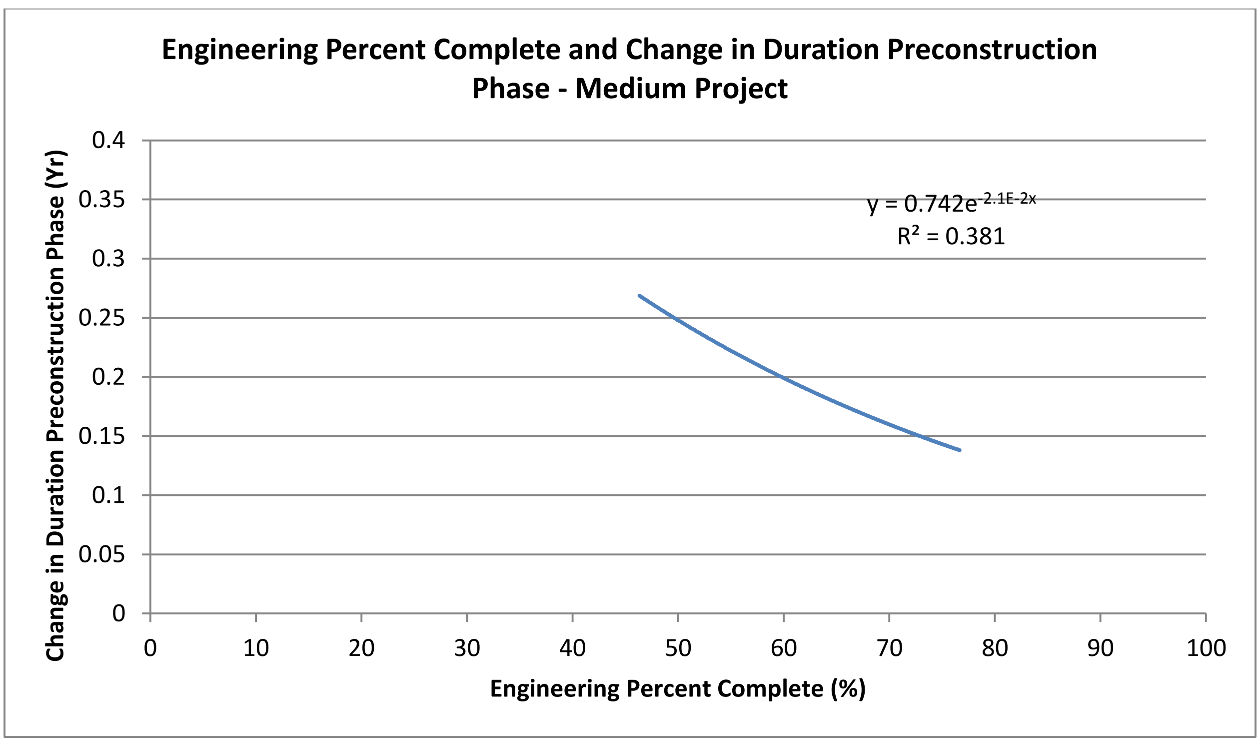

Engineering Percent Complete and Change in Duration Construction Phase - Large Project
Change in Duration Construction Phase (Yr)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)
y = 1.392e-2.0E-2x
R² = 0.267

