QUANTIFYING THE EFFECTIVENESS OF INNOVATIVE CONTRACTING STRATEGIES ON SCHEDULE, COST AND CHANGE ORDER

A Thesis

by

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ABSTRACT

The transportation infrastructure systems in the United States were built between the 50's and 80's, with 20 years design life. As most of them already exceeded their original life expectancy, State Transportation Agencies (STAs) are now under increased pressure to rebuild deteriorated transportation networks. Over the recent years, state transportation agencies (STAs) have taken into consideration various project delivery approaches apart from conventional project delivery approach to expedite project delivery.

Since the introduction of these new alternative delivery approaches, not many substantial studies were conducted that evaluated the performance of these new alternatives. The absence of systematic studies about the effectiveness of these strategies and lack of appropriate analytical tools to evaluate them inhibits the STAs from budgeting precisely and accurately these strategies when they are deliberated for being put into practice. This study tries to address these limitations by evaluating the effectiveness of these strategies.

The major objectives of this research were: 1) to evaluate the impact of contracting strategies on dealing with change orders 2) to evaluate the performance of different contracting strategies under varied work type for the state of Florida . For this research the study was conducted to quantify the changes to project duration and cost caused by change orders in the project under different contracting strategies and type of work. This was done through evaluating 2844 completed transportation infrastructure projects, completed between 2002 and 2011 in the state of Florida. These projects comprised of both the conventional projects and innovative alternative projects. The data was then statistically analyzed for evaluating the performance of these contracting strategies.

The research concluded that alternative contracting strategies perform much better than conventional contracting in controlling project schedule but are found not to be as effective in controlling the project cost growth. The study also established that project size and work type affect the effectiveness of the contracting strategies. The study indicates that A+B is the worst performing contracting strategy among all the strategies evaluated. The results of this study will help the STAs to make better informed decision regarding selection of contracting strategy for project delivery.

DEDICATION

Dedicated to my family members and all my friends

Satish Chandra Gaur

Anita Gaur

Bhagvati Devi

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Finally, thanks to my mother and father for their encouragement and support.

NOMENCLATURE

A+B	Cost –Plus- Time
Caltrans	California Department of Transportation
CCR	Cost Change Ratio
CCCGR	Contract Cost Change Growth Ratio
CSCGR	Contract Schedule Change Growth Ratio
DOTs	Department of Transportation
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
I/D	Incentive/Disincentive
ME	Management Effectiveness
MnDOT	Minnesota Department of Transportation
SCR	Schedule Change Ratio
SHAs	State Highway Agencies
TxDOT	Texas Department of Transportation
WisDOT	Wisconsin Department of Transportation

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1. INTRODUCTION

In United States Federal Highway Administration (FHWA) oversees all road networks in which majority of the roads require rehabilitation. (National Atlas of the US 2009).The State Transportation Agencies has improved the transportation network in the country to reduce the challenges by conducting massive reconstruction of the road network in the whole country costing billions of dollars. To conduct massive reconstruction of the road network the STAs in every region had to plan for successful projects and oversee the implementation of these through the delivery methods which will have minimum impact on the public and make sure the project is completed on time (Scanlon 2009). To allow the STAs (State Transportation Agencies) to conduct their work efficiently and renovate the highways with minimum impact and inconveniences to the public by closing most of the lanes in the highway the Obama administration set aside approximately $80billion for the reconstruction project (US News & World Report, Obama: March 1 2010).National Academy of Engineering also noted that improvement and rehabilitation of the transportation sector is one of the grand challenges in the 21st century (National Academy of Engineering, Grand Challenges for Engineering 2009).

Major disruption caused by massive re-construction of the road network leads to traffic inconveniences especially to the public and those who rely on the road network to transport their goods and services i.e. the commercial enterprises. It is estimated that approximately 30% of the road re-construction project which took place in U.S. was undertaken in the urban areas (Wisconsin Department of Transportation (WisDOT 2004).

Due to the massive loss of the revenue on the commercial enterprises and the public inconveniences and the country as a whole to delays brought up by the re-construction projects it is therefore important for the transportation agencies to look at effective ways in which they can reduce the impact to public by adopting innovative delivery methods to complete the work in time.

According to the Lee and Choi (2006) after conducting research on public perception about the impact of the construction projects they pointed out that the public are willing to pay more so long as they know that they will minimal disruption from the construction projects and that the project will be finished in time. The above sentiments were also highlighted by (Choi et al 2009), indicating that the public were willing to pay more so long as the project's shortened construction period will cause minimal inconveniences.

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1.1 Innovative and Alternative Contracting Strategies

The transportation infrastructure in the United States has substantially deteriorated due to age, thus it is important to adopt effective strategies for project implementation. Sufficient studies have not been conducted that have has prevented the State Highway Agencies to determine the accurate and realistic budget required for implementation. As a result of deteriorated infrastructure in the United States the nations does not only face the challenge of repairing the aging infrastructure, but simultaneously it is also struggling to minimize traffic inconvenience to the travelling public. Lee and Choi (2006) confirmed that congestion, risks to the public safety and limited access to the property are some of the challenges the transportation agencies and the public are facing during lane closures and massive reconstruction of the roads.

The Federal Highway Administration determined that it is not only important to expand the existing highway, but State Highway Agencies should focus on preserving and maintaining their existing highway system. FHWA challenged SHA to ensure that the current system works better, run more smoothly and last longer. FWHA has encouraged SHAs to develop strategies that will facilitate in addressing the deteriorating highway system. Due to the poor conditions of the road, the federal government developed the Transportation Equity Act (TEA) that resulted in significant increase in the funds required for constructing new roads and for rehabilitation. State DOTs who are responsible for building roads also began to consider the importance of maintaining the existing highways and began to make more investments in maintenance. They believed that outsourcing facilitates to reduce costs, increase efficiency and improve service quality.

A major factor that motivated DOTs to outsource was cost savings; however, there were also other factors that encouraged DOTs to outsource personnel for better and effective implementation. In response to this, Florida adopted an aggressive maintenance contracting program, based on which they were require to increase their outsourcing to 60%; hence, they witnessed a 20% decline in their costs, which indicates that this contracting strategy proved to be cost-beneficial. Furthermore, Massachusetts started a pilot program for the purpose of examining the efficiency that could be achieved by inviting maintenance employees to compete with contractors for performing maintenance activities

To reduce this impact the concerned parties must employ Innovative alternative methods delivery methods which ensure that the projects are completed on time and there is a win-win situation to both parties in the construction. These methods are simple to apply and are effective in nature. They include lump sum, incentive/disincentive method, lane rental method, and liquidity savings and so on. With the alternative methods it will be easier for the parties in the construction to estimate the impacts that the changes bring on the time and price which cannot be determined and quantified with the conventional methods (Lee and Choi 2006).

2. PROBLEM AND RESEARCH SETTING

Highway agencies find it a challenging job to work on highway work zone projects, since they are mostly located in urban areas and create a significant impact not only on the local traffic, but also on the business community and neighborhood hence, leading to multi-party involvement. Therefore, it needs to be ensured by the highway agencies that to ensure efficiency of the performance of the project they should not create a negative impact on the involved parties (Lee and Ibbs 2005). Thus, the problem is to identify the most suitable contracting strategies for the construction projects. A dynamic relationship exists between the stakeholders of the project and the performance of the project.

The decision made by the Highway agencies related to a particular project during the phase of planning and execution is not only likely to affect the performance indicator of any particular project that is, cost, quality, schedule, safety and public/ motorist satisfaction; however, it also creates an impact on the stakeholders. For instance, the limit on the working hours of any particular project will directly affect the duration of the project (Liautaud 2004). In addition to this, the contractor is also directly affected by such restrictions that are mandated by the state highway agencies (SHAs), in terms of costs, availability of material and equipment necessary for construction and labor productivity, as a result this will affect the final cost and the time duration required for the project. The importance of the dynamic relationship that exists between the stakeholders and the project should not be avoided as failure to do so will result in delays in schedule, cost overruns and various other legal problems. Furthermore, a marginal cost overrun will result in declining profits for the contractor. In addition to this, it will lead to rise in the agency costs and also public dissatisfaction. There are certain tangible and intangible variables that create an impact on the performance of highway work zone projects. These factors include technical factors, social or political factors, financial considerations, requirements of a contract and other factors such as issues related to utility and environmental permits (Vella, 2008).

2.1 Problem Statement

Motorists' safety and integrity are at risk because of the challenges they face in the transportation sector. This is because the roads that were constructed under the Federal Highway Administration (FHWA) in the 1950s and 1980s have approximately 20 years life span (National Atlas of the United States 2011). With this short life-span the road network in the United States need to be renovated and reconstructed. Currently the State Transportation Agencies which oversees the transportation network in the country have been able to reduce the challenges facing the transport sector by conducting massive reconstruction of the road network in the whole country costing billions of dollors . To ensure that SHAs effectively implement the project very well and complete them on schedule they have to adopt the innovative alternative methods. SHAs should also give the contractor a chance of determining the amount of time that he is able to complete the work in time is very important since it encourages the contractor to maximize his time and resources and ensure that the achieves his goals and objectives (FDOT 2008).

The innovative methods are very effective and ensure the projects schedule, cost and performance is enhanced. Although this has been noted it is hard for the implementing agency to effectively differentiate between the methods which one is more effective than the other because there is no documented research on the effectiveness of one method over the other.

2.1.1 Problem I: Disagreement about Effectiveness

The aim to fulfill the desires of public can be accomplished by the state highway agencies through an innovative means and ensuring that the projects will be completed early. In order to ensure that the projects are implemented effectively it is important to ascertain the most efficient strategy that should be adopted. State highway agencies are often unable to determine the necessary change needed for the providing the public with better quality constructions at lower costs (Timmerman 2009). However, there have been significant debates on determining the effectiveness of the contracting strategies. The use of A + B and I/D contracting strategies are likely to be advantageous for contractors' ingenuity by utilizing their realistic estimates of construction schedules. In United States the two most common methods used for contracting strategies are A + and I/D. Moreover due to lack of studies there has been a disagreement related to the effectiveness of the strategies (Timmerman 2009).

2.1.2 Problem II: Lack of Systematic Studies

Many studies have been able to focus on the effectiveness of method over the other but there is no systematic researches conducted on the alternative methods and assess the impact of each method on cost, schedule and performance. This can be highlighted from the above where individuals have been able to argue about the effectiveness of one method over the other. Due to lack of the documented results it has become essential for the implementing agencies to effectively manage road construction works and minimize disruptions to the public. To ensure that SHAs effectively implement the project very well and complete them on schedule they have to adopt the innovative alternative methods. SHAs should also give the contractor a chance of determining the amount of time that he is able to complete the work in time is very important since it encourages the contractor to maximize his time and resources and ensure that the achieves his goals and objectives (FDOT 2008).

2.1.3 Problem III: Lack of Standardized Methods and Analytical Tools

STAs as an implementing agency that oversees road network construction finds it hard for the agency to determine the overall impact of the previous projects before awarding another project to a contractor due to lack of standardized methods and tools to measure the impact of one project on time, cost and performance.

2.2 Research Structure and Deliverables

This research is focused on:

1) Quantitatively analyze measure and interpret data from the transportation agency from on innovative alternative methods.
2) Quantitatively analyze the total observed impacts of the contracting strategy on time, cost and performance.

2.3 Research Objectives

1) Investigate the performance of design-build projects compared to the conventionally delivered projects
2) Examine the performance of innovative contracting projects compared to the conventional contracting projects
3) Evaluate the performance of projects contracted with various innovative contracting methods
4) Assess the impacts of contract change orders on aspects of project performance such as cost and schedule.

2.4 Research Methodologies and Hypotheses

The following are research hypothesis which the researcher came up with when determining the ways in which the conventional and innovative alternative delivery methods can be used to quantify the impact brought due to change orders in the construction projects and reflect the impact on the future planning of the project. As a methodology, Student t test Dunnetts's control test for comparing means was used.

Hypothesis 1

DB projects were preferable to the conventionally delivered projects in cutting down the duration and cost of projects and the frequency of change orders

Hypothesis 2

Innovative contracting projects performed better than conventionally contracting projects in terms of schedule, cost and changes

Hypothesis 3

A+B contracting projects were more effective than conventional contracting projects.

Hypothesis 4

The time magnitude of change orders added to the project duration affects the overall duration of projects significantly

Hypothesis 5

The magnitude of change orders with regard to dollar amounts added to the initial project cost affects the total project costs significantly

Hypothesis 6

The magnitude of cost change orders was significantly affected by the size of projects (e.g., small, medium, large in terms of dollar amounts installed on the project).

Hypothesis 7

The magnitude of time change orders was significantly affected by the durations of projects.

2.5 Research Assumptions

1) All projects studied were independently implemented and completed
2) This research assumed that labor productivity is equivalent to projects that were constructed at nighttime and daytime.
3) Contractors are assumed to have the same level of project experience and performance.
4) Change orders on weather days and holiday time extensions were not considered.

2.6 Limitations

1) The study concentrated on the data from the Florida Department of Transportation which does not reflect the construction which takes place in the whole country.
2) Road construction was only captured.
3) Types of change orders which were not specific were capture rather than capturing the types of sources which affect the change orders.
4) Only a few contracting methods were studied and not all of them.

2.7 Contributions of the Research

"One of the issues we have faced is we tried to look at what's the percentage when you make the incentive/disincentive contract, but there's really no data out there (Special TxDOT commissioner meeting, 2008)."

There have been no research studies to date to investigate the effectiveness of innovative project delivery and contracting methods with regards to project type, size, and complexity due largely to the lack of data.The root problem this study addresses is how to determine when and what type of contracting/delivery methods to use in order to realize the maximum benefits for State Transportation Agencies (STAs), which potentially saves millions of taxpayer's dollars by understanding and choosing the most appropriate methods.

This study will provide comprehensive data drawing 2,844 projects completed from 2002 to 2011. This study would help STAs make better-informed decisions when they are considered to be implemented. This study is the first time of its kind in evaluating the impact of change orders.

3. LITERATURE REVIEW

3.1 Change Orders in Construction Project

Hsieh et al. (2004) and Wu et al. (2005) explained that construction is a project which is prone to changes and modifications because of various reasons brought out during development. Federal highway department came up with software of determining the duration the reconstruction and rehabilitation exercise is going to take. Changes in construction projects can refer to alteration to initial project design, building work or any other modifications to the initial plan of the construction project. The software took into consideration the estimated time, cost and the area the work is going to take place. This was done by examining the factors that affect project duration, project scope, strategies used in the construction, logistics, resource constraints and construction windows (Lee and Ibbs 2005).

3.2 Effects of Change Orders on Projects

Change can be defined as any deviation from an agreed upon well-defined scope and schedule (Thomas and Napolitan 1995). In addition to this, another way to differently define change is it is a modification to the contractual guidance that has been established for the contractor by the owner or owner's representative. The reason that an engineer might initiate a change order is due to the changes in site condition or new governmental regulation. On the other hand contractors are likely to originate a change as a result of design errors, value engineering, or field requirement. Previously studies that have been conducted highlighted that design changes may occur as a result of bringing improvement through better design process (Lee and Ibbs 2005).

3.2.1 Time and Cost Related Effects

The change orders adopted by the contractors or the engineers are likely to create a significant impact on the time duration and costs associated with the projects (Assaf and Al-Hejji 2006). Thus, it is important to determine the time and cost related effects of adopting any particular contracting strategies. There are not only negative effects of the change orders, but contractors can also benefit through the change orders. Thus, there are both advantages and disadvantages of implementation of change orders, these include increase in the cost of project, and the time duration for project is also likely to increase due to the delay in completion schedule. Furthermore, it may also result in providing additional revenue for contractors.

Dispute may also arise between contractors and owners; also there might be demolition and re-work (Sambasivan and Soon 2007). Therefore, it is essential to overcome these effects it is important to ascertain the most effective and the most appropriate contracting strategy. Increase in time and cost of the construction projects is usually due to increase of labor, equipment and time to deal with changes brought up. According to various researchers rework is the most negative effect that a project incurs and the parties within the project. Cost due to labor, equipment and removal of existing work will all be incurred in the case of rework.

3.2.2 Productivity Related Effects

Arain and Pheng (2005) and (Moselhi et al. 2005) conducted research and they acknowledge that project changes brought by one of the parties usually leads to productivity degradation. Hanna et al. (2005) concluded that degradation in productivity is caused by many changes which include lack of morale among employees, site congestion, motivational issues, and workers working in shifts, tight schedule and so on after conducting a series of research.

3.2.3 Risk Related Effects

Due to changes, tight schedule and the pressure from the parties, projects will be accelerated so that they are finished within the schedule without taking into consideration the changes that have occurred in the project. This makes the project to risk losing the original value (Hanna et al. 2004).

3.2.4 Other Effects

Strict supervision and management from main contractor's and pressure from the subcontractors usually affect the staff morale and causes fatigue if they are expected to work overtime and therefore reducing the productivity of work (Arain and Pheng 2005) and (Hanna et al. 2005). Contractor and the client usually come into terms after a contract is formalized and the two agree to work together.

3.3 Conventional (Traditional) Delivery Method

In order to ensure the success of any project it is important that the process of structuring and hiring of the project team is carried out effectively and efficiently. Owners and developers are available with several methods in the construction industry. There are certain conventional/ traditional methods that allow having more innovative methods through which time and costs can be saved and simultaneously provide a more coordinated team approach for minimizing litigation (Lee and Choi 2006). Each of these delivery methods provides both advantages and disadvantages. Therefore, it is crucial to evaluate these effects to achieve the objectives of each project. Furthermore, the goals of the project should be prioritize based on quality, schedule, cost and risk. The success of these methods is dependent on the capability of the owner to manage the delivery process of the project.

3.3.1 Design/Bid/Build

Public projects in the United States, have been able to employ the most acceptable and traditional project delivery approach to implement most of its projects. For example, Road construction projects have been accomplished for a period of time using the conventional methods or sometimes are referred to as conventional delivery methods, Design/Bid/Build strategy (Lee and Ibbs 2005). Design, Bid and Build method has three phases which are design the construction which you want to implement, then you bid and where as a contractor you may be awarded the contract or not and then if you are successful then you proceed with building which is the implementation stage. The conventional method is usually a competitive method and takes a lot of time during bidding and where the lowest bidder is usually given the bid or go ahead to implement the project. Because of the design the lump sum contract approach is usually applied in this approach.

