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Evaluation of cost and schedule growth trends during construction

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EVALUATION OF COST AND SCHEDULE GROWTH TRENDS DURING CONSTRUCTION

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TRENDS DURING CONSTRUCTION

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CHAPTER I

INTRODUCTION

Background

Changes in project scope, budget, or schedule are a source of concern for owners, designers, and contractors alike. In recent years, there has been a growing concern regarding the quantity and magnitude of changes which often cause excessive cost overruns, delays in time of completion, and reductions in the quality of the constructed facility.

Most studies of project changes, or impacts of changes, have been directed toward dispute resolutions or craft productivity on a project. Studies related to dispute resolutions are usually focused on a construction claim which is related to a specific project. Numerous studies have also been conducted to evaluate the impact of craft productivity due to changes in project scope or schedule. Although both of these types of studies have significantly contributed to improving the management of projects, the results have often been directed at specific issues which only relate to a limited number of projects.

Little effort has been given to the study of multiple projects, to identify those factors that can be used to indicate potential changes in the original planned cost or schedule of a project. To better control project changes and improve the cost effectiveness of the construction industry, there is a need to document and verify factors, that are known before the start of construction, which are indicators of increased costs and delayed schedules.

In an effort to improve the cost effectiveness of the construction industry in the area of changes, the Construction Industry Institute (CII), a national organization that sponsors construction research, formed a Change Order Impact Task Force in 1989 to study the impacts of changes in projects related to costs and schedules. This research study has been accomplished as a joint effort between the researchers and members of the CII Change Order Impact Task Force team.

Purpose and Objective of the Study

The purpose of this research study was to evaluate numerous completed construction projects to identify those factors which were present in projects which experienced significant changes in their original planned cost or schedule. The study's intent was to macro examine quantitative and qualitative factors known about a project and to correlate those factors with changes in the cost or schedule of construction.

The intent of this research effort is to study multiple projects as a group at the macro level, rather than to study any one particular project at the micro level. The primary objective of this research was to identify factors which are known prior to the commencement of construction, which are indicators of project cost and schedule growth. Principle parties in a project, owners and contractors, can improve the cost effectiveness and overall management of a project if they know, in advance, those factors which should be closely monitored in order to control and manage the change in cost and schedule.

Scope of the Study

To achieve the purpose and objective of this study, quantitative and qualitative data were collected from numerous completed construction projects. These data were used to develop a series of trend curves which show changes in project costs and schedules with respect to time. Evaluation of the trend curves provided the basis for hypotheses which were formulated to identify factors which are indicators of cost and schedule growth. The hypotheses were statistically tested using a 90% confidence limit.

The study was conducted in two phases. The first phase involved the development of a questionnaire designed to collect project information related to project administration, cost, and schedule data. Development of the questionnaire was accomplished as a joint effort between the researchers and members of the CII Task Force Team, who represent many years of experience in the construction industry. The questionnaire was tested by Task Force members, using data from their projects, before it was distributed to the 81 CII member companies. Each company was asked to submit data from 10 projects completed within the past 5 years. Questionnaires were returned from 23 companies, representing 159 separate projects that involved $4.5 billion of construction work.

The second phase of the project involved analysis of data, development of trend curves, formulation of hypotheses related to cost and schedule growth, and identification of factors that are indicators of changes in cost and schedule of projects during construction.

A summary of previous research work related to quantitative analysis of project changes is discussed in Chapter II. Chapter III presents the data collection and organization, and discusses the formulation of the research plan, the population addressed, and the design of the data gathering tool.

Analysis of the data was separated into two categories; projects which were administered by a fixed price method of contracting and projects which were administered by a cost reimbursable method. This separation in analysis was necessary because the project strategy is significantly different between the two types of contracting. Generally, fixed price contracts are selected for projects when minimal changes are expected, whereas cost reimbursable contracts are selected when extensive changes during construction are anticipated. Therefore, cost and schedule growth patterns are considerably different between these two types of contracts for construction projects. An analysis of the data for fixed price and cost reimbursable projects is presented in Chapters IV and V respectively. Macro level cost growth trend curves and schedule growth patterns are presented based on median values. An analysis of the cost and schedule growth patterns in these two chapters was used to formulate the hypotheses that were developed in this research.

An assessment of cost and schedule growth trend curves and the results of statistical tests of the hypotheses, which were developed in this research study, are discussed in Chapter VI. The statistical testing was performed using average values rather than median values.

A brief discussion of "ripple effect", which is the result of the impact of changes, is presented in Chapter VII. "Ripple effect" is a term that is commonly used in the construction industry to describe successive changes which occur in a project as the result of a prior change or changes.

Chapter VIII provides a discussion of the industry Task Force suggestions for better management of the factors identified by this study. Finally, Chapter IX presents the summary, conclusions, and recommendations for future research. The questionnaire which was used in this research is shown in the Appendix.

Definitions

A "change order" is defined, for the purpose of this study, as a modification to a construction contract where the resultant impact on cost and time must be mutually agreed upon by the owner and contractor. The "cost growth" is defined as the increase in construction cost, taken as a percentage of the original contract dollar amount. The "schedule growth" is defined as the increase in construction duration, taken as a percentage of the original approved contract duration.

The "timing of changes" is an important issue in the study of project changes. When a change is issued before the beginning of construction the affected work items may have an effect on schedule and some processing fees, whereas, a change issued while construction is progressing may require rework of existing work and can have significant effects on schedules and crews. For this study the "timing of changes" is considered at 25% intervals of construction duration. These time milestones, called "quartiles", are defined in Webster's Dictionary as: the value which marks the boundary between two consecutive intervals in a frequency distribution of four intervals with each containing one quarter of the total population. These quartiles are used as a bench mark for this macro study of the accumulation of changes in a number of projects.

CHAPTER II

BACKGROUND OF RESEARCH

The objective of this research was to identify the factors which are indicators of cost and schedule growth in projects. These factors are known prior to the construction and form a unique background to each specific project. The model which includes these factors of interest is shown in Figure 2-1.

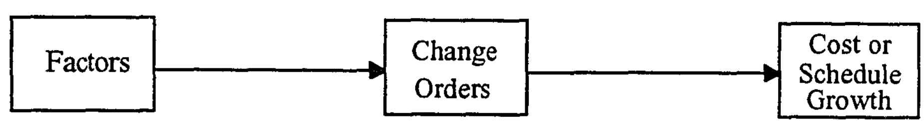

Figure 2-1. Model of Factors Indicating Cost and Schedule Growth

The hypotheses which were developed and tested in this study included the factors which are indicated in the previous model. Those factors addressed the manner in which a construction contract is administered, i.e., methods of contracting, selection of bidders, and method of pricing.

There are two major contract pricing categories considered in this study: fixed price and cost reimbursable. The "Contractual Arrangements" report (1) presents the definitions of the various formats under these categories. The fixed price category includes both lump sum and unit price formats. The lump sum contract requires the contractor to build the project in accordance with the detailed plan and all applicable laws and regulations for a stipulated fixed sum. The contractor generally executes the work at his discretion and is solely responsible for costs that exceed the contract price. The unit price contract requires the provision of a detailed list of estimated pay quantities prior to selection of the contractor. The owner assumes the risk of quantity variations. The amount of quantities to be installed determine the price of each bid item.

The cost reimbursable category includes cost plus fixed fee, cost plus percentage, target price, incentives, and guaranteed maximum price. The cost plus fixed fee is based on cost of work plus a fixed sum or fee . The contractor is reimbursed for job costs and is paid a lump sum fee for overhead and profit. The cost plus percentage is the same as cost plus fixed fee with the replacement of the fee with a percentage, or multiplier of the project cost, rather than the fixed sum or fee. Target price and incentive forms have "an aimed for price" calculated for the entire scope of the project by a method normally based on completed contract documents, performance specifications, unit prices, and/or standard square footage costs. The contractor's fee is based on this sum. Typically, financial arrangements make provision for the contractor to share any savings below the target price or participate in the liability of cost overruns. The guaranteed maximum price method is classified for the purpose of this research as cost reimbursable although the contractual arrangements report defines it as fixed price. The owner is granted a guaranteed maximum price, to which the contractor is bound, with a bonus and penalty clauses for cost underruns and overruns.

Most literature in the field of project changes addresses the legal implications of changes or the impact on worker productivity related to project changes. This study addresses the lack of quantitative information, related to cost and schedule growth, by providing quantitative measures of the factors which are common to changes in project costs and schedules.

A study by Jahren and Ashe (2) highlighted some factors which were found to influence the change order rate. The researchers stated that no quantitative studies were found in the literature which analyzed factors that influence the change order rate, and that the effects of these factors are hard to quantify. In their study of selected Navy projects costing under one million dollars, they found the median cost overrun rate increased as project size increased. They gave one possible explanation for these results; projects become more complex as they become larger. However, Jahren and Ashe also mentioned that on large projects, managers may make special efforts to keep cost overrun rates from becoming excessive.

Jahren and Ashe presented a definition of "change order rate" as the ratio between the dollar amount of change orders and the award amount - which is the definition for "cost growth" in this study. The researchers stated that although the change order rate is not identical to the "cost overrun rate", it is likely that the two terms are influenced by the same factors because the change order rate is a large part of most cost overrun rates. The "cost overrun rate" is defined as the percent difference in cost, plus or minus, between the final contract cost and the contract award amount. The "final contract amount" is the cost of the contract including change orders and outstanding claims. The "award amount" is the dollar value at which the contract was awarded.

The data for the study by Jahren and Ashe were obtained from the contract status reports of two engineering field divisions that administer the Navy's store facility construction in two widely separated geographic areas. Data from 1,576 construction projects were studied. For each project, the contract status report contained the following information: project title, date of award, award amount, cost overrun amount, number of change orders and claims, beneficial occupancy date, and final contract amount. The projects were categorized by project size based on the following award amounts: $25,000 - $75,000, $75,000 - 200,000, $200,000 - $1,000,000, and over $1,000,000. These limits were chosen because they correspond with the Naval Facilities (NAVFAC) limits for contracting authority at various levels within the chain of command.

The shape of the frequency distribution for the cost overrun rate was revealed by producing histograms. The median was used to indicate the central tendency of the distributions. By comparing the project size histograms, Jahren and Ashe found that the cost overrun rate of 1 to 11% was more likely to occur on larger projects than smaller ones.

A special data base of 41 projects was created that included the government estimate for each project in addition to the standard information which was available in the larger data base. These data were analyzed to ascertain whether the number of bidders influenced the percent difference between the award amount and the government estimate, and whether the award estimate difference influenced the cost overrun rates. The statistical analysis supported the finding that the risk of high cost overrun rates was greater when the award amount was less than the government estimate.

In a study of the use of influence diagrams to assess the cost and schedule impact of construction changes, Kuprenas (3) stated that none of the available techniques for pricing change orders was adequate because of either a lack of usable data and records to incorporate into the assessments, an inability to utilize records presently available, or an inflexibility in modelling of impacts.

A new approach for assessment of cost and schedule impacts of changes was developed through the use of influence diagrams. Influence diagrams present a flexible, easily understood, decision analysis tool for obtaining the structure and solving complex problems. A standard Change Order Management Procedure (COMP) model was developed and illustrated the strength of influence diagrams as a change management tool. By combining construction activity influence diagram nodes, a model of the job was created and utilized to forecast direct, indirect, and consequential impacts of a change. Through a complete diagram, change impacts may be traced through a job leading to an expected impact at the final node of the diagram.

This chapter has indicated the lack of research work that addresses the quantitative factors, shown in the model of Figure 2-1. The discovery of new information about these factors, was the main justification for this research study. This information about the factors which indicate cost and schedule growth could then be used for future intensive research studies of each individual factor.

CHAPTER III

DATA COLLECTION AND ORGANIZATION

Introduction

The research findings of this study were developed from the data which were collected from 23 companies of the Construction Industry Institute. A questionnaire (reference Appendix) was developed with extensive input from members of the construction industry Task Force. Selection of specific projects was left to the discretion of each company to provide a representative sample of successful and problem projects. One hundred and fifty nine questionnaires were received from twenty three CII member companies, an average of seven projects per company.

The construction industry firms which responded to the questionnaire provided the research team with both quantitative and qualitative information. The project data were received between November, 1990 and May, 1991. Upon completion of the data collection phase, a spreadsheet data base was created for trend analysis and statistical testing of the hypotheses which were developed in this research. This chapter discusses development of the data collection questionnaire, and the spreadsheet data base that was created to analyze the data.

Data Gathering Tool

Prior to this research, the factors which impact changes in the cost and schedules of a project were not known. Therefore, a special effort was made in designing the questionnaire to include every conceivable item which might be used to detect factors which indicate change.

The development of the questionnaire was based on knowledge of construction Task Force members and the experience of the research team in analysis of data. A series of meetings and discussions involved brainstorming sessions to formulate the content and format of the questionnaire. The first few meetings involved brainstorming of ideas about the content of the questionnaire. A listing of factors, which were believed to be indicators of cost and schedule growth due to changes, was developed and agreed upon by the Task Force. Other meetings were held to work on the format of the questionnaire. This included the separation of the chosen factors under the major groups and subgroups of questions which were used in the questionnaire, reference Appendix. The ease of understanding and responding to the questionnaire were also addressed at these meetings.

Several drafts were prepared, discussed, and revised to obtain all possible information which was believed to be related to project changes. After several enhancements, the questionnaire was sent for pilot testing by Task Force member companies. After receiving the results and comments from the pilot testing, additional modifications were made and the final revision of the questionnaire was then distributed to companies in the Construction Industry Institute.

The companies were asked to select 10 or more construction projects from various projects that they were involved with as either owner, contractor, or construction manager. Respondents were asked to complete the questionnaire for successful and problem projects which had a contract amount of $5 million or more, and were completed during the past 5 years within the United States. International projects were omitted from the scope of the study because of the difficulty in analysis of currency exchange rates. Nuclear power and dam facilities were also omitted from the scope because of their specific natures.

The companies were instructed that completion of each survey form should be coordinated by the project manager who was in charge during construction of the project. They were also instructed that pilot testing of the survey indicated that it would take between 30 and 60 minutes to complete each form which included three main sections: project data, cost data, and schedule data.

Project Data

The project data section was divided into three groups of information. The first group included facility data which contained information about the project location, owner type (government or private), project type (new, remodel, addition), and facility type (buildings, petrochemical, processing, and several others).

The second group of information in this section included contractual aspects of the projects which addressed execution format (design/bid/build, design/build, construction management, and others), distribution of work (direct hire and subcontracting), pricing format (fixed price and cost reimbursable), solicitation of bids (open bids and approved bidders list), origin of contract documents (federal, owner corporate, contractor, and others), owner-contractor relationship, relationship of principal parties, and litigations and arbitrations.

The third group of information in the project data section of the questionnaire included the execution aspects of the project. This included labor category (union, open shop, and combination), significant changes of key personnel, safety performance of the contractor, uniqueness of the project, and the primary driving factors (quality, cost, or schedule).

Cost Data

The cost data section of the questionnaire was divided into two sub-sections. One sub-section was for the owner firms and the other sub-section was for the contractor firms. This division was needed because owners and contractors usually have access to different types of cost information.

The information included in this cost section included the bidding process, "original contract amount" which is the dollar value at which the contract was awarded, the number and dollar amount of change orders by quartiles of the construction duration, penalties or bonuses, "final contract amount" which is the cost of the contract including change orders and all penalties and bonuses, and a subjective rating for the ripple effect on the project's cost. The ripple effect was defined in the glossary of terms attached to the questionnaire (reference Appendix). For the purpose of this study the "ripple effect" means the multiple impact of unanticipated changes resulting from a prior change or changes.

Schedule Data

The schedule data section of the questionnaire solicited information about the dates of the major milestones of the construction project. These dates, as shown in Figure 3-1, included actual bid date, assumed award date, actual award date, first work in place date, planned completion date, original contract completion date, contractually approved final contract completion date, final mechanical completion date, and 100% physical completion date. The definitions of these dates were explained in the survey's glossary, reference Appendix. There was also a subjective question regarding the ripple effect on the project's schedule as used in the cost data section. Ripple effect was rated as high, medium, low, and none.

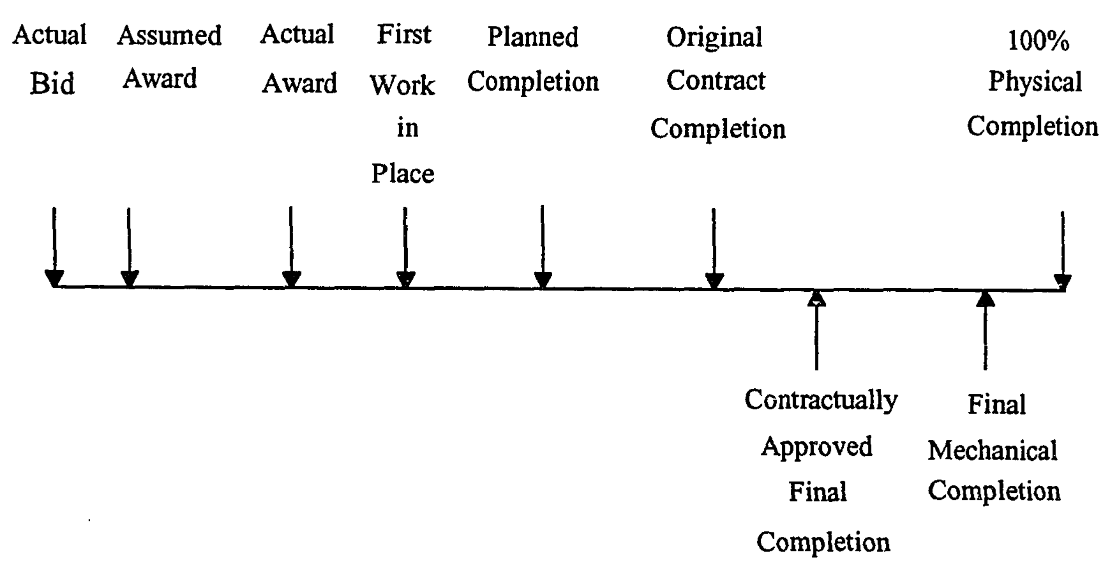

Figure 3-1. Complete Schematic of a Project Life

Data Base

A spreadsheet data base was developed using the software package Lotus 1-2-3. Each row in the spreadsheet represents all of the information that was received for a single project, i.e. 159 rows for the 159 projects. There are 88 cells that form each row, one cell for each response to the questions in the questionnaire.