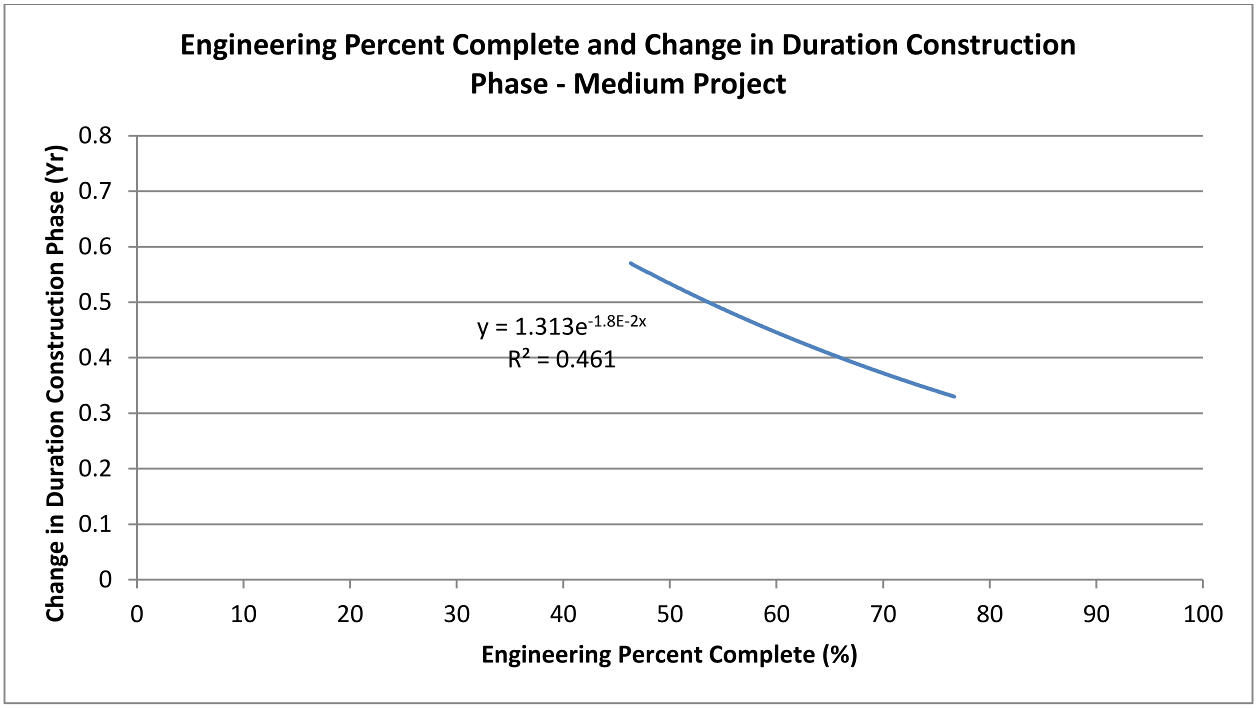

Engineering Percent Complete and Change in Duration Commissioning Phase - Large Project
Change in Duration Commissioning Phase (Yr)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complee (%)
y = 0.191e-3.2E-3x
R² = 0.008