This approach is considered to be the most commonly used method for project delivery. For this particular method the owner builds separate contracts with the design team and the construction team. Furthermore, this method provides a sequential form of work. The initial step is the design phase, and then second is the bidding phase and lastly the construction phase. This method facilitates the owner to have better quality work with competitive pricing. However, on the other hand there are certain disadvantages that should be overcome these limitation include slower schedule, greater number of claims for delay and pricing is more fluctuation and therefore, less predictable.

3.4 Innovative Alternative Contracting Strategy and Project Delivery

The construction of various projects requires certain complex and difficult processes. Therefore, it is important to appropriate planning and scheduling of project activities as it will enable to avoid delays in construction and other challenges that are faced during the construction. For instance delay in any project for a day can cost millions of dollars. Thus, it is essential to adopt innovative methods for construction.

3.4.1 Cost – Plus- Time (A+B)

Cost- plus Time bidding can also be referred to as A + B bidding, which involves time along with certain costs that is associated with it. Contractors that offers low bid as compared to other items of the contract bid is selected and also the time needed for completing the critical portion of the project or for the completion of the entire project. The formula mentioned below is used under the A + B approach.

Lump Sum delivery methods enable the contractors to place a fixed amount of money at the beginning of the project and he will work with the budget until the project comes to an end. It is effective with simple and basic projects because the method has risks which the contractor faces it the project are big and underestimated.

In A+B A is the Sum bid of the items included in the contract and also determines the dollar amount that is required for performing the work mentioned under the contract. B is the total number of calendar days that will be needed for completing the project that is determine by the bidder which is then multiplied by the cost of user per day. State highway agencies use this method of bidding for encouraging and motivating the contractors by providing them contract incentives that will ensure to reduce the time of delivery for high priority and high volume roadways (Scanlon 2009). As compared to other methods cost- plus time can prove to be an effective approach that will assist in significantly decreasing the impact of high road user delays. This method has facilitated in reducing the costs to an acceptable level and simultaneously maintaining the quality. The aim of this approach is to motivate contractors for managing and organizing their work efficiently, which will assist in reducing the time of construction and also the inconvenience to the public.

Many of the researcher have argued that the inherent inaccuracy which the contractors use when specifying contract time in when they come up with bids making it to very ineffective. However, Timmerman (2009) disagreed with the statement and stated that A+B bidding can prove to be more effective, inexpensive than the I/D strategy because it enables the contractor to have better plans and schedules on the construction project and encourages competitive bidding in construction.

3.4.2 Incentive/Disincentive

It is common for contractors to ensure of providing certain incentive to the contractors for improving the performance that will facilitate in reducing the time of project completion along with delivering quality work and simultaneously ensuring to comply with the safety rules and regulations. Sukumaran et al (2006) indicated that construction agencies can adopt time-based I/D strategies in implementing the construction work because it ensures that the projects complete the work on time and there is a win-win situation on both parties and help the State Transportation Agencies to implement the projects successfully. The method enables the contractor to receive incentives if he completes the work early and it provides a penalty and sanctions which the contractor has to face when he or she completes the work after the deadline.

It is important for the contracting agencies to determine the monetary value of the time saved if the project is completed early and use that when coming up with the amount of Incentives to offer the contractors (Sillars and Riedl 2007). Incentive/disincentive form of contract strategy is developed for providing reward for improved and better performance or penalizing for not delivering better performance. Incentive/Disincentive strategy is one of the important and most appropriate strategies which can help the contractors to complete the work on time. The owner has the responsibility to ascertain the amount of Incentive/ Disincentive, which should then be negotiated with the contractors. The most common is the schedule incentive, which is offered by the owners to complete the project before time. Quality incentives are also provided for delivering quality.

Additionally, the owner or the state highway agencies may also provide safety if the contractor is able to comply with the safety rules and regulations. Furthermore, the state highway agencies can also provide other incentives such as providing incentives for innovations that is likely to result in cost saving for the owner. On the contrary, owners will penalize the contractor for depicting poor performance.

3.4.3 Lump Sum

Another important contract strategy that has been developed with the aim to decrease the cost of design and administration is the Lump Sum contract. The contract is known as Lump Sum as the contractor is responsible for submitting a total and global price rather than bidding on individual terms. This type of contracting is most commonly used for simple and small projects, for instance contractors that are involved in projects with a well-defined scope or construction projects where the risk of different site condition is minimized.

The basics of the contract include that the supplier should provide the services that have been specified for a stipulated or fixed price. In this particular approach the agency (state highway agencies) assigns the entire risk to the contractor; therefore, the contractor is likely to ask for a greater mark-up to manage the unforeseen incidents. Lump Sum delivery methods enable the contractors to place a fixed amount of money at the beginning of the project and he will work with the budget until the project comes to an end. It is effective with simple and basic projects because the method has risks which the contractor faces it the project are big and underestimated.

The supplier who is involved in a lump sum agreement has the responsibility to execute the job properly along with its means and methods for completion of the work. It is a cost effective method, as it is developed by determining the labor costs, material costs and also to add a certain amount for covering the overhead of the contractor and profit margin. Each constructer uses a different approach for calculating the amount of overhead (Vella 2008). However, to choose the appropriate method will be based on the ability to assess risk and the expertise of the labor. The Lump sum contract proves to be beneficial for the contractor as they can have a greater control over the profit expectation. Although, the time required to award such contract is comparatively larger, but it will assist in reducing the change orders during construction.

3.4.4 Design/Build

According to Murdoch and Hughes, 2007 and Riley et al., 2005 Design and Build strategy is very important since it gives the contractor the liability of being in charge of all contractual remedies for the client since he is the one who designs and goes on with the work as a single point of responsibility. In this innovative/ alternate method the owner hires only one entity that has the responsibility of providing both design and construction services. The responsibility of arranging the finances lies with the owner (Vella 2008).

The effectiveness of the method can be assessed by the requirements of the method. It requires the owner to have a clearly defined scope of work for instance and existing prototype design. The owner is obliged to make a commitment related to the cost during the early phase of the design process. In addition to this, this method is more commonly used for a portion of the work. This innovative method provides the fastest schedule with least amount of owner claims and best control cost. However, it places a significant cost pressure on the agencies and is also likely to result in eroding the quality of value engineering (Vella 2008).

3.4.5 No Excuse Bonus

"The No Excuse Bonus concept is intended to shorten the construction time that would normally be required to perform the work by providing the contractor with a substantial bonus to complete a project within a specified time frame regardless of any problems or unforeseen condition that might arise. An additional advantage of the use of this technique is that it serves as a tool to motivate efficient construction as it encourages the contractor to keep projects on schedule. Bonuses are intended to reward a contractor for early completion, thereby reducing disruption and inconvenience to the public".(FDOT)

3.5 Case Studies

The alternative contracting methods have been applied in the Florida Department of Transportation (FDOT) since they are effective and can be easily applied and meet the stipulated time, cost and performance. Many researchers have been able to come up with the evaluation programs about the effectiveness of the project delivery methods (Molenaar 2007).

3.5.1 Existing Case Studies on Alternative Contracting Strategies

Between the year 2000 and 2005 a series of evaluation studies have been conducted on the innovative alternative methods to determine their performance of the contracting methods. The effectiveness of the methods was conducted on the Minnesota Department of Transportation (MnDOT) where a detailed report indicated the performance of the delivery methods in various projects. It was reported that A+B delivery method was efficient in time savings especially for low bid days versus maximum days (15%) and 11% on the actual construction time.

Caltrans came up with the report indicating that A+B method is efficient in time-savings as compared to other methods. They were not able to show if the methods has cost overruns in different projects. This is illustrated in the figure 1 below.

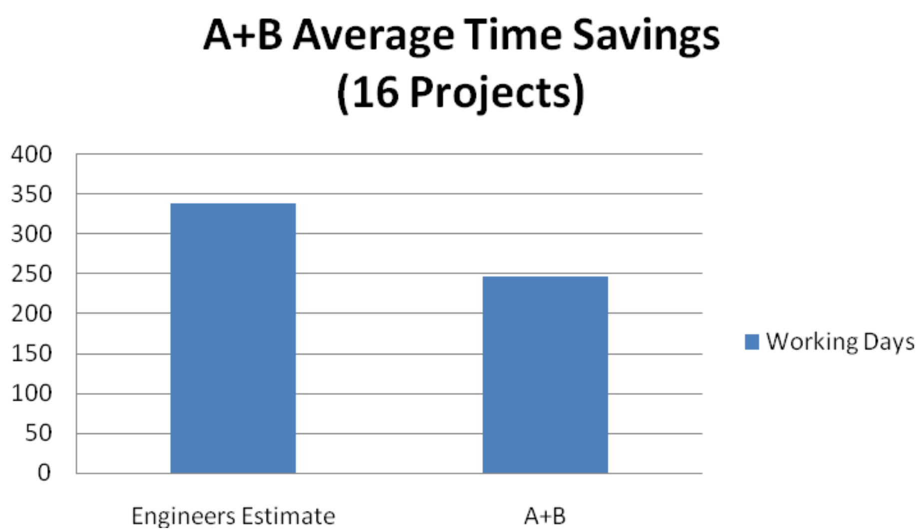

Figure 1: Pinnacle's 2004 A + B Average Time Savings

It is also evident that the method is effective when it comes to time delivery and performance of the contracting strategy. From the study conducted on the 120 innovative alternative completed projects and 28 Design/Bid/Build methods. It was found out that alternative methods were efficient on time delivery of the projects as compared to conventional method. This is a shown in the figure below.

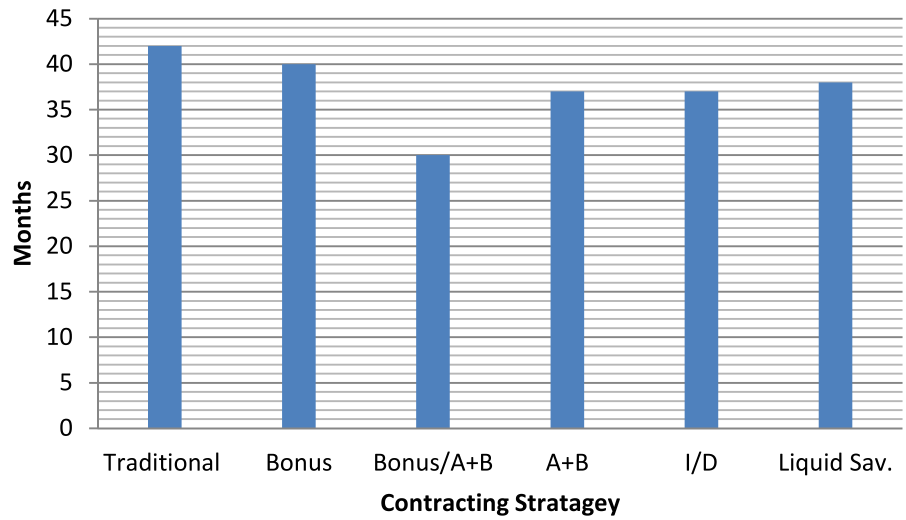

Figure 2: FDOT Alternative Contract Performance Duration for Arterial

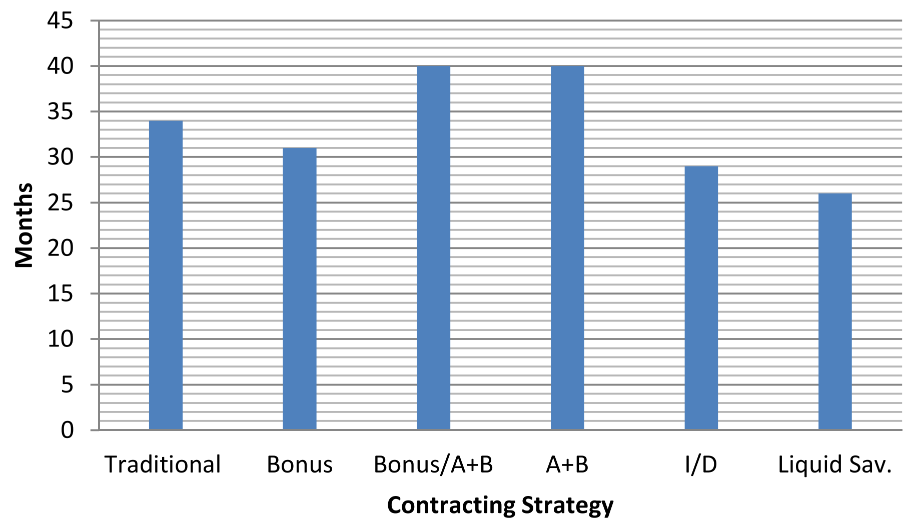

Figure 3: FDOT Alternative Contract Performance Duration for Resurfacing

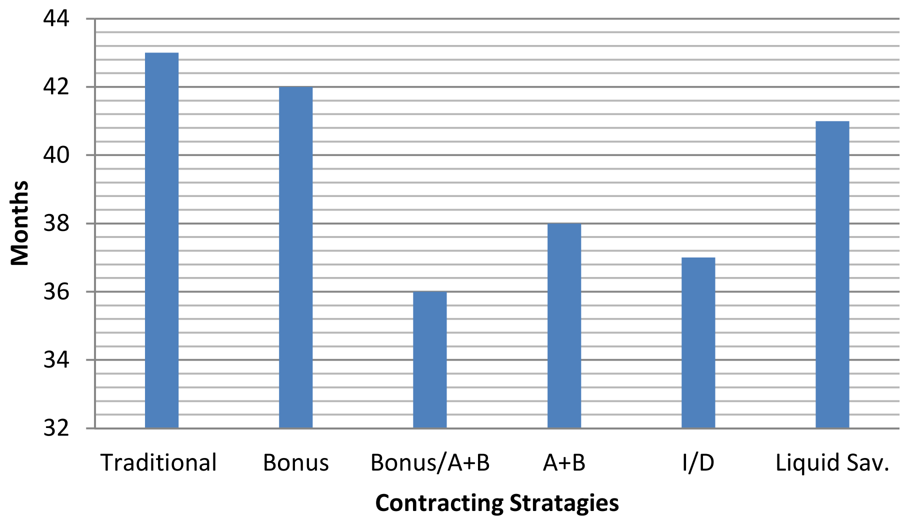

Figure 4: FDOT Alternative Contract Performance Duration for Bridge

It is very evidently clear from figure 2, figure 3 and figure 4 that alternative contracting methods are effective in time-saving as compared to conventional methods.

3.5.2 Florida and Other States

Alternative methods were introduced in Florida after the agency overseeing the transportation projects after incurring the huge expenses due to the contractors overestimating the projects due to delays and other causes. Other states have embraced alternative contracting methods by ensuring that the bids are awarded to contractors who are able to show that they can finish the work in time and use the estimated cost with minimum public inconveniences. In Illinois, several projects conducted for a period of 5years used I/D provisions and the result was that all the projects were finished on schedule without any delays. From 1999 to 2002 highway construction projects in

Kentucky were effectively implemented using the time based Incentive/Disincentive methods (Choi and Kwak 2012).

4. DATA COLLECTION

4.1 Introduction

This objective of the study is to evaluate effectiveness of alternative contracting strategies in terms of cost, schedule and change orders. The study will determine the exploring which alternative contracting strategy most effectively reduces construction time as compared with conventional contracting strategies. To evaluate their effectiveness, alternative contracting projects were compared with conventionally contracted projects and with each other as well. The following six different types of contracting projects were compared:

- A+B
- Lump Sum
- Conventional
- Design Build
- Incentive/Disincentive
- No Excuse Bonus

Public projects in the United States, have been able to employ the most acceptable and traditional project delivery approach to implement most of its projects. Conventional methods or sometimes are referred to as conventional delivery methods, Design/Bid/Build strategy. The conventional method is usually a competitive method and takes a lot of time during bidding and where the lowest bidder is usually given the bid or go ahead to implement the project.

Statistical analysis was conducted using predefined performance indicators measuring the impact of contracting strategies on schedule, cost and change orders. The performance of the alternative contracting strategies was compared with the conventional contracting strategy by using these performance indicators. Statistical analysis was also carried out to compare the performance of these contracting strategies with each other using the same performance indicators.

4.2 Data Collection

This research used the data from the original Florida department of Transportation to conduct quantitative study. The original data from the year 2002 to 2011 was sorted and a total of 2844 projects were included in the study. The data collected and sorted was used to analyze the impacts of the project schedule, cost and change order and determine which type of strategy is most effective and the type of project which can be used to apply the strategy.

The detailed and elaborate explanation of the type of data collected for the research has been given in table 1 below.

Table 1: **Description of the Collected Data**

	S.no	Information Provided in The Data	Description
Project Summary	1	Contract ID Number	5 Digit Unique Project ID
	2	District	
	3	Let Date	Final Bid Date
	4	Project Work Type Description	7 Different Types
	5	Contracting Type	Innovative or Conventional
	6	Contractor Name	
	7	Contractor Vendor ID	
	8	Type Of contract Change Order	7 Different Types
Time	9	Original Contracting Days	Planned Schedule Duration
	10	Work Begin Date	
	11	Contract Change Order Days	Actual Work Begin Date
	12	Present Contract Days	Time Adjustments Due to Change Orders
	13	Days Used	Submission of S.no 9 and S.no 11
	14	Project Time Change	Difference Between S.no 13 and S.no 9
Cost	15	Original Contracting Amount	Initial Bid amount
	16	Contract Change Order Amount	Change in Contact cost Due to Change Order
	17	Present Contract Amount	Submission of S.no 15 and S.no 16
	18	Final Project Cost	Total Actual Expenditure on the project
	19	Project Cost Change	Difference Between S.no 15 and S.no 18
	20	Work Orders	

4.3 Data Classification

The data was classified and sorted depending on the type of quantitative analysis that the researcher needed to conduct. The data was classified into the type of contracting strategy, type of work and the size of the project.

The work type was classified as follows:

1. The "3R" infrastructure project renewals: resurfacing, interstate rehabilitation, and reconstruction
2. Bridge projects: bridge construction, bridge repair.
3. New construction: new construction of any type of roadway infrastructure projects, interstate new construction.
4. Capacity added projects: addition of new lanes and widening of existing lanes, this is accompanied by resurfacing too.
5. Traffic operations: traffic operations, signaling, new equipment additions.
6. Miscellaneous construction: construction of bike paths/trails, sidewalks,
7. Other: maintenance operations, drainage construction, and unknown.

