COST COMPARISON OF COLLABORATIVE AND IPD-LIKE PROJECT DELIVERY METHODS VERSUS COMPETITIVE NON-COLLABORATIVE PROJECT DELIVERY METHODS

A Thesis

by

ADITI SATISH KULKARNI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2012

Major Subject: Construction Management

Cost Comparison of Collaborative and IPD-Like Project Delivery Methods versus Competitive Non-Collaborative Project Delivery Methods

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Approved by:

Chair of Committee,	Zofia Rybkowski
Committee Members,	José L Fernández-Solís
	Mardelle Shepley
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ABSTRACT

Cost Comparison of Collaborative and IPD-Like Project Delivery Methods versus Competitive Non-Collaborative Project Delivery Methods. (May 2012)

Aditi Satish Kulkarni, B.Arch., National Institute of Technology

Chair of Advisory Committee: Dr. Zofia Rybkowski

Collaborative project delivery methods are believed to contribute to faster completions times, lower overall project costs and higher quality. Contracts are expected to influence the degree of collaboration on a given project since they allow or restrict certain lines of communication in the decision making process. Various delivery systems rank differently on the spectrum of collaboration. Because collaborative project delivery methods require owners and AEC stakeholders to meet frequently early in the delivery process, they are thought to add additional upfront costs to the project. The purpose of this study is to test if collaborative project delivery methods impart enough value so that the upfront cost incurred at the beginning of project is eventually surpassed by realized savings. Ideally, the extreme forms of project delivery methods, that is, Integrated Project Delivery (IPD) and Design-Bid-Build (DBB), should be compared to test the effects of collaboration on benefits to the owner. Due to difficulty in obtaining data on IPD and similarly scaled DBB projects, for this study, their close cousins, CM-at-Risk (CMR) and Competitive Sealed Proposal (CSP) were compared.

The study engaged statistical comparison of cost of change orders and overall project cost performance of 17 CMR and 13 CSP projects of similar scales by same owner. Project cost performance observed under CMR projects was found significantly more than those under CSP. This study is expected to help boost confidence in the benefits of collaborative project delivery methods. It is likely that the results will encourage acceptance of IPD for public projects. Owners who were previously discouraged by the increased upfront cost of collaborative projects may also find interest in the results of this study.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Zofia Rybkowski, and my committee members, Dr. José L Fernández-Solís and Dr. Mardelle Shepley, , for their guidance and support throughout the course of this research. Your dedication and passion have spurred me on push myself to achieve greater heights and will always be a source of inspiration. I extend my warm gratitude to my amazing friends who have had to endure me during my best and worst days, but have always been a pillar of encouragement all through graduate school.

To my parents have never given up hope in their constantly-messing-up child, I hope I can someday completely express the amount of love, affection and gratitude I feel for what you have done for me all through the years.

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CHAPTER I

INTRODUCTION

There are many definitions recognized for a project delivery system by researchers as well as practitioners in construction industry. One of the most acceptable definitions is that it is "*allocation of relationships, roles and responsibilities of project team members and the sequence of activities required for the deployment of a capital project"* (Konchar and Sanvido 1998). No project delivery method can be considered a perfect project delivery as several aspects of projects vary drastically from one project to another. Previous research identifies 12 different types of construction project delivery systems that are considered to be used widely in the industry. Different delivery systems involve different degrees of collaboration and integration of key parties involved. Design-bid-build (DBB) is a considered the most traditional form of project delivery although it was not common until late 19th century. It is based on concept where owner gets a set of design from designer and bids it to be built for a lowest fixed price (Thomson 2004). Competitive Sealed Proposal (CSP) approach is the same as DBB except the fact that in case of CSP the contractor is selected on a 'best value' offer, that is, qualifications of the contractor is also be considered and not just the low bid (Grasberg et al. 2009). One of the common integrated team approaches to design and construction of projects, for controlling schedule and budget while ensuring quality for the owner, is Construction Manager-at-Risk (CMR) (Grasberg and Riemer 2008).

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This thesis follows the style of *Journal of Construction Education.*

CMR is a widespread alternate project delivery method for private work. CMR also offers an alternative to public owners to gain benefits of collaboration on their projects without getting into a multi-party contract (Konchar and Sanvido 1998). Another approach to project delivery, Integrated Project Delivery (IPD), is considered the most collaborative form of delivery method. It is defined as *"a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction"* (AIA 2011).

This study is majorly focused on *collaboration* and its effect on benefits to the owner. As mentioned earlier, there is no perfect project delivery system, but there is an expectation that collaborative projects weigh higher on benefits over non-collaborative projects. The two extreme ends of project delivery spectrum in terms of degree of collaboration are DBB and IPD. In the state of Texas, the closest cousins to these methods are CSP and CMR. This study paper is an attempt to investigate these methods in terms of

- Costs of change orders (Errors and Omissions, and Design Modifications)
- Observed cost performance (budgeted cost- actual cost)

CHAPTER II

PROBLEM STATEMENT

Approximately twenty to twenty five percent of construction expenditure in the United States is comprised of public work (U.S. Census Bureau 2011a). The long recession of late 2000's, also called as a great recession started in Dec 2007 and is considered comparable or even worse than that of the depression in the 1930's (Gascon 2009).

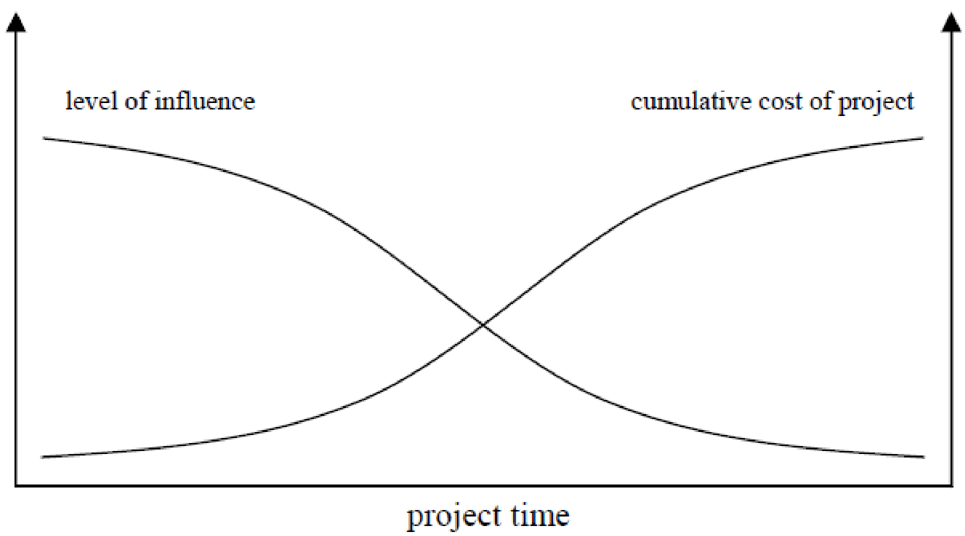

Figure 1: Influence/Cost Diagram (after Paulson 1976)

It becomes extremely critical during such times for public entities to make full justice to public assets. Boyd Paulson (1976) suggested relationship between level of influence and cumulative cost of project as shown in figure 1. He found that the level of influence is high during the early stages of construction and gradually reduces over the project life. Similar well-known preposition was made by Patrick McLeamy, CEO, HOK at the 2004 Construction User's Roundtable to illustrate advantages of IPD.

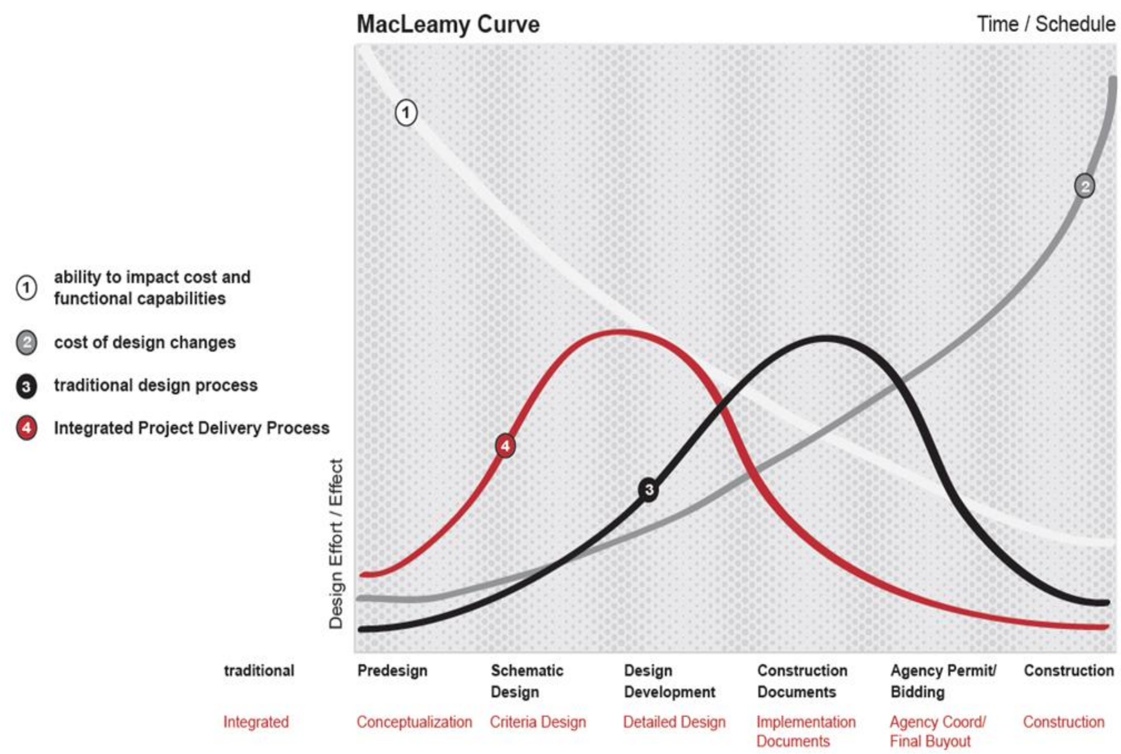

Figure 2: The Mcleamy Curve (Mcleamy 2004)

The McLeamy curve, as shown in figure 2, plots correlation between ability to affect cost, cost of design changes, historical workflow, and integrated project delivery workflow over the successive timeline of a project. This hypothesis has been tested and proved true several times by several researchers over number of years. Collaborative project delivery gives the owners benefit of having major role players of projects involved in early stages of design and construction. The integrated processes, thus, reduce time delays, waste of motion, material and labor and save money as they are driven by collaboration and teamwork (Wilhelm 2007). Hence there is a need for cost analysis to be done on collaborative projects. Although there are many ways to compare performance of a delivery system on cost, due to constraints on time, cost changes only on change orders and construction are analyzed under this study .This study tests the following hypotheses:

- $C.O._{\$/collaborative} < C.O._{\$/non\text{-}collaborative}$
- $C.S._{\$/collaborative} > C.S._{\$/non\text{-}collaborative}$

Where,

$C.O._{\$/collaborative}$ is cost of change orders in collaborative projects (CMR)

$C.O._{\$/non\text{-}collaborative}$ is number of change orders in non-collaborative projects (CMR)

$C.S._{\$/collaborative}$ is cost benefits in collaborative projects (CMR)

$C.S._{\$/non\text{-}collaborative}$ is cost benefits in non-collaborative projects (CMR)

CHAPTER IIII

RESEARCH GOALS AND OBJECTIVES

Research Goals

The primary goal of this research is to compare the benefits achieved within integrated delivery systems over the cost incurred to attain those benefits with the same for non-integrated delivery systems. It is possible to create production systems that reach the seemingly impossible end goals through collaboration of all project participants at early stages of planning (Ballard et al. 2001). Goal of this study is to investigate if the amount of upfront cost required for creating such production systems reaching impossible goals is significantly worth for the owners.