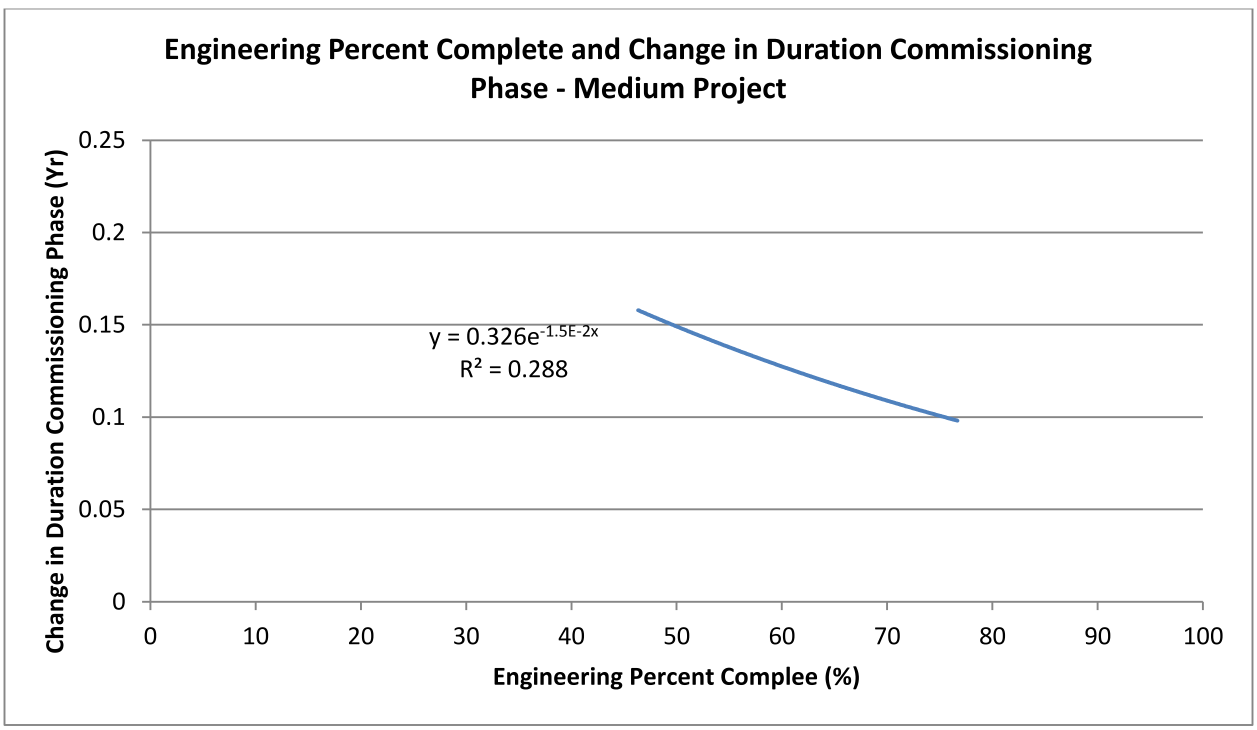
Medium Duration



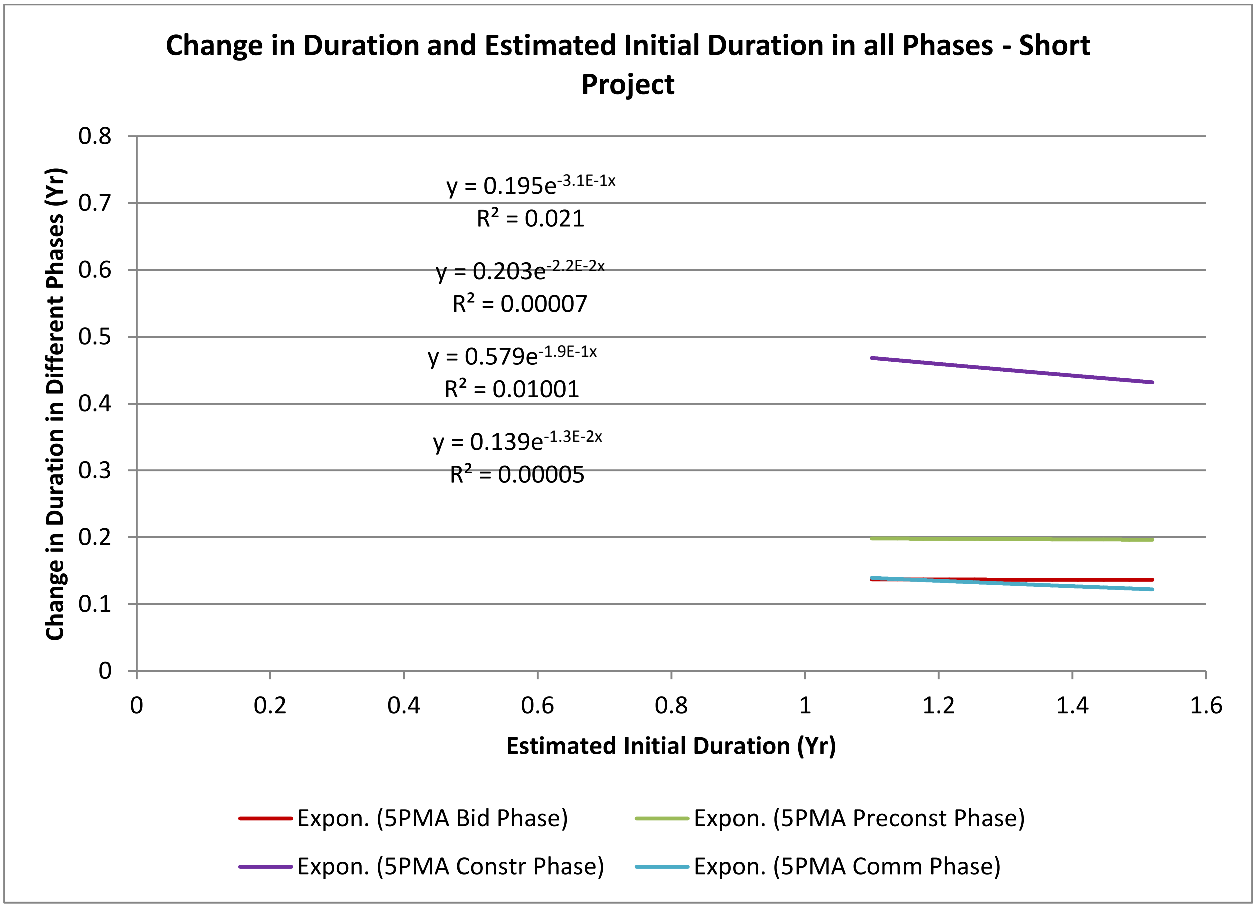

Engineering Percent Complete and Change in Duration Bid Phase - Medium Project
y = 0.343e-1.5E-2x
R² = 0.389
Change in Duration (Yr)
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