This software package provided the capability of primary and secondary sorting of the data to analyze and perform trend analysis. If more than a second sorting was needed, the secondary sorting was taken as primary and the third sorting was the secondary. This process was continued for as many sorts as needed.

Before performing this research, the researchers signed a confidentiality statement to ensure that no revelation of any company's propriety data would occur. To maintain confidentiality, a coding system was used to code each project in the data base. This system allowed for easy sorting of the data based on whether the project was provided by an owner or a contractor, whether it was government or private, and the project's location. Every response on the questionnaire was also given a code for the ease of statistical analysis.

Data Reduction

The ASTM standard for dealing with outlying observations (4) was used as a guideline for checking the entire data set. According to the ASTM standard, an outlying observation may be merely an extreme manifestation of the random variability inherent in the data. If this is true, the value should be retained and processed in the same manner as the other observations in the sample. On the other hand, an outlying observation may be the result of gross deviation from prescribed experimental procedure or an error in calculating or recording the numerical value. In such cases, it may be desirable to institute an investigation to ascertain the reason for the aberrant value. The observation may be rejected as a result of the investigation, though not necessarily so.

The criteria previously mentioned in the data gathering tool section of this chapter was used to check the completed questionnaires before entry in the spreadsheet data base. This criteria included projects within the United States with a contract amount of at least $5 million completed within the past 5 years. Nuclear plants and dam facilities were rejected from the scope of this study. Fifty three of the collected forms did not meet the criteria, reducing the data base to one hundred and six projects. Eleven projects had a contract amount less than the specified five million dollars, seven projects were of the excluded dam facility type, three projects were still in progress at the time of completing the questionnaires, and thirty two projects had inappropriate data reported. The inappropriate data category included missing original contract amounts, missing change orders amounts, missing dates, and abnormal project data. A total of 106 projects were found usable for this research.

Data Division

Due to the difference in the contracting strategy between fixed price and cost reimbursable categories, each of the two categories was analyzed separately in this study. The fixed price method of pricing projects is usually selected for projects which have a well defined scope, small anticipated number of project changes by the owner, and no urgent need for an unusually short construction duration. The cost reimbursable method of pricing projects is usually selected by owners who desire a compressed schedule and/or desire flexibility for making project changes during construction.

The method of handling changes in costs and schedules is also different in these two types of contracting strategies. On fixed price projects, the price and schedule adjustments may be negotiated before work on a change is started. If the project is totally or partially unit price, the unit prices may provide the pricing of the changed items or the contractor may be directed to proceed on a change with adjustments that are negotiated based on the time and materials expended. On a cost reimbursable project, the contractor may be asked to evaluate a change before it is implemented or may be directed to implement the change without prior evaluation. In either case, the cost and schedule consequences are fully absorbed by the owner. Thus, separation of fixed price and cost reimbursable projects was necessary to obtain any possible trends in the collected data without being biased by the different expectations of those pricing formats. Table 3-1 provides the types of fixed price and cost reimbursable projects used in this study. This research involved 71 fixed price and 35 cost reimbursable projects.

TABLE 3-1

TYPES OF FIXED PRICE AND COST REIMBURSABLE PROJECTS

Fixed Price	Cost Reimbursable
Lump Sum	Cost Plus Fixed Fee
Unit Price	Cost Plus % Fee
	Guaranteed Maximum
	Target Price
	Incentive

Demography of Projects

Figure 3-2 shows the distribution of projects between government and private owners. Of the 106 projects, 42 projects are government projects (forty percent), and 64 projects are private projects (sixty percent).

Figure 3-3 shows the distribution of projects reported by owners and contractors. Of the 106 projects, 69 projects were reported for owners (sixty five percent), and 37 projects were reported for contractors (thirty five percent).

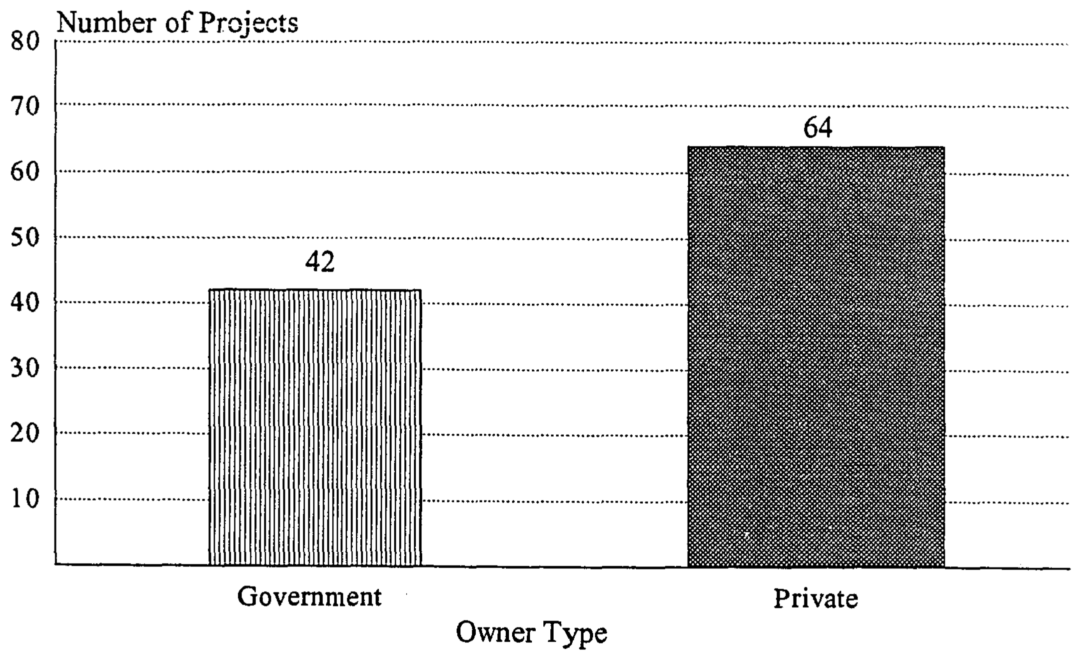

Figure 3-2. Distribution of Government and Private Projects

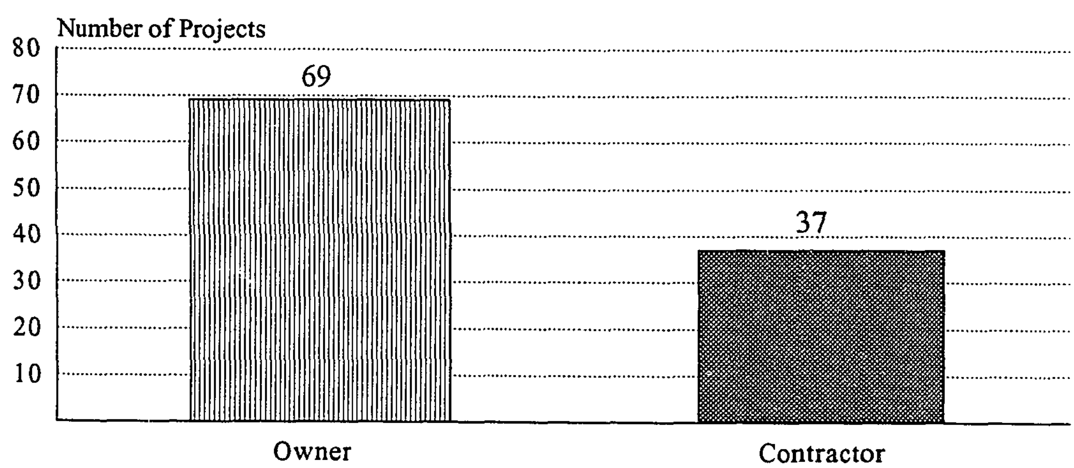

Figure 3-3. Distribution of Projects by Owners and Contractors

Table 3-2 shows the distribution of projects by facility type. The projects cover 16 different facility types. The majority of the projects are from the building category (40 projects), and the pharmaceutical / chemical category (11 projects).

TABLE 3-2

DISTRIBUTION OF FACILITY TYPE

Facility Type	Number of Projects	Facility Type	Number of Projects
Building	40	Treatment Plant	2
Power Plant	8	Refinery	3
Electrical Utility	1	Petroleum/N. Gas	4
Municipal Utility	4	Pharmaceutic/Chem.	11
Highway	2	Plastic/Rubber	2
Airport	1	Food Processing	8
Marine	2	Pulp/Paper	7
Manufacturing	6	Other	1

For this research, the project size is defined as the original contract amount. Figure 3-4 shows the distribution of project sizes and the number of projects for each project size range. A wide variety of project sizes is present in the data base.

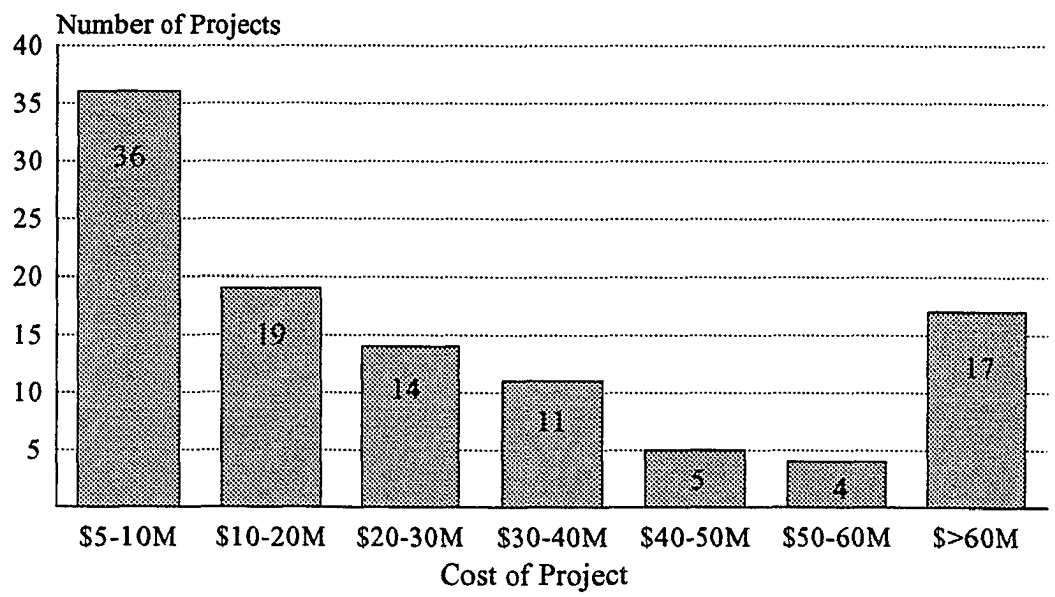

Figure 3-4. Distribution of Project Sizes

Projects from 27 states (fifty four percent of the country) were received and studied in this research. The majority of the projects were located in Texas (14 projects), New Jersey (13 projects), New York (12 projects), and California (9 projects). For the purpose of creating groups of similar geographic characteristics, the United States was divided into two groups: northern / northeastern states and southern / southwestern states as shown in Figures 3-5 and 3-6.

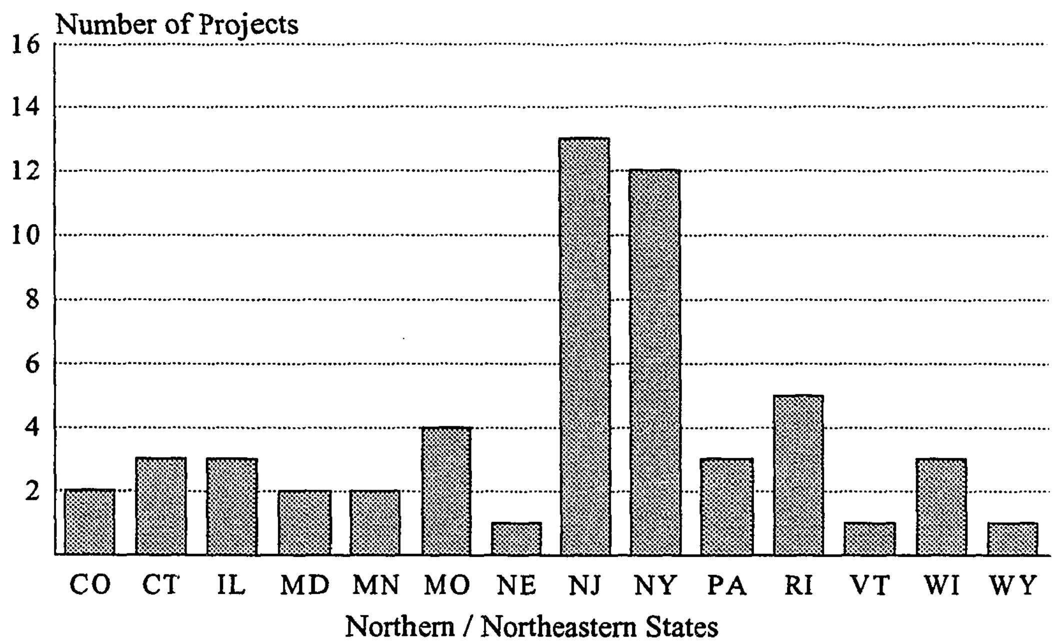

Figure 3-5. Distribution of Projects by Northern States

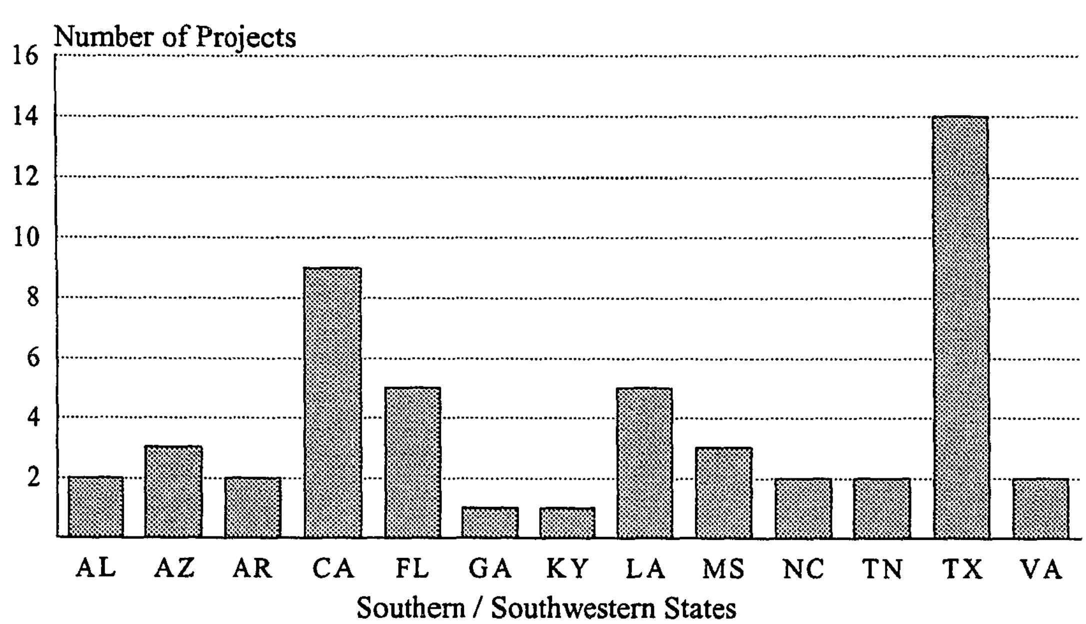

Figure 3-6. Distribution of Projects by Southern States

CHAPTER IV

ANALYSIS OF COST AND SCHEDULE GROWTH OF FIXED PRICE PROJECTS

The entire analysis of this research project is based upon separating all projects into two main groups. All projects that were administered by a lump sum or unit price format are analyzed in one group as fixed price projects and the remainder of the projects (those administered as cost reimbursable) are analyzed in another group. As discussed in Chapter III, this separation of the collected data was made because of the differences in contracting strategy of fixed price and cost reimbursable projects.

This Chapter presents the analysis of cost growth and schedule growth for fixed price projects. Two groups of factors are included in the analysis: factors from the project data section of the questionnaire such as execution format, method of bid solicitation, owner type, origin of contract documents, and labor category within a certain geographic location. The second group of factors reflects the cost data section of the questionnaire and includes money left on the table, which is the difference between the lowest bid and the next higher bid, and number of bidders.

The distribution of the 106 projects included in this study includes 71 fixed price and 35 cost reimbursable projects. The 71 fixed price projects include 64 lump sum and 7 unit price projects.

Project Cost Growth Analysis

The primary objective of this research is the analysis of cost and schedule growth of projects during construction. Throughout this research report the following equation was used to calculate the cost growth of a project:

$$CostGrowth = \frac{AmountofChangeOrders}{OriginalContractAmount} \tag{4.1}$$

The "amount of change orders" is the total cost (in dollars) of all change orders which were approved during construction. The "original contract amount" is the cost (in dollars) that was agreed upon between the owner and contractor prior to the start of construction.

Using the above equation, cost growth is defined as a dimensionless quantity and is shown as a percentage on the cost growth trend curves that are presented in subsequent discussions of this report.

The cost data collected in this research included the number and the dollar amount of change orders in a project during each quarter of construction duration, reference Appendix. Using Equation 4.1, the cost growth is calculated at 25% increments of construction duration (quartiles of construction).

The costs of change orders in each construction quarter, their accumulation, and the accumulated percentages of cost growth at the end of each quarter were analyzed in this research. The project information that was received in this study showed a wide variation in the minimum and maximum values of cost growth, from -0.5% to +72.9%.