Projects were also classified based on their size into following categories.

1. Small (less than $10 Million)
2. Medium (greater than $10 Million and less than $50 Million)
3. Large (greater than $50 Million

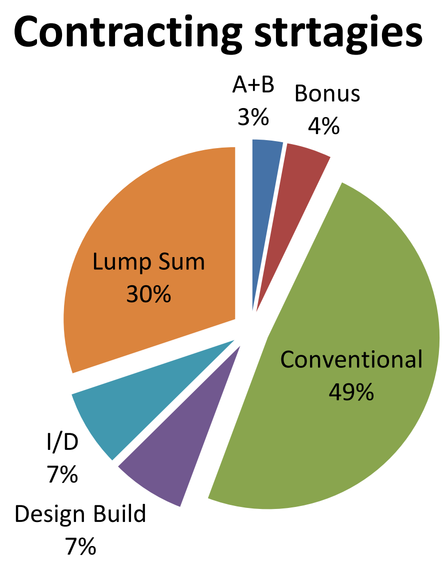

Figure 5: Distribution of Projects by Contracting Strategies

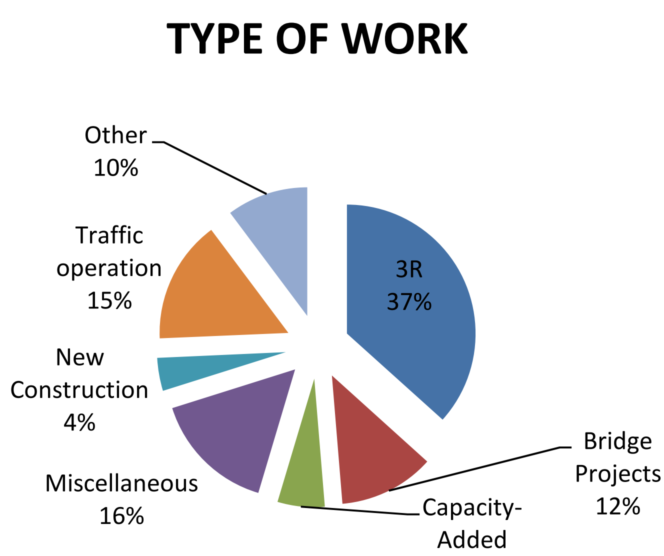

Figure 6: Distribution of Projects by Type of Work

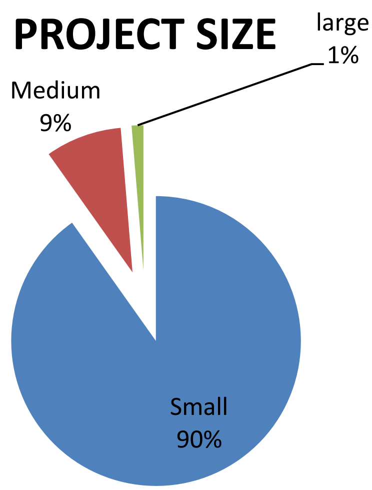

Figure 7: Distributions of Projects by Project Size

From figure 5, figure 6 and figure 7 few things evidently clear. Firstly out of the 2844 project studied close to 50 percent of the projects were followed by lump sum projects. Secondly 3R projects have the largest share of the work type distribution of the projects. Lastly most of the projects studied fall into small project size category followed by few medium scale projects and extremely few large projects.

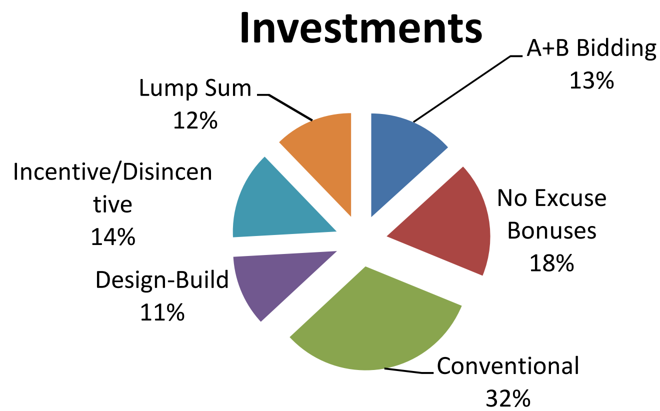

Figure 8: Distribution Contracting Strategy by Total Investment

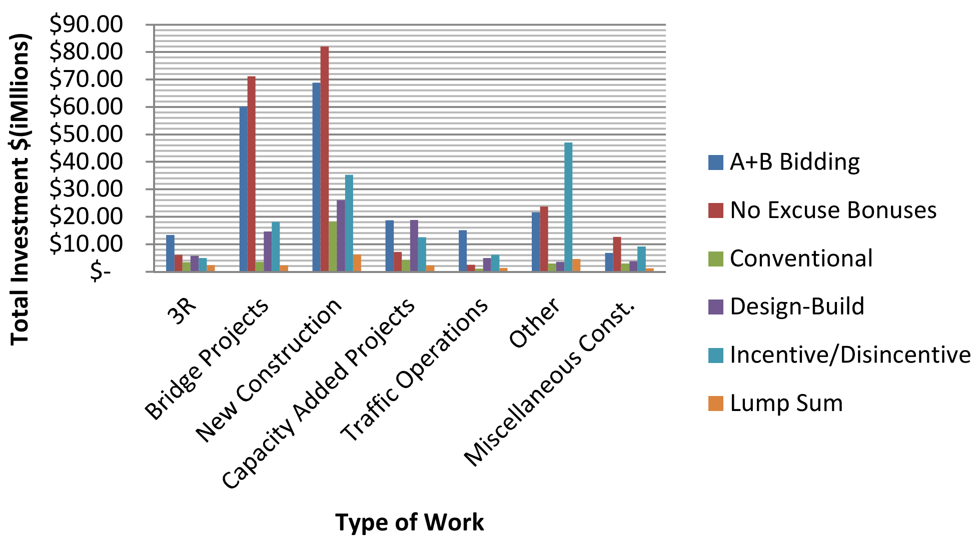

Figure 9: Average Investments in Each Contracting Strategy by Type of Work

Figure 8 and figure 9 depict fairly equal distribution of the investments among different contracting strategies. The maximum investment is done in the conventional project which is acceptable as it has the maximum number of the project count. The above figure shows that each work type has different distribution on investment for different contracting strategy and there is a huge variation in the distribution among different work type.

4.4 Change Orders

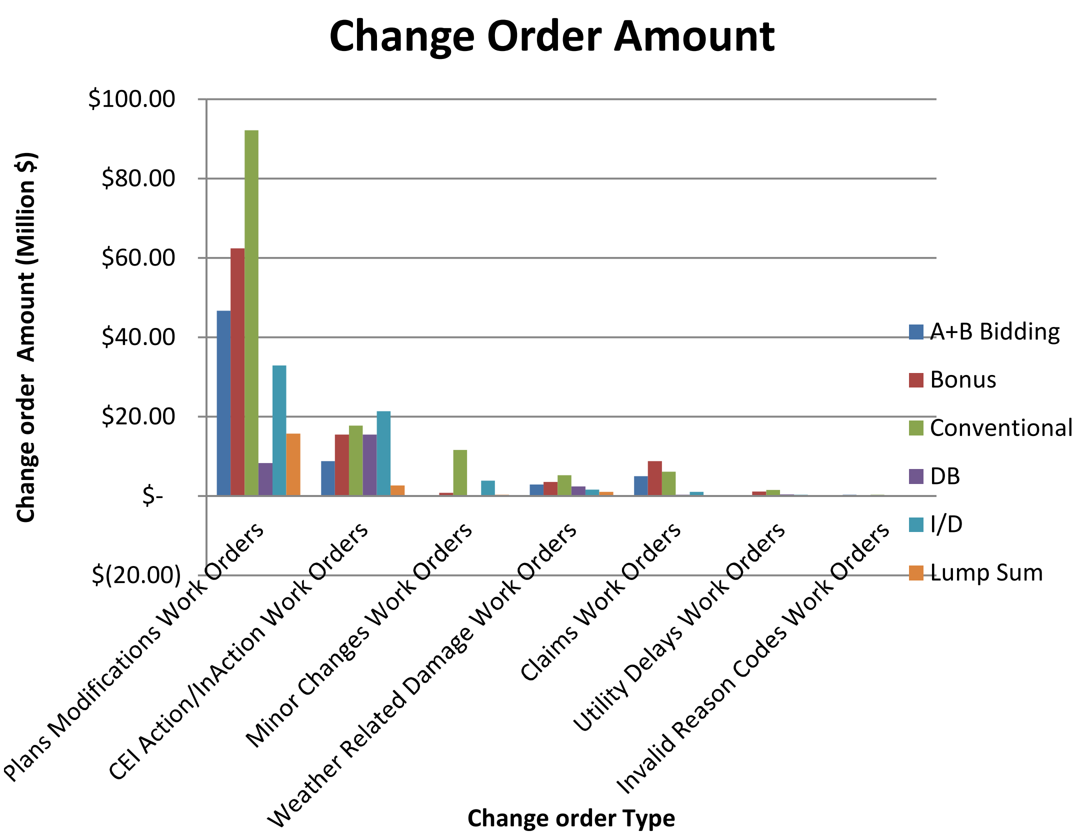

Figure 10: Expenditure on Each Change Order Type by Contracting Strategies

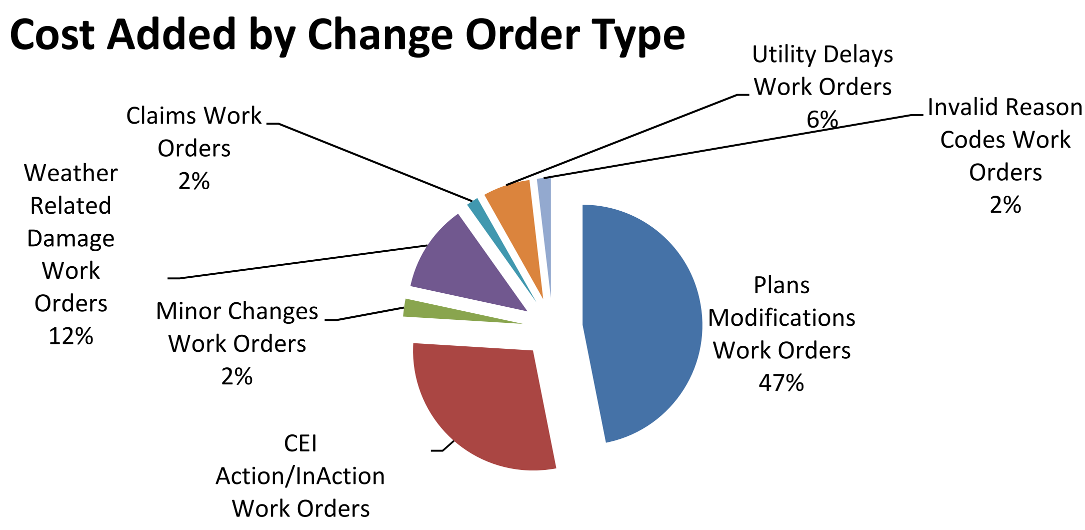

Figure 11: Distributions of Change Order Costs by Type of Change Order

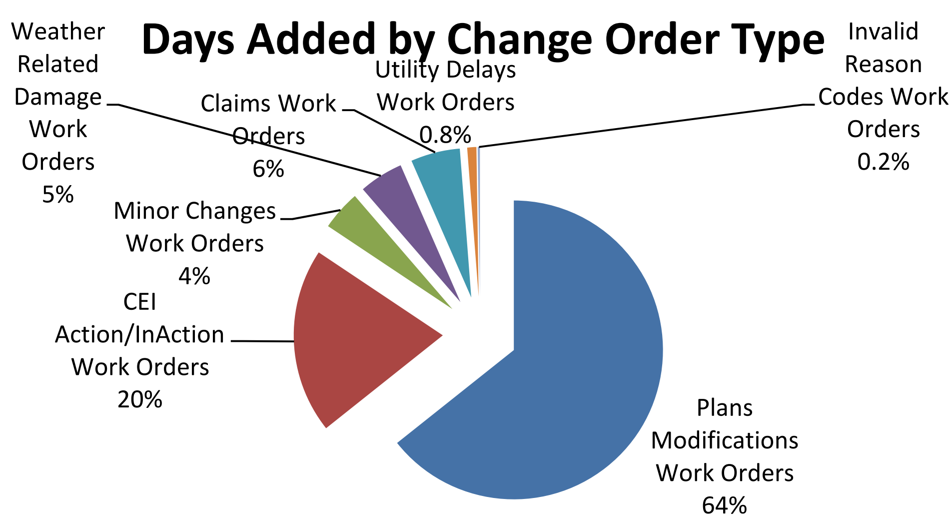

Figure 12: Distributions of Change Order Days by Type of Change Order

From figure 10, figure 11 and figure 12 it is clear that Plans modification work orders have the greatest impact on the project performance both in terms of cost and schedule. It has a negative impact on the project by increasing both project cost and project schedule. The second most impactful change order type was CEI Action/Inaction Work order having a negative impact on project cost and project duration.

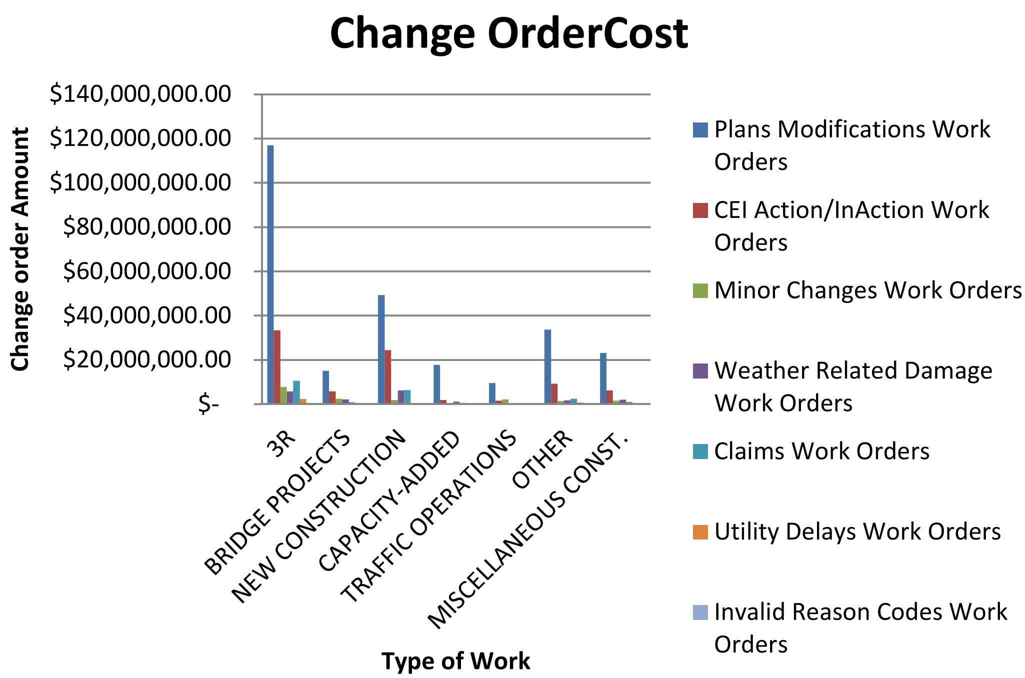

Figure 13: Total Change Order Cost of Change Order Types by Type of Work

Figure 13 depicts the impact of different type of change order on different types of road construction projects. It highlights the impact of change orders on project performance by measuring the change order costs added to the projects by the introduction of the change orders.

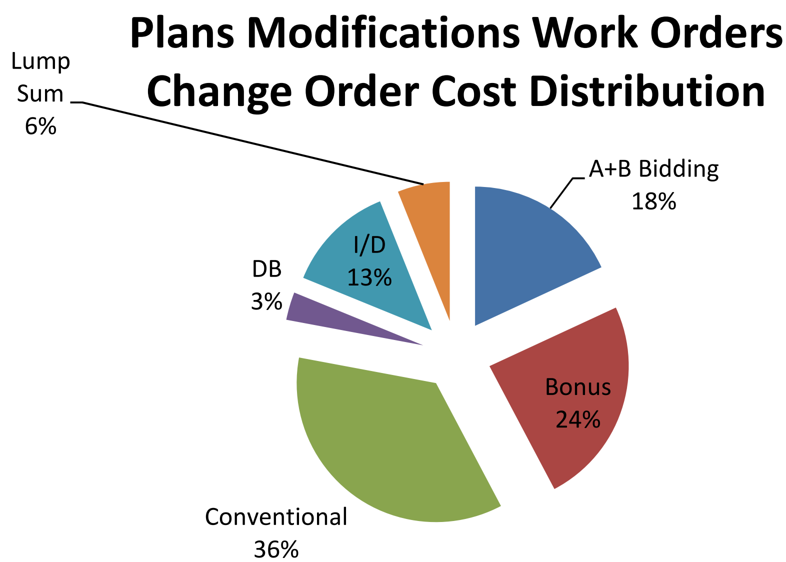

Figure 14: Plans Modification Work Order Costs by Contracting Strategy

Figure 14 depicts the percentage distribution of change order costs of plans modification work order as added by different type of contracting strategies. Conventional projects have the highest percentage and design build projects have the lowest percentage.

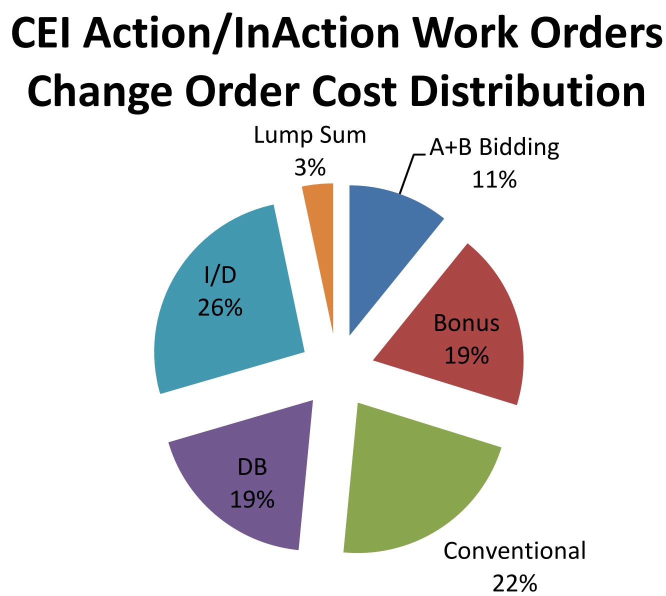

Figure 15: CEI Action/Inaction Work Order Costs by Contracting Strategy

Figure 15 depicts the percentage distribution of change order costs of CEI action/inaction work order as added by different type of contracting strategies. I/D projects have the highest percentage and lump sum projects have the lowest percentage.