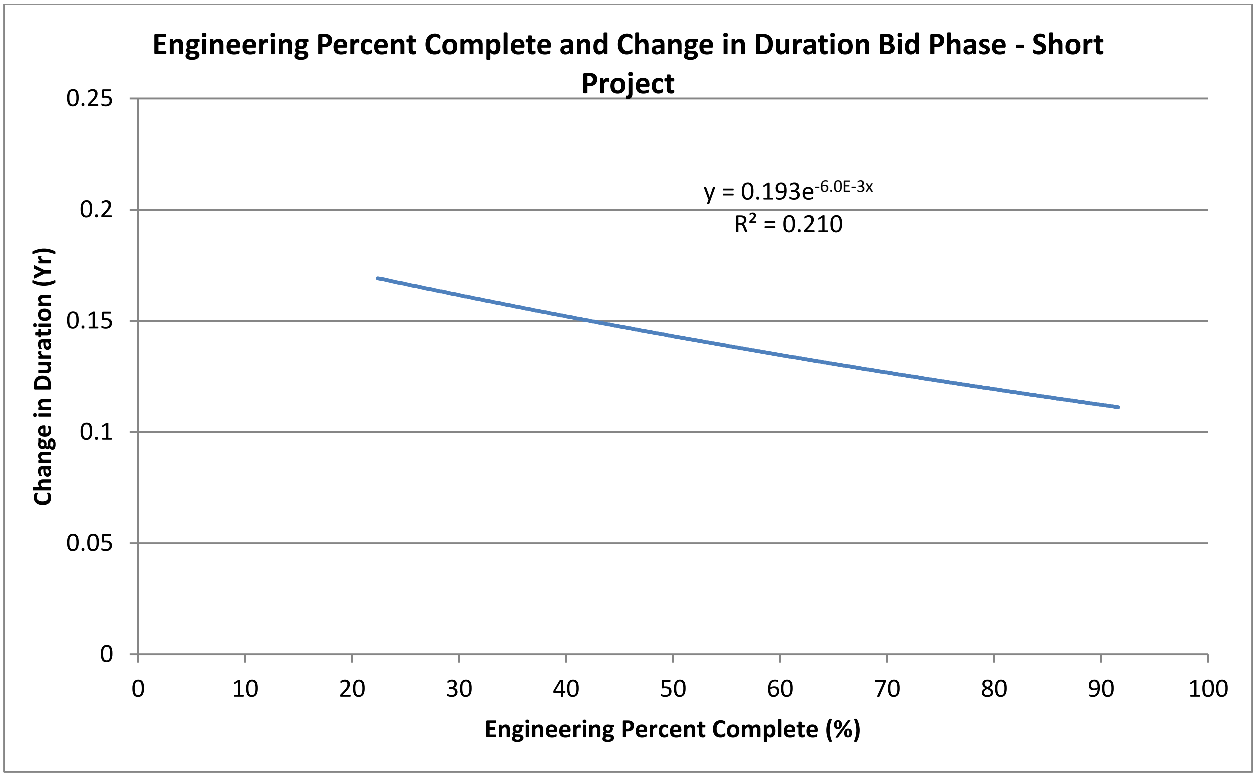

Engineering Percent Complete and Change in Duration Preconstruction Phase - Medium Project
y = 0.742e-2.1E-2x
R² = 0.381
Change in Duration Preconstruction Phase (Yr)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