For all of the 71 fixed price projects, the average cumulative cost growth was 11.5% and the median cumulative cost growth was 8.6% at the end of the fourth quarter. These percentages are based on the original contract amount of each individual project.

This difference between the average and median values of all the 71 projects is relatively small. However, for the analysis of a smaller set of data, the average value of cost growth can misrepresent the data. For example, a sort of the data to evaluate execution format may only show 18 construction management projects. If only one of the 18 projects has a 60% cost growth and the remaining 17 projects have a cost growth of less than 20%, using the average value of percentage of cost growth would show high compared to using the median value. A median value is the mid point in a set of ranked numbers, so the number of values above the median is equal to the number of values below the median. Using median values, in lieu of average values, prevents abnormal distortion of the data that can occur when a few projects have an unusually high or low cost growth. Therefore, median values of cost growth are used in this research, instead of average values.

An analysis of cost growth includes the original contract amount, which varied from $5 million to $225 million for the 71 fixed price projects. As discussed in the preceding paragraph the median cost growth is 8.6%, based upon the original contract amount of each project. Actually there were two projects that had an 8.6% cost growth, one with $6 million and the other with a $26 million original contract amount. Thus, the 8.6% cost growth is more significant for the $26 million project than the $6 million project. To reduce the effect of wide variations in the original contract amount, the median value of original contract amount for each set of data is used as the base for calculating cost growth in this research. For the total data set of 71 fixed price projects, the median contract amount was $13.6 million which produced a 5.3% median value of cost growth. For each sorting of the total data base, the median original contract amount is determined for that subset and is used for calculating cost growth.

There were also wide variations in the cost growth in each of the quarters of construction duration. This can be illustrated using the two projects, discussed in the preceding paragraph, that had a cost growth at or near the median value of all the 71 fixed price projects. The $26 million project had a uniformly increasing cost growth through each of the quarters of construction duration. However, the $6 million project actually had a decrease in cost growth between the third and fourth quarters. Another project, which had a fourth quarter cost growth near the median, had little cost growth through each of the first three quarters, then a sudden increase in the fourth quarter. Throughout this research only the fourth quarter values of cost growth are used for statistical testing. The first, second, and the third quarters cost growth values are plotted on the cost trend curves to show the general pattern of cost growth.

The intent of this research effort was not to study any one particular project, but to study multiple projects as a group at the macro level. Figure 4-1 shows the macro cumulative cost growth curve for all the 71 fixed price projects. This curve is developed based upon the median original contract amount of all projects and the cumulative cost growth at each quartile that represents the median value of all projects. Thus, it does not represent any one project, but is a composite of all projects and is intended to show a profile of the cost growth pattern of the 71 fixed price projects that are studied in this research. For this set of projects the median original contract amount is $13.6 million and the 5.3% represents the median accumulative cost growth of all of the projects at the end of the fourth quarter of construction.

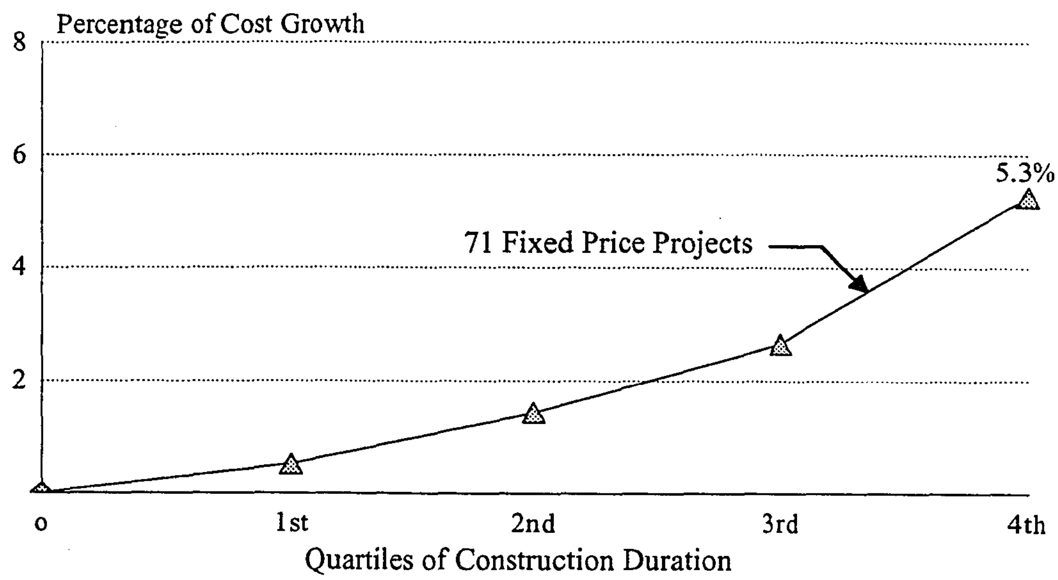

Figure 4-1. Cost Growth Trend Curve for All Fixed Price Projects

Project Schedule Growth Analysis

One of the primary objectives of this research is the analysis of the schedule growth of construction projects. For this research, schedule growth is defined as the ratio of schedule increase to the original duration of a project, reference Equation 4.2.

$$ScheduleGrowth = \frac{ScheduleIncrease}{OriginalDuration} \quad (4.2)$$

"Schedule Increase" is the time which is required to complete the project beyond the original anticipated completion date. The "Original Duration" is the time which is anticipated to complete a project before the start of construction. Figure 4-2 is a time-line of major milestone dates to illustrate these significant values.

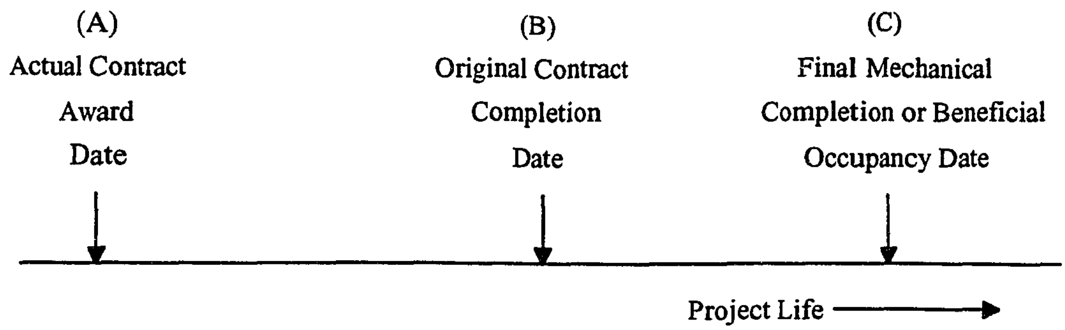

Figure 4-2. Major Milestone Dates for Fixed Price Projects

From Figure 4-2, the following equations can be developed:

$$ScheduleIncrease = FinalDuration - OriginalDuration = (C - A) - (B - A) \quad (4\text{-}3)$$

$$OriginalDuration = OriginalCompletion - ActualAward = (B - A) \quad (4\text{-}4)$$

The median values are used for all the schedule growth calculations. The median value of schedule growth for all fixed price projects is 9% and is used in chapter VI for the statistical testing of the hypotheses.

Factors Related to Cost or Schedule Growth

The remainder of this chapter presents additional sorting and analysis of the research data to identify factors which exist in projects experiencing high or low cost and/or schedule growth. This chapter discusses those factors, in fixed price projects, which showed the most significant trends of changes in costs and/or schedules: project data factors and cost data factors.

Project Data Factors

Execution Format versus Cost and Schedule Growth

The majority of the projects in this research effort are either Design/Bid/Build, Design/Build, or Construction Management. The "Design/Bid/Build" (D/B/B) is a three party arrangement involving the owner, designer, and contractor. This execution format involves three steps: a complete design is prepared, followed by solicitation of competitive bids from contractors, and award of a contract to a construction contractor to build the project. The "Design/Build" (D/B) is a two party arrangement between the owner and the design/build firm. A "Construction Management" (CM) contract is assigned to a construction management firm to coordinate the work for the owner. It is usually a four party arrangement involving the owner, designer, construction management firm, and the contractor.

The cost data which were collected in this research project indicate that the Construction Management execution format is a common factor for projects which experienced high cost growth. Figure 4-3 indicates a higher cost growth at the end of the fourth construction quarter (12.1%) for Construction Management fixed price projects as compared to Design/Bid/Build projects (2.5%) or Design/Build projects (4.6%).

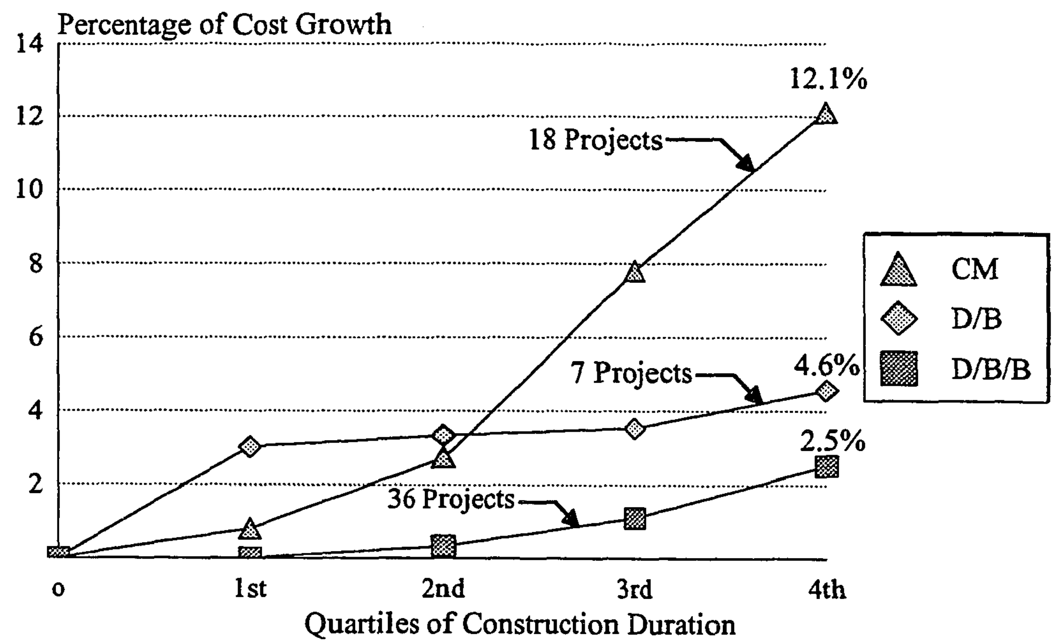

Figure 4-3. Cost Growth Trend Curves for Projects which were Administered by Different Execution Formats

The schedule growth for Design/Bid/Build projects (10%) is significantly higher than the 2% and 0% schedule growth for Construction Management and Design/Build projects respectively. The different schedule growth values for the various execution formats are shown in Figure 4-4. Thus, for the projects studied in this research it appears that Construction Management projects traded higher costs for decreases in time, compared to Design/Bid/Build projects.

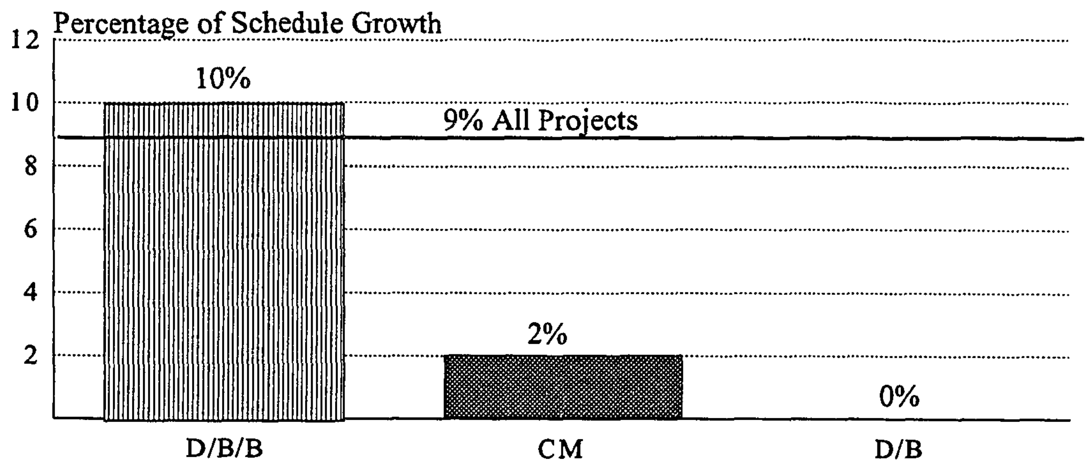

Figure 4-4. Schedule Growth Trends for Projects which were Administered by Different Execution Formats

Bid Solicitation versus Cost and Schedule Growth

One of the methods of bid solicitation is an open bid invitation, where any qualified contractor is invited to submit a bid for the proposed construction work. The other common form of bid solicitation is an approved bidders list, where a limited pre-qualified group of contractors are allowed to submit their bids. The pre-qualification process usually includes several factors related to the contractor's experience and financial stability.

The difference at the end of the fourth construction quarter, shown in Figure 4-5, between the cost growth of open bid projects (4.6%) and approved bidders list projects (6.4%) is not excessive. However, the schedule growth difference, shown in Figure 4-6, is highly observable for projects with approved bidders list, 18% for open bids versus 0% for approved bids. Thus, for the projects studied in this research, it appears that there is a small saving in cost growth, but a higher chance of schedule growth for open bids, compared to an approved bidders list.

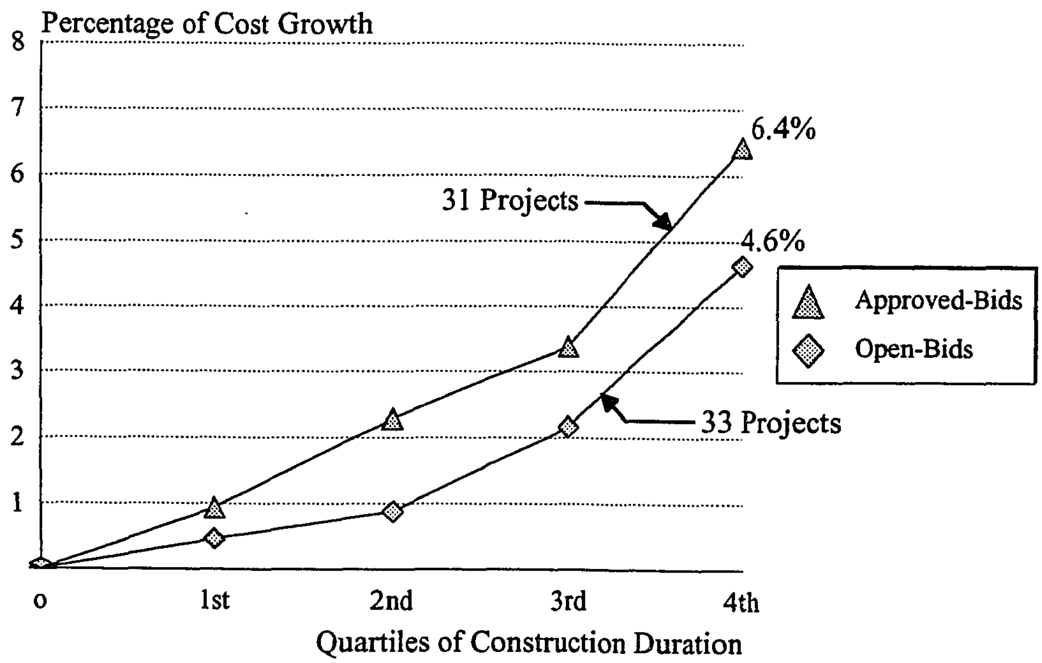

Figure 4-5. Cost Growth Trend Curves with Respect to Solicitation of Bids

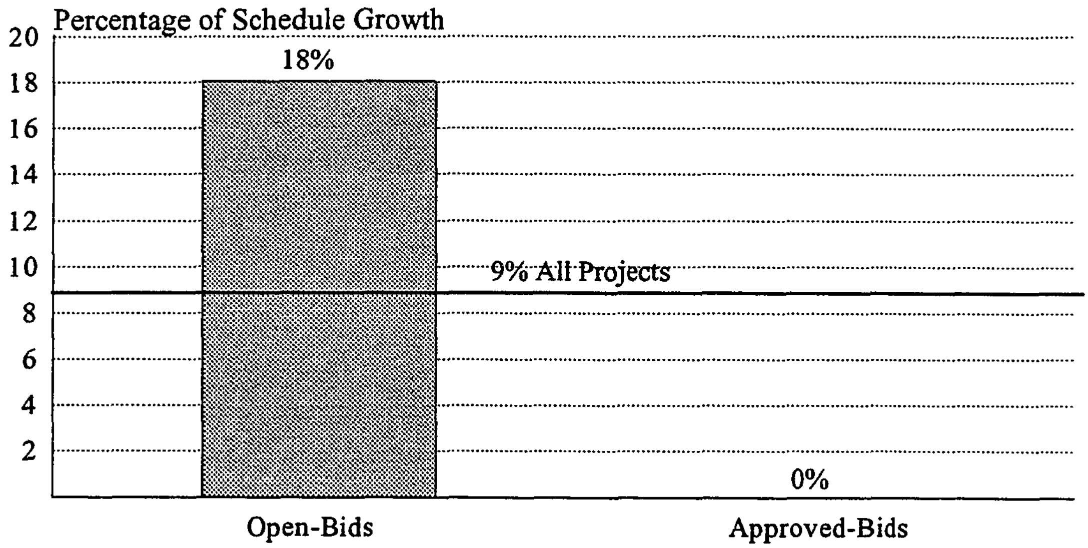

Figure 4-6. Schedule Growth Trends with Respect to Solicitation of Bids

Owner Type versus Cost and Schedule Growth

The owner of a project can be either private or government (or public). The cost and schedule data which were collected in this research project indicate that a private owner is a common factor for projects which experienced high cost growth, and a government owner is a common factor for projects which experienced high schedule growth.