Research Objectives

The first objective for this research is to perform preliminary benefit cost analysis public educational facilities done under CMR and Competitive Sealed Proposal (CSP). CSP is similar to traditional Design-Bid-Build (DBB), except the contractor is selected on 'best-value' approach (Thomson 2004). The second objective is to find if there are considerable differences between benefits achieved within CMR and CSP education facility projects for public owners.

"Benefit-cost analysis can play an important role in legislative and regulatory policy debates on protecting and improving health, safety, and the natural environment" (Arrow 1996). Results from this study are expected to help shape legislative policies regarding alternative project deliveries for public work. The third and last objective of

this study is to generalize the results by validating them using the same testing methodology on industrial projects with similar size, scope, budget and duration span. Validation using a secondary database is expected to help establish confidence in inferences drawn from this research.

CHAPTER IV

SIGNIFICANCE OF THIS STUDY

Legislative policies are lagging behind while the agreement on need of wider possibilities of alternative project delivery methods for public work is increasing rapidly. Based on the Construction State Law Matrix updated annually by the Associated General Contractors of America, 16 states still do not permit use of CMR delivery system for horizontal public works while 10 states permit within certain limitations (AGC 2010). One of the frequently asked questions about Integrated Project Deliveries, as posted on AIA website (2011) is, "*Some professionals insist IPD is expensive to implement (especially in training costs associated with BIM and collaboration). What is the value proposition for Integration?*" Recent research done at Texas A&M University done on Texas elementary school projects states that CSP (a non-collaborative project delivery method) saved a tremendous $4000 per student over CMR (Reinisch 2011). The research was based on data collected by surveys sent to superintendents. After looking at the results, even the researcher agrees that there could be mixing up between total project cost and cost of construction by the superintendents. This research did not consider the degree of collaboration achieved by early involvement of the contractors during design phases. Based on personal conversation with Leslie H. Feigenbaum, there persists distrust on the benefits that are usually expected from collaborative project deliveries like CMR. Also, no specific previous research was found that established a correlation between cost and levels of collaboration achieved on projects, although notes are provided on the potential impact of different systems (Skitmore and Thomas 2003). All the above establish a need to test similar hypothesis on a different dataset with accurate costs for construction and benefits incurred.

Assumptions

This study is based on following three assumptions. The first is that all the projects, irrespective of the change in contractor or architect/engineer, have closely the same degree of collaboration since the owner is same for all projects. The second assumption is that CMR is very close to IPD, CSP is very close to DBB, and hence the results of this study will make a foundation for comparative benefit-cost analysis between the two extremes that are IPD and DBB. The data includes projects of varied typologies; ranging from research facilities, recreational facilities, laboratories, offices, administration to health care. Thus, the final and the third assumption made as a basis of this study is that the building typologies of projects within data do not have any influence on their benefit-cost ratio.

Delimitations & Limitations

Scope of this study (delimitations) is restricted to comparison between non-multi party collaborative contracts between owner and the general contractor/ construction manager and best value non-collaborative contract that is CSP. I understand that the most ideal cost comparison to solve the problems set at the center of this study is between IPD and DBB. But since there is a time as well as accessibility constraint on data available to us students, I have tried to analyze the difference between benefit over cost only for CMR and CSP projects. The owner ensures a certain degree of collaboration between important parties involved on projects within the dataset used for this study and is highly involved with the project developments throughout the phases of design and construction. As there are several levels of collaboration even within CMR delivery approach (Thomson 2004), the results of this study may not be applicable for all CMR projects with varied levels of collaboration. In addition, since the data does not contain any IPD as delivery approach projects, the purest form of IPD with an integrated multi-party contract might not follow the findings of this study. It is expected that the study results will be used as a basis for triggering research on cost analysis of IPD projects. Similarly, change in cost percentages for projects using CSP delivery approach may be different from those using DBB, as CSP contractors are selected on best-value basis. It is observed that in case of many CSP projects, a small extent of value engineering on an accepted design can be observed to be facilitated by owner. This might affect the cost performance on these CSP projects. Thus, the findings from this study cannot be expected to be replicated by all CSP projects. Due to constraint on time available to complete this research, the researcher will not be able to provide any corrections for the above restraints within the data. The data is restricted to certain delivery processes and will not completely generalizable for the rest.

CHAPTER V

LITERATURE REVIEW

Prior Work on the Problem

Variations in project objectives gave birth to different project delivery systems. With evolution and experimentation of these techniques, construction researchers have attempted to better understand the benefits of these systems (Konchar and Savio 1998). Following are some examples of studies on various delivery systems. Successes and failures of various delivery systems have been studied over years by several researchers in the forms of case studies (Reina 1997). Others have conducted opinion surveys of clients who frequently procure design and construction services to investigate attitudes toward specific delivery methods (Songer and Molenaar 1996). Several case studies of industry builders and clients, such as the U.S. Postal Service, explain variations in the way project delivery systems are administered both privately and in the public sector (Bruns 1997). Three principal project delivery systems being used in the United States today are identified as CMR, design-build (DB) and DBB (Konchar and Savio 1998). There has been research where a comparison between cost changes and delivery methods has been tested by researchers. (Konchar and Sanvido 1998) found that generally DBB projects face 5.2% more change orders than DB projects. CMR has many advantages as selection of contractor based upon qualifications, experience and team; design phase assistance by contractor in budget and planning, continuous budget control, screening of subcontractors, quality screening, faster schedule than traditional bid; fast track construction etc. A comparison of delivery systems, completed by CII/ Penn State University on constructions in the United States, states that CMR costs 1.5% less than DBB, completes 5% faster than DBB, and performs equal to or better than DBB on most quality measures (Konchar and Sanvido 1998). However, substantial efforts by owners to downsize in-house project management manpower, costly disputes between design and construction parties, and various levels of owner experience have forced several owners toward single source DB contracting (Dell'Isola 1987). Rojas and Kell (2008) studied successfully completed construction projects based on the degree of collaboration and established that the degree of collaboration/integration has a significant relationship with the team practices imposed by the project procurement approach. The research was completely survey based and made no comparisons with the cost benefits achieved on the projects based on the level of integration and delivery system. Pocock (1996) developed a method for assessing the control of project integration over the performance of public sector projects and used multivariate analysis techniques to compare the budget, duration and quality performance of 332 DB and DBB projects recently build in the United Kingdom. Development of a team involving the owner, the design professionals, and the CM/contractor without deviating drastically from the traditional legal framework is possible with the use of CMR delivery approach. The Associated General Contractors of America (AGC) describes three levels of collaboration to elaborate integration achieved on construction projects, as shown in figure 3. Following are the three collaboration levels established by AGC:

- Collaboration Level One – *Typical*; collaboration not contractually required

- Collaboration Level Two – *Enhanced*; some contractual collaboration requirements
- Collaboration Level Three – *Required*; collaboration required by a multi-party contract (NASFA et al. 2010). The projects that fit the second level of collaboration is be considered for this study, which are closest to multi-party IPD delivery system.

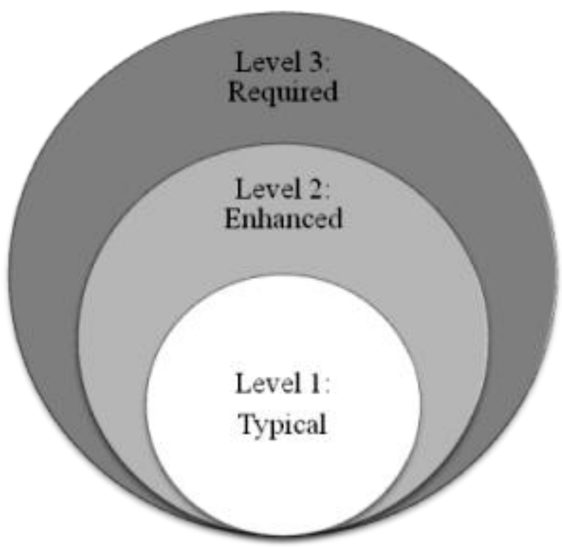

Figure 3: AGC Levels of Collaboration (AGC 2010)