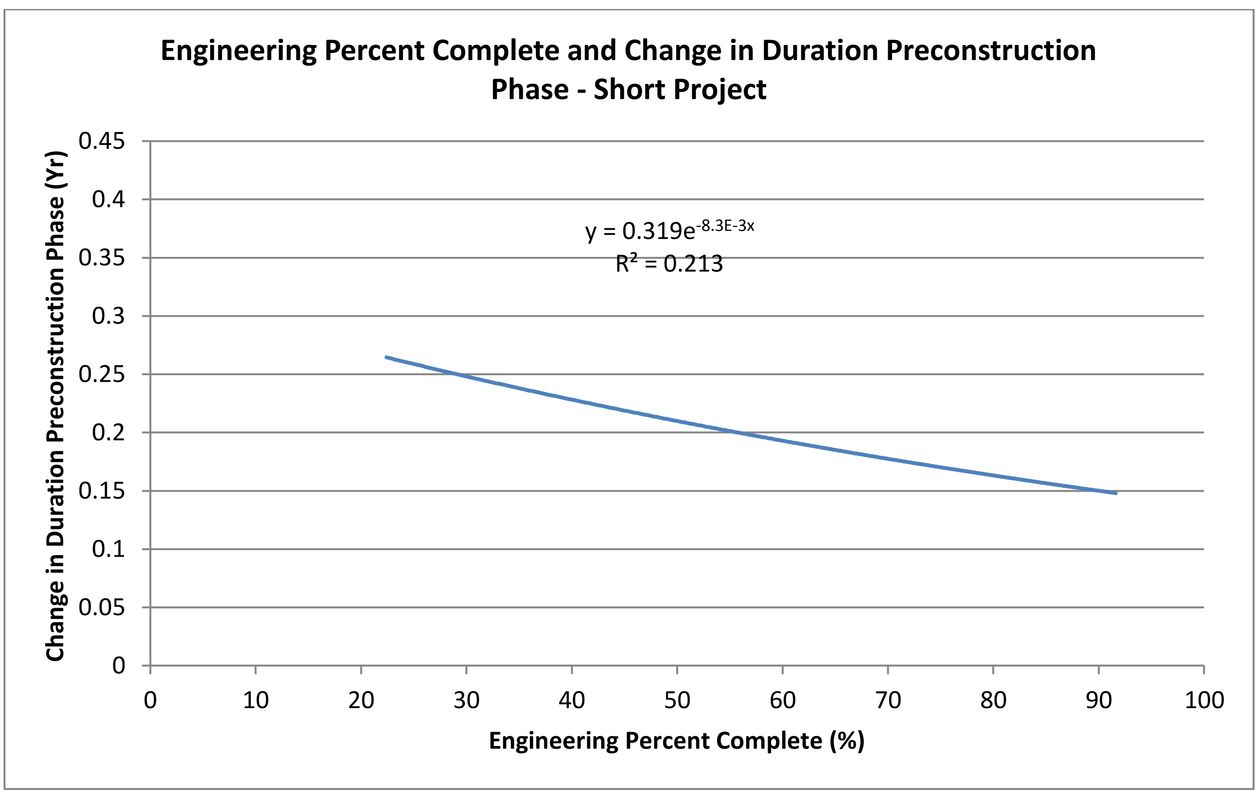

Engineering Percent Complete and Change in Duration Construction Phase - Medium Project
Change in Duration Construction Phase (Yr)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
y = 1.313e^-1.8E-2x
R² = 0.461
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)

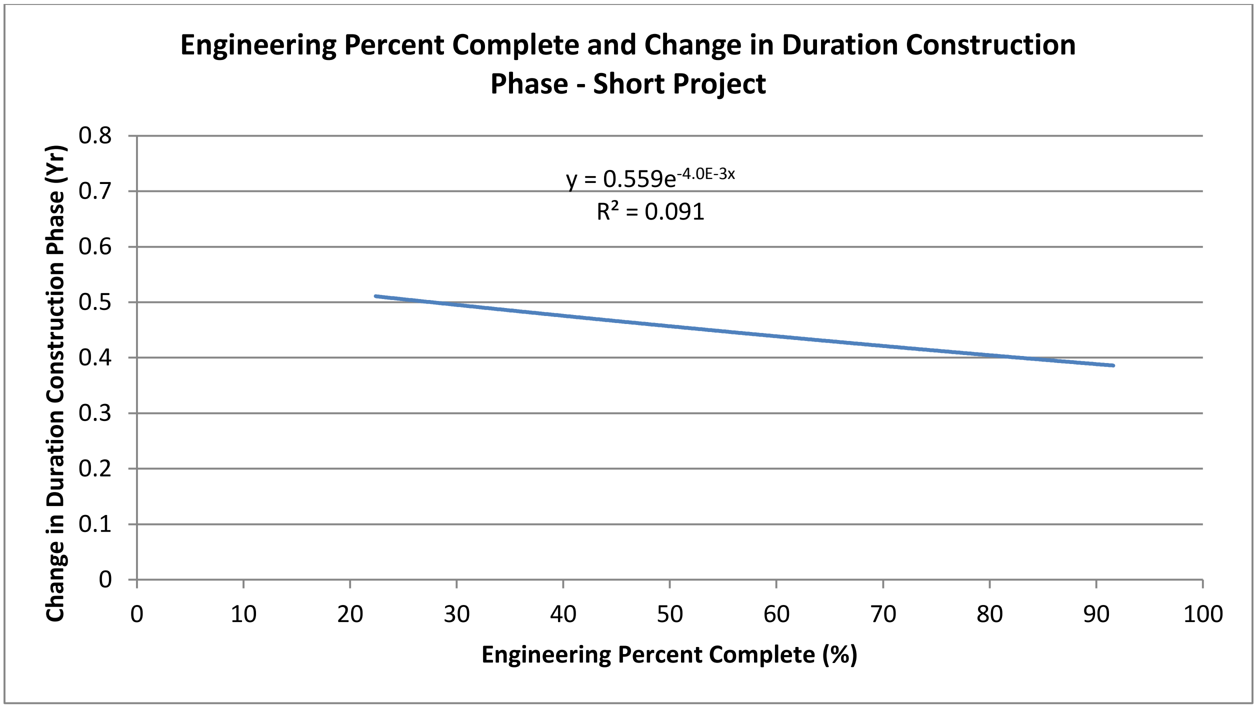

Engineering Percent Complete and Change in Duration Commissioning Phase - Medium Project
Change in Duration Commissioning Phase (Yr)
0.25
0.2
0.15
0.1
0.05
0
y = 0.326e^-1.5E-2x
R² = 0.288
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complee (%)