The cost growth at the end of the fourth quarter for privately owned projects (8.1%), as shown in Figure 4-7, is more than twice the value of government owned projects (3.6%) and is an indication of a high cost growth trend in private projects. The schedule growth for government projects is 17%, as shown in Figure 4-8, and is considerably higher than the corresponding 0% median schedule growth in private projects.

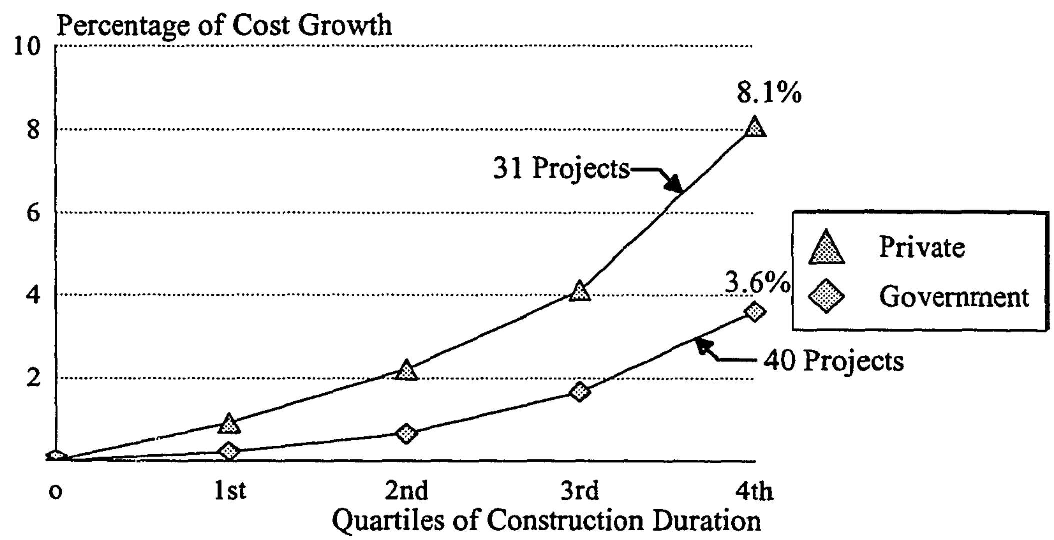

Figure 4-7. Cost Growth Trend Curves for Projects with Different Ownership

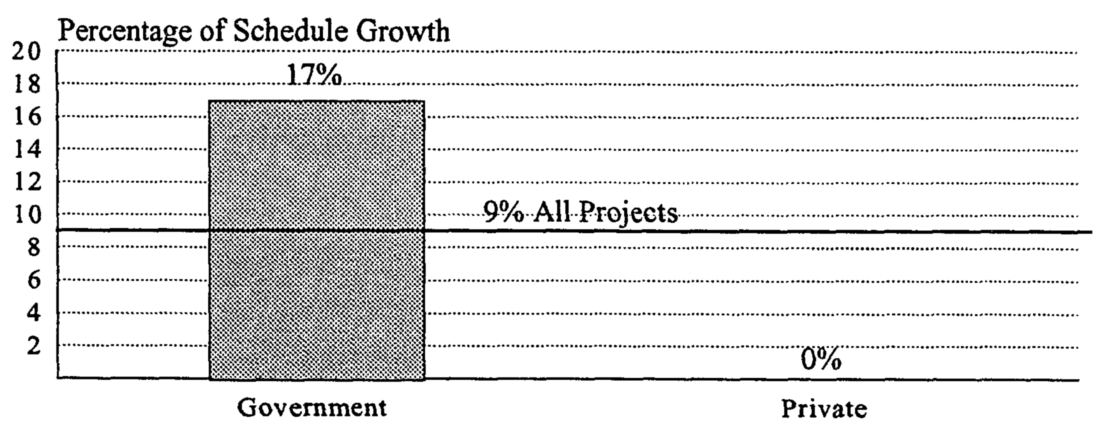

Figure 4-8. Schedule Growth Trends for Projects with Different Ownership

Origin of Contract Document versus Cost and

Schedule Growth

The "Standard General Conditions" (5) defines the intent of the contract documents. The contract documents comprise the entire agreement between the owner and the contractor concerning the work. The contract documents are developed in accordance with the laws at the location of the project with the intent to describe a functionally complete project to be constructed.

The origin of contract documents can be federal, owner corporate, or the contractor. The data which were collected for this study show no appreciable difference in the cost growth for the three origins of contract documents, reference Figure 4-9. The difference is observable in the schedule growth, reference Figure 4-10.

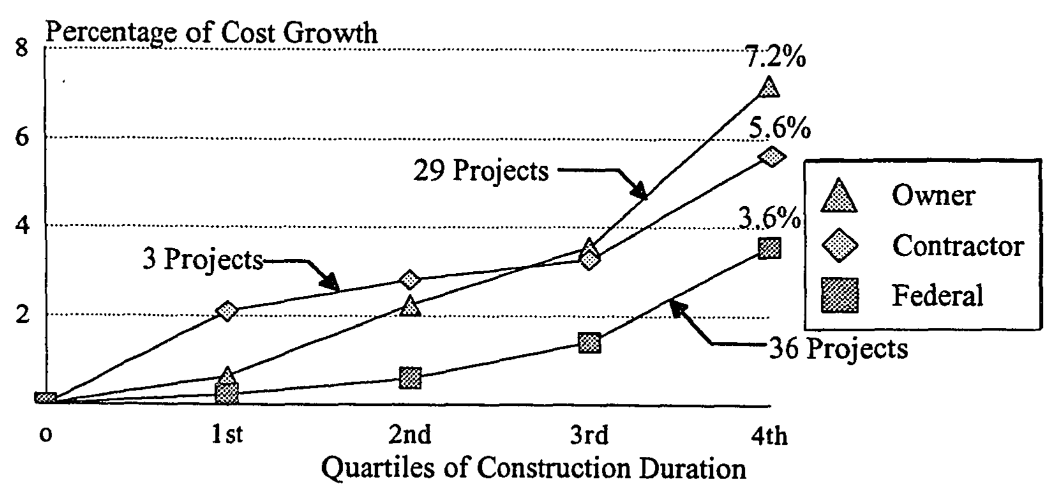

Figure 4-9. Cost Growth Trend Curves with Respect to Origin of Contract Documents

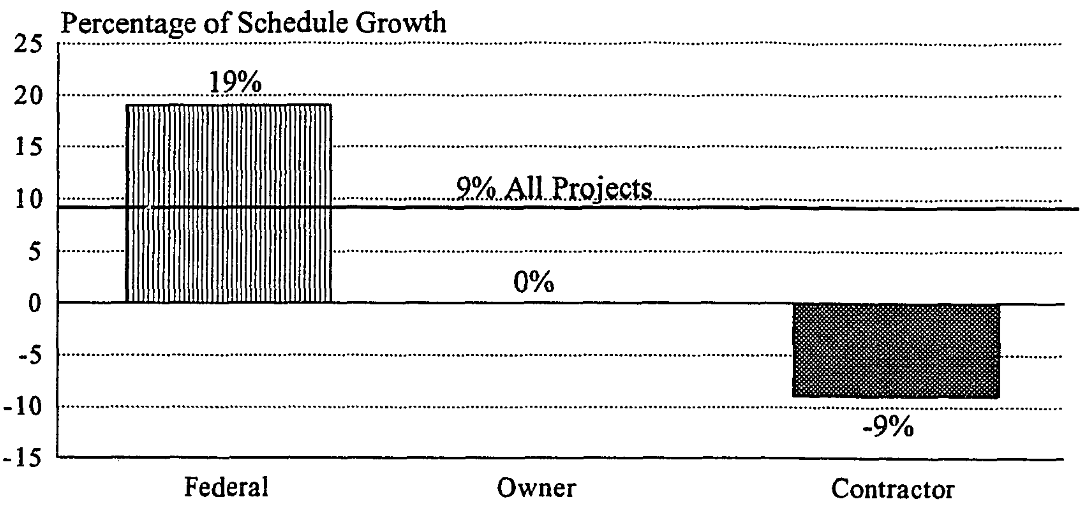

Figure 4-10. Schedule Growth Trends with Respect to Origin of Contract Documents

Combined Labor Category versus Schedule Growth

The labor categories considered in this study are union, open shop, and a combination of the two. The geographic distribution of the projects in this study was presented in Chapter III. For the projects studied in this research, there was an overlay between the labor categories and geographic locations. The union projects in the collected data are prevalent in the northern states, whereas the open shop projects are located in the southern states, reference Figures 3-5 and 3-6.

The schedule data which were collected in this study indicate that combined labor category is a common factor for projects which experienced high schedule growth. For combined labor projects the median value of schedule growth is 14.5% which is considerably high when compared to 5% on both union and open shop projects, reference Figure 4-11.

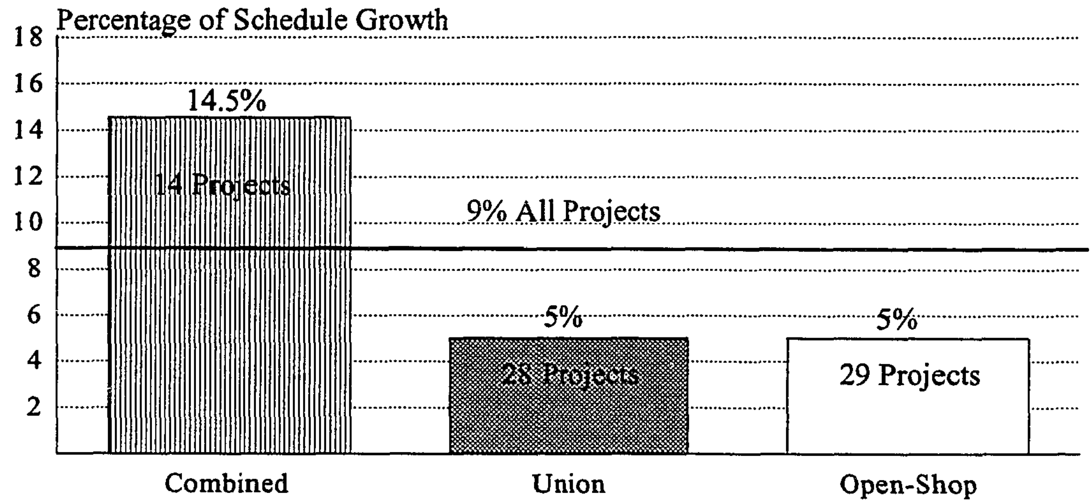

Figure 4-11. Schedule Growth Trends for Projects with Different Labor Categories

Cost Data Factors

Money Left On the Table versus Cost and Schedule Growth

The "Money Left On the Table" (MLOT) is the difference between the low bid and the next higher bid. The term MLOT only applies to fixed price projects and was obtained only from the owners who responded to the research questionnaire, because the contractors do not have access to this information, except for a public opening of the bids.

The "percentage of MLOT" is the ratio of the difference between original low bid and the next higher bid to the original low bid. The median value of MLOT percentage for all of the 71 fixed price projects was 4.0%. Thus, for this research report, "high MLOT" is defined as greater than 4.0% and "low MLOT" is defined as less than 4.0%.

The cost and schedule data which were collected in this study indicate that high MLOT is a common factor for projects which experienced high cost growth and high schedule growth. The cost growth trend curves in Figure 4-12 show that the cost growth at the end of the fourth quarter for projects with high MLOT is 12.1% or about 3 times that value for projects with low MLOT (3.9%). This figure shows that cost growth may be higher for projects that have high MLOT. High MLOT may be a result of several factors. Examples are missing an item in the estimate, poorly developed contract documents, or misinterpretation of the work that must be performed.

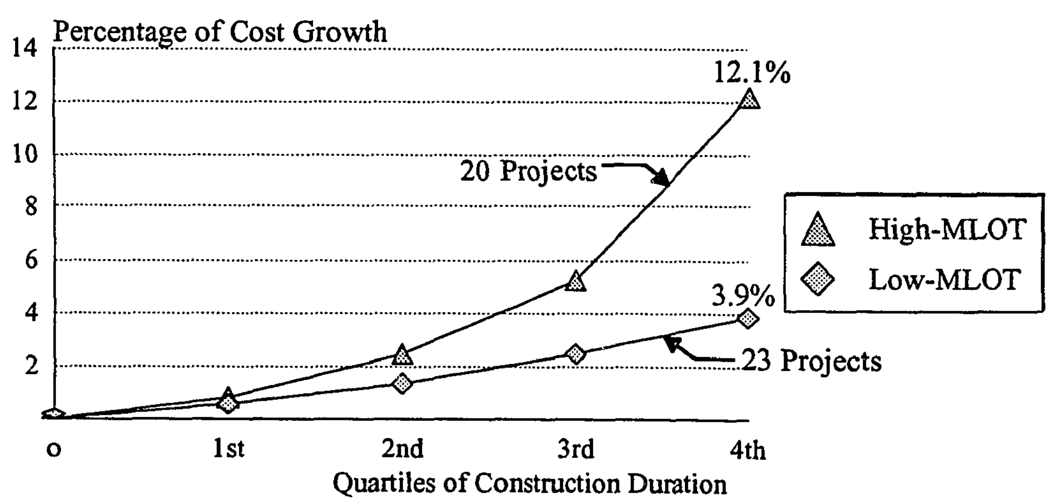

Figure 4-12. Cost Growth Trend Curves for Projects with High and Low MLOT

The projects that had high MLOT also experienced significant schedule growth. Figure 4-13 shows a 19% increase in projects with high MLOT compared to only 6% increase in schedule for low MLOT projects.

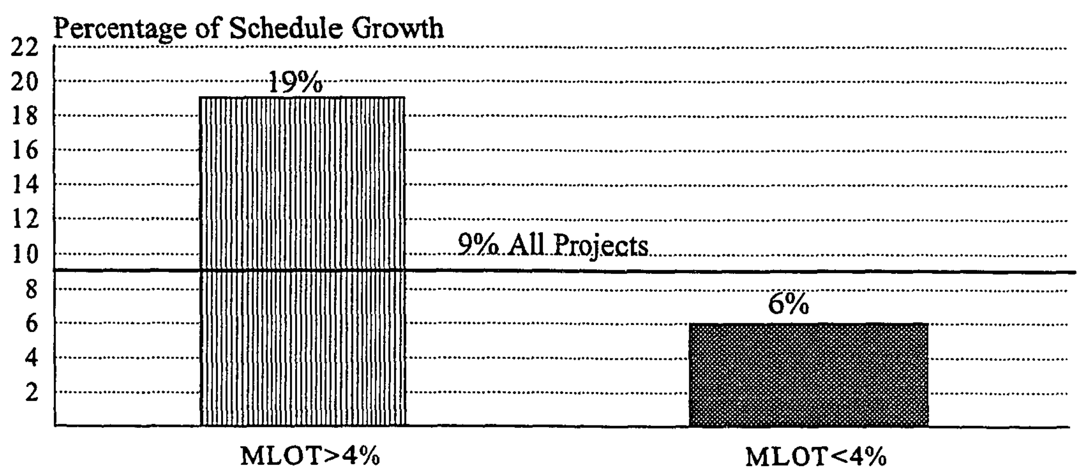

Figure 4-13. Schedule Growth Trends for Projects with High and Low MLOT

Number of Bidders versus Cost and Schedule Growth

The number of bidders can vary depending on level of competition, the economic status, or the owner's strategy in the bidding process. The median value of the number of bidders for all the 71 fixed price projects was 5 bidders. For this study, "high number of bidders" is defined as greater than 5 bidders and "low number of bidders" is defined as less than 5 bidders.

The cost and schedule data which were gathered in this research indicate that low number of bidders is a common factor for projects which experienced high cost and schedule growth. The cost growth at the end of the fourth construction quarter for projects with low number of bidders is about 2.5 times the value for projects with high number of bidders, as shown in Figure 4-14. The median value of schedule growth for projects with low number of bidders is 21.5%, about 1.9 times that value for projects with high number of bidders (11.5%), reference Figure 4-15.