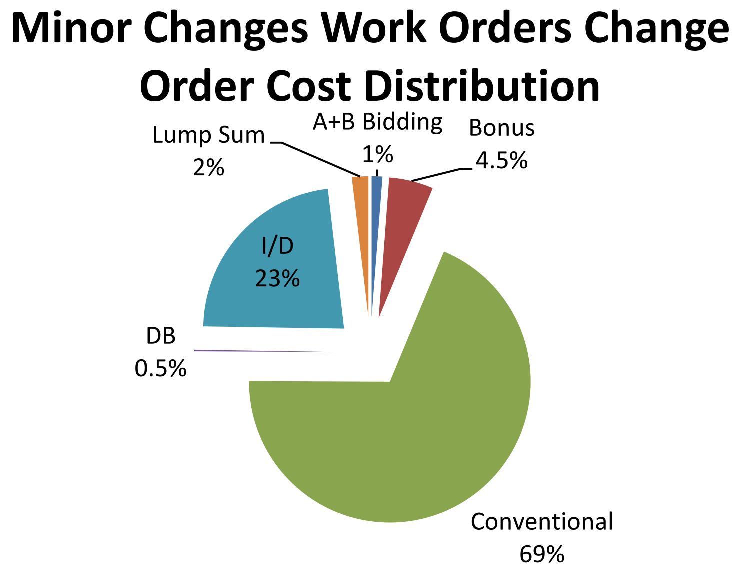

Figure 16: Minor Change Work Order Cost by Contracting Strategy

Figure 16 depicts the percentage distribution of change order costs of minor change work order as added by different type of contracting strategies. Conventional projects have the highest percentage and design build projects have the lowest percentage

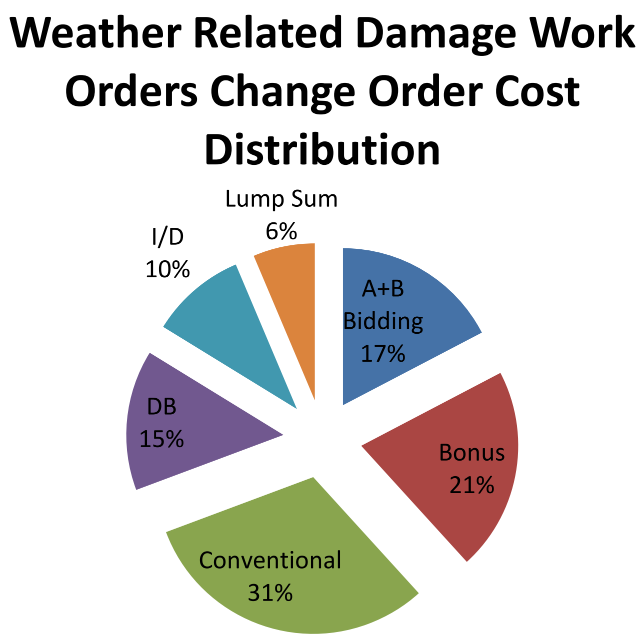

Figure 17: Weather Related Damage Work Order Cost by Contracting Strategy

Figure 17 depicts the percentage distribution of change order costs of weather related damage work order as added by different type of contracting strategies. Conventional projects have the highest percentage and lump sum projects have the lowest percentage

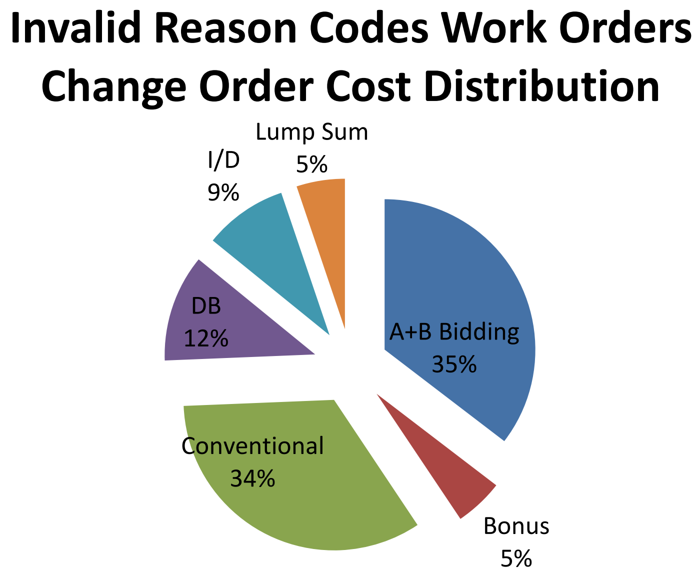

Figure 18: Invalid Reason Codes Work Order Cost by Contracting Strategy

Figure 18 depicts the percentage distribution of change order costs of invalid reason codes work order as added by different type of contracting strategies. A+B projects have the highest percentage and lump sum projects have the lowest percentage

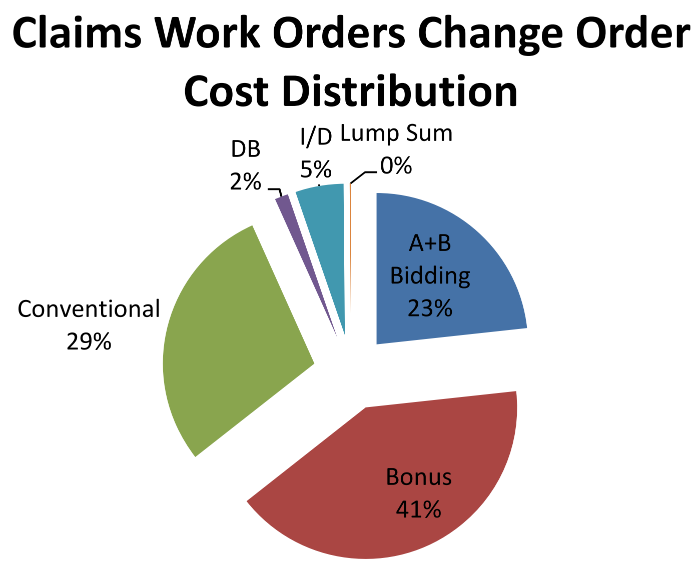

Figure 19: Claims Work Order Cost by Contracting Strategy

Figure 19 depicts the percentage distribution of change order costs of claims work order as added by different type of contracting strategies. Bonus projects have the highest percentage and lump sum projects have the lowest percentage

Figure 20: Total Days Added by Each Change Order Type for Type of Work

Figure 20 depicts the distribution of change orders days added by the different type of change orders to different type of road construction projects.

4.5 Performance Indicators

4.5.1 Management Effectiveness Ratio

This indicator (ME) is the ration between final contract amount contract and the final contracting time. Management Effectiveness (ME) = Final contract amount ($) / final contract time (days). With this type of indicator a researcher is able to understand the average amount of money the contractor spends in a day during project implementation phase. The higher the rate the efficiency is the construction system and the lower the rate the inefficient is the system.

4.5.2 Schedule Change Ratio (SCR)

This ratio brings a clear picture the project completion taking into consideration the planned schedule during the design stage. The indicator usually has both positive and negative values. The positive value indicates that the projects were after the end of the schedule and the negative value indicates that the projects were completed before the end of the schedule. SCR is an indicator which looks at the difference between final contract time and original contract time to the original contract time.

Schedule Change Ratio (SCR) = (final contract time – original (and amended) contract time / original (and amended) contract time) (Choi 2008)

4.5.3 Cost Change Ratio (CCR)

The cost change ratio indicator evaluates the level of projects growth to project cost. It indicates how the projects have increased because of the change orders brought in the project during project delivery. Therefore this indicator evaluates the original contract cost i.e. the initial cost that the contractor bided and he was awarded and the cost due to change orders. Thus any cost due to amendments in the projects will be considered as the amended cost.

CCR = (final contract amount – original (and amended) contract amount / original (and Amended) contract amount) (Choi 2008)

4.5.4 Contract Change Growth (CCG)

This indicator takes into consideration both the schedule changes and the cost changes due to the change orders. Therefore the indicator will measure both the contract cost change growth (CCCG) and the contract schedule growth (CSCG).

CCCG = contract change order amount ($) / original contract amount ($)

CSCG = contract change order extensions (days) / original contracting time (days)

4.6 Initial Results

Table 2: Management Effectiveness of Contracting Strategies by Project Size

	MANAGEMENT EFFECTIVENESS		
Type of Contract	SMALL SIZE	MEDIUM SIZE	LARGE SIZE
A+B Bidding	21186.59	31384.28	76933.22
No Excuse Bonuses	13487.46	30492.64	83438.27
Conventional	7813.36	27559.91	67178.98
Design-Build	6854.36	31123.31	69622.27
Incentive/Disincentive	12833.24	35836.49	78531.81
Lump Sum	10130.09	35269.70	0

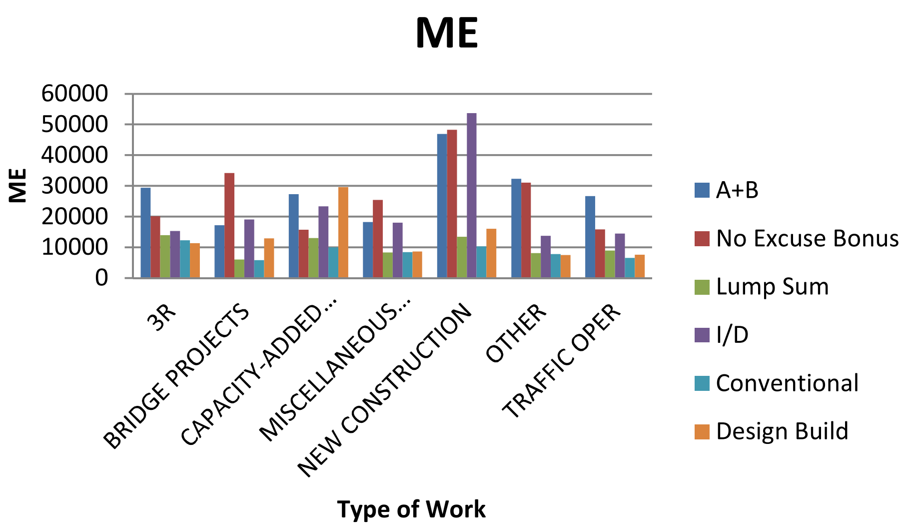

Figure 21: Management Effectiveness of by Type of Work

Figure 21 and table 2 clearly shows that the conventional project delivery is worst performing in terms of management effectiveness when compared with other alternative contracting strategies.

Table 3: Schedule Change Ratio of Contracting Strategies by Project Size

	SCHEDULE CHANGE RATIO (SCR)		
Type of Contract	SMALL SIZE	MEDIUM SIZE	LARGE SIZE
A+B Bidding	0.23	0.25	0.18
No Excuse Bonuses	0.13	0.06	0.11
Conventional	0.22	0.36	0.21
Design-Build	0.14	0.25	0.24
Incentive/Disincentive	0.06	0.06	0.08
Lump Sum	0.14	0.24	0

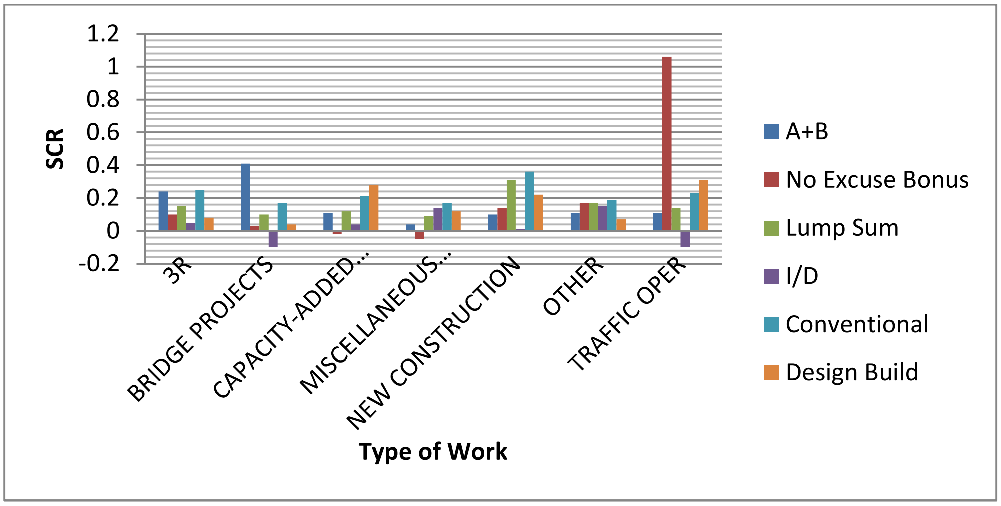

Figure 22: Schedule Change Ratio by Type of Work

Figure 22 and table 3 clearly shows that the conventional project delivery is worst performing in terms of Schedule change ratio when compared with other alternative contracting strategies.

Table 4: Cost Change Ratio of Contracting Strategies by Project Size

	COST CHANGE RATIO (CCR)		
Type of Contract	SMALL SIZE	MEDIUM SIZE	LARGE SIZE
A+B Bidding	0.04	0.09	0.10
No Excuse Bonuses	0.05	0.06	0.07
Conventional	0.03	0.07	0.17
Design-Build	0.03	0.03	0.01
Incentive/Disincentive	0.02	0.09	0.11
Lump Sum	0.02	0.04	0

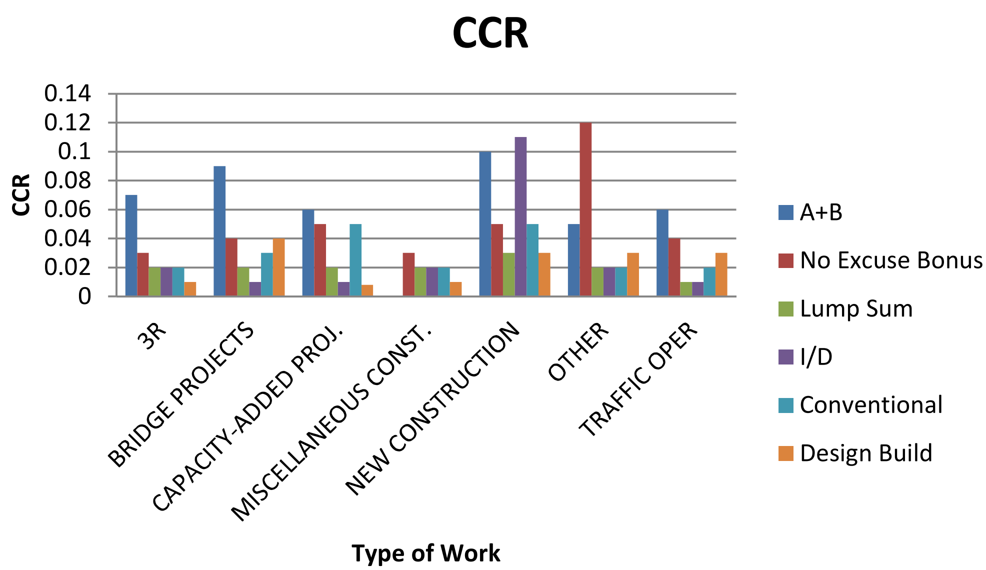

Figure 23: Cost Change Ratio of by Type of Work

Figure 23 and table 4 clearly shows that the conventional project delivery is worst performing in terms of Cost change ratio when compared with other alternative contracting strategies except for A+B.

Table 5: CSCGR of Contracting Strategies by Project Size

CONTRACT SCHEDULE CHANGE GROWTH RATIO (CSCGR)			
Type of Contract	SMALL SIZE	MEDIUM SIZE	LARGE SIZE
A+B Bidding	0.27	0.32	0.26
No Excuse Bonuses	0.19	0.16	0.13
Conventional	0.26	0.30	0.23
Design-Build	0.18	0.25	0.26
Incentive/Disincentive	0.19	0.17	0.16
Lump Sum	0.21	0.29	0.00

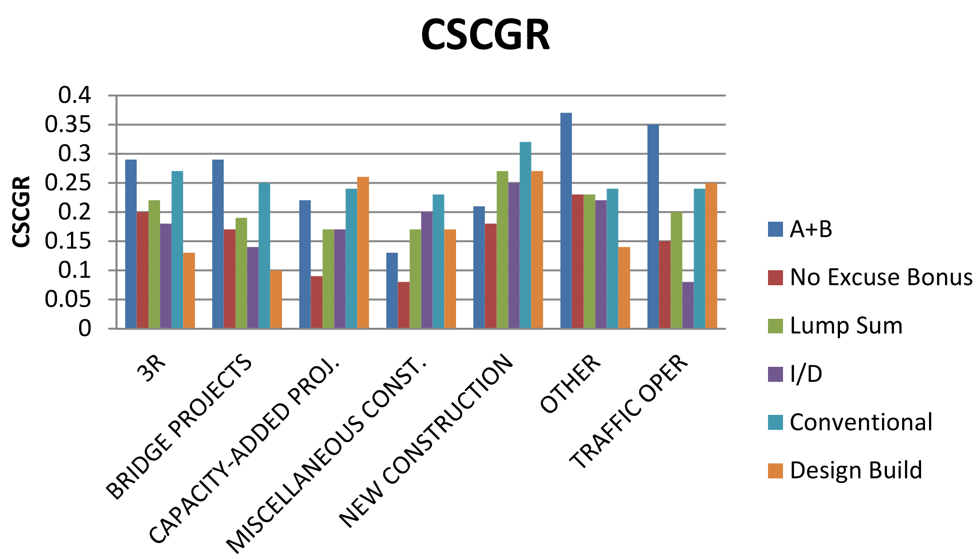

Figure 24: Contract Schedule Change Growth Ratio by Type of Work

Figure 24 and table 5 clearly shows that the conventional project delivery is worst performing in terms of contract schedule change Growth ratio when compared with other alternative contracting strategies except for A+B.