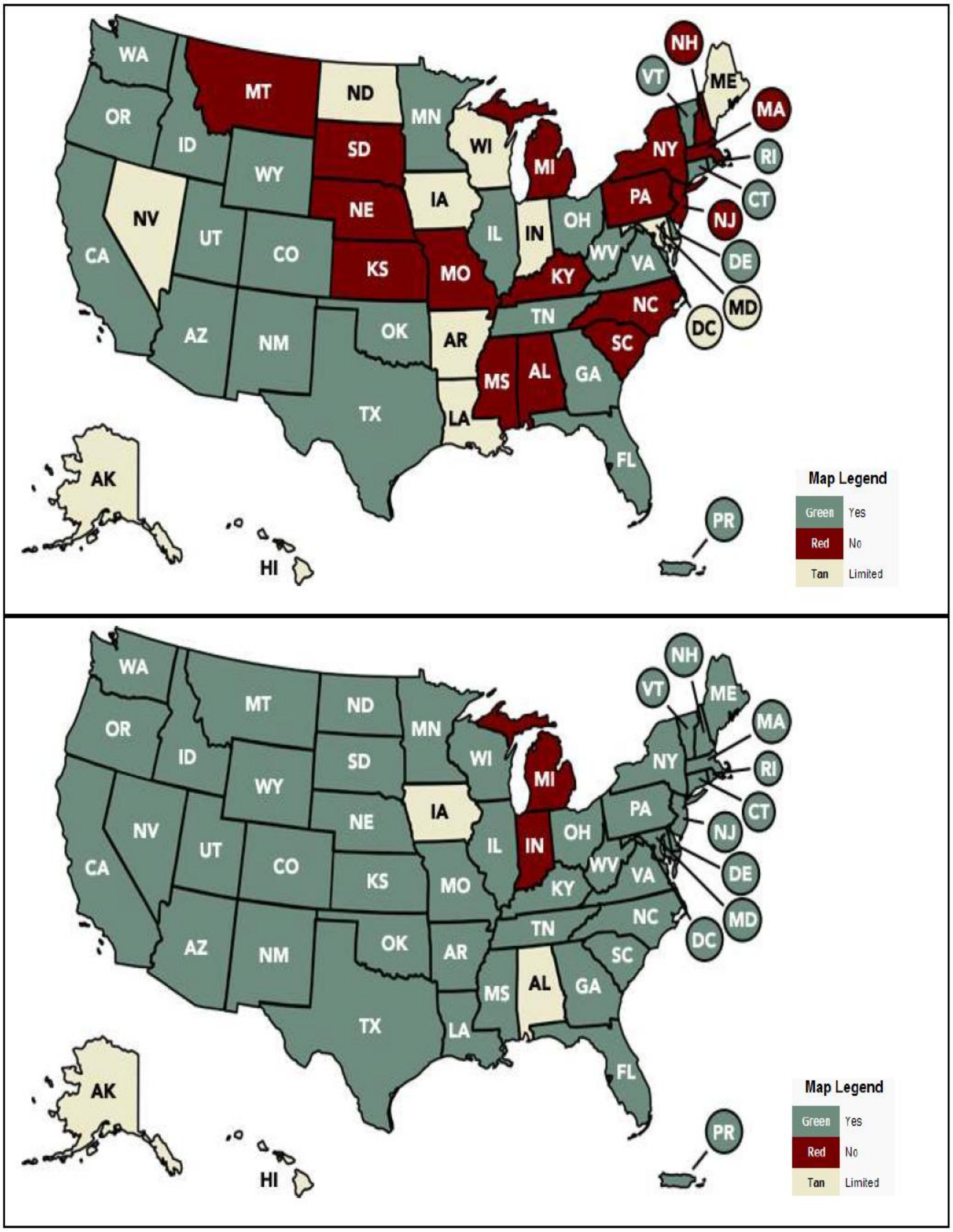

Figure 4: Construction State Law Matrix on CMR, Top: Horizontal Construction, Bottom: Vertical Construction (AGC 2010)

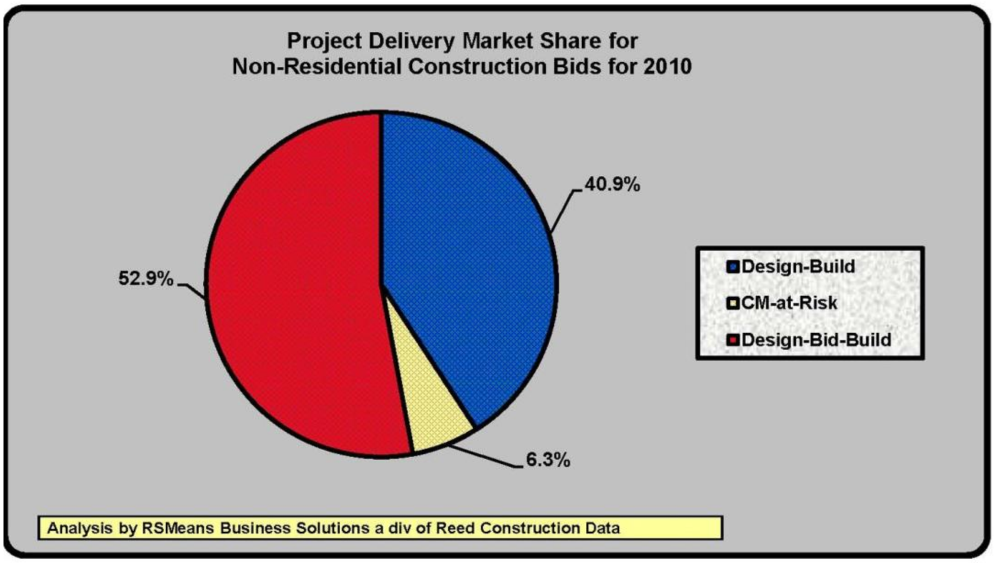

Figure 5: DBIA Project Delivery Preference Matrix (DBIA 2010)

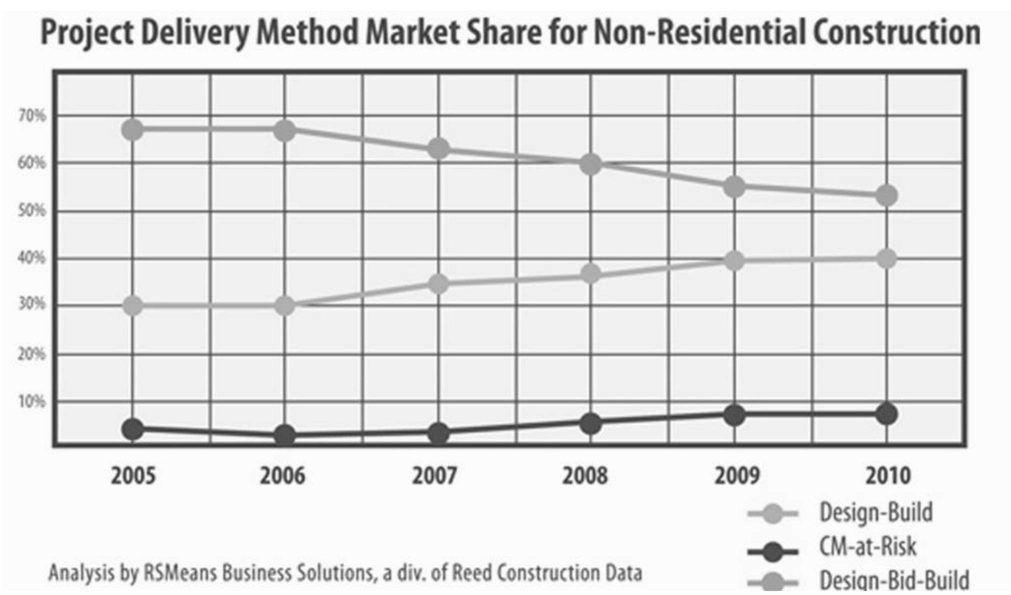

Figure 6: DBIA Project Delivery Market Share (DBIA 2010)

The regulation for vertical public works is better than horizontal. Only two states prohibit CMR for vertical public projects and three states allow them under limitations as shown in figure 4.

In spite of various benefits observed within CMR delivery, only 6% of non-residential construction uses CMR as a delivery approach on projects (DBIA 2010). Although market share for traditional DBB is reducing, the balancing increase is observed in DB projects rather than CMR, which is considered equal in terms of level of collaboration, as shown in figures 5 and 6.

This study is a comparision between collaborative and non-collaborative project delivery methods. As mentioned earllier DBB and CSP are exactly the same under the aspects of collaboration and early involvement of key parties. Similarly CMR is similar ro IPD as suggested by the AGC matrix for levels of collaboration as shown in Table 1. Although it is desirable to analyse differeces between DBB and IPD for ideal results, CSP and CMR projects is used for this research as a proxy for the most extreme ends of the project delivery range because of unavailability of data on IPD projects within the state of Texas.

Table 1: IPD: Degrees of Collaboration (AGC 2010)

	Classic Collaboration	**Non-multiparty IPD**	**True IPD**
Level of Collaboration	**low** →		**high**
Delivery Approach	CMR	CMR/DB	IPD
Contractor hired	at 25% - 75%CDs	Programming/ before 25%SDs	Project Development
Nature of Agreement	Transactional	Transactional	Relational
Basis of reimbersement	GMP	GMP	EMP
Legal framework	No contract language for collaboration	Contract languague for collaboration	Legally enforced Collaboration

Many other references also indicate that the projects chosen for this study are IPD-like. For example, IPD project delivery increases transparency between the stakeholders, mangers and laborers, while CMR projects under dataset used for this study use an 'open-book' approach establishing transparency between parties. Major stakeholders are involved in the project during early design phases like front end planning and design (Ballard and Howell 2000).

Figure 8 shows Competitive Sealed Proposal (CSP) is the closest to the traditional Design-Bid-Build (DBB) delivery method. Architect/Engineer on projects selected for this study were engaged during the programming or conceptual design stage of each project as shown in figure 9. The only difference between these two delivery systems is that the contractors are selected on a 'best-value' in case of CSP and on 'low bid' in case of DBB. Thus, CSP is a close cousin of traditional DBB project delivery as can be seen from figure 7.

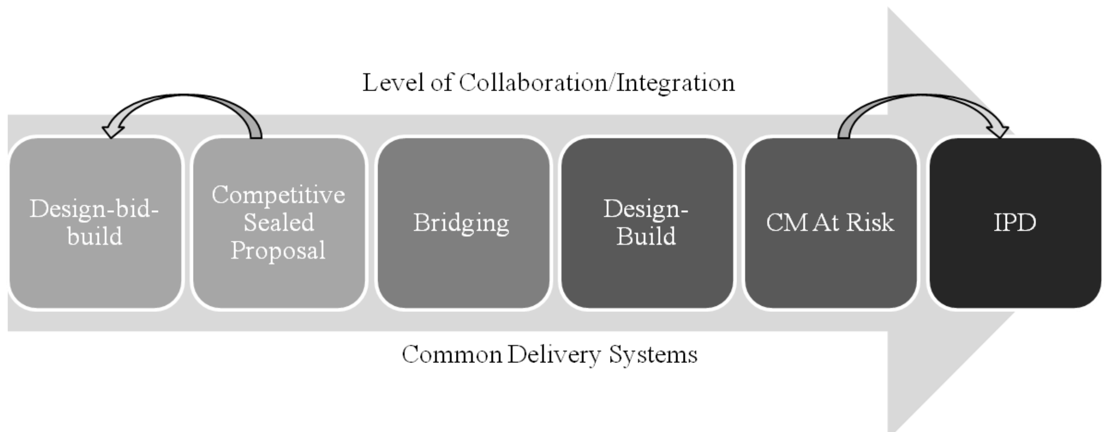

Figure 7: Increasing Degree of Collaboration (Illustration by Author)

There are certain difficulties involved to perform a comparative analysis between IPD and DBB. There is very little data on IPD accessible to students while it is rare for DBB and other collaborative projects by same owner to occur during the same time range. Hence, the delivery systems closest to the ideals are chosen for this comparison.