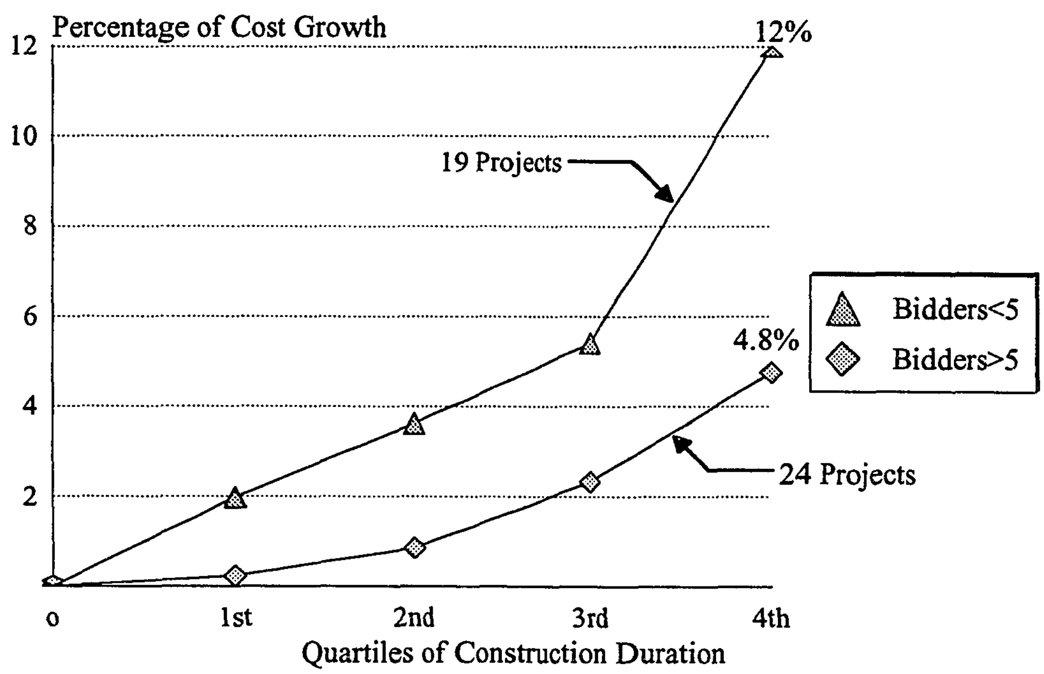

Figure 4-14. Cost Growth Trend Curves for Projects with High and Low Number of Bidders

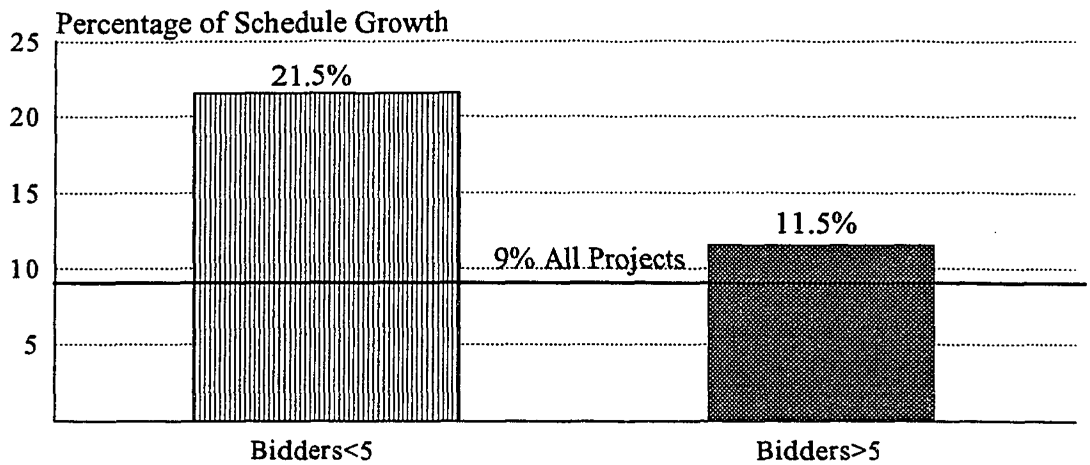

Figure 4-15. Schedule Growth Trends for Projects with High and Low Number of Bidders

CHAPTER V

ANALYSIS OF COST AND SCHEDULE GROWTH OF COST REIMBURSABLE PROJECTS

Projects which are administered by the cost reimbursable pricing format do not have a firmly established fixed dollar amount at the beginning of the project. The contracting strategy is different than fixed price projects since the scope is usually not well defined, the owner plans to develop the scope during engineering and construction, and the work is sometimes of a unique nature. For the cost reimbursable projects studied in this research, respondents reported an original contract amount of each project which represented the anticipated cost of the project prior to construction.

This chapter presents an analysis of cost growth and schedule growth for cost reimbursable projects. The distribution of the 35 cost reimbursable projects analyzed in this study includes 8 cost plus fixed fee projects, 4 cost plus percentage fee projects, 20 guaranteed maximum price projects, and 3 target price projects. These various categories were defined in the background of research chapter of this document.

Two groups of factors are included in the analysis: factors from the project data section of the questionnaire such as primary driving factor, execution format, distribution of work, and labor category within a certain geographic location. The second group of factors reflects the cost data section of the questionnaire and includes size of projects.

Project Cost Growth Analysis

As previously discussed in Chapter IV, the primary objective of this study is the analysis of cost and schedule growth of projects and the same Equation 4.1 is used to calculate the cost growth of cost reimbursable projects.

$$CostGrowth = \frac{AmountofChangeOrders}{OriginalContractAmount} \tag{4.1}$$

The "amount of change orders" is the total cost (in dollars) of all change orders which were approved during construction. The "original contract amount" is the cost (in dollars) that was agreed upon between the owner and contractor prior to the start of construction.

The costs of change orders in each construction quarter, their accumulation, and the accumulated percentages of cost growth at the end of each quarter were analyzed in this research. The project information that was received in this study showed a wide variation in the minimum, median, and maximum values of cost growth percentages in each quarter. At the end of the fourth quarter, the maximum cost growth is 164.7%, the minimum cost growth is 0%, the median cost growth is 8.9%, and the average cost growth is 18.4%.

Median values of original contract amounts and cost growth are used in the analysis of cost reimbursable projects, similar to the fixed price projects. As described in the cost growth analysis of Chapter IV, the median values are used to reduce the effect of wide variations in original contract amounts and wide variations of cost growth in each quarter of construction duration.

The cost growth trend curve for all of the cost reimbursable projects is shown in Figure 5-1 which illustrates a median value of cost growth percentage of 6.8% at the end of the fourth construction quarter. This value is based on the $30 million median original contract amount of the 35 cost reimbursable projects. This 6.8% median cost growth value is larger than the 5.3% cost growth value for the fixed price projects. The shape of the curve is convex, in contrast to the concave shape of fixed price projects, which indicates an early accumulation of change order costs.

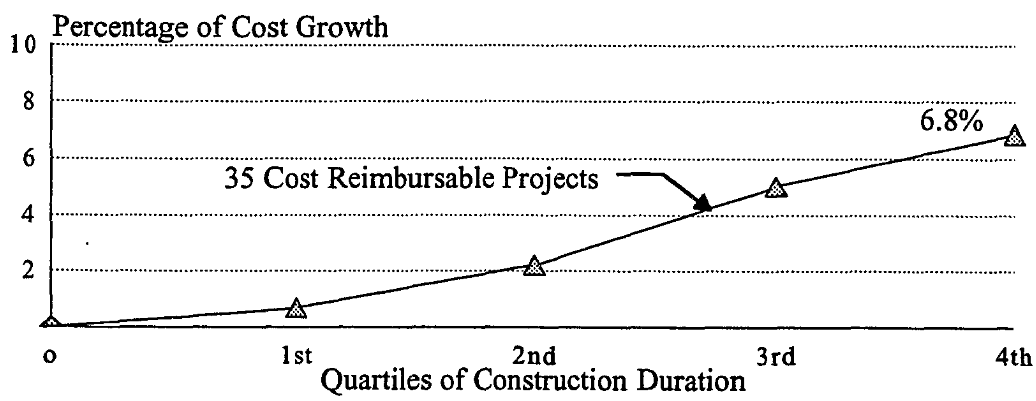

Figure 5-1. Cost Growth Trend Curve for All Cost Reimbursable Projects

Project Schedule Growth Analysis

One of the primary objectives of this study, as stated in the previous chapter, is the analysis of the schedule growth of construction projects. Equation 4.2, which was used in Chapter IV for the analysis of fixed price projects, is also used for the calculation of schedule growth for cost reimbursable projects.

$$ScheduleGrowth = \frac{ScheduleIncrease}{OriginalDuration} \qquad (4.2)$$

"Schedule Increase" is the time which is required to complete the project beyond the original anticipated completion date. The "Original Duration" is the time which is anticipated to complete a project before the start of construction. Figure 5-2 is a time-line of major milestone dates to illustrate these significant values. The actual contract award date for fixed price projects is replaced with the first work in place date for cost reimbursable projects because of the different contract strategy.

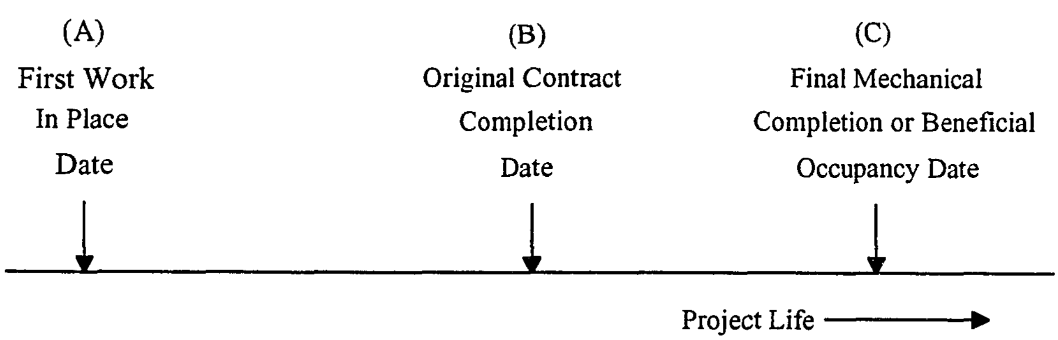

Figure 5-2. Major Milestone Dates for Cost Reimbursable Projects

From Figure 5-2, the following equations can be developed:

$$ScheduleIncrease = FinalDuration - OriginalDuration = (C - A) - (B - A) \qquad (5.1)$$

$$OriginalDuration = OriginalCompletion - FirstWorkInPlace = (B - A) \qquad (5.2)$$

The median values are used for all the schedule growth calculations. The median value of schedule growth for all cost reimbursable projects is 7.5% and will be used in Chapter VI for the statistical testing of the hypotheses. The 7.5% is less than the 9.0% value for fixed price projects. In the projects studied in this research, cost reimbursable projects had higher cost growth and lower schedule growth than the fixed price projects. This indicates a trade-off of increased costs for a reduction of schedule which is often the intent of selecting cost reimbursable type contract.

Factors Related to Cost or Schedule Growth

The remainder of this chapter presents additional sorting and analysis of the collected data to identify factors which exist in projects experiencing high or low cost and/or schedule growth. This chapter discusses those factors, in cost reimbursable projects, which showed the most significant trends of changes in costs and/or schedules: project data factors and cost data factors.

Project Data Factors

Primary Driving Factor versus Cost and Schedule Growth

The quality, cost, and schedule of a project is a primary concern of all participants in a project. The numerous decisions that are necessary during construction are often governed by the primary driving factors of quality, cost, and schedule. Respondents to the data collection questionnaire were asked to rank the relative importance of these three driving factors.

Owners establish the primary driving factor for the project at the beginning of construction, although changes may be made to them during construction. Quality is a term which can mean different things to different people and is difficult to quantify. Quality usually refers to a level of performance set by the owner at the outset of a project which the contractor has to achieve for the constructed facility. Cost as a driving factor can mean that the decisions on the particular project will be made in favor of economy, compared to time of completion. When schedule is used as a driving factor, decisions are usually made in favor of time of completion rather than economy.

The cost and schedule data which were collected in this study indicate that quality as a driving factor is a common factor for projects which experienced low cost and schedule growth. Schedule as a driving factor is common for projects which experienced high cost growth, and cost as a driving factor is common for projects which experienced high schedule growth. The cost growth trend curves in Figure 5-3 illustrate the relative different cost growth for each of the driving factors.

The median values of schedule growth for the projects with different driving factors indicate the merit of having quality as the primary driving factor. For projects driven by quality, the median value of schedule growth is 4.5% and is half the corresponding value for projects driven by schedule (9%) or less than third that value for projects driven by cost (15%), reference Figure 5-4.

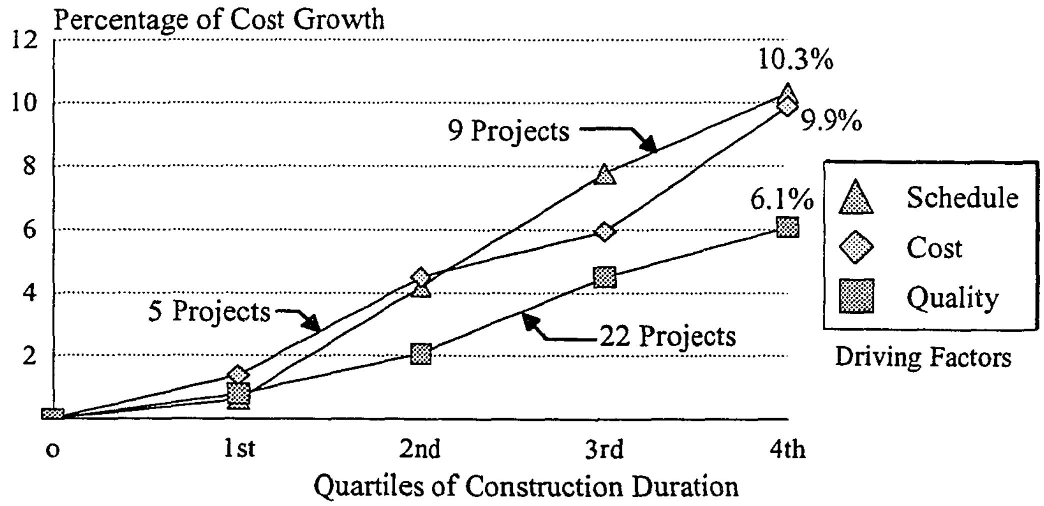

Figure 5-3. Cost Growth Trend Curves for Projects with Different Driving Factors

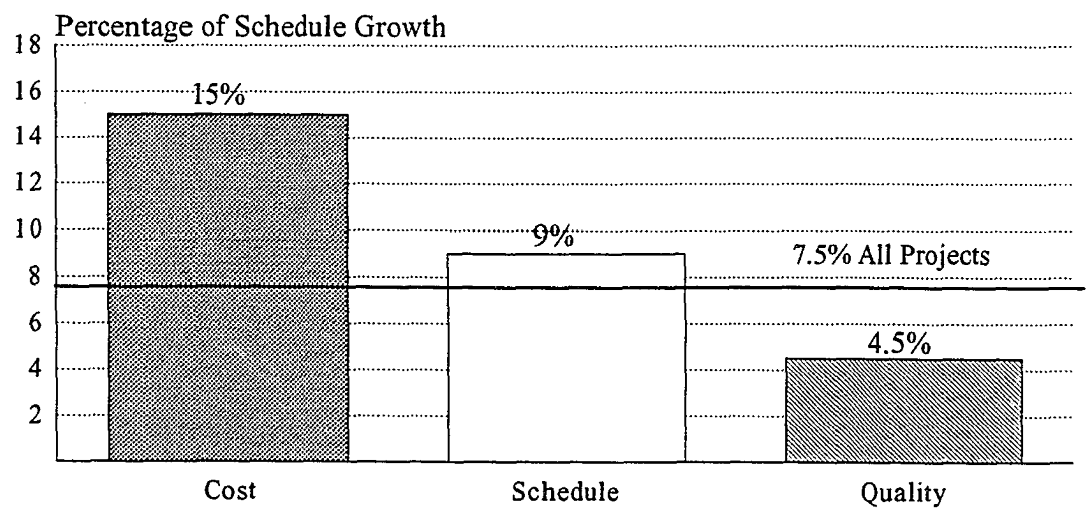

Figure 5-4. Schedule Growth Trends for Projects with Different Driving Factors

Execution Format versus Cost and Schedule Growth

Similar to fixed price projects, the Construction Management Execution format is a common factor for cost reimbursable projects which experienced high cost growth. The data gathered in this study also indicate that the Construction Management execution format is a common factor for cost reimbursable projects which experienced high schedule growth.

Figure 5-5 shows the trend of cost growth accumulation for the various execution formats: Design/Bid/Build (D/B/B), Design/Build (D/B), and Construction Management (CM). The percentage of cost growth at the end of the fourth quarter for CM projects (9.5%) is considerably higher than that for D/B/B projects (6.4%) or D/B projects (5.3%), but not considerably different than the 6.8% cost growth for all cost reimbursable projects.

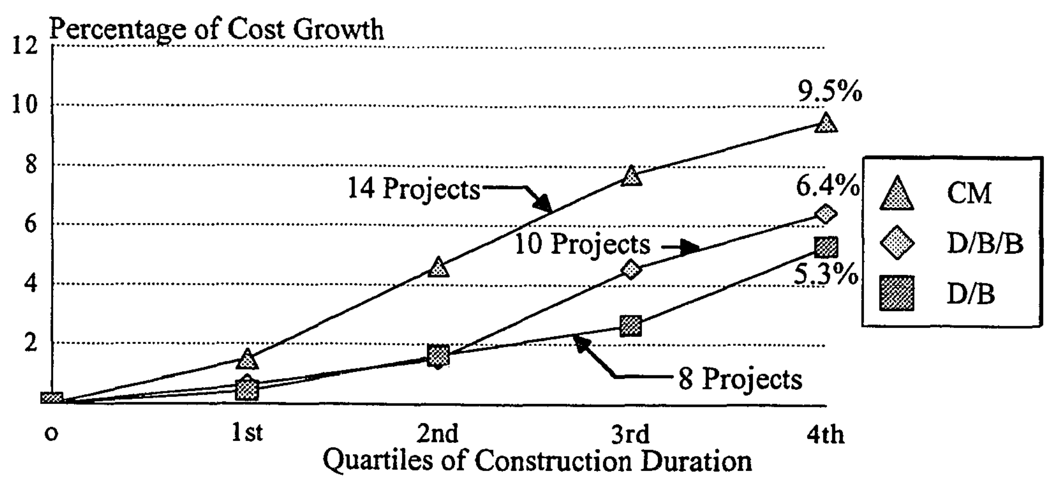

Figure 5-5. Cost Growth Trend Curves for Projects which were Administered by Different Execution Formats

The schedule growth is shown in Figure 5-6. The high percentage of schedule growth is even more extensive in CM projects (13%) when compared to the 3% in D/B/B projects or the 4.5% in D/B projects.