Table 6: CCCGR of Contracting Strategies by Project Size

CONTRACT COST CHANGE GROWTH RATIO (CCCGR)			
Type of Contract	SMALL SIZE	MEDIUM SIZE	LARGE SIZE
A+B Bidding	0.03	0.05	0.04
No Excuse Bonuses	0.05	0.04	0.05
Conventional	0.03	0.04	0.09
Design-Build	0.03	0.03	0.00
Incentive/Disincentive	0.03	0.07	0.06
Lump Sum	0.01	0.01	0

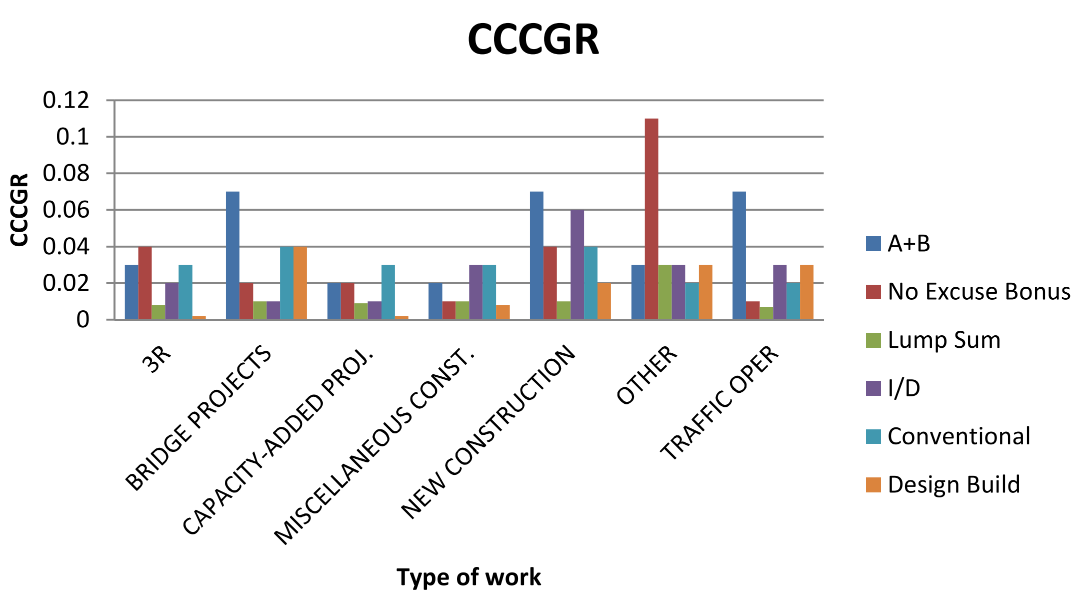

Figure 25: Contract Cost Change Growth Ratio by Type of Work

Figure 25 and table 6 clearly shows that the conventional project delivery is as efficient as alternative contracting strategies in terms of contract cost change Growth ratio

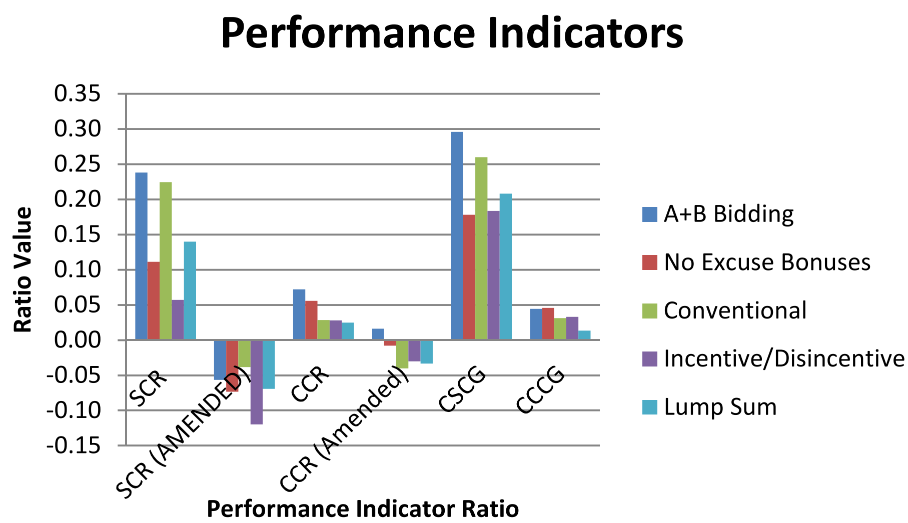

Figure 26: Comparison of Contracting Strategies by Performance Indicators

Figure 26 shows a clear comparison of the 6 contracting strategies, comparing their performance on different performance indicators. From the figure it becomes evidently clear that both conventional and A+B contracting strategy lack behind in terms of performance when compared with the reaming contracting strategies.

5. EFFECT OF ALTERNATING CONTRACTING STRATGIES ON PROJECT SCHEDULE

5.1 Introduction

Traditionally the transport agencies have been using the conventional project delivery and contracting strategies, where the lowest bidder wins the contract. This adoption of conventional approach though might result in lowest cost but it is believed to lengthen the project duration. The increased project duration causes public inconvenience and may also result in increased cost. Therefore there is an urgent need to change or modify this present contracting approach to suit the present time need of early project completions. Alternative contracting strategies are an effective means to fast-track construction of the projects that usually are bid by conventional contacting method resulting in longer durations. Alternative contracting strategies tries to incentivize the early project completion for the contractors, prompting them to finish project in minimum possible duration and thus completing the project ahead of the originally planned schedule. The schedule of the project may also be greatly affected by change orders and thus an effective contracting strategy should have minimum effect of change orders on schedule effectiveness of the contracting strategy. The analysis in this chapter evaluates the schedule performance of various contracting strategies against the changes brought to the project schedule as a result of change orders issued during the life time of the project.

To evaluate their effectiveness, alternative projects were compared with: (1) projects contracted conventionally; and (2) other alternative contracting strategies. In addition to this the conventional project delivery was also compared with Design Build project delivery method. As a methodology, Student t test Dunnetts's control test was used to meet the following objectives:

- To test whether the changes in contract duration change were affected by the application of an alternating contracting strategy.
- To conclude whether alternative contracting projects result in lower project duration changes levels as compared to the level of changes observed in the conventional projects.
- To compare the effect of individual contract strategies on changes in project duration change.

5.2 Impact of a Contracting Strategy on Overall Project Schedule

The primary reason for choosing alternative and innovative contracting strategy over the conventional project delivery and contracting strategy is to avail the time saving benefits of these contracting strategy and project delivery methods

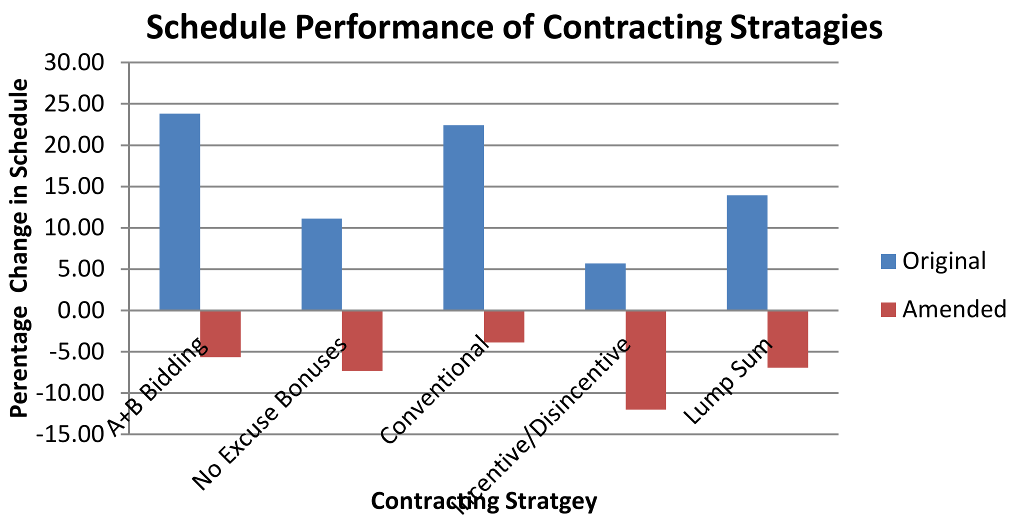

Figure 27: Comparison of Schedule Performance by Contracting Strategy

Figure 27 compares the mean change in the project schedule both original and amended in different contracting strategies. The original project duration experienced increase in all the projects but the worst performing contracting strategies were A+B and conventional contracting strategies with 24% and 23% increase in the original schedule respectively. Incentive/ disincentive (I/D) projects experienced minimum growth in the original schedule of 6%. The project duration for amended schedule has decreased the most in incentive/ disincentive (I/D) contracting strategy (-12%) whereas the minimum change in the project duration occurred in conventional contracting strategy (-4%) clearly suggesting that all the innovative contracting strategy deliver better performance in terms of project schedule when compared to conventional contracting strategy. Furthermore the negative value indicates the average project completion time is less than the amended project duration of the contract. Though it is quite clear from the figure above that there exists a difference in terms of schedule performance between conventional projects and alternative projects, the statistical significance of the differences will be tested later in this chapter to establish the validity of the results.

5.3 Schedule Performance of Contracting Strategies versus Project Types

5.3.1 3R Projects

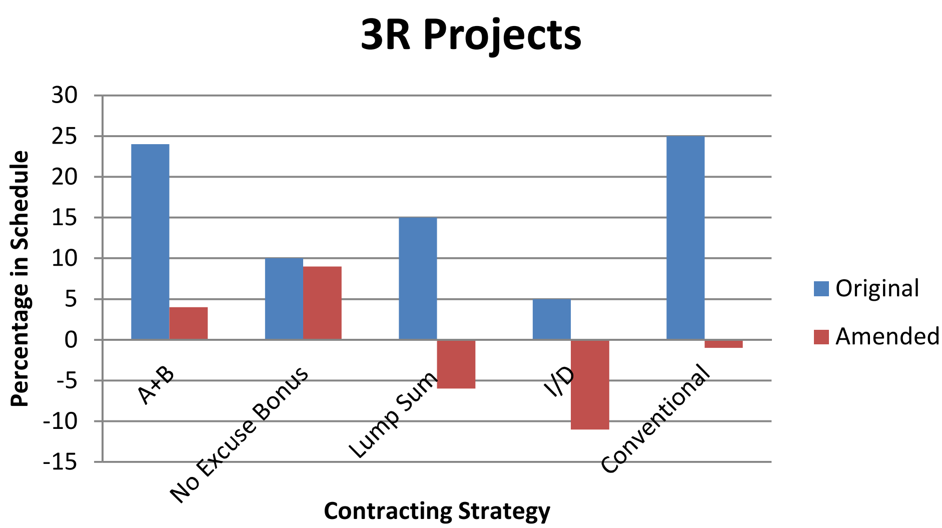

Figure 28: Schedule Performance of 3R Projects by Contracting Strategy

Figure 28 compares the mean change in the project schedule both original and amended under different contracting strategies for 3R projects. I/D contracting strategy has least growth in original project schedule of 5% indicating it is the best performing contracting strategy for 3R projects to achieve best schedule performance. Conventional contracting strategy has worst schedule performance for 3 projects experiencing as much as 25% of growth on the original project schedule. For amended schedule I/D was the best performing contracting strategy having a schedule change of -11% whereas no excuse bonus is the worst performing contracting strategy with a growth of 9 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule .A positive change in schedule indicates completion of project after the contracted schedule.

5.3.2 Bridge Projects

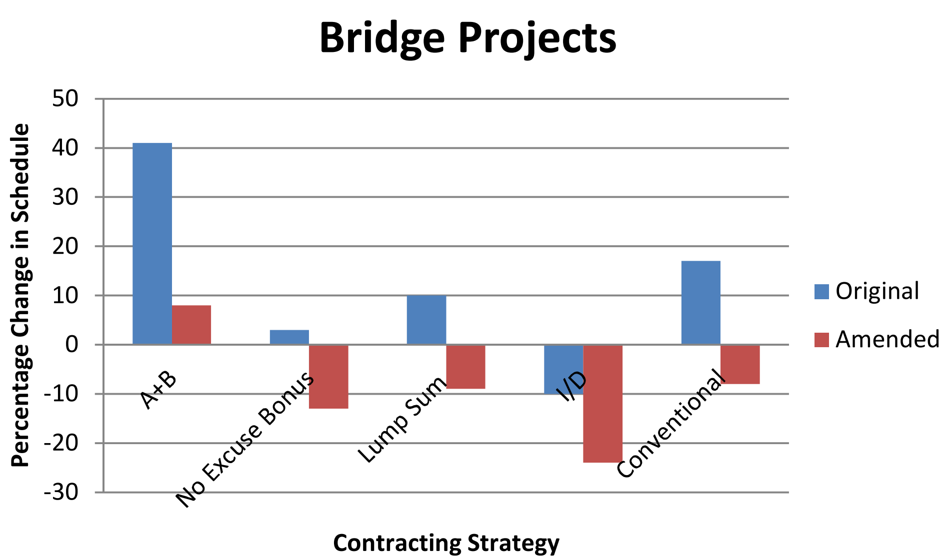

Figure 29: Schedule Performance of Bridge Projects by Contracting Strategy

Figure 29 compares the mean change in the project schedule both original and amended under different contracting strategies for bridge projects. I/D contracting strategy has least growth in original project schedule of -10% indicating it is the best performing contracting strategy for bridge projects to achieve best schedule performance. A+B contracting strategy has worst schedule performance for bridge projects experiencing as much as 42% of growth on the original project schedule. For amended schedule I/D was the best performing contracting strategy having a schedule change of -22% whereas A+B is the worst performing contracting strategy with a growth of 8 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule a positive change in schedule indicates completion of project after the contracted schedule.

5.3.3 Capacity Added Projects

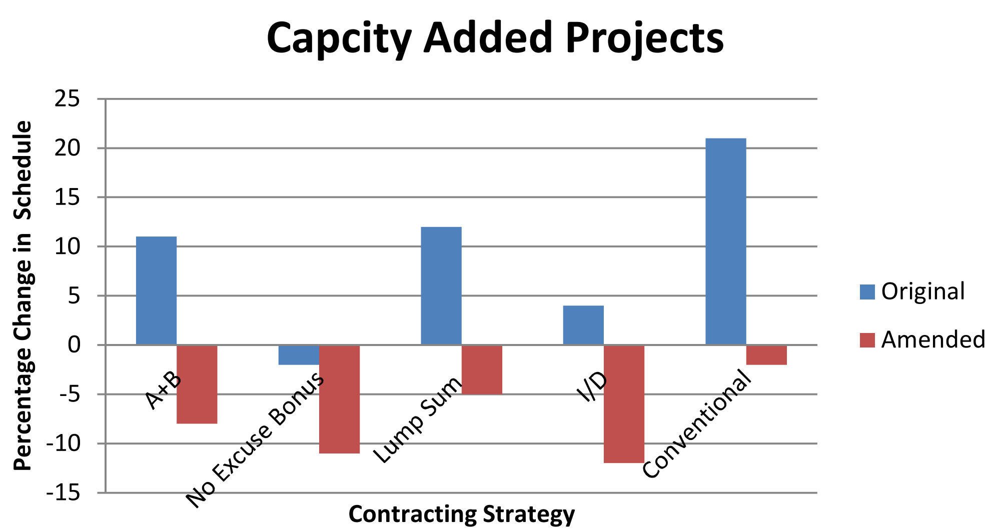

Figure 30: Schedule Performance of Capacity Projects by Contracting Strategy

Figure 30 compares the mean change in the project schedule both original and amended under different contracting strategies for capacity added projects. No excuse bonus contracting strategy has least growth in original project schedule of -2% indicating it is the best performing contracting strategy for capacity added projects to achieve best schedule performance. Conventional contracting strategy has worst schedule performance for capacity added projects experiencing as much as 21% of growth on the original project schedule. For amended schedule I/D was the best performing contracting strategy having a schedule change of -12% whereas conventional contracting strategy is the worst performing contracting strategy with a growth of -1 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule. A positive change in schedule indicates completion of project after the contracted schedule

5.3.4 Miscellaneous Projects

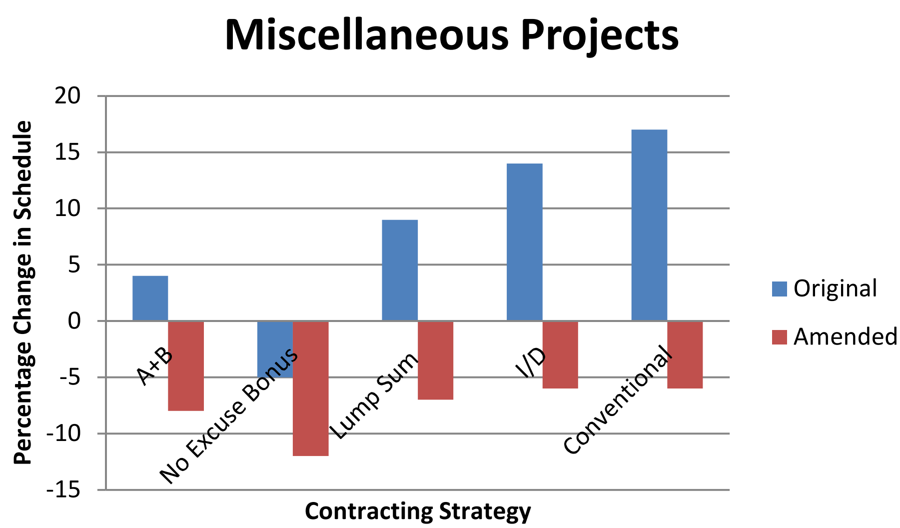

Figure 31: Schedule Performance of Miscellaneous Projects by Contracting Strategy