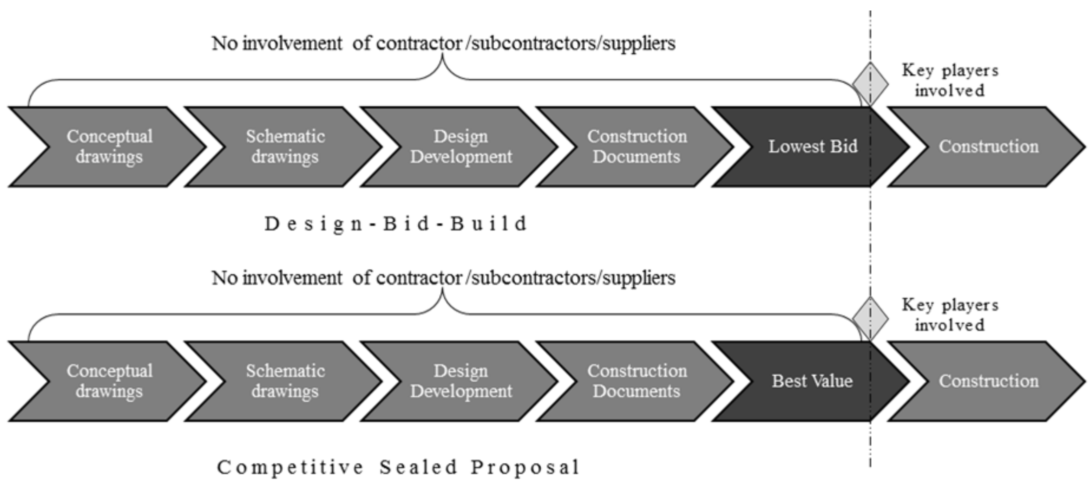

Figure 8: Typical Project Timelines for DBB and CSP (Illustration by Author)

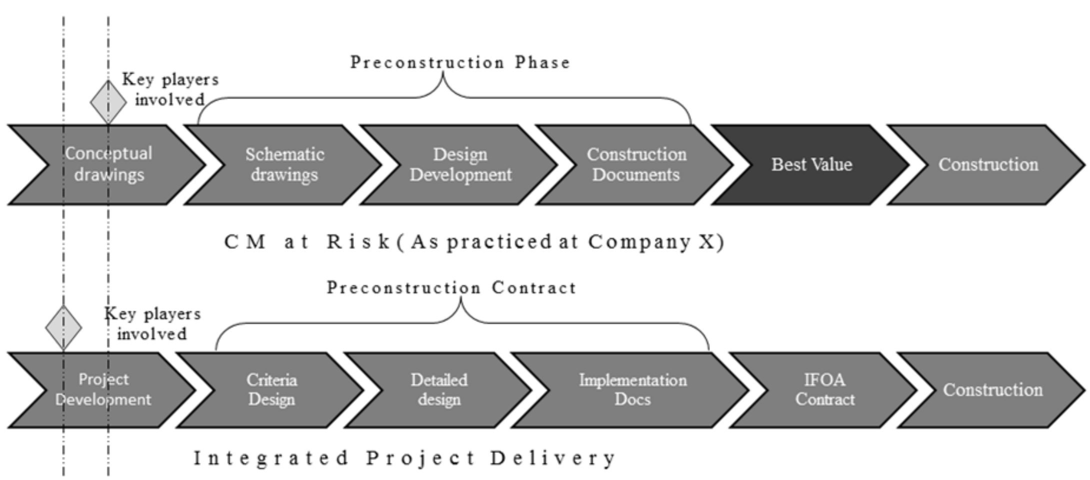

Figure 9: Typical Project Timelines for CMR and IPD (Illustration by Author)

CHAPTER VI

METHODOLOGY

Sources of Data

The source of data used for this study is one of the largest systems of higher education in the nation, serving 11 universities, 7 state agencies and a comprehensive health science center. The source entity acts as a public owner and currently in a phase of gradual shift to more collaborative methods like CMR and Design-Build. The source is termed as 'Company X' throughout this study for the sake of writing convenience. The data is collected over time through personal communication with Company X. After establishing a relationship of trust with the source, most data was gathered through email communication with Company X. The data was sent to researcher in the form of project reports and change order logs. Change order information for different projects needed for this research was segregated out from the reports while data for budgeted costs and actual construction costs were compiled and provided by the source itself. The actual dataset from Company X can be found in Appendix A,B and C. Due to confidentiality requested by the source of data, the researcher cannot reveal any other details regarding the entity and their projects. The data for validation of the findings from this study is taken from Construction Industry Institute (CII). The data is pulled from version 10.5 of Large Project Questionnaire of Benchmarking and Matrix Project Surveys by CII. This research is designed to be a quantitative research. Stratified random selection is used to collect the data. A dataset of total 30 projects of delivery systems (CMR & CSP) is considered for statistical testing.

Research Method and Analysis

The study consists of two parts. First is to compare the costs incurred due to change orders in CSP and CMR projects. The whole idea behind collaboration of parties in early stages of design is to eliminate unnecessary rework both before and during construction. Based on the logic, CMR, the collaborative system, should have significantly fewer costs incurred due to change orders than CSP, the non-collaborative system. Change orders have negative impact on many aspects of construction such as budget overruns, delays in completion, relationship between parties due to potential disputes, and even labor efficiency. Hence reduction in change order cost can be seen as a major benefit of collaborative construction delivery systems.

Company X uses following change orders categories to maintain their logs:

Category	Relevance
1. Errors	Relevant to this study
2. Omissions	Relevant to this study
3. Design Modifications	Relevant to this study
4. Changed Conditions	Irrelevant to this study
5. Unforeseen Conditions	Irrelevant to this study
6. Owner requirement	Irrelevant to this study
7. User Requirement	Irrelevant to this study
8. Weather Delays	Irrelevant to this study
9. Other	Irrelevant to this study

The only categories included in this study are: Errors, Omissions and Design Modifications. It is assumed that project delivery system had no impact on cost incurred due to the rest of the categories.

The mean Errors' cost for CSP is observed to be only slightly greater than CMR while the mean Omissions' cost in CSP exceeds by $102,499.09. Even higher difference of $ 262,339.80 can be seen in mean Design Modification's costs. The difference in means of total change order costs for CMR and CSP data is $376,703.10, CSP being on the higher side. The absolute values of change orders are normalized by taking their percentages over total construction cost. Ranges of percent change orders are shown in figures 10-18.

Student's t-test for comparing means cannot be used here since the sample sizes are less than 30. The non-parametric version of sample t-test, Wilcoxon Rank Sum test or the Mann-Whitney-U test is used for the statistical analysis of the change order data for this study. Although the Mann-Whitney-U test does not assume normality of underlying population, it does make an assumption of same variances of the two populations being compared. Hence, a non-parametric Levene's test is required to be done on the data before proceeding to the Mann-Whitney.

Non-parametric Levene's test is done by ranking the data irrespective of the sample categories and then performing a one-way Anova on the difference between the ranks of sample points and their respective means. The data for Company X is tested on above principles for statistical significance in SPSS. From the SPSS Levene's test results, it was clear that there is no significant difference between the variances of underlying populations for any of the percent change order cost data for CMR and CSP projects, which strengthens the power of Mann-Whitney results on all the above samples.

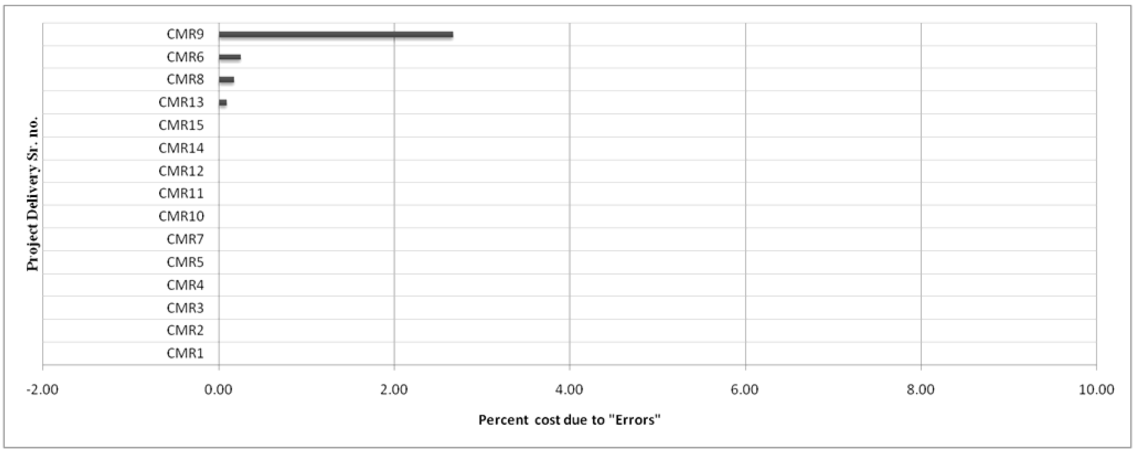

Figure 10: Percent Costs Incurred in CMR Projects due to "Errors"