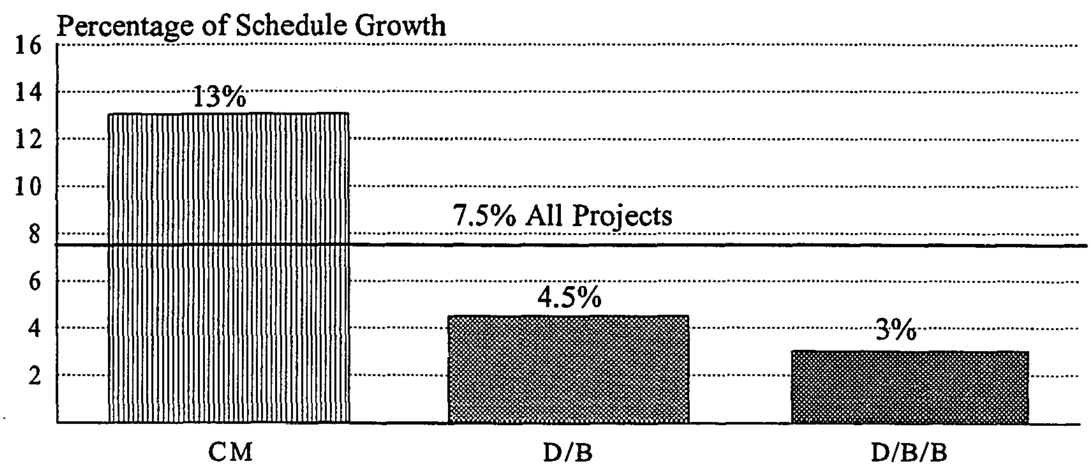

Figure 5-6. Schedule Growth Trends for Projects which were Administered by Different Execution Formats

<u>Work Distribution versus Schedule Growth</u>

Respondents to the data collection questionnaire were asked to identify the percent of distribution of work into two categories: direct hire and subcontract. For the 35 cost reimbursable projects, the median value of schedule growth was 13.1% for projects which were performed by subcontracting and - 0.8% median schedule growth for direct hire projects.

Labor Category within a Geographic Location versus Schedule Growth

The labor categories and geographic location of the collected project data are correlated. Because the two sets of information overlap, it can not be determined whether the labor category or the geographic location is the factor which is related to schedule growth.

Union labor projects were located in the northern and northeastern states and open shop labor projects were located in the southern and southwestern states. The states under the two geographic blocks were discussed in Chapter III.

Cost Data Factors

Size of Project versus Cost Growth

For this research, the project size is defined as the original contract amount. Figure 5-7 shows the distribution of project sizes for cost reimbursable projects and the number of projects is shown for each project size range. A wide variety of project sizes is represented in the data base, from $5 million to $226 million. For the 35 cost reimbursable projects studied in this research, the median original contract amount is $30 million.

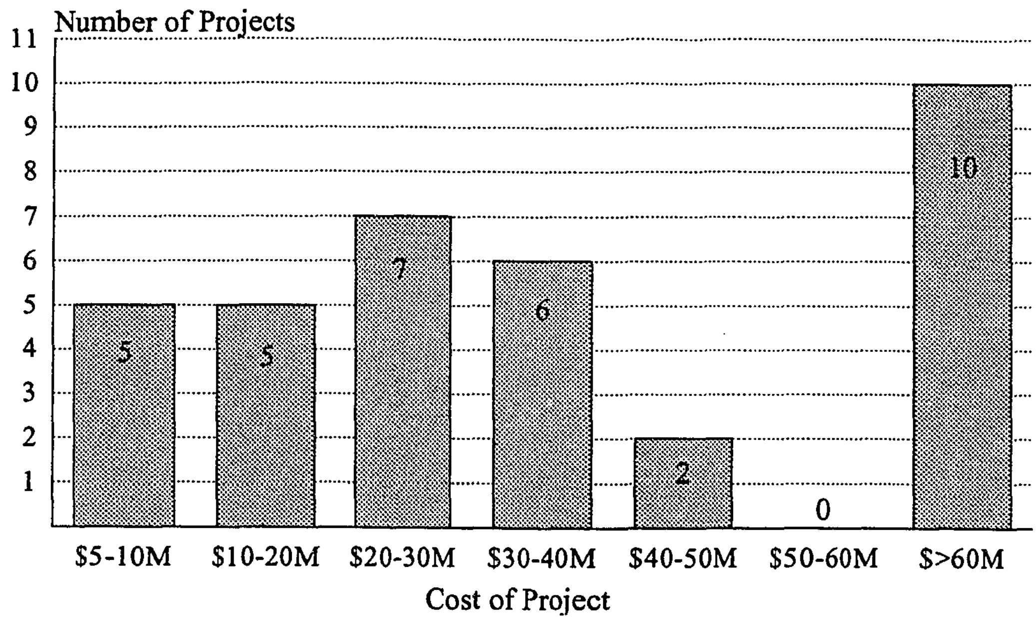

Figure 5-7. Distribution of Cost Reimbursable Project Sizes

For the purpose of comparing small and large project sizes, the $30,000,000 median value was chosen for this study as the boundary between "large projects" (greater than $30,000,000) and "small projects" (less than $30,000,000). The difference in the median cost growth trend between large and small size projects is shown in Figure 5-8. Based upon the collected data, it appears there is only a slight difference between large and small size projects. The difference is even less in the comparison of schedule growth of large and small projects.

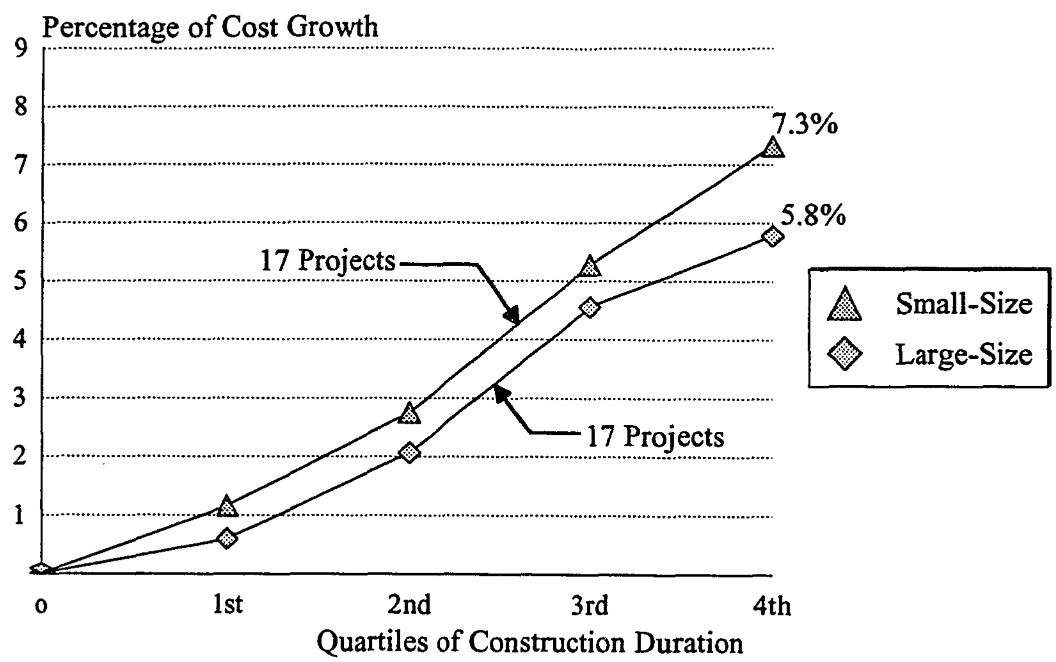

Figure 5-8. Cost Growth Trend Curves for Large and Small Size Projects

CHAPTER VI

ASSESSMENT OF COST AND SCHEDULE GROWTH TREND CURVES

Assessment Methodology

The analysis and trend curves that were presented in Chapters IV and V identified factors which were indicators of cost and schedule growth of projects during construction. Those macro project trend curves were developed based on the median values of cost growth for each set of data that was analyzed. The purpose of developing the trend curves was to detect factors which might be indicators of cost and schedule growth.

The statistical testing evaluated the average values. Since average values were used, some of the factors showed significant, although they were not apparent in the trend curves. For example, Figure 5-8 showed only a slight difference in median value of cost growth between small and large size projects. However, statistical testing indicated small size projects as significant because average values were used in the analysis.

The factors studied were presented in two main groups: project data and cost data. Within each group the different factors form families which represent items related to the administration of construction contracts. An example of a family is the execution format of a project which may be Design/Bid/Build, Design/Build, or Construction Management. Two questions are addressed in analyzing the growth trends. The first question pertains to significant deviations of trends between factors in the same family. The second question is significant deviations from industry expectations for all projects in that contracting format, whether fixed price or cost reimbursable. These expectations were chosen by the research team and the industry Task Force as the median percentages of cost and schedule growth values of all projects in both groups. As shown in Chapter IV for fixed price projects these values are 5.3% and 9% for cost and schedule growth respectively. For cost reimbursable projects, as discussed in Chapter V, these values are 6.8% and 7.5% for cost and schedule growth respectively.

Based on these two questions the research team and the members of the industry Task Force assessed the various trends to identify those factors which indicate cost and/or schedule growth. The factors which were identified to be common in keeping cost or schedule growth to a minimum and the factors which were common in keeping high cost or schedule growth were tested to find out if their divergence from the expected industry values was statistically meaningful.

Statistical Testing

In analyzing the trends, a number of postulates arose as areas which have either a positive or negative impact on cost and/or schedule growth. These postulates were reworded and reformulated to specific hypotheses and grouped under two headings - project data and cost data.

In testing hypotheses (6), the problem is formulated in a way that one of the claims is favored. This favored claim, called the null hypothesis, will not be rejected in favor of an alternate one, called the alternative hypothesis, unless the data does not support it. For this study, the t-test (a comparison between two group means which takes into account the differences in group variation and group size of the two groups) was used to test the hypotheses. The t-test is used when attempting to determine if the difference between two means is greater than that which could be expected from chance.

The following equations were used in the testing of the hypotheses for cost and schedule growth:

$NullHypothesis: H_o : C = C_o$ for Cost Growth Testing

or

$NullHypothesis: H_o : T = T_o$ for Schedule Growth Testing

$TestStatistic: t = \frac{m - C_o}{s/\sqrt{n}}$ for Cost Growth

or

$TestStatistic: t = \frac{m - T_o}{s/\sqrt{n}}$ for Schedule Growth

Alternative Hypothesis:	Rejection Region for a level α test:
$H_a : C > C_o$ or $H_a : T > T_o$	$t \geq t_{\alpha,n-1}$
$H_a : C < C_o$ or $H_a : T < T_o$	$t \leq -t_{\alpha,n-1}$

Where:

C = Percentage of Cost Growth

T = Percentage of Schedule Growth

C_o = Reasonable expectation for cost growth based on the data collected, 5.3% in fixed price projects and 6.8% in cost reimbursable projects

T_o = Reasonable expectation for schedule growth based on the data collected, 9% in fixed price projects and 7.5% in cost reimbursable projects

m = Average value of the percentage of cost or schedule growth

S = Sample Standard Deviation

$$S = \sqrt{\frac{\sum X_i^2 - \left(\sum X_i\right)^2 / n}{n-1}}$$

X = Data points

n = Number of observations

α= Selected significance level

Tables 6-1 and 6-2 present the several hypotheses for fixed price and cost reimbursable projects respectively which were tested using the t - test. The numbered hypotheses listed in Tables 6-1 and 6-2 were tested using a 90 % confidence limit. Tables 6-3 and 6-4 present a summary of the calculations performed on the data and the decisions made based on the testing.

The testing of the hypotheses which formulate the findings of this study only shows that for any of the factors supported by the data, the average value of cost or schedule growth is either significantly higher or lower than the chosen acceptable industry median value of either cost or schedule growth. The testing performed on any particular factor neglects the effects of any other factor or the combined effect of a group of factors which is customarily the cause of complexity in understanding the behavior of construction projects.

TABLE 6-1

FIXED PRICE HYPOTHESES

Project Data Hypotheses
1. Low Cost Growth is a characteristic for projects with D/B/B execution format
2. High cost growth is a characteristic for projects with CM execution format *
3. Low cost growth is a characteristic for projects with unrestricted bidding
4. High schedule growth is a characteristic for projects with unrestricted bidding *
5. High cost growth is a characteristic for private projects *
6. Low cost growth is a characteristic for government projects
7. High schedule growth is a characteristic for government projects *
8. Low cost growth is a characteristic for projects with federal documents
9. High schedule growth is a characteristic for projects with combined labor category *
Cost Data Hypotheses
10. High cost growth is a characteristic for projects with high MLOT *
11. High schedule growth is a characteristic for projects with high MLOT *
12. High cost growth is a characteristic for projects with low number of bidders *
13. High schedule growth is a characteristic for projects with low number of bidders *

* denotes hypothesis supported by the data

TABLE 6-2

COST REIMBURSABLE HYPOTHESES

Project Data Hypotheses
1) Low cost growth is a characteristic for projects with quality as driving factor *
2) Low schedule growth is a characteristic for projects with quality as driving factor*
3) High schedule growth is a characteristic for projects with cost as driving factor *
4) High cost growth is a characteristic for projects with schedule as driving factor *
5) High cost growth is a characteristic for projects with CM execution format *
6) High schedule growth is a characteristic for projects with CM execution format *
7) High schedule growth is a characteristic for projects with subcontracting *
8) High schedule growth is a characteristic for union projects/northern states*
9) Low schedule growth is a characteristic for open shop projects and southern states *
Cost Data Hypotheses
10) High cost growth is a characteristic for small size projects *

* denotes hypothesis supported by the data

TABLE 6-3

FIXED PRICE HYPOTHESES TESTING

Hypothesis Number	Number of Data Points	Average Value	S	t-calculated	t-table	Decision
1	36	9.34	8.84	2.71	1.3	Reject
2	18	14.5	9.95	3.95	1.33	Accept
3	33	9.05	8.37	2.61	1.37	Reject
4	31	157.31	758.59	1.09	1.31	Accept
5	31	13.74	14.68	3.22	1.31	Accept
6	40	9.69	11.23	2.5	1.3	Reject
7	39	151	688.17	1.29	1.31	Accept
8	36	9.5	11.63	2.19	1.3	Reject
9	14	380.78	1108.53	1.26	1.35	Accept
10	20	11.21	10.2	2.61	1.33	Accept
11	20	271.52	956.51	1.23	1.33	Accept
12	24	11.08	10.7	2.67	1.32	Accept
13	24	229.23	853.13	1.27	1.32	Accept

S = Sample Standard Deviation
t = Test Statistic

TABLE 6-4

COST REIMBURSABLE HYPOTHESES TESTING

Hypothesis Number	Number of Data Points	Average Value	S	t-calculated	t-table	Decision
1	22	12.5	20.28	1.3	1.32	Accept
2	19	6.79	13.19	-0.02	1.33	Accept
3	5	9.44	5.16	1.12	1.53	Accept
4	11	29.61	48	1.57	1.37	Accept
5	14	10.78	5.48	2.68	1.35	Accept
6	12	11.86	9.65	1.79	1.36	Accept
7	18	10.55	19.18	0.68	1.33	Accept
8	21	10.75	19.1	0.93	1.33	Accept
9	9	-1.76	9.07	-2.85	1.4	Accept
10	17	25.28	42.18	1.8	1.34	Accept

S = Sample Standard Deviation
t = Test Statistic

Model Development

The model which includes the factors which indicate cost and schedule growth, as presented in Chapter II, is shown in Figure 6-1.

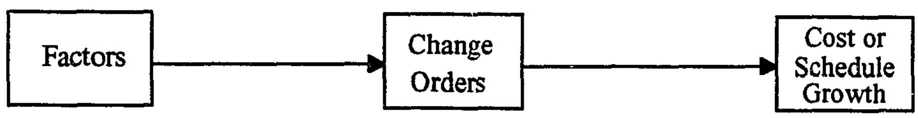

Figure 6-1. Model of Factors Indicating Cost and Schedule Growth

For the model, this study identified several project and cost data factors which are common in projects with change orders resulting in high or low cost and/or schedule growth. Tests were performed to attempt statistical verification of the various hypotheses formulated.

To develop a quantitative model which will allow study of the individual relationship between any of the factors and the cost or schedule growth, it is necessary to isolate the effects of the other factors. To understand the different relationships completely and be able to develop such an ideal model, data could be collected as shown in the matrix of Figure 6-2.

This figure shows the need to collect the data for two or even three factors in a two dimensional or a three dimensional matrix in predefined ranges of their values based on the results of this study. The example in the figure covers Money Left On the Table (MLOT), number of bidders, and the corresponding values of cost growth (CG).

Number of Bidders	3%	5%	7%	9%
4	CG1	CG4	CG7	CG10
6	CG2	CG5	CG8	CG11
8	CG3	CG6	CG9	CG12

MLOT →

Figure 6-2. Data Collection Matrix

A relationship can be developed and a variety of models which predict the cost and/or schedule growth can be formulated for the different project and cost factors in this study. However, such a data collection approach may be a difficult task to accomplish in the construction industry due to the difficulty in obtaining complete project files, special time and effort from project personnel who understand the project, and the availability of these specific data requirements.

CHAPTER VII

RIPPLE EFFECT

Background

Ripple effect is a term used in the construction industry to describe a cascade of changes. High ripple projects are the ones with a high number and dollar amount of successive changes because of a previous change, whereas low ripple projects are the ones with a low number and dollar amount of successive changes because of a previous change.

Changes have a tendency to multiply since one change impacts other crafts and areas of the project. This "ripple effect" concerns both contractors and owners because of its effect on high cost growth, schedule growth, and productivity losses of projects. Ripple effect is difficult to quantify. Additionally, the project activities are interrupted to allow for a change causing productivity losses. Also, there are usually downstream effects on project performance resulting from extending schedule and losses in productivity on the project activities that follow the changed activity.

Ripple Projects in the Study

Some projects in the study were identified as having high or low ripple effects. The ripple term is subjective and is rated from the perspective of the respondents as either high, medium, low, or none. If the respondent marked high ripple on either cost or schedule, the project was considered a high ripple project. If the respondent marked low ripple on either cost or schedule, the project was considered a low ripple project. Figure 7-1 shows the cost growth for high and low ripple fixed price projects as compared to the cost growth of all fixed price projects. Also the median percentage of schedule growth for high ripple fixed price projects (22%) is considerably higher than that value for low ripple projects (1.5%).