Figure 31 compares the mean change in the project schedule both original and amended under different contracting strategies miscellaneous construction projects. No excuse bonus contracting strategy has least growth in original project schedule of -5% indicating it is the best performing contracting strategy for undertaking miscellaneous construction projects to achieve best schedule performance. Conventional contracting strategy has worst schedule performance for miscellaneous construction projects experiencing as much as 17% of growth on the original project schedule. For amended schedule No excuse bonus was the best performing contracting strategy having a schedule change of -12% whereas conventional contracting strategy is the worst performing contracting strategy with a growth of -6 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule. A positive change in schedule indicates completion of project after the contracted schedule

5.3.5 Other Projects

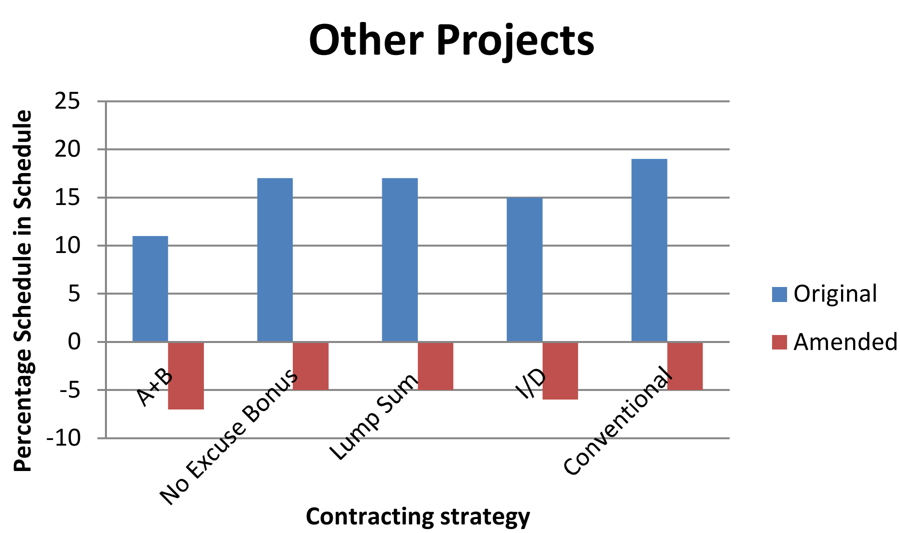

Figure 32: Schedule Performance of Other Projects by Contracting Strategy

Figure 32 compares the mean change in the project schedule both original and amended under different contracting strategies other construction projects. A+B contracting strategy has least growth in original project schedule of 11 % indicating it is the best performing contracting strategy for undertaking other construction projects to achieve best schedule performance. Conventional contracting strategy has worst schedule performance for other construction projects experiencing as much as 17% of growth on the original project schedule. For amended schedule A+B was the best performing contracting strategy having a schedule change of -7% whereas conventional contracting strategy is the worst performing contracting strategy with a growth of -5 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule. A positive change in schedule indicates completion of project after the contracted schedule

5.3.6 New Projects

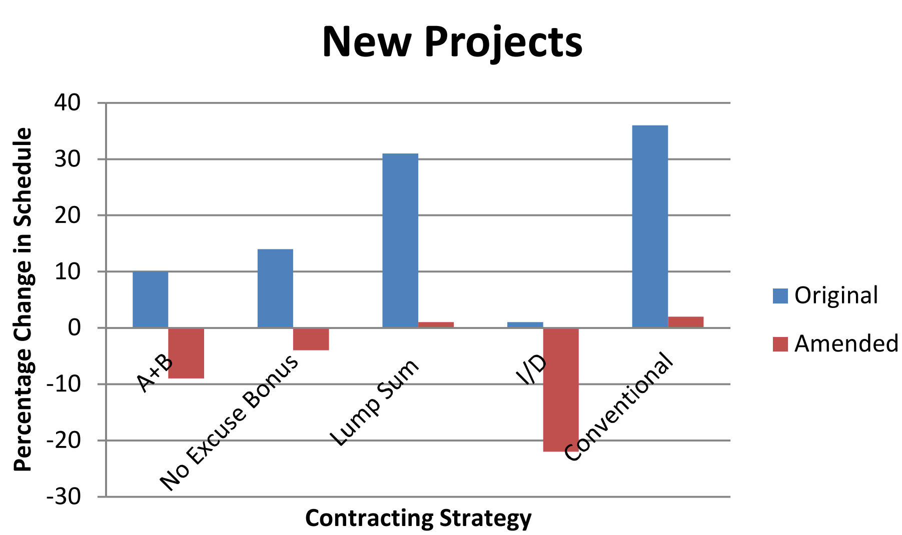

Figure 33: Schedule Performance of New Projects by Contracting Strategy

Figure 33 compares the mean change in the project schedule both original and amended under different contracting strategies new construction projects. A+B contracting strategy has least growth in original project schedule of 10 % indicating it is the best performing contracting strategy for undertaking new construction projects to achieve best schedule performance. Conventional contracting strategy has worst schedule performance for new construction projects experiencing as much as 35% of growth on the original project schedule. For amended schedule I/D was the best performing contracting strategy having a schedule change of -12% whereas conventional contracting strategy is the worst performing contracting strategy with a growth of 2 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule. A positive change in schedule indicates completion of project after the contracted schedule

5.3.7 Traffic Operation Projects

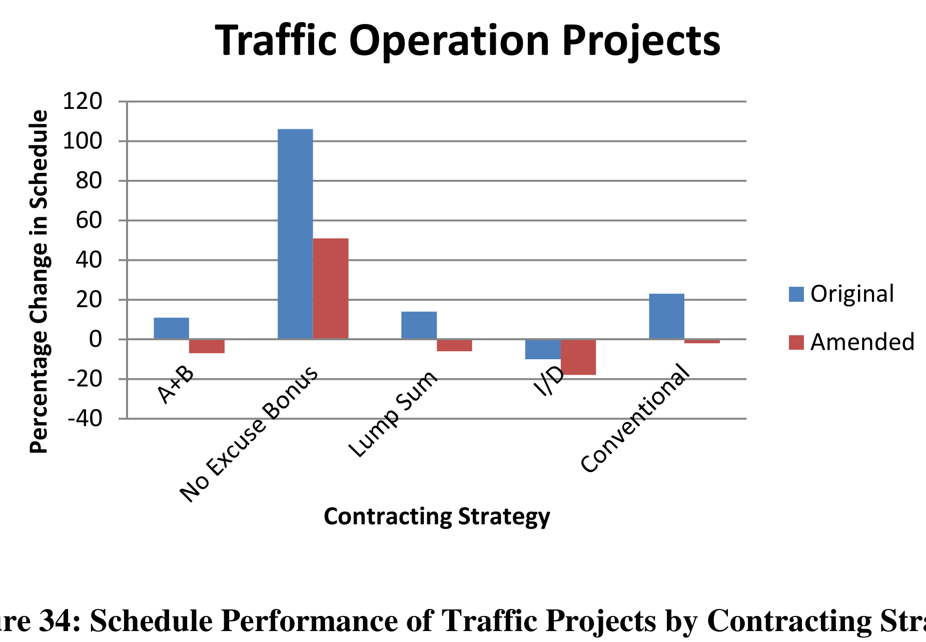

Figure 34: Schedule Performance of Traffic Projects by Contracting Strategy

Figure 34 compares the mean change in the project schedule both original and amended under different contracting strategies traffic operation projects. I/D contracting strategy has least growth in original project schedule of -10 % indicating it is the best performing contracting strategy for undertaking traffic operation projects to achieve best schedule performance. No excuse bonus contracting strategy has worst schedule performance for traffic operation projects experiencing as much as 106% of growth on the original project schedule. For amended schedule I/D was the best performing contracting strategy having a schedule change of -18% whereas no excuse bonus contracting strategy is the worst performing contracting strategy with a growth of 50 % in amended project schedule. A negative change in schedule indicates completion of project before contracted schedule. A positive change in schedule indicates completion of project after the contracted schedule

5.4 Research Hypothesis Testing

5.4.1 Design of Research Hypotheses

Based on the results obtained in this chapter, it was established that alternative projects were more effective than conventional projects in reducing project duration. To further explore this case, comparison of the means of the schedule ratios of the data was conducted to check the statistical significance of the differences:

- Project duration is affected by the application of an Alternative contracting strategy

- Alternative contracting strategies decreases the project duration considerably more as compared to conventional contracting strategies.
- For decreasing project duration different alternative contracting strategies give different results.

Contractors' individual production performance and work experience are assumed to be identical. Productivity of the contractor is assumed to be equivalent during daytime and nighttime.

5.4.2 Normality of the Data

The size of the data is extremely large, there are total of 2844 projects that were used for undertaking this study .Since the data sample size is extremely large the data can be assumed to be normally distributed. For all the analysis of mean of the data student's t test and Dunnett's control test were used.

5.4.3 Analysis of Testing Results

Table 7: Summary of Descriptive Statistics of Contracting Strategies for SCR

SCR								
					95% Confidence Interval for Mean			
Contracting Strategy	Number	Mean	Std Dev	Std Err Mean	Lower Bound	Upper Bound	Min	Max
A + B	82	0.235196	0.365012	0.04031	0.15499	0.3154	-0.33	1.44
BONUS	120	0.110778	0.544128	0.04967	0.01242	0.20913	-0.6	5.01
CONVENTIONAL	1382	0.223107	0.461545	0.01242	0.19875	0.24746	-1	4.19
I/D	206	0.058796	0.36597	0.0255	0.00852	0.10907	-0.96	1.91
LUMP SUM	857	0.138478	0.44359	0.01515	0.10874	0.16822	-0.98	5.33

Table 7 shows the summary of the descriptive statistics of the student's t test for the schedule change ratio for the different contracting strategies and project deliver methods. It gives the idea of the mean, means range, maximum and the minimum value of the mean and its standard deviation. The maximum mean value of the SCR is observed for no excuse bonus contracting strategy (0.2351) while the minimum value is observed for no excuse bonus contracting strategy (0.1107). The maximum individual value is observed for no excuse bonus contracting strategy(5.01) while lowest individual value is observed for conventional contracting strategy (-1) .

Table 8: Result of Student's t Test of Schedule Change Ratio

SCR						
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	Lower CL	Upper CL	p-Value
A + B	I/D	0.1764004	0.0577443	0.063175	0.289626	0.0023
	LUMP SUM	0.096718	0.0511198	-0.00352	0.196954	0.0586
	BONUS	0.124418	0.0633624	0.000177	0.248659	0.0497
LUMP SUM	I/D	0.0796824	0.034316	0.012396	0.146969	0.0203
	A + B	-0.096718	0.0511198	-0.19695	0.003518	0.0586
	BONUS Year	0.0277001	0.0431042	-0.05682	0.112219	0.5205
I/D	A + B	-0.1764004	0.0577443	-0.28963	-0.06318	0.0023
	LUMP SUM	-0.0796824	0.034316	-0.14697	-0.0124	0.0203
	BONUS Year	-0.0519824	0.0507853	-0.15156	0.047597	0.3061
BONUS	A + B	-0.124418	0.0633624	-0.24866	-0.00018	0.0497
	LUMP SUM	-0.0277001	0.0431042	-0.11222	0.056819	0.5205
	I/D	0.0519824	0.0507853	-0.0476	0.151562	0.3061

$\alpha = 0.05$

A student's t test was conducted to compare the mean of alternative contracting strategies with each other. The result of the tests are depicted in table 8.The contracting strategies were compared on their SCR. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference indicates SCR of contracting strategy i is smaller than contracting strategy j. A positive difference in mean indicate SCR of contracting strategy i is greater than contracting strategy j The smaller the mean value of SCR the better performing is the contracting strategy. Hence for a P value of less than 0.05 and negative difference in the mean value, contracting strategy i is better performing than contracting strategy j. For a P value less than 0.05 and positive difference in the mean value, contracting strategy j is better performing than contracting strategy i. According to the results A+B is the least affective strategy in controlling project schedule while incentive/disincentive appears to the best performing contracting strategy.

Table 9: Result of Dunnett's Control Test for Schedule Change Ratio

SCR				
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	p-Value
A + B	CONVENTIONAL	0.01209	0.0502647	0.9997
DESIGN/BUILD	CONVENTIONAL	-0.08408	0.0336789	0.0606
LUMP SUM	CONVENTIONAL	-0.08463	0.0192281	0.0001
BONUS	CONVENTIONAL	-0.11233	0.0420866	0.0373
I/D	CONVENTIONAL	-0.16431	0.0330287	0.0001

α= 0.05

A Dunnett's control test was conducted to compare the mean of alternative contracting strategies with conventional contracting strategy. The results of the tests are depicted in table 9. The contracting strategies were compared on their SCR. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference indicates SCR of conventional contracting strategy is smaller than alternative contracting strategy. A positive difference in mean indicate SCR of conventional contracting strategy is greater than alternative contracting strategy. According to the results A+B is the least affective strategy in controlling project schedule while incentive/disincentive appears to the best performing contracting strategy when compared with conventional contracting strategy.

Table 10: Summary of Descriptive Statistics of Contracting Strategies for CSCGR

CSCGR								
					95% Confidence Interval for Mean			
Contracting Strategy	Number	Mean	Std Dev	Std Err Mean	Lower Bound	Upper Bound	Min	Max
A + B	82	0.293542	0.276819	0.03057	0.23272	0.35437	0.016	1.19
BONUS	120	0.176339	0.224507	0.02049	0.13576	0.21692	-0.05	1.05
CONVENTIONAL	1382	0.258946	0.35065	0.00943	0.24044	0.27745	-0.58	3.81
I/D	206	0.185396	0.252776	0.01761	0.15067	0.22012	-0.02	1.61
LUMP SUM	857	0.208478	0.335682	0.01147	0.18597	0.23098	-0.52	5.33

α= 0.05

Table 10 shows the summary of the descriptive statistics of the student's t test for the contract schedule change growth ratio for the different contracting strategies and project deliver methods. It gives the idea of the mean, means range, maximum and the minimum value of the mean and its standard deviation. The maximum mean value of the CSCGR is observed for A+B contracting strategy (0.2935) while the minimum value is observed for I/D contracting strategy (0.1853). The maximum individual value is observed for lump sum contracting strategy(5.33) while lowest individual value is observed for conventional contracting strategy (-0.58) .

Table 11: Result of Student's t Test of Contract Schedule Change Growth Ratio

CSCGR						
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	Lower CL	Upper CL	p-Value
A + B	I/D	0.1081461	0.0425051	0.024802	0.19149	0.011
	LUMP SUM	0.0850639	0.0376288	0.011281	0.158847	0.0239
	BONUS	0.1172029	0.0466405	0.02575	0.208656	0.012
LUMP SUM	I/D	0.0230822	0.0252597	-0.02645	0.072611	0.3609
	A + B	-0.0850639	0.0376288	-0.15885	-0.01128	0.0239
	BONUS	0.032139	0.0317287	-0.03008	0.094353	0.3112
I/D	A + B	-0.1081461	0.0425051	-0.19149	-0.0248	0.011
	LUMP SUM	-0.0230822	0.0252597	-0.07261	0.026447	0.3609
	BONUS	0.0090568	0.0373826	-0.06424	0.082357	0.8086
BONUS	A + B	-0.1172029	0.0466405	-0.20866	-0.02575	0.012
	LUMP SUM	-0.032139	0.0317287	-0.09435	0.030075	0.3112
	I/D	-0.0090568	0.0373826	-0.08236	0.064243	0.8086

$\alpha = 0.05$

A student's t test was conducted to compare the mean of alternative contracting strategies with each other. The results of the tests are depicted in table 11. The contracting strategies were compared on their CSCGR; it measures the impact of change order days on the overall duration of the project. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 for the test we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference in mean indicate CSCGR of contracting strategy i is smaller than contracting strategy j. A positive difference in mean indicate CSCGR of contracting strategy i is greater than contracting strategy j The smaller the mean value of CSCGR the better performing is the contracting strategy. Hence for a P value of less than 0.05 and negative difference in the mean value, contracting strategy i is better performing than contracting strategy j. For a P value less than 0.05 and positive difference in the mean value, contracting strategy j is better performing than contracting strategy i. According to the results A+B is the least affective strategy in controlling project schedule growth due to change orders while other contracting strategies perform similar to each other.

Table 12: Result of Dunnett's Control Test for Contract CSCGR

CSCGR				
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	p-Value
A + B	CONVENTIONAL	0.0346	0.0369994	0.8779
LUMP SUM	CONVENTIONAL	-0.05047	0.0141536	0.0018
I/D	CONVENTIONAL	-0.07355	0.0243121	0.0124
DESIGN/BUILD	CONVENTIONAL	-0.08114	0.0247907	0.0054
BONUS	CONVENTIONAL	-0.08261	0.0309796	0.0376

$\alpha = 0.05$

A Dunnett's control test was conducted to compare the mean of alternative contracting strategies with conventional contracting strategy. The results of the tests are depicted in table 12. The contracting strategies were compared on their CSCGR. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference indicates CSCGR of conventional contracting strategy is smaller than alternative contracting strategy. A positive difference in mean indicate CSCGR of conventional contracting strategy is greater than alternative contracting strategy. According to the results A+B is the least affective strategy in controlling project schedule while no excuse bonus appears to the best performing contracting strategy when compared with conventional contracting strategy

5.5 Section Summary

The purpose of employing innovative and alternative contracting strategies instead of conventional contracting strategy is to achieve project completion as early as possible by incentivizing the early project completion for the contractors so that they get motivated to achieve early project completion. All the alternative contracting strategies with the exception of A+B prove to be more schedule effective when compared with conventional contracting strategy. The reduced duration of the projects will result in reduced inconvenience to the road users although this reduced duration may result in increased project cost. The effect of the contracting strategies on project cost will be discussed in the next chapter. The analysis of the data clearly indicates that the A+B contracting strategy do not bring about the desired schedule performance and perform similar to conventional contracting strategy. Though there might be some difference in schedule performance of A+B and conventional projects the difference is not statistically significant. One of the probable cause for this could be underestimations of contract duration by contractors while bidding for A+B.