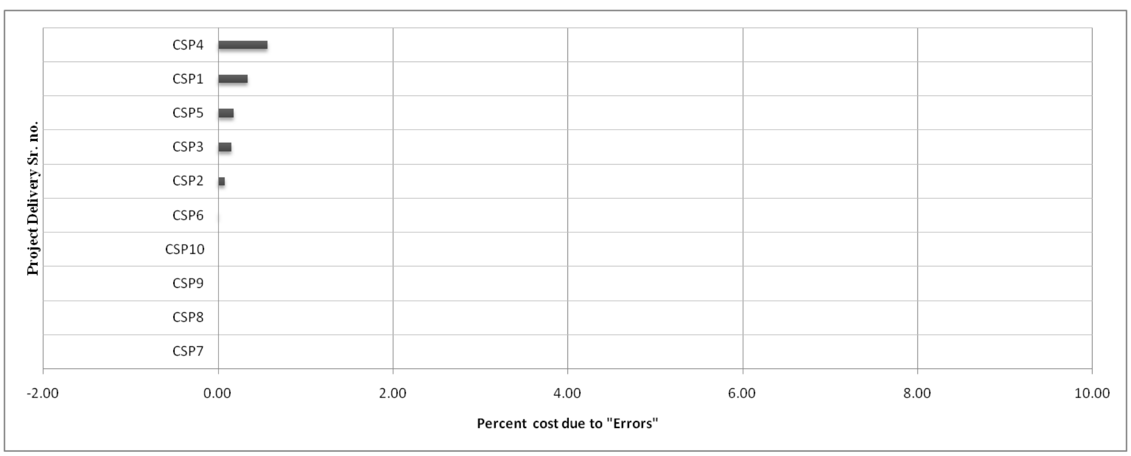

Figure 11: Percent Costs Incurred in CSP Projects due to "Errors"

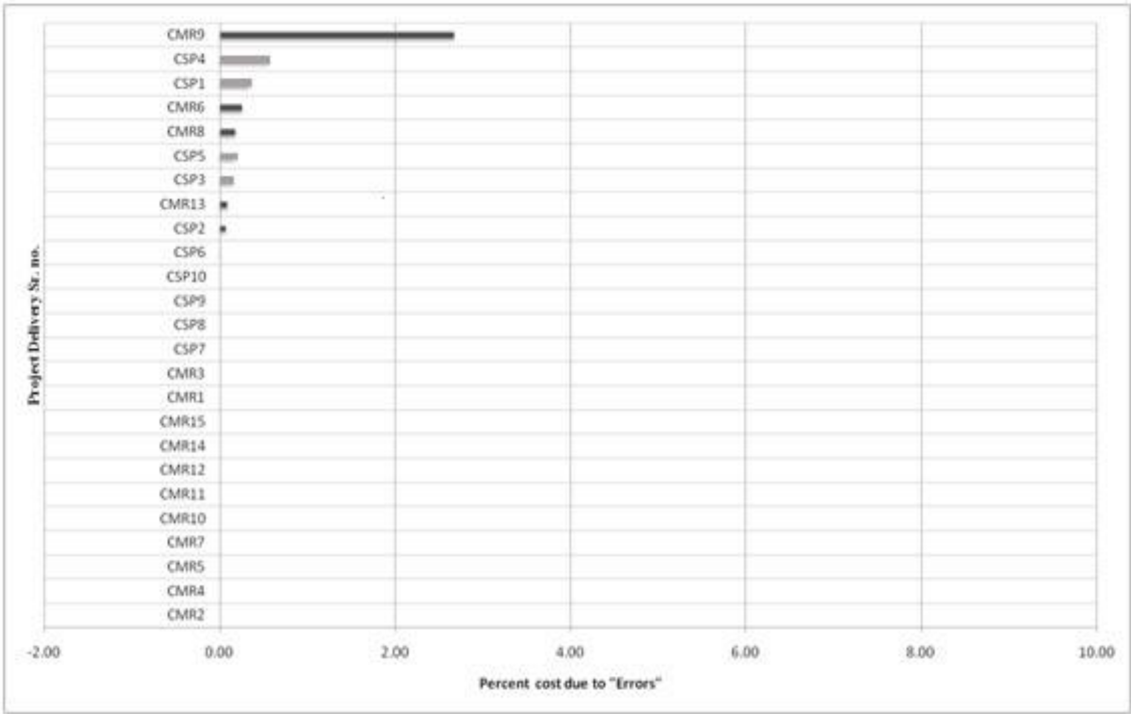

Figure 12: Percent Costs Incurred for All Projects due to “Errors”

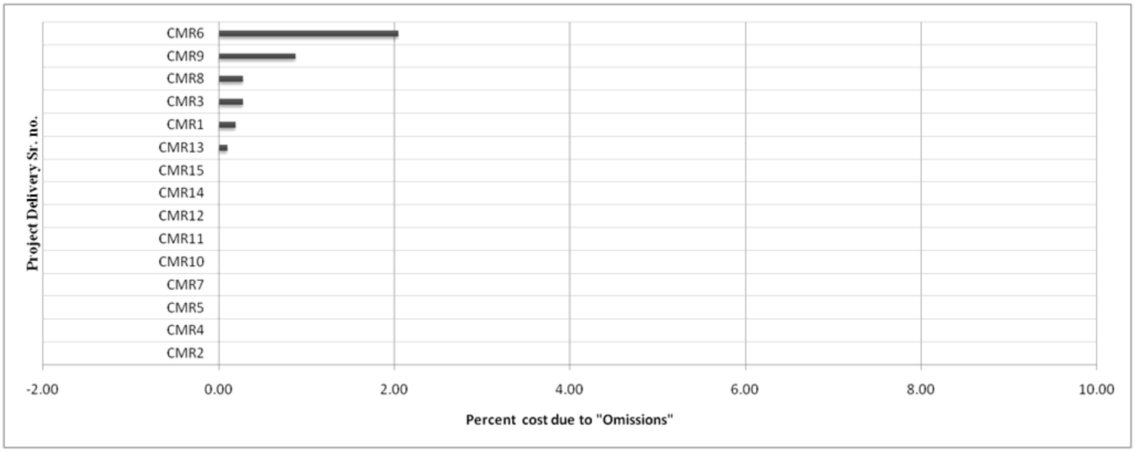

Figure 13: Percent Costs Incurred in CMR Projects due to “Omissions”

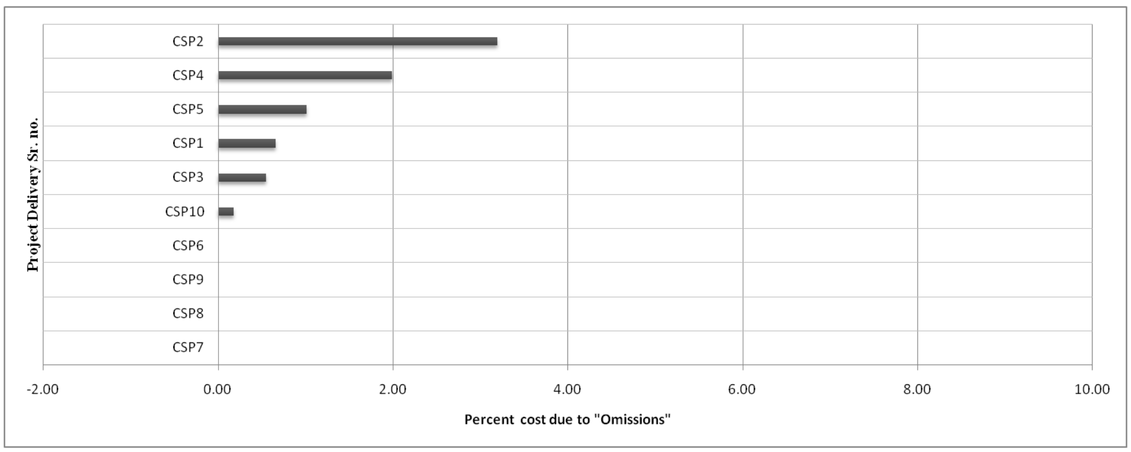

Figure 14: Percent Costs Incurred in CSP Projects due to “Omissions”

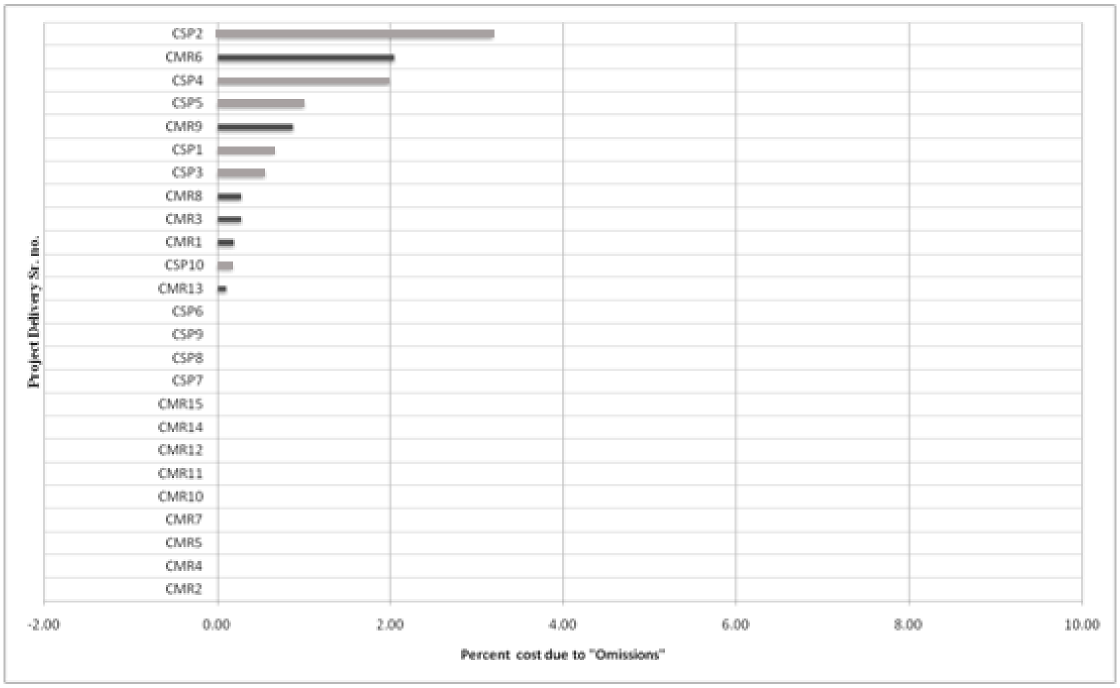

Figure 15: Percent Costs Incurred for All Projects due to “Omissions”