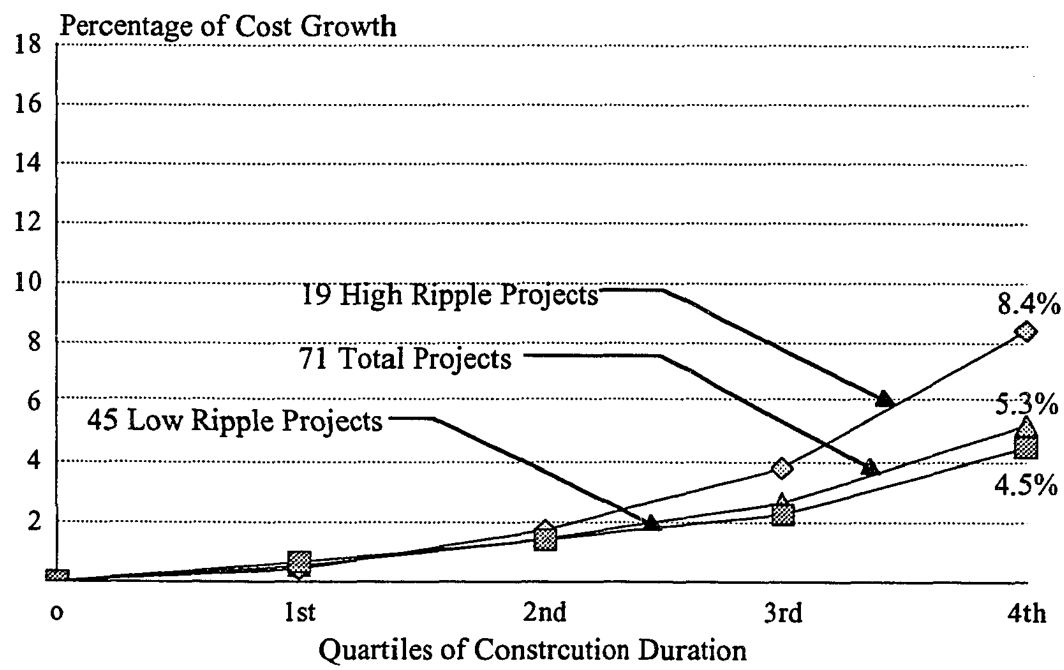

Figure 7-1. Cost Growth Trend Curves for Fixed Price Projects Compared to High and Low Ripple Projects

Figure 7-2 shows the cost growth trend curves for cost reimbursable high and low ripple projects as compared to all reported projects within that contracting format. Also, the schedule growth for high ripple cost reimbursable projects (9.5%) is considerably higher than that for low ripple projects (4.5%).

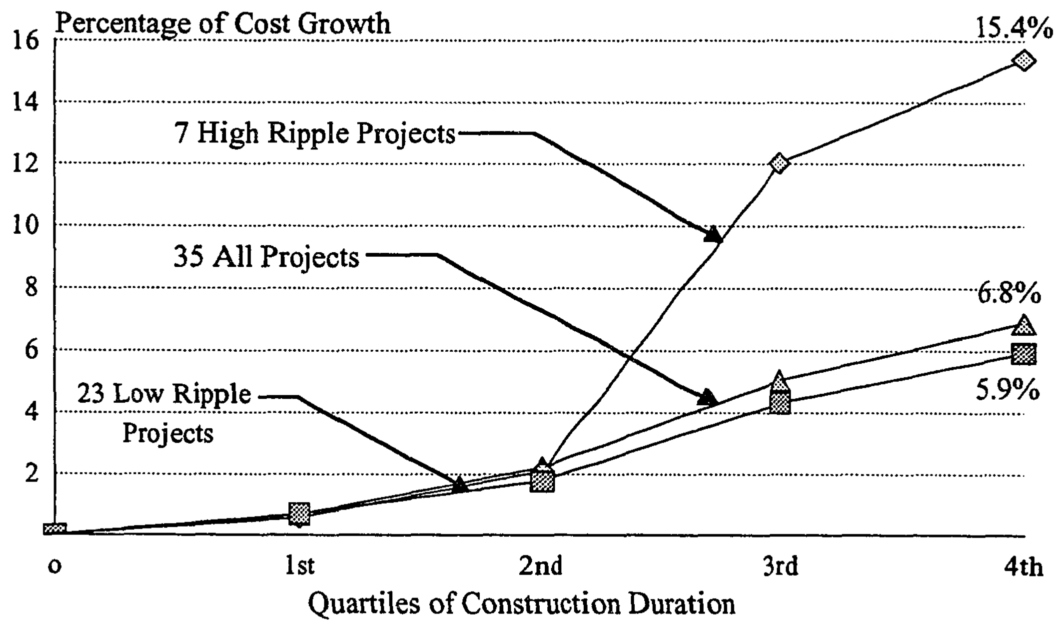

Figure 7-2. Cost Growth Trend Curves for Cost Reimbursable Projects Compared to High and Low Ripple Projects

Similar trend curves were developed for several of the project and cost data factors which were analyzed in Chapter IV and V. However, many of these trends were opposite to the common expectations of what high and low ripple should be. For example, respondents identified several projects as high ripple, but the cost and schedule growth for these projects were actually low. In other instances, respondents indicated projects as low ripple, but the projects had high cost and schedule growth. Thus, there could be no correlation between cost and schedule growth and the rating of ripple effects as noted by the respondents. This problem is most likely due to misunderstanding of the subjective term of ripple effect.

Proposed Method for Ripple Measurement

The understanding of how one change leads to many more changes is a complex area and needs further research. There is a relationship between the change in a certain work item and the number and type of other work items that subsequently need changes. These subsequent changes, due to the previous change, are referred to as impact of changes.

In an effort to measure the ripple effect of the changes above and beyond the direct change, a ripple tree as illustrated in Figure 7-3 was used in this research project to quantitatively measure ripple effect. The compilation of information for one ripple tree required about one hour without interruption. For the specific project tested, it took about two weeks to find the old project files and send them to the appropriate individual who needed to develop the information required to construct a ripple tree for each change. The process was further complicated because each individual had to rely on his or her memory for parts of the tree. Based upon the experience gained from this effort, it is recommended that the ripple tree method be accomplished while a project is in progress during the construction phase.

Figure 7-3 illustrates the ripple tree concept for evaluating the direct and the consequential effects of a change. In this simple ripple tree, the original change (move door) has a direct cost of $ 1,200 and a duration of 6 days. The ripple effect of that change is $ 3,400 of consequential expenses and an additional duration of 10 days. With more changes the effect can multiply throughout the project affecting critical areas of the work, and causing projects to become over-budgeted and behind schedule.

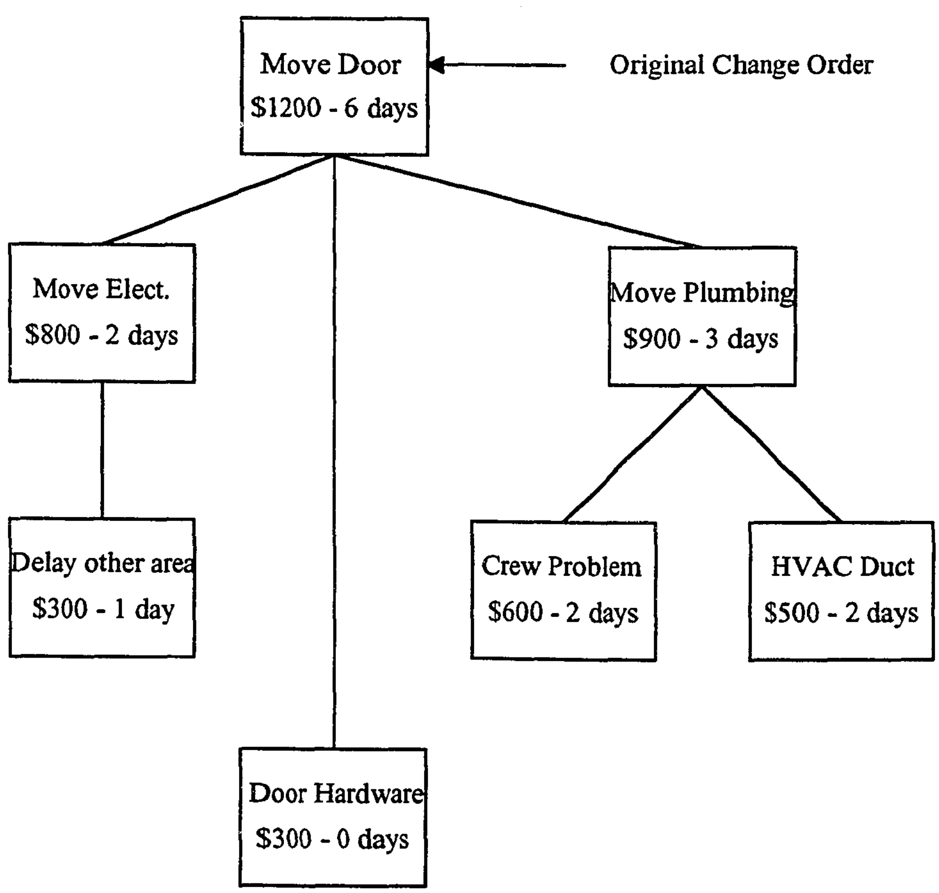

Figure 7-3. Example of a Ripple Tree

CHAPTER VIII

INDUSTRY SUGGESTIONS

To supplement the findings of this research project, the industry Task Force members, consisting of owners and contractors, gave their input in the form of suggestions. This was done using a brainstorming session which covered the most significantly supported hypotheses. The brainstorming session was conducted by the research team for the Task Force members and covered the topics: quality as a driving factor, cost as a driving factor, schedule as a driving factor, private and government owners, and money left on the table.

The brainstorming session was conducted using the force-field analysis, a method of evaluation that was developed by the organizational researcher Kurt Lewin (7). Force-field analysis is usually performed by a group that is working on a particular problem. A line is drawn down the center of a flip chart to represent the "as-is" situation (what currently exists). At the right hand edge of the sheet, a second vertical line is drawn parallel to the first to represent the situation as it should be (the desired state). Table 8-1 shows the force-field analysis format that was used by the Task Force members.

TABLE 8-1

FORCE-FIELD ANALYSIS

Contributing Factors	Preventing Factors
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To facilitate the brainstorming session the card-poll system (8) was used. In this technique the questions are phrased to be answered in note form. The notes are written by each participant on cards which are then sorted and attached onto a board or chart, so that the corresponding ideas are placed together into "clusters". Using the card-poll, the answers emerge independently of one another so every participant can take part in the "discussion" at the same time without creativity constraints. The clusters give an optical picture of the intensity of the thought process that is involved as the group members sort through problems and answers to the given questions.

The results of this brainstorming session are shown in the following tables. The different ideas listed under the two groups of contributing and preventing factors should be understood and handled separately since these two groups are not necessarily the opposite of one another.

TABLE 8-2

QUALITY AS A DRIVING FACTOR

Contributing Factors	Preventing Factors
Engineering and Planning	Engineering and Planning
Better scope definition which results in fewer changes and less rework	Engineering done on a lump sum contract where the money limitations could shorten the time provided for engineering
Good operation input of goals and objectives	Lack of quality assurance and quality control programs
Knowing what we want to design before we start	No constructability
Better engineering job by taking enough time to design right and using 3 D CAD	
More reviews early in the job during the engineering phase	
Good planning on the front end	
Reasonable scheduling which allows proper quality checking	
Better constructability	
Strategy	Strategy
More management attention	Lack of the right management input balance
More experienced personnel	Perception that quality costs time and money
Improved working relationships	Overemphasis of short term profit
Reduced waste and minimum rework	Subcontractors may not have the incentive to be part of the team

TABLE 8-2 (Continued)

Contributing Factors	Preventing Factors
Strategy	Strategy
Everyone is bought into the objectives	Unwillingness to devote manpower resources
Quality focus puts the emphasis on the right drivers for success	Lack of executive sponsor
Doing the right things and doing them right the first time	Insisting on excessive checking and auditing of efforts which shows the lack of trust
Attention to detail	Hammer on cost and schedule day to day
Focus is on the factors which organize the project	
More cost and schedule evaluation emphasis built in the strategy	
Team Work	
Getting everyone involved at the beginning	
With good team building owners and contractors basically want projects to be successful	
Customer involvement	
Good open communication	
A thorough execution plan which everyone agrees on	

TABLE 8-3

COST AS A DRIVING FACTOR

Contributing Factors	Preventing Factors
Strategy	Strategy
Features left out of design due to cost and are restored during construction if funds are available causing schedule growth	Penalty/incentive for schedule changes
Changes create rework which causes schedule growth	Adopt no changes philosophy
Redesign to reduce overruns	Fix fee so contractor would want to get off the job
Issue only 100% complete design	Be realistic by creating contingency fund and be willing to use it
Minimum over time so as to save dollars	Careful attention to costs during design
Lump sum engineering results in incomplete engineering	Evaluate the cost of time extension versus indirect costs from extra equipments and shifts
The use of low bidders even if they are not qualified	Use of better scope eliminates unnecessary schedule growth
So concerned with cost that owner can't make objective, rational decisions	Pre-planning and constructability input
Natural result of cost control is schedule growth if changes take place	
No constructability reviews	

TABLE 8-4

SCHEDULE AS A DRIVING FACTOR

Contributing Factors	Preventing Factors
Strategy	Strategy
Get more revenue than the cost to complete	Better and more open estimate of worst case cost to keep on schedule
Deadline to meet scheduled products	Quit demanding an unrealistic completion date and relax the penalty clause
Poor productivity from personnel density	Reward for finishing on cost
High cost to expedite and high use of over time	Evaluate cost impacts versus economic benefits
Throwing money at the problem rather than a more deliberate analysis and plan	Careful attention to impacts caused by a change
Inescapable fact that time costs money	Lack of Partnering
	Put better people on the project
	Complete scope and design of elements prior to construction phase

TABLE 8-5

PRIVATE PROJECT OWNERS

Contributing Factors	Preventing Factors
Engineering and Planning	Engineering and Planning
Unclear plans and specs or scope that does not match plans and specs	A quality engineering job
Poor contracting documents	Have complete drawings and specs based on complete scope development
No or little constructability during design	Involve users and operators in the scope development process
Owners are not sure what they want	Perform constructability review early
Late client / user comments	Use standard proven documents like CSI format
Poor on-site coordination	More time for design
Strategy and Policy	Strategy and Policy
Project is schedule driven	Don't allow changes
Lack of involving operations and maintenance	Get supplier to be a part of the team
Inexperienced owner manager and other project personnel	Have good open communication
Inexperienced contract administrators permit contractors to take advantage	Train project personnel to be knowledgeable of the construction process and the cost growth factors
Deliberate strategy to add items after award	Competent contract administration

TABLE 8-5 (Continued)

Contributing Factors	Preventing Factors
Strategy and Policy	Strategy and Policy
Allowing continuing changes by operations during construction with little appreciation of their impact	Open up bidders list so as to get more competition
Changing government regulations	Freeze design development once construction starts

TABLE 8-6

GOVERNMENT PROJECT OWNERS

Contributing Factors	Preventing Factors
Strategy	Strategy
Contractors know that the projects are cost driven and not time sensitive	Should not be prevented if the desire is to obtain lowest cost with good tight specs to assure quality
Government's deliberate strategy that shares time risks allowing for schedule growth	Bonus for early completion, and accelerate by buying back time
"Be nice to the contractor" mentality	Quit being nice
Government often allows late construction changes if funds are available	Put better people on the project if schedule is a driving factor
Customer is always right so give him what he wants if dollars are available	Change contract documents and strategy

TABLE 8-7

MONEY LEFT ON THE TABLE

Contributing Factors	Preventing Factors
Bidding Process	Bidding Process
Low number of bidders	Refuse to award to low bidder
Plans and specs are not clear as to real scope of work and some bidders know what is really required and bid that scope	Interpretable bid documents
Non qualified bidders	Pre-qualify an adequate number of bidders
Mistake in bid	When bidders bid different scopes of work resolve the differences before the award of contract
Poor bid documents	Owner should be always honest and ethical in dealing with bidders
Bid time is too short	Allowing sufficient time for bidding
Choosing low bid without evaluation	Evaluations of bid in detail
Contractor's desire to recoup dollars left on the table	Offering low bidder the chance to withdraw
Bad estimators	Demand quantity assessments
Economic Times	Economic Times
Poor economic conditions and some contractors buy the jobs to keep their staff employed	Owners should be aware of contractors who are in poor financial condition and are trying to buy the jobs

CHAPTER IX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The impact of project changes on the cost and schedule of a project is complex and influenced by numerous interrelated factors. The objective of this research study was to perform a macro trend analysis to identify various factors, that are known prior to the start of construction, which are indicators of cost and schedule growth in projects.

For this study, a questionnaire was developed to address a group of project data, cost data, and schedule data. The responses on the questionnaire provided a sample of projects from owners and contractors in the government and private sectors of the construction industry. A total of 106 projects were found usable from the 159 projects which were received from 23 companies. All of the received data were entered into a data base for the sorting and analysis that was used to develop the conclusions of this research.

The total separation of fixed price and cost reimbursable projects was a key element in the analysis of this research data, due to the major differences in the contracting strategy of the two pricing formats. Chapters IV and V of this document showed the results of the trend analysis of the different project and cost factors of fixed price and cost reimbursable projects respectively. These trends were evaluated and the significant ones provided the hypotheses for this study which were statistically evaluated using a 90% confidence limit, as shown in chapter VI of this document.

Chapter VII presented a brief discussion of the ripple effect resulting from successive changes due to a prior change. A method for ripple measurement by the use of ripple trees, which document all changes resulting from an original change, was proposed. Chapter VIII provided a summary of the contributing and preventing tips for some of the cost and/or schedule growth indicators which were identified in this research. These tips were developed based upon the experience of Task Force members, to benefit the industry for better management of changes and improvement of the cost effectiveness of construction projects.