6. EFFECT OF ALTERNATIVE CONTRACTING STRATGIES ON PROJECT COST

6.1 Introduction

In the previous chapter we examined the schedule effectiveness of various project delivery methods and contracting strategies. As established in the previous chapter the application of alternative and innovative contracting strategies result in reduced project duration which in turn rests in reduced public inconvenience due to these construction projects. The reduced project schedule though extremely beneficial in reducing public inconvenience, may cause an increase in the overall project cost. The trade of between decreased duration of the project and the increased cost as a result of the implementation of alternative contracting strategies for schedule compression should be carefully analyzed before judging the viability of the alternative contracting strategy. The additional cost incurred should never out weight the benefits achieved by spending that additional cost on alternative contracting strategies. The cost of the project may also be affected by change orders and thus an effective contracting strategy should have minimum effect of change orders on cost effectiveness of the contracting strategy. The analysis in this chapter evaluates the cost performance of various contracting strategies against the changes brought to the project cost as a result of change orders issued during the life time of the project

To evaluate their effectiveness, alternative projects were compared with: (1) projects contracted conventionally; and (2) other alternative contracting strategies. In addition to this the conventional project delivery was also compared with Design Build project delivery method. As a methodology, Student t test Dunnetts's control test for comparing means was used to meet the following objectives:

- To test whether the contract cost changes were affected by the application of an alternating contracting strategy.
- To conclude whether alternative contracting projects experience cost changes that are lower than the levels witnessed in the conventional projects.
- To compare the effect of individual contract strategy to reduce project cost

6.2 Impact of a Contracting Strategy on Overall Project Schedule

The primary reason for choosing alternative and innovative contracting strategy over the conventional project delivery and contracting strategy is to avail the time saving benefits of this contracting strategy and project delivery methods but there has to be a considerable amount of cost benefit to be associated with the implementation of these alternative contracting strategies to make the implementation economically feasible.

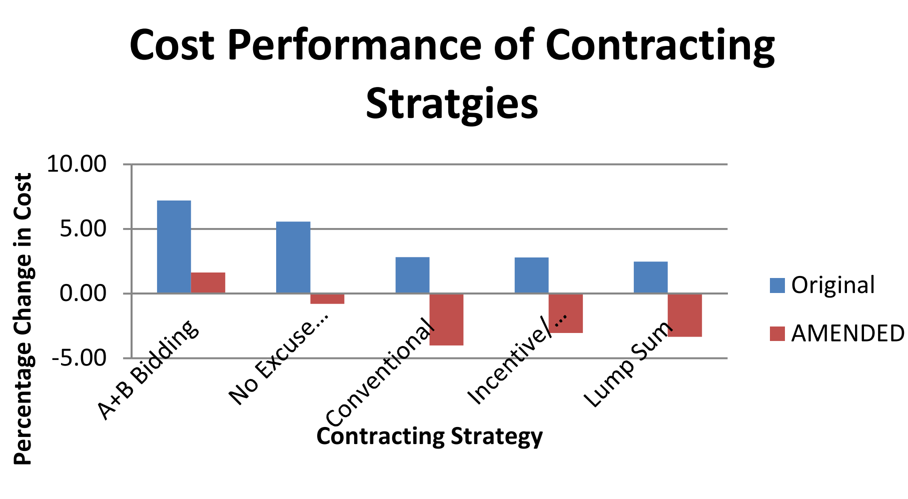

Figure 35: Cost Performance by Contracting Strategy

Figure 35 compares the mean change in the project cost both original and amended in different contracting strategies. The original project cost experienced increase in all the projects but the worst performing contracting strategies was A+B with 7% increase in the original cost. Lump Sum projects experienced minimum growth in the original cost of 2.5%. The project cost for amended cost has decreased the most in incentive/ disincentive (I/D) contracting strategy (-4%) whereas the minimum change in the project cost occurred in A+B contracting strategy (1.5%).Furthermore the negative value indicates the average project cost is less than the amended project cost of the contract. Though it is quite clear from the figure above that there exists a difference in terms of cost performance between conventional projects and alternative projects, the statistical significance of the differences will be tested later in this chapter to establish the validity of the results.

6.3 Schedule Performance of Contracting Strategies versus Project Types

6.3.1 3R Projects

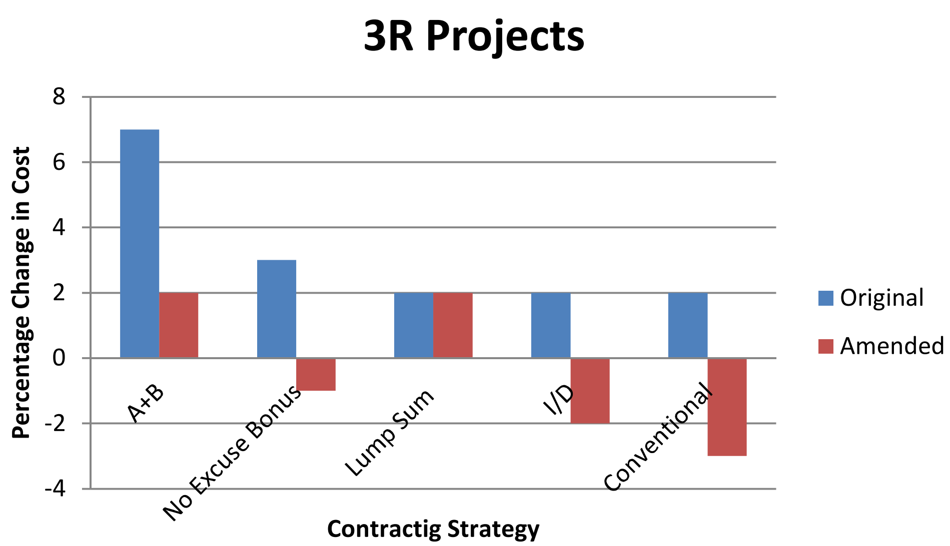

Figure 36: Cost Performance of 3R Projects by Contracting Strategy

Figure 36 compares the mean change in the project cost both original and amended under different contracting strategies for 3R projects. Lump sum, conventional I/D contracting strategy have least growth in original project schedule of 2% each indicating they are the best performing contracting strategies for undertaking 3R projects to achieve best cost performance. A+B contracting strategy has worst cost performance for 3 projects experiencing as much as 7% of growth on the original project cost. For amended cost conventional was the best performing contracting strategy having a cost change of -3% whereas A+B is the worst performing contracting strategy with a growth of 2 % in amended project cost. A negative change in cost indicates completion of project under contracted cost a positive change in cost indicates completion of project over the contracted cost.

6.3.2 Bridge Projects

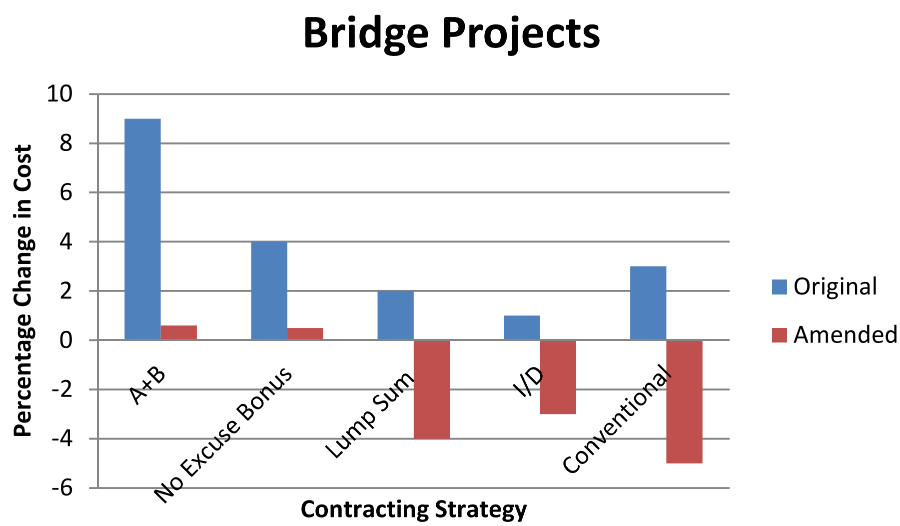

Figure 37: Cost Performance of Bridge Projects by Contracting Strategy

Figure 37 compares the mean change in the project cost both original and amended under different contracting strategies for bridge projects. I/D contracting strategy have least growth in original project schedule of 1% each indicating it is the best performing contracting strategy for undertaking bridge projects to achieve best cost performance. A+B contracting strategy has worst cost performance for bridge projects experiencing as much as 9% of growth on the original project cost. For amended cost conventional was the best performing contracting strategy having a cost change of -5% whereas A+B and no excuse bonus are the worst performing contracting strategies with a growth of 1% each in amended project cost. A negative change in cost indicates completion of project under contracted cost. A positive change in cost indicates completion of project over the contracted cost.

6.3.3 Capacity Added Projects

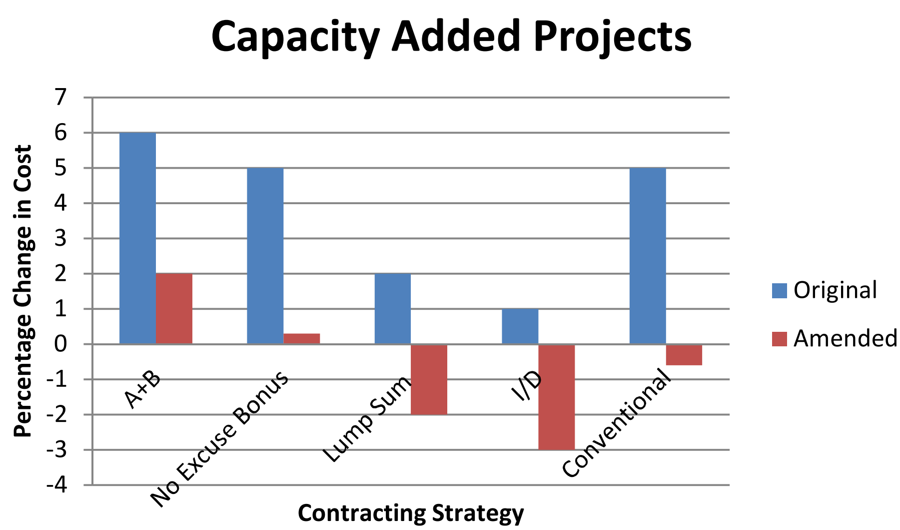

Figure 38: Cost Performance of Capacity Added Projects by Contracting Strategy

Figure 38 compares the mean change in the project cost both original and amended under different contracting strategies for capacity added projects. I/D contracting strategy have least growth in original project schedule of 1% each indicating it is the best performing contracting strategy for undertaking capacity added projects to achieve best cost performance. A+B contracting strategy has worst cost performance for capacity added projects experiencing as much as 6% of growth on the original project cost. For amended cost I/D was the best performing contracting strategy having a cost change of -3% whereas A+B was the worst performing contracting strategies with a growth of 2% in amended project cost. A negative change in cost indicates completion of project under contracted cost a positive change in cost indicates completion of project over the contracted cost.

6.3.4 Miscellaneous Projects

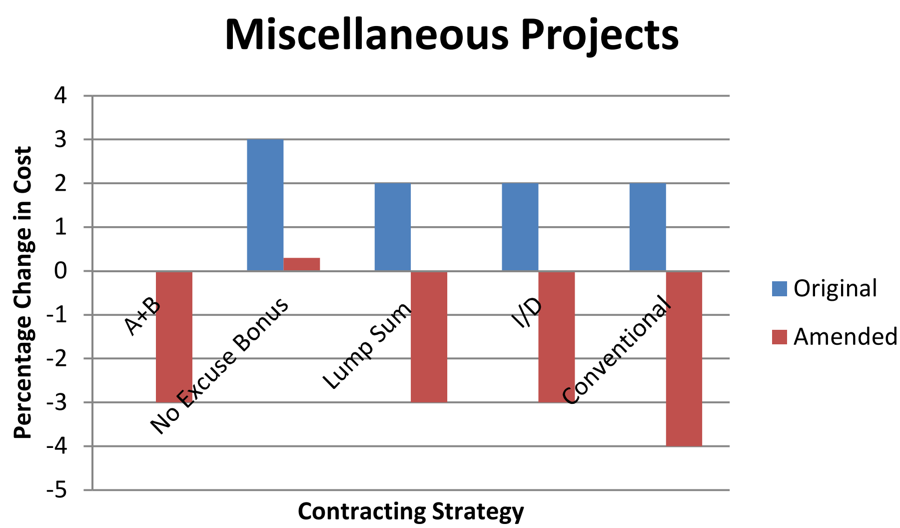

Figure 39: Cost Performance of Miscellaneous Projects by Contracting Strategy

Figure 39 compares the mean change in the project cost both original and amended under different contracting strategies for miscellaneous projects. A+B contracting strategy have least growth in original project schedule of 0% indicating it is the best performing contracting strategy for undertaking miscellaneous projects to achieve best cost performance. No excuse bonus contracting strategy has worst cost performance for miscellaneous projects experiencing as much as 3% of growth on the original project cost. For amended cost conventional contracting strategy was the best performing contracting strategy having a cost change of -4% whereas no excuse bonus was the worst performing contracting strategies with a growth of 0.5% in amended project cost. A negative change in cost indicates completion of project under contracted cost. A positive change in cost indicates completion of project over the contracted cost.

6.3.5 Other Projects

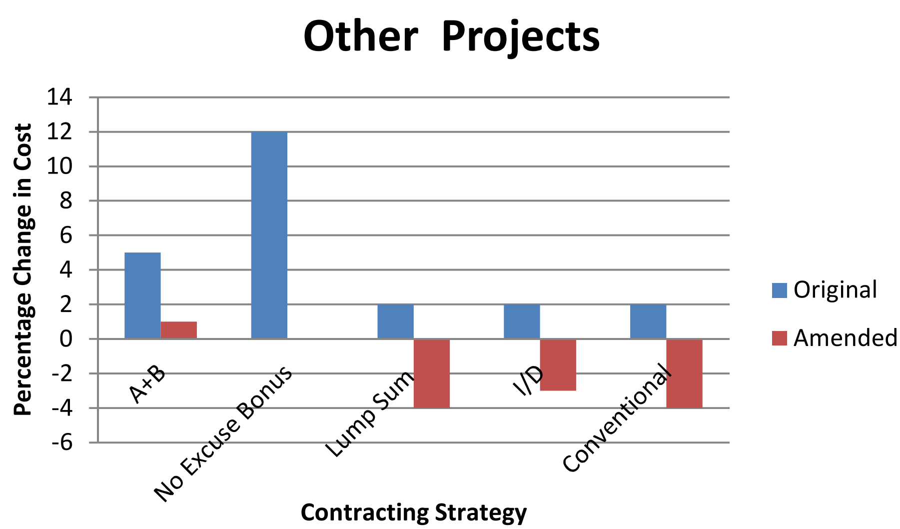

Figure 40: Cost Performance of Other Projects by Contracting Strategy

Figure 40 compares the mean change in the project cost both original and amended under different contracting strategies for other projects. Lump sum, I/D and conventional contracting strategies have least growth in original project schedule of 2% each indicating they are the best performing contracting strategies for undertaking miscellaneous projects to achieve best cost performance. No excuse bonus contracting strategy has worst cost performance for miscellaneous projects experiencing as much as 12% of growth on the original project cost. For amended cost conventional contracting strategy was the best performing contracting strategy having a cost change of -4% whereas A+B was the worst performing contracting strategies with a growth of 1% in amended project cost. A negative change in cost indicates completion of project under contracted cost. A positive change in cost indicates completion of project over the contracted cost

6.3.6 New Projects

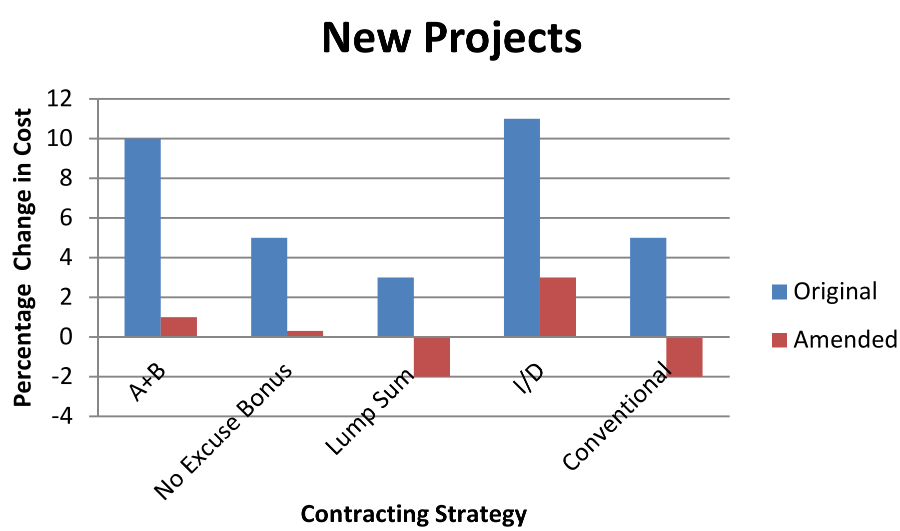

Figure 41: Cost Performance of New Projects by Contracting Strategy

Figure 41 compares the mean change in the project cost both original and amended under different contracting strategies for new projects. Lump sum contracting strategy have least growth in original project schedule of 3% indicating it is the best performing contracting strategies for undertaking new projects to achieve best cost performance. I/D contracting strategy have worst cost performance for new projects experiencing as much as 11% of growth on the original project cost. For amended cost conventional contracting strategy was the best performing contracting strategy having a cost change of -2% whereas I/D was the worst performing contracting strategy with a growth of 3% in amended project cost. A negative change in cost indicates completion of project under contracted cost. A positive change in cost indicates completion of project over the contracted cost.