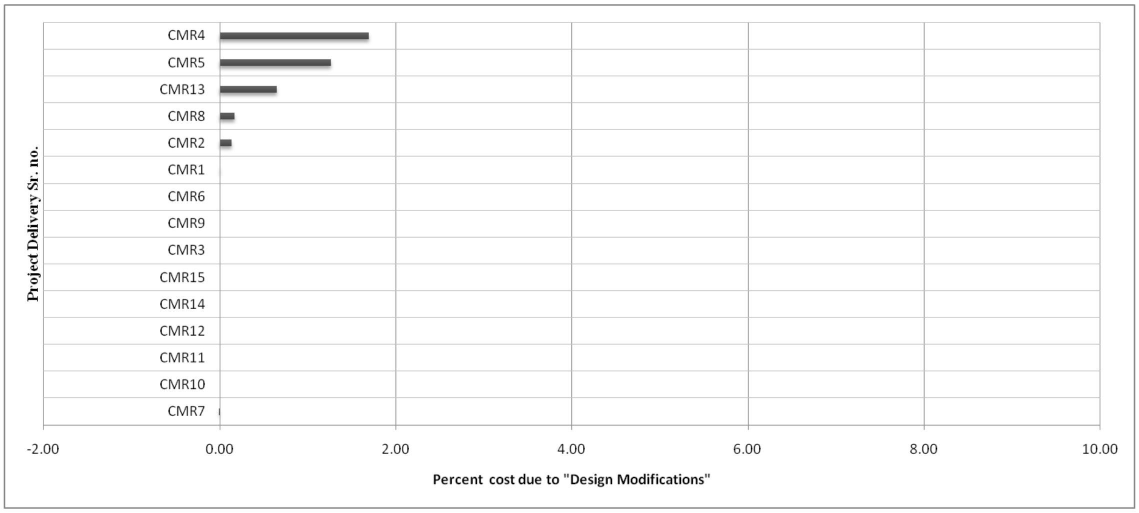

Figure 16: Percent Costs Incurred in CMR Projects due to "Design Modifications"

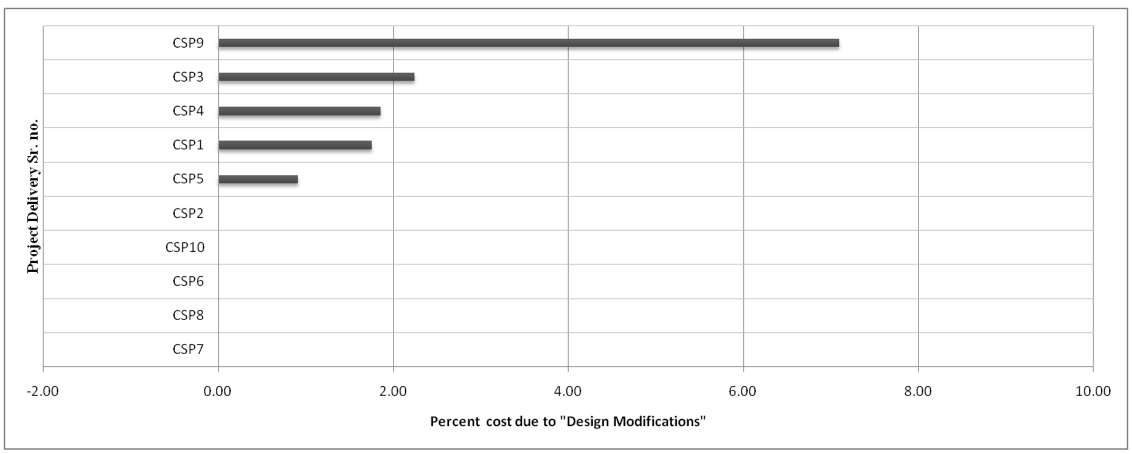

Figure 17: Percent Costs Incurred in CSP Projects due to "Design Modifications"

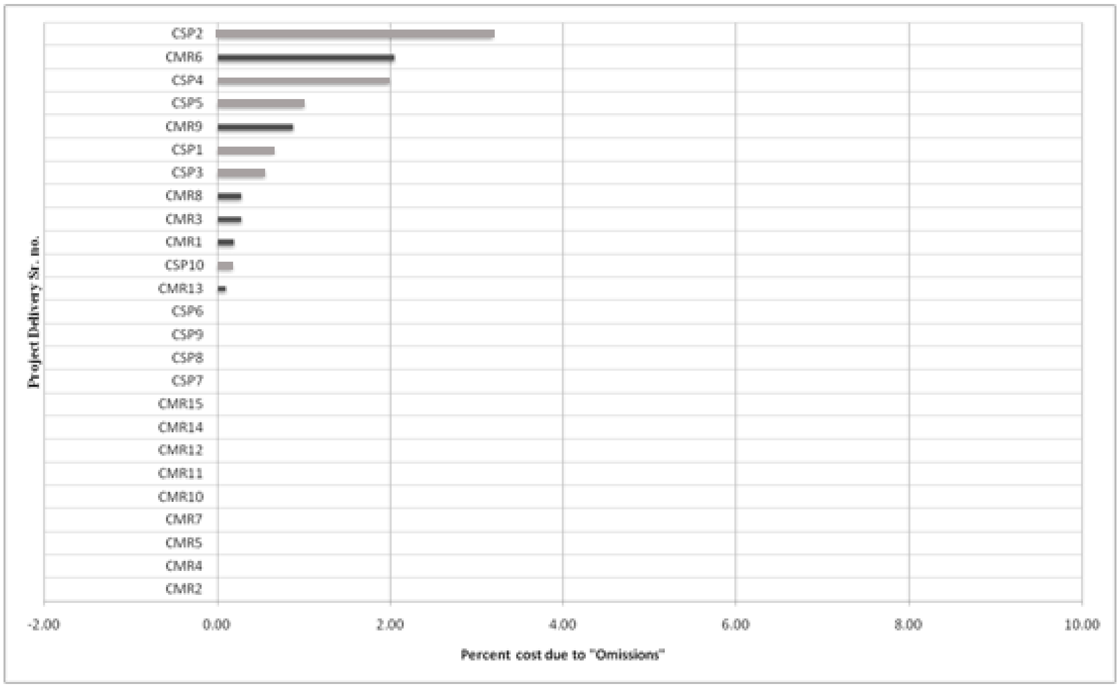

Figure 18: Percent Costs Incurred for All Projects due to “Design Modifications”

Wilcoxon Rank Sum or the Mann-Whitney test is performed to statistically analyze significance of difference between CMR and CSP change order data as well as cost performance data. The results showed that there is no significant difference between the percent savings achieved under CMR projects and those under CSP projects. The estimated budget available for construction and corresponding actual construction costs were provided by Company X. The cost savings are calculated as the difference between the expected and actual costs on each project. To reduce the influence of size of projects, percent values of savings over the expected are considered for statistical testing.

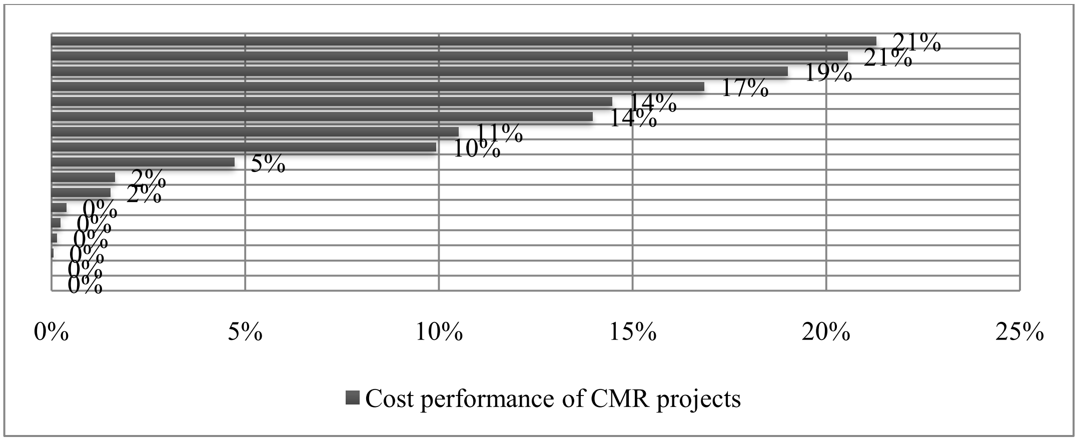

Figure 19: Cost Performance for CMR Projects by Company X

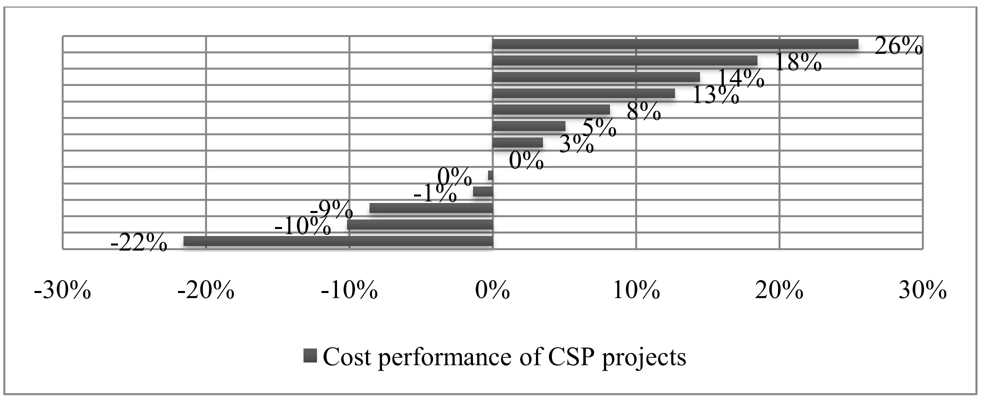

Figure 20: Cost Performance for CSP Projects by Company X

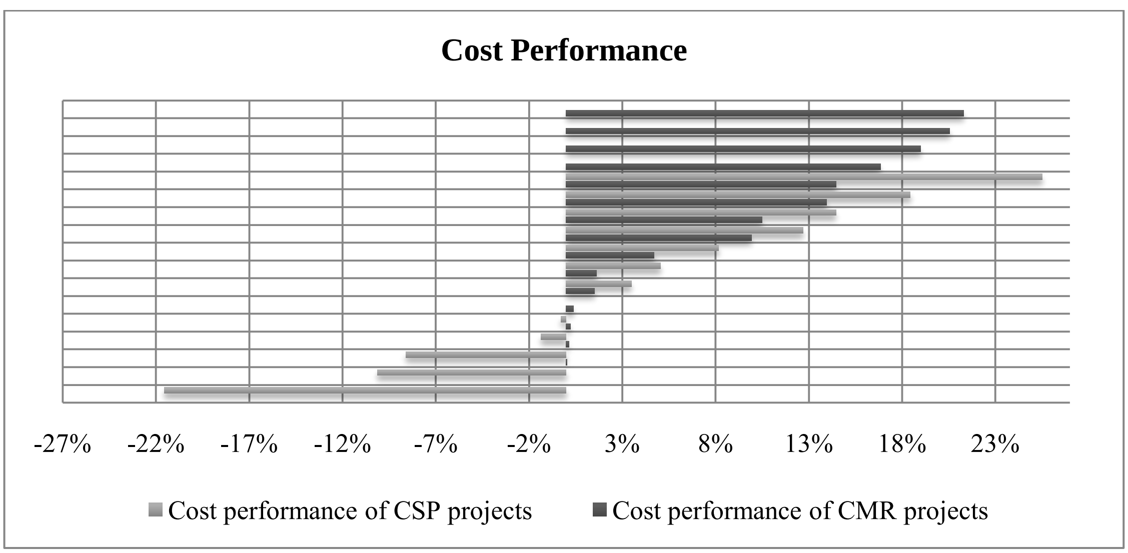

Figure 21: Cost Performance for CMR and CSP Projects by Company X

Following formulae are used to calculate the percent change order costs and cost performances of each project in the database:

- Percent change order cost= cost of change orders/ budgeted cost of project* 100
- Percent cost performance= (budgeted cost- actual cost)/ budgeted cost of project*100

It can be observed from data represented in figures 19, 20 and 21 that the range of CSP data approximately doubles that of CMR. The Levene's test results on the percent cost savings data suggested that there is no significant difference between the underlying populations of CSP and CMR projects. The Mann-Whitney results of this test clearly show that percent savings in CMR are significantly greater than CSP.

CHAPTER VII

VALIDATION

The results of the study are weighed against the data that has been collected by CII through their Questionnaire of Benchmarking and Matrix Project Surveys. CII dataset contains projects with Total Project Cost greater than $5Million, duration longer than 14 months, completed within 2007 & 2009 and managed by dedicated project team (CII 2010). The dataset is categorized under typologies such as buildings, heavy industrial, light industrial and infrastructure. The data is from 21 different countries including the United States. The original dataset contained 1945 projects with various delivery methods. Only CMR and DBB projects are considered for validation of this study. As the data is collected through survey questionnaires, there are extreme outliers in the data.

The sample size for CMR is 86 and that for DBB is 279. CMR project data does not indicate if the contracts were guaranteed maximum price contracts and hence even negative project savings or losses can be observed on projects within this dataset. Project savings are calculated as a difference between expected cost (budget) and final project cost. Outliers as strong as 60% to -120% are found in the data. It can be speculated that scope additions and hence budget revisions were probably not included for some projects in this dataset. Although the data include majorly industrial and building facilities, the large sample size is expected to provide compelling results for validation of results of this study. Due to constraints on time, the researcher was unable to carry detailed analysis for validation dataset leaving an opportunity open for future researchers. Size of this dataset fits the requirements of student's t-test. However, non-parametric testing is considered more robust than parametric. The advantage of nonparametric methods over their parametric counterparts is the absence of assumptions about the distribution underlying population. Hence, non-parametric Mann-Whitney U test is used for the validation process as well. The percent data is shown in figures 22 and 23. Mann-Whitney results on CII data confirmed only the first hypothesis of this study. Percent savings cost is found statistically significantly greater in case of DBB than CMR projects while the percent change costs for CMR is found to be lower than those under DBB.