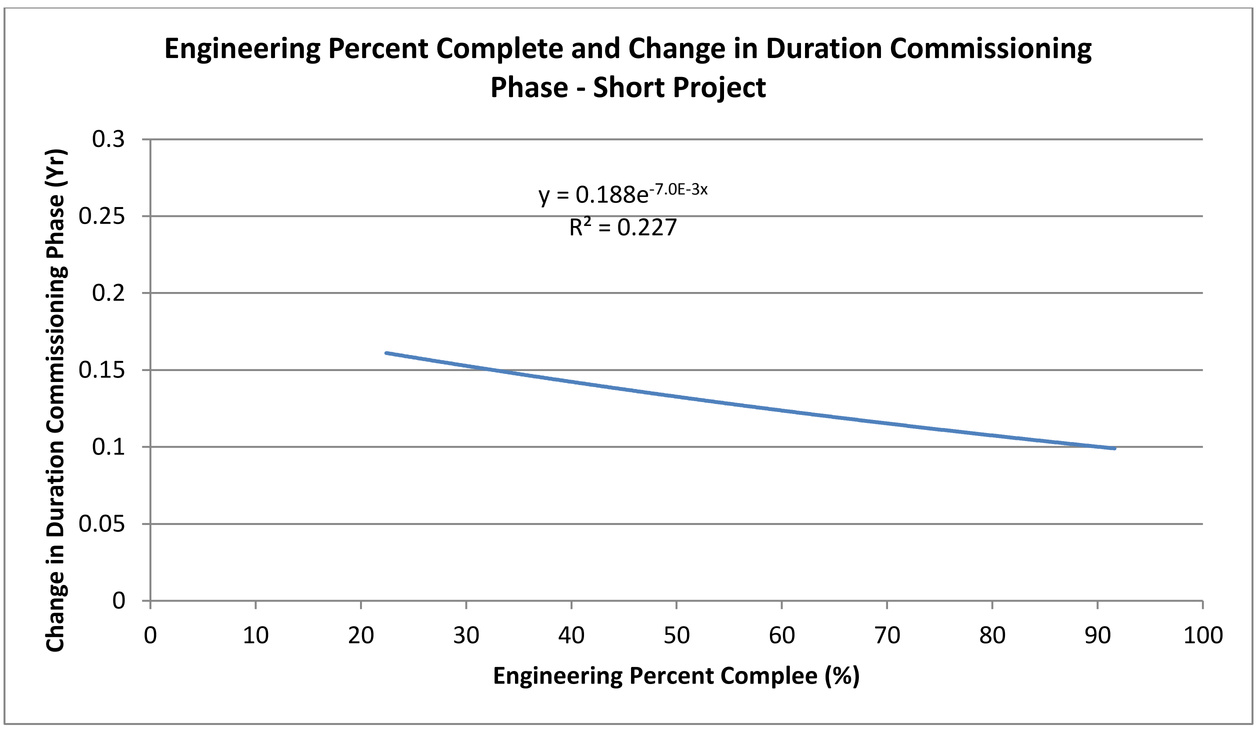
Short Duration




Engineering Percent Complete and Change in Duration Bid Phase - Short Project
y = 0.193e^-6.0E-3x
R² = 0.210
Change in Duration (Yr)
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)


Engineering Percent Complete and Change in Duration Preconstruction Phase - Short Project
y = 0.319e^-8.3E-3x
R² = 0.213
Change in Duration Preconstruction Phase (Yr)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)


Engineering Percent Complete and Change in Duration Construction Phase - Short Project
y = 0.559e^-4.0E-3x
R² = 0.091
Change in Duration Construction Phase (Yr)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complete (%)


Engineering Percent Complete and Change in Duration Commissioning Phase - Short Project
y = 0.188e^-7.0E-3x
R² = 0.227
Change in Duration Commissioning Phase (Yr)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
10
20
30
40
50
60
70
80
90
100
Engineering Percent Complee (%)