6.3.7 Traffic Operation Projects

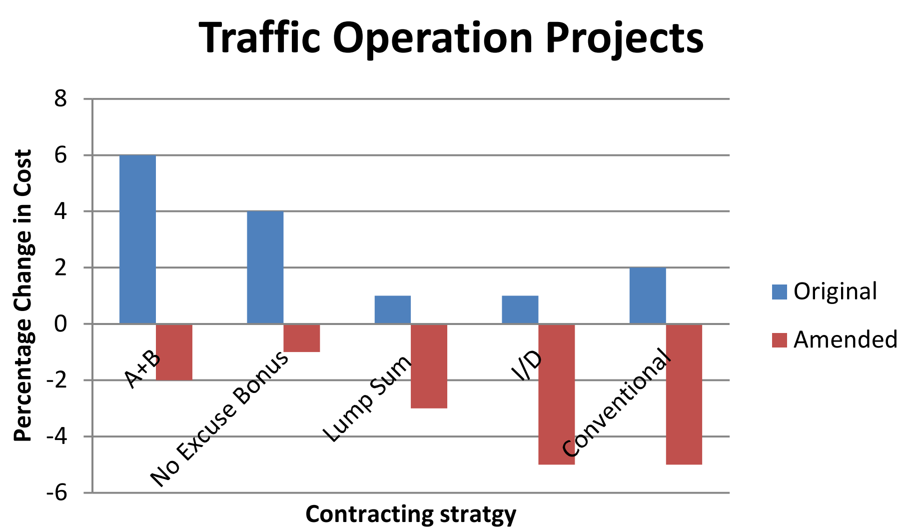

Figure 42: Cost Performance of Traffic Projects by Contracting Strategy

Figure 42 compares the mean change in the project cost both original and amended under different contracting strategies for traffic operations projects. I/D contracting strategy have least growth in original project schedule of 1% indicating it is the best performing contracting strategies for undertaking new projects to achieve best cost performance. A+B contracting strategy has worst cost performance for traffic operations projects experiencing as much as 6% of growth on the original project cost.

For amended cost conventional contracting strategy was the best performing contracting strategy having a cost change of -5% whereas no excuse bonus was the worst performing contracting strategy with a growth of -1% in amended project cost. A negative change in cost indicates completion of project under contracted cost. A positive change in cost indicates completion of project over the contracted cost.

6.4 Research Hypothesis Testing

6.4.1 Design of Research Hypotheses

Based on the results obtained in this chapter, it was established that alternative projects were more effective than conventional projects in reducing project cost as incurred by change orders. To further explore this case, comparison of the means of the cost ratios of the data was conducted to check the statistical significance of the differences:

- Contract cost changes are affected by the application of an Alternative contracting strategy
- Cost of project employing alternative contracting strategies are affected to a lesser extent by change orders when compared projects employing conventional contracting method.
- Alternative contracting strategies give different results for the changes in the project cost a result of change orders.

It is assumed that contractors' individual production performance and work experience are identical. Contractor productivity during daytime and nighttime is also assumed to be equivalent.

6.4.2 Normality of the Data

The size of the data is extremely large, there are total of 2844 projects that were used for undertaking this study .Since the data sample size is extremely large the data can be assumed to be normally distributed. For all the analysis of mean of the data student's t test and Dunnett's control test were used.

6.4.3 Analysis of Testing Results

Table 13: Summary of Descriptive Statistics of Contracting Strategies for CCR

CCR								
					95% Confidence Interval for Mean			
Contracting Strategy	Number	Mean	Std Dev	Std Err Mean	Lower Bound	Upper Bound	Min	Max
A + B	82	0.070732	0.091985	0.01016	0.05052	0.09094	-0.15	0.51
BONUS	120	0.049083	0.094602	0.00864	0.03198	0.06618	-0.26	0.66
CONVENTIONAL	1382	0.029334	0.146424	0.00394	0.02161	0.03706	-0.99	1.54
I/D	206	0.026214	0.096293	0.00671	0.01299	0.03944	-0.29	0.37
LUMP SUM	857	0.024357	0.076808	0.00263	0.0192	0.02951	-0.78	0.77

Table 13 shows the summary of the descriptive statistics of the student's t test for the cost change ratio for the different contracting strategies and project deliver methods. It gives the idea of the mean, means range, maximum and the minimum value of the mean and its standard deviation. The maximum mean value of the CCR is observed for

A+B contracting strategy (0.0707) while the minimum value is observed for Lump sum contracting strategy (0.2243). The maximum individual value is observed for conventional contracting strategy(1.54) while lowest individual value is observed for conventional contracting strategy (-0.99) as well.

Table 14: Result of Student's t Test of Cost Change Ratio

CCR						
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	Lower CL	Upper CL	p-Value
A + B	IE/D	0.0445181	0.0154608	0.014203	0.074834	0.004
	LUMP SUM	0.0463742	0.0136878	0.019535	0.073213	0.0007
	BONUS	0.0216484	0.016965	-0.01162	0.054913	0.202
LUMP SUM	I/D	-0.0018561	0.009189	-0.01987	0.016162	0.8399
	A + B	-0.0463742	0.0136878	-0.07321	-0.01954	0.0007
	BONUS	0.0277001	0.0431042	-0.05682	0.112219	0.5205
I/D	A + B	-0.0445181	0.0154608	-0.07483	-0.0142	0.004
	LUMP SUM	0.0018561	0.009189	-0.01616	0.019874	0.8399
	BONUS	-0.0228697	0.0135975	-0.04953	0.003792	0.0927
BONUS	A + B	-0.0216484	0.016965	-0.05491	0.011617	0.202
	LUMP SUM	0.0247259	0.0115418	0.002095	0.047357	0.0323
	I/D	0.0228697	0.0135975	-0.00379	0.049532	0.0927

$\alpha = 0.05$

A student's t test was conducted to compare the mean of alternative contracting strategies with each other. The results of the tests are depicted in table 14. The contracting strategies were compared on their CCR. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference in the mean indicate CCR of contracting strategy i is smaller than contracting strategy j. A positive difference in mean indicate CCR of contracting strategy i is greater than contracting strategy j. Smaller the mean value of CCR the better performing is the contracting strategy. Hence for a P value of less than 0.05 and negative difference in the mean value, contracting strategy i is better performing than contracting strategy j. For a P value less than 0.05 and positive difference in the mean value, contracting strategy j is better performing than contracting strategy i. According to the results A+B is the least affective strategy in controlling project cost while other contracting strategies perform similar to each other.

Table 15: Result of Dunnett's Control Test for Contract CCR

CCR				
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	p-Value
A + B	CONVENTIONAL	0.0414	0.0134581	0.0105
BONUS	CONVENTIONAL	0.01975	0.0112685	0.3333
I/D	CONVENTIONAL	-0.00312	0.0135975	0.9983
DESIGN/BUILD	CONVENTIONAL	-0.00477	0.0090174	0.9886
LUMP SUM	CONVENTIONAL	-0.00498	0.0051501	0.8625

α= 0.05

A Dunnett's control test was conducted to compare the mean of alternative contracting strategies with conventional contracting strategy. The results of the tests are depicted in table 15. The contracting strategies were compared on their CCR. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference indicates CCR of conventional contracting strategy is smaller than alternative contracting strategy. A positive difference in mean indicate CSCGR of conventional contracting strategy is greater than alternative contracting strategy. According to the results A+B is the least affective strategy in controlling project schedule while all other contracting strategies appears to be behaving similar to conventional contracting strategy.

Table 16: Summary of Descriptive Statistics of Contracting Strategies for CCCGR

CCCGR								
					95% Confidence Interval for Mean			
Contracting Strategy	Number	Mean	Std Dev	Std Err Mean	Lower Bound	Upper Bound	Min	Max
A + B	82	0.043993	0.07688	0.00849	0.0271	0.06089	-0.08	0.51
BONUS	120	0.040142	0.081889	0.00748	0.02534	0.05494	-0.05	0.67
CONVENTIONAL	1382	0.031319	0.104974	0.00282	0.02578	0.03686	-0.98	1.21
I/D	206	0.031866	0.065119	0.00454	0.02292	0.04081	-0.05	0.36
LUMP SUM	857	0.013252	0.067382	0.0023	0.00873	0.01777	-1	0.89

Table 16 shows the summary of the descriptive statistics of the student's t test for the contract cost change growth ratio for the different contracting strategies and project deliver methods. It gives the idea of the mean, means range, maximum and the minimum value of the mean and its standard deviation. The maximum mean value of the CCCGR is observed for A+B contracting strategy (0.04399) while the minimum value is observed for Lump sum contracting strategy (0.1325). The maximum individual value is observed for conventional contracting strategy(1.21) while lowest individual value is observed for Lump Sum contracting strategy (-1).

Table 17: Result of Student's t Test of CCCGR

CCCGR						
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	Lower CL	Upper CL	p-Value
A + B	IE/D	0.0121278	0.0116436	-0.0107	0.034959	0.2977
	LUMP SUM	0.0307409	0.0103078	0.010529	0.050953	0.0029
	BONUS	0.0038518	0.0127764	-0.0212	0.028904	0.7631
LUMP SUM	I/D	-0.0186131	0.0069195	-0.03218	-0.00505	0.0072
	A + B	-0.0307409	0.0103078	-0.05095	-0.01053	0.0029
	BONUS	-0.0268891	0.0086916	-0.04393	-0.00985	0.002
I/D	A + B	-0.0121278	0.0116436	-0.03496	0.010703	0.2977
	LUMP SUM	0.0186131	0.0069195	0.005045	0.032181	0.0072
	BONUS	-0.0082761	0.0102404	-0.02836	0.011803	0.4191
BONUS	A + B	-0.0038518	0.0127764	-0.0289	0.0212	0.7631
	LUMP SUM	0.0268891	0.0086916	0.009847	0.043932	0.002
	I/D	0.0082761	0.0102404	-0.0118	0.028355	0.4191

$\alpha = 0.05$

A student's t test was conducted to compare the mean of alternative contracting strategies with each other. The results of the tests are depicted in table 17. The contracting strategies were compared on their CCCGR; it measures the impact of change order days on the overall cost of the project. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 for the test we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference in mean indicate CCCGR of contracting strategy i is smaller than contracting strategy j. A positive difference in mean indicate CCCGR of contracting strategy i is greater than contracting strategy j The smaller the mean value of CCCGR the better performing is the contracting strategy. Hence for a P value of less than 0.05 and negative difference in the mean value, contracting strategy i is better performing than contracting strategy j. For a P value less than 0.05 and positive difference in the mean value, contracting strategy j is better performing than contracting strategy i. According to the results A+B is the least affective strategy in controlling project cost growth due to change orders while lump sum is the most effective contracting strategy.

Table 18: Result of Dunnett's Control Test for Contract CCCGR

CCCGR				
Contracting Strategy (I)	Contracting Strategy (J)	Difference(I-J)	Std Err Dif	p-Value
A + B	CONVENTIONAL	0.01267	0.0101354	0.6851
BONUS	CONVENTIONAL	0.00882	0.0084864	0.8227
I/D	CONVENTIONAL	0.00055	0.0066599	1
DESIGN/BUILD	CONVENTIONAL	-0.01088	0.006791	0.4312
LUMP SUM	CONVENTIONAL	-0.01807	0.0038772	0.0001

α= 0.05

A Dunnett's control test was conducted to compare the mean of alternative contracting strategies with conventional contracting strategy. The results of the tests are depicted in table 18. The contracting strategies were compared on their CCCGR. The level of significance for the test was 0.05 so for a P value of less the 0.05 we conclude that there is enough statistical evidence to conclude that the means of the contracting strategies are different from each other. For a P value greater than 0.05 we conclude that there in not enough statistical evidence to conclude that the mean of the contracting strategies differ. Furthermore the results give the difference between the means of the contracting strategies. A negative difference indicates CCCGR of conventional contracting strategy is smaller than alternative contracting strategy. A positive difference in mean indicate CCCGR of conventional contracting strategy is greater than alternative contracting strategy. According to the results lump sum is the most effective strategy in controlling project cost while all other contracting strategies appears to be performing similar to conventional contracting strategy.

6.5 Section Summary

The analysis of the effect of the contracting strategies on the cost changes in the project were conducted in this chapter. The change order introduced in a project for varies reason more than often results in increased project costs. In this chapter we tried to analyze how the project cost of various contracting strategies was affected by the changes introduced in the project. Contracting strategies showed clear evidence of acting differently to cost changes in the project and the difference between the cost changes between different contracting strategies is statistically significant. The results also indicate that alternative contracting strategies are not different form conventional contracting strategy in terms of cost performance.

7. CORRELATION ANALYSIS

7.1 Introduction

In the previous chapter we have evaluated the schedule and cost effectiveness of various contracting strategies. This effectiveness was measured as the ability to minimize the impact of change order cost and duration on the overall project cost and project duration. In this chapter we will be measuring the impact of the change order on the project duration and project cost by establishing a correlation between change order and project changes in terms of cost and time. This establishment of the correlation will strengthen will help us justifying the evaluation of change order impact on project performance.

7.2 Research Hypothesis Testing

7.2.1 Design of Research Hypotheses

Based on the results obtained in this chapter, it was established that alternative projects were more effective than conventional projects in reducing project duration and project cost. To further explore the impact of change orders on the project cost and project duration the aspects were tested for correlation:

- The amount of change order time affects the overall duration of the project
- The amount of change order cost affects the total change in project cost.
- The amount of change order time is affected by the cost of the project
- The duration of change order time is affected by the duration of the project.

7.2.2 Analysis of the Results

Hypothesis 1

The amount of change order time increases the overall duration of the project

The above hypothesis will be tested using correlation test between

- Change order days
- Total change in project duration

Table 19: Correlation Between Change Order Days and Change in Project Duration

Project Delivery/ Contracting Strategy	Correlation	P-Value
Conventional	0.7307	0.0001
Design Build	0.6878	0.0001
A+B	0.7954	0.0001
Lump Sum	0.7756	0.0001
No Excise Bonus	0.6817	0.0001
Incentive/Disincentive	0.7150	0.0001

$\alpha = 0.05$

From the above results depicted in table 19 it is evident that the amount of change order time increases the overall duration of the project. This is evident from the table 19 which shows that there is significant correlation between the change order time and overall duration of the project ($r>0.6$ in all the strategies at p-value = 0.0001)

Hypothesis 2

The amount of change order cost increases the total change in project cost.

The above hypothesis will be tested using correlation test between

- Change order cost
- Total change in project cost

Table 20: Correlation Between Change Order Cost and Change in Project Cost

Project Delivery/ Contracting Strategy	Correlation	P-Value
Conventional	0.8153	0.0001
Design Build	0.9688	0.0001
A+B	0.8994	0.0001
Lump Sum	0.5362	0.0001
No Excise Bonus	0.9579	0.0001
Incentive/Disincentive	0.7543	0.0001

α= 0.05

From the above results depicted in table 20 it is evident that the amount of change order cost increases the total change of the project cost. This is evident from the table 20 which shows that there is significant correlation between the change order time and overall duration of the project (r>0.5 in all the strategies at p-value = 0.0001)

Hypothesis 3

The amount of change order cost is affected by the cost of the project

The above hypothesis will be tested using correlation test between

- Change order cost
- Total project cost

Table 21: Correlation Between Change Order Cost and Project Cost

Project Delivery/ Contracting Strategy	Correlation	P-Value
Conventional	0.5887	0.0001
Design Build	0.1462	0.0403
A+B	0.3818	0.0004
Lump Sum	0.3442	0.0001
No Excise Bonus	0.7060	0.0001
Incentive/Disincentive	0.6216	0.0001

α= 0.05

From the above results depicted in table 21 it is evident that the amount of change order time is affected by the cost of the project. This is evident from the table 21 which shows that there is significant correlation between the change order time is affected by the cost of the project ($r>0.1$ in all the strategies at p-value = 0.0001). The relation appears to be weak in Design build, A+B and lump sum.

Hypothesis 4

The duration of change order time is affected by the duration of the project

The above hypothesis will be tested using correlation test between

- Change order days
- Total project duration

Table 22: Correlation Between Change Orders Duration and Project Duration

Project Delivery/ Contracting Strategy	Correlation	P-Value
Conventional	0.6659	0.0001
Design Build	0.6779	0.0001
A+B	0.4181	0.0001
Lump Sum	0.6102	0.0001
No Excise Bonus	0.7522	0.0001
Incentive/Disincentive	07040	0.0001

α= 0.05

From the above results depicted in table 22 it is evident that the amount of change order time is affected by the duration of the project. This is evident from the table 22 which shows that there is significant correlation between the change order time and overall duration of the project (r>0.4 in all the strategies at p-value = 0.0001)

8. CONCLUSIONS

The main objective of employing alternative contracting strategies by transportation agencies is to expedite the execution of projects and completing the projects in the least time possible. This is done through undertaking various majors to incentivize the early completion of the project for the contractors and conversely penalizing any delay in the project completion. It was observed that most state transportation agencies employ these alternative contracting strategies without having an effective preconstruction design phase, which results in unforeseen schedule and cost overruns later on projects by change orders. The construction projects success reflects on the effectiveness of the management and the coordination of the activities between the main contractors, sub-contractors and the employees and the collaboration between the parties within the project. This is important because it will help them manage the change orders brought in by various factors during the design and construction phases. It is important for the managing agencies (State Transportation Agencies) to understand which contracting strategy is the best under which condition and the type of project taking into consideration the change order impacts. To understand this it is important for them to know the impacts of the change orders which can only be obtained through the quantification of cost, schedule and the performance of the various project delivery methods is focused in this study.

Change in construction projects are usually inevitable because the projects do not have adequate resources to reduce and minimize the changes that usually occurs during various stages of the project implementation. Therefore no matter the type of project it is usually important to quantify the change orders and compare the strategies to see if there is any difference between one strategy and the other. From the results it is evident that Alternative contracting strategies perform better in terms of schedule effectiveness and cost effectiveness when compared with the conventional contracting strategy. The alternative contracting strategies were compared with conventional contracting strategy in terms of performance indicators such as cost change ratio, schedule change ratio, Contract schedule change ratio and Contract Cost change Ratio. The ratios evaluated the performance of contracting strategies in time and cost changes arising for the change order introduced in the project. The statistical tests conducted established the validity of the results. The only contracting strategy which was less effective than conventional contracting strategy was A+B which was least effective in terms of cost and time. The results also concluded that the alternative contracting strategies are more efficient in controlling the schedule of the project whereas it might not be as effective in controlling the cost of the project. The correlation analysis also established that there is a strong positive correlation between change order amount and total change in project cost indicating that change order amount greatly impact the total change in the project cost. The correlation analysis also established that there is a strong positive correlation between change order time and total change in project duration indicating that change order time greatly impacts the total change in the project time. The study also established that the change order amount is positively correlated to the project cost and the change order time is positively correlated to the project duration.

Even though the study was thorough and extensive few areas still need to be probed so it is important to recommend that the following areas be addressed on future studies to better assist state transportation agencies:

- In order to have a more controlled impact of change orders, a future study needs to be conducted studying the change order sources from the change order types. These could give more specific reasons to know why change orders occur frequently and find a solution.

- There is a need to further evaluate the effect of the change order occurrences to further evaluate the impact a change order occurrence on the project performance

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