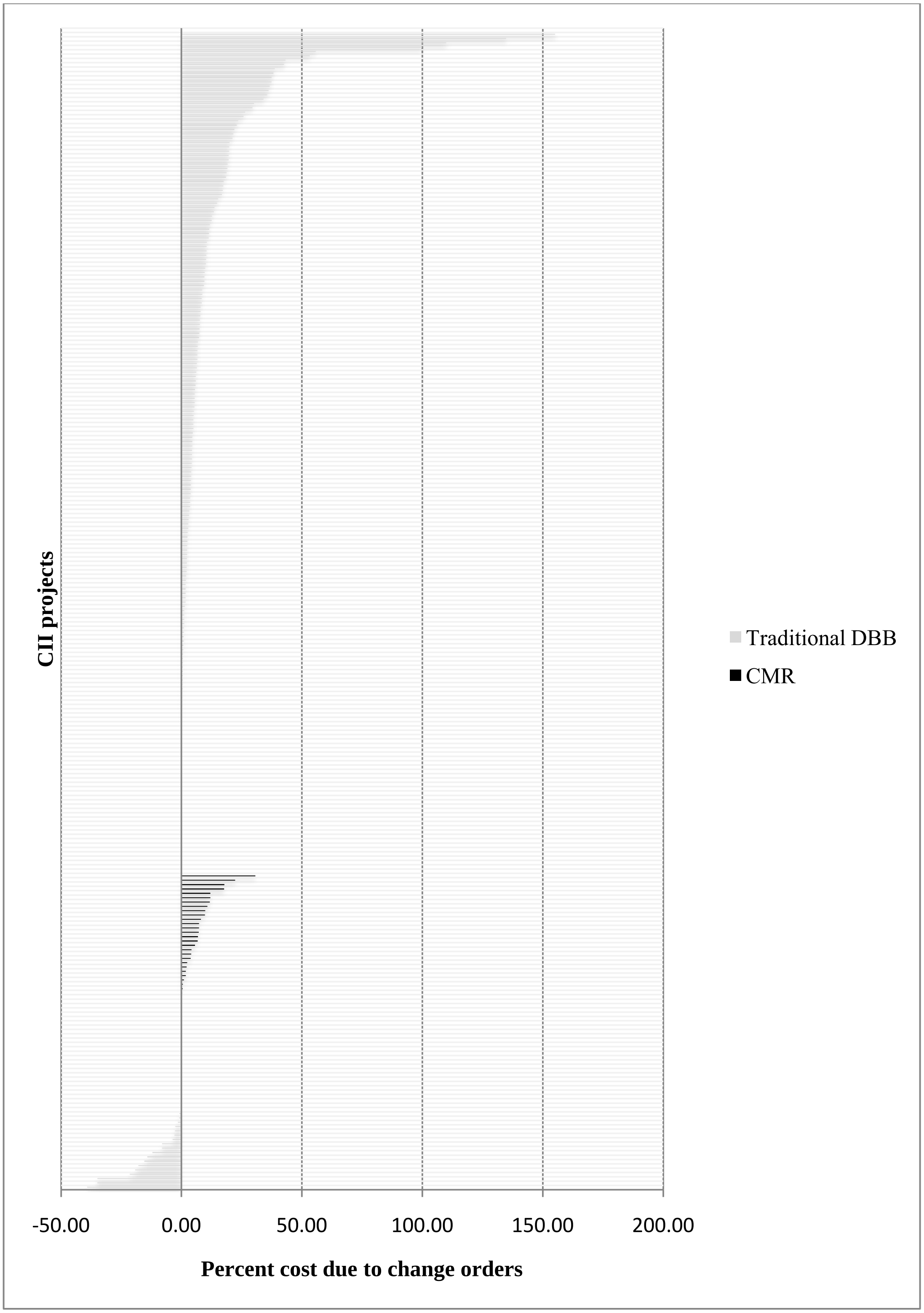

Figure 22: CII Total Project Change Data

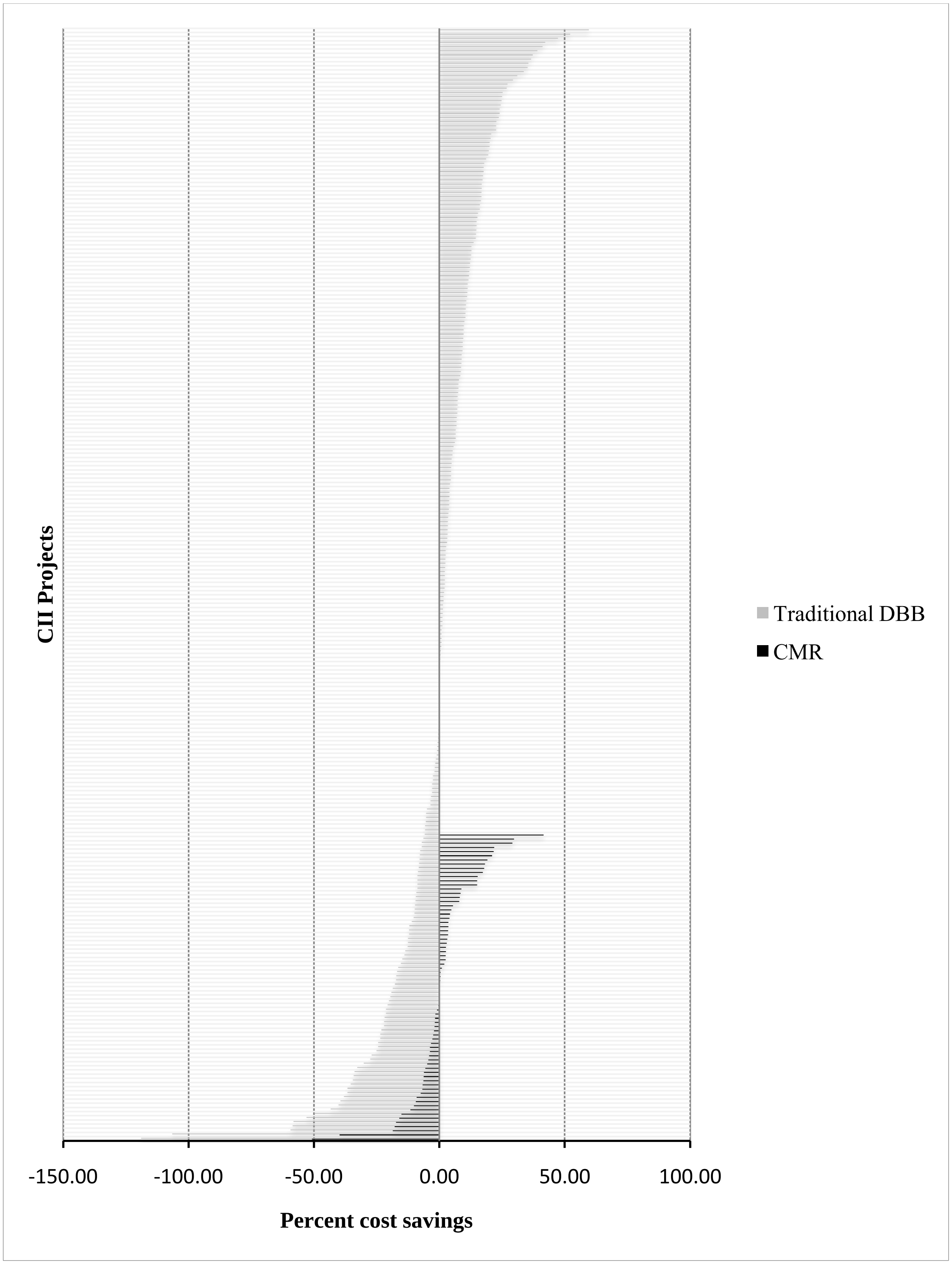

Figure 23: CII Percent Cost Savings Data

CHAPTER VIII

CONCLUSION

The purpose of this study was to compare the costs associated with change orders and savings for CMR and CSP projects by Company X. It was hypothesized that under collaborative method (CMR), the change order costs are reduced while the savings are increased. Only one of the above hypotheses has been proven right by the statistical testing that is the mean percent cost savings for CMR are significantly more than CSP. Statistical test on change order data show that there is no significant difference between their percentages over actual costs in both delivery methods. The same hypothesis is found to be right under the CII validation.

From the results, it is clear that the collaborative project delivery systems do save money for public owners. Unlike as hypothesized in this study, the savings do not have to come directly from reduction in costs of change orders. There might be several other reasons behind observed savings in collaborative delivery systems, which needs to be dealt into in detail by future researchers.

An informal poll on a professional networking site also indicates that CMR is considered more beneficial for public owners than other delivery systems. One of the respondents even went on saying, "*I did a lot of CMAR work while I was with Nestle. It beats the daylights out of DB and DBB. The GC sends his lawyer home and he[the contractor] sits next to you at the table to work on getting the project built. A lot of the adversarial relationship stuff between the designer and the builder goes away*".

Although this study does show substantially significant in CMR delivery approach over CSP, there is a need of qualitative research on the topic, which take into account the level of collaboration on projects. Results of this study indicate that public owners like Company X, who are moving from traditional delivery methods to more collaborative systems, are investing public funds in right direction.

In addition, it is also observed from the data that the level of uncertainty is extremely high in case of traditional DBB or CSP projects, while CMR give owner more control over his budget. Both Company X and CII data show a wide spread of percent changes on their DBB or CSP projects. Thus, as a result of this study, CMR can be assumed with confidence to be more desirable for more complex and risk prone projects.

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APPENDIX A

Project Delivery Method	**Change Orders**					
	Errors & Omissions			**Scope Change**		**TOTAL**
Sr. no.	**Error (A)**	**Omission (B)**	**TOTAL**	**Design Modifications (C)**	**TOTAL**	
CMR1	$ -	$ 156,801.00	$ 156,801.00	$ 4,143.00	$ 4,143.00	$ 160,944.00
CMR2	$ -	$ -	$ -	$ 37,000.00	$ 37,000.00	$ 37,000.00
CMR3	$ -	$ 118,052.00	$ 118,052.00	$ -	$ -	$ 118,052.00
CMR4	$ -	$ -	$ -	$ 302,458.00	$ 302,458.00	$ 302,458.00
CMR5	$ -	$ -	$ -	$ 202,116.36	$ 202,116.36	$ 202,116.36
CMR6	$ 40,479.00	$ 325,700.00	$ 366,179.00	$ -	$ -	$ 366,179.00
CMR7	$ -	$ -	$ -	$ (9,282.00)	$ (9,282.00)	$ (9,282.00)
CMR8	$ 64,429.00	$ 101,701.00	$ 166,130.00	$ 59,601.00	$ 59,601.00	$ 225,731.00
CMR9	$ 500,997.00	$ 164,510.00	$ 665,507.00	$ -	$ -	$ 665,507.00
CMR10	$ -	$ -	$ -	$ -	$ -	$ -
CMR11	$ -	$ -	$ -	$ -	$ -	$ -
CMR12	$ -	$ -	$ -	$ -	$ -	$ -
CMR13	$ 21,285.00	$ 24,262.00	$ 45,547.00	$ 158,570.79	$ 158,570.79	$ 204,117.79
CMR14	$ -		$ -	$ -	$ -	$ -
CMR15	$ -	$ -	$ -	$ -	$ -	$ -
CSP1	$ 178,786.00	$ 352,134.00	$ 530,920.00	$ 939,005.00	$ 939,005.00	$ 1,469,925.00
CSP2	$ 2,565.00	$ 115,989.00	$ 118,554.00	$ -	$ -	$ 118,554.00
CSP3	$ 22,707.00	$ 82,486.00	$ 105,193.00	$ 336,889.00	$ 336,889.00	$ 442,082.00
CSP4	$ 272,054.00	$ 965,927.00	$ 1,237,981.00	$ 900,568.00	$ 900,568.00	$ 2,138,549.00
CSP5	$ 18,199.00	$ 104,423.00	$ 122,622.00	$ 94,126.00	$ 94,126.00	$ 216,748.00
CSP6	$ 28.00	$ -	$ 28.00	$ -	$ -	$ 28.00
CSP7	$ -	$ -	$ -	$ -	$ -	$ -
CSP8	$ -	$ -	$ -	$ -	$ -	$ -
CSP9	$ -	$ -	$ -	$ 754,667.00	$ 754,667.00	$ 754,667.00
CSP10	$ -	$ 40,479.00	$ 40,479.00	$ -	$ -	$ 40,479.00

APPENDIX B

Project Delivery Method	Expected cost	Percent costs for Change Orders		
		%Errors	%Omissions	%Design Modifications
Sr. no.	(D)	A/D*100	B/D*100	C/D*100
CMR1	$ 82,926,346.00	0.00	0.19	0.00
CMR2	$ 28,336,847.00	0.00	0.00	0.13
CMR3	$ 42,575,000.00	0.00	0.28	0.00
CMR4	$ 17,847,790.00	0.00	0.00	1.69
CMR5	$ 15,977,568.00	0.00	0.00	1.27
CMR6	$ 15,900,000.00	0.25	2.05	0.00
CMR7	$ 63,310,005.00	0.00	0.00	-0.01
CMR8	$ 36,485,000.00	0.18	0.28	0.16
CMR9	$ 18,749,000.00	2.67	0.88	0.00
CMR10	$ 20,965,000.00	0.00	0.00	0.00
CMR11	$ 9,600,000.00	0.00	0.00	0.00
CMR12	$ 7,200,000.00	0.00	0.00	0.00
CMR13	$ 24,448,440.00	0.09	0.10	0.65
CMR14	$ 31,388,000.00	0.00	0.00	0.00
CMR15	$ 29,986,793.00	0.00	0.00	0.00
CSP1	$ 53,664,020.00	0.33	0.66	1.75
CSP2	$ 3,636,898.00	0.07	3.19	0.00
CSP3	$ 15,055,668.00	0.15	0.55	2.24
CSP4	$ 48,529,679.00	0.56	1.99	1.86
CSP5	$ 10,379,812.00	0.18	1.01	0.91
CSP6	$ 805,078.00	0.00	0.00	0.00
CSP7	$ 21,400,000.00	0.00	0.00	0.00
CSP8	$ 10,600,000.00	0.00	0.00	0.00
CSP9	$ 10,637,485.00	0.00	0.00	7.09
CSP10	$ 23,224,620.00	0.00	0.17	0.00

APPENDIX C

	A: Expected cost		B: Actual Cost				
Contract Type	**CMAR: GMP(Guaranteed Maximum Price)**		**CMAR-Buyout**		**Difference (Savings)**		**Percent Savings**
	CSP-AACC(Amount Available for Construction Contract)		**CSP-Bid**		**A-B**		**A-B/A*100**
CMR1	$	4,385,000	$	4,385,000	$	-	0%
CMR2	$	58,329,910	$	58,329,910	$	-	0%
CMR3	$	30,000,000	$	29,986,793	$	13,207	0%
CMR4	$	20,387,565	$	20,358,342	$	29,223	0%
CMR5	$	36,485,000	$	36,400,000	$	85,000	0%
CMR6	$	9,637,100	$	9,600,000	$	37,100	0%
CMR7	$	42,800,000	$	42,148,724	$	651,276	2%
CMR8	$	41,946,630	$	41,258,782	$	687,848	2%
CMR9	$	24,375,000	$	23,224,620	$	1,150,380	5%
CMR10	$	27,621,424	$	24,879,498	$	2,741,926	10%
CMR11	$	18,750,000	$	16,780,166	$	1,969,834	11%
CMR12	$	20,965,000	$	18,036,832	$	2,928,168	14%
CMR13	$	24,448,440	$	20,909,542	$	3,538,898	14%
CMR14	$	15,900,000	$	13,221,053	$	2,678,947	17%
CMR15	$	17,778,600	$	14,400,000	$	3,378,600	19%
CMR16	$	7,200,000	$	5,720,119	$	1,479,881	21%
CMR17	$	82,529,346	$	64,952,121	$	17,577,225	21%
CSP1	$	16,700,000	$	20,299,000	$	(3,599,000)	-22%
CSP2	$	9,884,000	$	10,885,000	$	(1,001,000)	-10%
CSP3	$	11,165,000	$	12,123,693	$	(958,693)	-9%
CSP4	$	15,600,000	$	15,811,299	$	(211,299)	-1%
CSP5	$	3,280,000	$	3,289,553	$	(9,553)	0%
CSP6	$	12,213,000	$	12,213,000	$	-	0%
CSP7	$	15,440,000	$	14,900,000	$	540,000	3%
CSP8	$	3,529,000	$	3,350,000	$	179,000	5%
CSP9	$	4,268,400	$	3,919,400	$	349,000	8%
CSP10	$	10,366,651	$	9,050,000	$	1,316,651	13%
CSP11	$	55,952,100	$	47,861,650	$	8,090,450	14%
CSP12	$	52,047,900	$	42,443,350	$	9,604,550	18%
CSP13	$	1,040,450	$	775,000	$	265,450	26%

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