Appendix M - Exponential Line Graph Equations

Categories	Phase	Equation	
		Y	R^2
Large Cost	Bid	$111.534e^{1.4E-4x}$	0.392
	Preconstruction	$215.775e^{1.4E-4x}$	0.680
	Construction	$769.46e^{1.9E-4x}$	0.837
	Commissioning	$100.598e^{1.3E-4x}$	0.556
Medium Cost	Bid	$9.706e^{2.4E-3x}$	0.520
	Preconstruction	$15.674e^{2.8.E-3x}$	0.728
	Construction	$42.273e^{3.8E-3x}$	0.849
	Commissioning	$5.603e^{3.4E-3x}$	0.787
Small Cost	Bid	$1.395e^{2.2E-2x}$	0.633
	Preconstruction	$1.888e^{3.1E-2x}$	0.554
	Construction	$4.436e^{3.4E-2x}$	0.743
	Commissioning	$1.052e^{2.9E-2x}$	0.707
Long Duration	Bid	$0.057e^{3.6E-1x}$	0.451
	Preconstruction	$0.224e^{1.8E-2x}$	0.0007
	Construction	$0.205e^{2.7E-1x}$	0.274
	Commissioning	$0.139e^{4.3E-2x}$	0.007
Medium Duration	Bid	$0.188e^{-2.2E-1x}$	0.013
	Preconstruction	$0.304e^{-3.0E-1x}$	0.011
	Construction	$0.709e^{-3.3E-1x}$	0.025
	Commissioning	$0.287e^{-5.7E-1x}$	0.061
Short Duration	Bid	$0.139e^{-1.3E-2x}$	0.00005
	Preconstruction	$0.203e^{-2.2E-2x}$	0.00007
	Construction	$0.579e^{-1.9E-1x}$	0.010
	Commissioning	$0.195e^{-3.1E-1x}$	0.021

Categories	Phase	Equation	
		Y	R^2
Large Cost and Engineering	Bid	$285.213e^{-1.0E-2x}$	0.009
	Preconstruction	$1,307.034e^{-3.0E-2x}$	0.112
	Construction	$12,229.370e^{-5.0E-2x}$	0.230
	Commissioning	$576.261e^{-3.0E-2x}$	0.111
Medium Cost and Engineering	Bid	$89.472e^{-2.7E-2x}$	0.289
	Preconstruction	$184.059e^{-2.9E-2x}$	0.344
	Construction	$672.351e^{-2.9E-2x}$	0.218
	Commissioning	$97.374e^{-3.3E-2x}$	0.323
Small Cost and Engineering	Bid	$3.818e^{-3.5E-3x}$	0.007
	Preconstruction	$8.125e^{-6.0E-3x}$	0.009
	Construction	$36.361e^{-1.5E-2x}$	0.074
	Commissioning	$6.320e^{-1.3E-2x}$	0.074
Long Duration and Engineering	Bid	$0.534e^{-2.0E-2x}$	0.289
	Preconstruction	$0.634e^{-2.0E-2x}$	0.202
	Construction	$1.392e^{-2.0E-2x}$	0.267
	Commissioning	$0.191e^{-3.2E-3x}$	0.008
Medium Duration and Engineering	Bid	$0.343e^{-1.5E-2x}$	0.389
	Preconstruction	$0.742e^{-2.1E-2x}$	0.381
	Construction	$1.313e^{-1.8E-2x}$	0.461
	Commissioning	$0.326e^{-1.5E-2x}$	0.288
Short Duration and Engineering	Bid	$0.193e^{-6.0E-3x}$	0.210
	Preconstruction	$0.319e^{-8.3E-3x}$	0.213
	Construction	$0.559e^{-4.0E-3x}$	0.091
	Commissioning	$0.188e^{-7.0E-3x}$	0.227