The following two Tables 9-1 and 9-2, for fixed price and cost reimbursable projects respectively, summarize the quantitative values obtained from the trend analysis of the factors studied in this research. These tables show the values that are significantly different from the baseline median value of cost and schedule growth of all projects. This baseline was chosen for this research study as the median values of cost and schedule growth for the all projects reported in the two contract strategies, fixed price and cost reimbursable. For fixed price projects, these values were 5.3% and 9% for cost and schedule growth respectively. For cost reimbursable projects, these values were 6.8% and 7.5% for cost and schedule growth respectively. The labor category was not included in the tables since it was coincidence with the geographic location of the projects reported in this study.

TABLE 9-1

FIXED PRICE FINDINGS

Factor	Cost Growth *	Schedule Growth **
Money Left On Table		
MLOT > 4%	12.1%	19.0%
MLOT < 4%	(3.9%) ***	6.0%
Number of Bidders		
Number of Bidders < 5	12.0%	21.5%
Number of Bidders > 5	(4.8%)	11.5%
Execution Format		
Construction Management	12.1%	2.0%
Design/Build	4.6%	0.0%
Design/Bid/Build	(2.5%)	10.0%
Bid Solicitation		
Approved Bidders List	6.4%	0.0%
Open Bids	(4.6%)	18.0%
Owner Type		
Private	8.1%	0.0%
Government	(3.6%)	17.0%

* The median cost growth for all 71 fixed price projects was 5.3%.
** The median schedule growth for all 71 fixed price projects was 9.0%.
*** The values in brackets indicate the values which did not pass the t-test with a 90% confidence level.

TABLE 9-2

COST REIMBURSABLE FINDINGS

Factor	Cost Growth *	Schedule Growth **
Primary Driving Factor		
Quality	6.1%	4.5%
Cost	9.9%	15.0%
Schedule	10.3%	9.0%
Execution Format		
Construction Management	9.5%	13.0%
Design/Build	5.3%	4.5%
Design/Bid/Build	(6.4%) ***	3.0%
Work Distribution		
Direct Hire	10.8%	-0.8%
Subcontract	(8.0%)	13.0%

* The median cost growth for all 35 cost reimbursable projects was 6.8%.
** The median schedule growth for all 35 cost reimbursable projects was 7.5%.
*** The values in brackets indicate the values which did not pass the t-test with a 90% confidence level.

Conclusions

This research has identified several factors that are early warning signals of cost and/or schedule growth during construction. Caution should be exercised in reviewing the findings of this study. It should be noted that cost growth in this study is based on the dollar amount of approved change orders during construction and does not include the costs of claims and/or settlements at the end of the project. The study has addressed the fixed price and cost reimbursable projects separately.

Fixed Price Projects

For fixed price projects the early warning signals are in the categories of money left on the table, number of bidders, execution format, and bid solicitation. Professionals in the construction industry can use these factors to effectively manage project changes and control costs.

For a fixed price project that has high money left on the table (MLOT), the study indicated high cost and schedule growth. A careful evaluation of the bids should be performed before award of contract to determine the cause of high MLOT. Better staffing is required to better manage and control the construction. The owner should plan to set aside some contingency funds to cover the possible cost and schedule growth.

The low number of bidders was an indicator of cost and schedule growth in this study. The pre-qualification of an adequate number of bidders should raise the competition and encourage a proper study of the bids. Several bids can help the owner to detect possible mistakes in the bid and award the contract to the best qualified bidder.

The construction management execution format showed a trade-off between cost and time. The study indicated a high cost growth and a low schedule growth for fixed price projects which were handled by the construction management execution format. Projects using construction management are usually schedule driven which results in the increase in costs. Better understanding and application of construction management should result in a lower cost growth to encourage its use.

For the method of bidding, the study showed that an approved bidders list indicates a low schedule growth with a slightly higher cost growth, as compared to open bids. This result shows the advantage of working with a pre-qualified group of bidders with known experience and financial capabilities.

Cost Reimbursable Projects

For cost reimbursable projects the early warning signals are in the categories of primary driving factors, execution format, and work distribution. With quality as a driving factor for cost reimbursable projects, low cost and schedule growth were indicated. This finding is even more extensive if quality as a driving factor is compared to the other two driving factors, cost and schedule. This agrees with the emphasis on quality as taught by Dr. W. Edward Deming (9) who assisted the Japanese in improving the quality of their products. Better scope definition results in fewer changes and less rework. Enough time should be spent on the right design, planning, and constructability at the front end of the project.

The construction management execution format has indicated a high cost and schedule growth when used for cost reimbursable projects. Problems in the understanding and application of construction management should be solved to be able to gain the benefits of this execution format for cost reimbursable projects.

The distribution of the construction work indicated a low schedule growth in using direct hire as compared to subcontracting. Subcontracting can result in extended schedule growth because of the coordination problems that can arise when dealing with different subcontractors. Better staffing to manage and control the various subcontracts should help in decreasing this problem.

Recommendations

During this macro study of the factors indicating cost and schedule growth, a variety of topics for further evaluation and investigation were identified. These areas include micro study of each of the findings, the study of ripple effect, the improvement of the practices of the construction companies, and the effect of the timing of the study.

The micro aspects of each of the findings of this study are important to determine why the factors have an indicated positive or negative impact on cost and/or schedule. Several studies can be conducted to study each of the individual factors. After reaching conclusive results regarding each of the factors and the reasoning behind its effect, a combined study should examine the integration of the effects based on the knowledge gained from understanding the behavior of each factor separately. At this stage, a model can be developed with the objective of predicting the cost and/or schedule growth for a certain range of the factors included in that model.

The area of ripple effect requires future research to quantitatively measure ripple effect. The ripple trees, proposed in Chapter VII of this study, should be drawn for a variety of changes in several projects during the construction phase. These ripple trees can reveal knowledge useful in understanding the consequential effect of changes.

The improvement of the practices of the construction companies can be achieved through the use of the questionnaire that was developed in this study. The questionnaire should entail more explicit definitions of terms to avoid misunderstandings. The information which is requested on the questionnaire is typically available in project files at job close out. Similar trends to the ones developed in this study could be acquired for each company and be used to provide management with the feedback that is useful in making continuous improvement in construction operations.

The effect of the timing of the study can be addressed by repeating this research project in time intervals of five years. The parameters of the construction industry vary with time and it would be useful to find the variation in cost and schedule trends. This can be used to plot a trend for the construction industry that can help the industry in constantly improving the system of practice in order to achieve cost effective construction work.

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APPENDIX

DATA GATHERING TOOL

This appendix presents the questionnaire that was used as the major data gathering tool for conducting this research project. The transmittal letter introduces the objectives of the research. The cover page of the questionnaire is the instructions sheet which describes the purpose of the study, the number of projects expected per company, and the criteria that the projects should meet. The instructions also specify who is to fill in the questionnaire, and the person to contact for the questions and the return of the completed questionnaires. Reference is made to the glossary and to the degree of data confidentiality.

The first page of the questionnaire covers main project data. Various information about the facility, the contractual aspects, and the execution aspects of the projects are asked on this page. The answers to these questions provide some of the main sorting factors for this study.

The second and third pages are for project cost data. Page two is for the owners to fill in and page three is for the contractors. Several questions are asked about original contract amount, changes by quarters of construction duration, and final contract amount. The cost growth is calculated based on the information provided in this section.

The fourth page is for project schedule data. The schematic shown on this page covers the main milestones dates requested in this survey. The actual start of the construction work, the planned completion data, and the mechanical completion date are among the most important information which is used in the calculation of the schedule growth.

The fifth page covers some respondent's demographics. This information is useful for further clarification and for further contacts regarding more details in specific projects.

Two pages of terms follow under the glossary section. The glossary is divided following the sequence of the questionnaire. It covers the important terms used in the project data, cost data, and schedule data sections of the questionnaire.

COLLEGE OF ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN

Construction Industry Institute
3208 Red River St., Suite #300 · Austin, Texas 78705-2650 · (512) 471-4319 · FAX # (512) 499-8101

MEMORANDUM

TO: CII Board of Advisors

FROM: Richard L. Tucker

DATE: October 3, 1990

The CII Task Force on Change Order Impacts is in the process of collecting information regarding project changes and the impact of changes during construction. This part of the research is being conducted in two phases by Oklahoma State University under the guidance of the CII Task Force.

The first phase will collect and analyze data from numerous completed projects from a wide spectrum of the industry. The purpose of this phase is to identify common factors among projects related to changes. The second phase will involve a detailed analysis of specific projects selected from the first phase. The purpose of this phase is to better identify the full impact of changes and to evaluate the ripple effect of changes related to timing and other factors.

We are asking your input for the first phase by completing the attached form for at least 10 projects that have been completed in the 50 states during the last 5 years. Please make copies of this form and have your Project Manager complete one form for each project. A set of instructions is attached. Please return your survey forms for 10 projects directly to Dr. Garold Oberlender at Oklahoma State University by November 20, 1990.

The information gathered in this research study will benefit your company, and the industry, to better evaluate and control project changes and improve cost effectiveness.

INSTRUCTIONS

The data that you provide on this form is the first phase of the research study on the impacts of project changes during construction. This research is sponsored by the Construction Industry Institute (CII). Your input is valuable to us and will benefit your company and the industry. Below are some instructions to help you in completing this form.

1) Please select 10 or more projects from the variety of construction projects which you were involved with as either owner, constructor or construction manager. It is desirable to select projects which had a CII member as the other party. In addition, each project should meet the following criteria:

   * Bid amount of $5 million or more.
   * Project was completed during the last 5 years.
   * Project was completed in the 50 states.
   * Successful and problem projects should be considered.

2) Please make 10 copies or more of this survey form and complete one form for each project. Please return the forms by November 20, 1990 to the following address:

   Dr. Garold D. Oberlender
   School of Civil Engineering
   Oklahoma State University
   Stillwater, Oklahoma 74078
   Phone: (405) 744-5189
   Fax: (405) 744-7673

3) The completion of each survey form should be coordinated by the Project Manager who was responsible during construction of the project. Our testing of this form indicates that it will take between 30 and 60 minutes to complete.

4) A glossary of terms is attached to this survey form to assist in completion of the form. Also a phone number for questions is shown at the bottom of each page of the form.

5) Your data is to be returned directly to the researcher who will number each copy, remove company identification, and remove project identification. Task force members will not have access to your response form or specific data which would identify your form. The information you will provide will be kept in strict confidentiality.

PAGE 1 OF 5

PROJECT DATA

Facility:

1. Project Description: ______________________________

2. Project Location: City ______________ State ______________ Zip ______________
   If remote, give general location ______________________________

3. Owner Type: Government ______________ Private ______________

4. Project Type: Provide the distribution of costs to the nearest 10% of total cost.
   New _____% Remodel _____% Addition _____%

5. Facility Type: Please check the facility type that best describes the project (exclude nuclear plants & dams)
   ___ Commercial Building ___ Pipeline ___ Petroleum/Natural Gas
   ___ Power Plant ___ Marine ___ Pharmaceutical/Chemical
   ___ Utility (electrical) ___ Mining ___ Ore Processing
   ___ Utility (municipal) ___ Manufacturing ___ Plastic/Rubber
   ___ Highway ___ Treatment Plant ___ Food Processing
   ___ Airport ___ Refinery ___ Pulp/Paper
   Other, describe: ______________________________

Contractual:

6. Execution Format: Design/Bid/Build ___ Design/Build ___ Const Mgmt ___ Turnkey ___ Fast Track ___ Other ___

7. Distribution of Work: Direct Hire ___% Subcontract ___%

8. Pricing Format: Provide the distribution of costs to the nearest 10% of total cost.
   Lump Sum ___% Cost Plus Fixed Fee ___% Guaranteed Maximum ___% Incentive ___%
   Unit Price ___% Cost Plus % Fee ___% Target Price ___% Other: ______________

9. Solicitation of Bids: Open Bid Project ___ Approved Bidders List ___ Other, describe: ______________

10. Origin of Contract Documents: Federal ___ Owner Corporate ___ Contractor ___ AIA ___ EJCDC ___ AGC ___
    Other, list: ______________________________

11. What was the owner-contractor relationship? First Time ___ Repetitive ___ Partnering ___

12. Working Relationship of Principal Parties: Excellent ___ Good ___ Fair ___ Poor ___

13. Is there any litigation/arbitration resulting from this project? Yes ___ (Amount $ ________) No ___

Execution:

14. Labor Category: Union ___ Open Shop ___ Combination ___

15. Were there significant changes of key personnel on this project? Very High ___ High ___ Medium ___ Low ___

16. What was the safety performance of the contractor? Good ___ Average ___ Poor ___

17. Was there any uniqueness about the project? Secrecy Agreements ___ Clean Rooms ___ Pilot Plant ___
    None ___ Others, describe: ______________________________

18. Rank the primary driving factors for this project.
    Rank 1 for highest to 3 as lowest for the following 3 factors:
    Quality ___ Cost ___ Schedule ___

For questions, please call Dr. Garold Oberlender, (405) 744-5189

OWNER COST DATA

If your company was the Owner for this project, please complete this page. If your company was the Contractor for this project, skip this page and go to page 3.

Total number of bidders = _______

Owner's Estimate (to the nearest $1,000) = $ __________

Original Low Bid (to the nearest $1,000) = $ __________

Second Low Bid (to the nearest $1,000) = $ __________

Original Contract Amount (to the nearest $1,000) = $ __________

Percent of Construction Duration	Number of Change Orders	Amount of Change Orders (to the nearest $1,000)
0 - 25 %	__________	$ __________________
26 - 50 %	__________	$ __________________
51 - 75 %	__________	$ __________________
76 - 100 %	__________	$ __________________

Amount of Penalty/Bonus/Others (to nearest $1,000) = $ ___________

Final Amount Paid to Contractor (to nearest $ 1,000) = $ ___________

Did any of the parties experience financial difficulty? Yes___ No ___

Rate the ripple effect on this project's cost:
High ____ Medium ____ Low ____ None ____

(Please refer to the attached glossary for clarification of terms)

For questions, please call Dr. Garold Oberlender, (405) 744-5189

CONTRACTOR COST DATA

Complete this page if your company was the Contractor for this project.

There are 2 types of variances: those that lead to a Change Order and those that do not. We need the Change Orders and the variances and their timing of occurrence as shown in the table below.

Original Bid/Budget Amount (to the nearest $1,000) = $ ____________

Original Contract Amount (to the nearest $1,000) = $ ____________

Percent of Construction Duration	Number of Approved Change Orders	Amount of Change Orders (to $1,000)	Number of Variances Not Leading to Change Orders	Amount of Variances Not Leading to a Change Order (to $1,000)
0-25 %	________	$ ________	________	$ ________
26-50 %	________	$ ________	________	$ ________
51-75 %	________	$ ________	________	$ ________
76-100 %	________	$ ________	________	$ ________

Amount of Penalty/Bonus/Others (to nearest $1,000) = $ ____________

Final Contract Amount (to nearest $1,000) = $ ____________

Did any of the parties experience financial difficulty? Yes___ No___

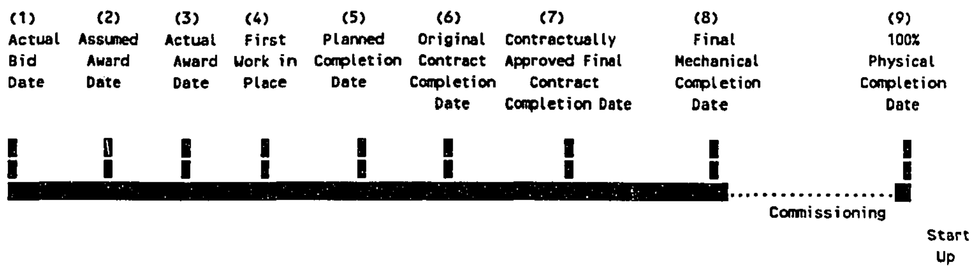
Rate the ripple effect on this project's cost:
High ____ Medium ____ Low ____ None ____

(Please refer to the attached glossary for clarification of terms)

For questions, please call Dr. Garold Oberlender, (405) 744-5189

SCHEDULE DATA

Below is a schematic of a project life. Please complete this page regardless of your Owner or Contractor status.



Provide the **month & year** for the following 9 events. Please refer to the attached glossary for further information about these events.

(1) Actual Bid Date: ________

(2) Assumed Award Date: ________

(3) Actual Award Date: ________

(4) First Work in Place Date: ________

(5) Planned Completion Date: ________

(6) Original Contract Completion Date: ________

(7) Contractually Approved Final Contract Completion Date : ________

(8) Final Mechanical Completion Date,
Beneficial Occupancy Date, Etc.: ________

(9) 100% Physical Completion Date: ________

Rate the ripple effect on this project's schedule:
High ____ Medium ____ Low ____ None ____

For questions, please call Dr. Garold Oberlender, (405) 744-5189

RESPONDENT'S INFORMATION

Your Name : ______________________________

Company : ______________________________

City Address : ______________________________

City/State/Zip: ______________________________

Phone :
(With area code) ______________________________

Fax Number : ______________________________

Are you willing to share data for phase II of this study?
Yes _____ No _____

Is the other party (Owner or Contractor) a CII member?
Yes _____ No _____

Comments:

____

____

____

____

____

____

Return this form to the researcher's address shown below. This response form will be numbered, company identification removed, and project identification removed. Task force members will not have access to your response form or specific data which would identify your form.

Return by November 20, 1990 to:

Dr. Garold D. Oberlender
School of Civil Engineering
Oklahoma State University
Stillwater, Oklahoma 74078
Phone: (405) 744-5189
Fax: (405) 744-7673

Form Serial# __________
Company Code# __________

GLOSSARY OF TERMS

CII Task Force on Change Order Impacts

Project Data

Project Type (Question 4)	- New: all new (no prior existing facility) Remodel: rework of existing facility Addition: addition to existing facility

Cost Data

Contractor	- The party responsible for overall construction of the project, acting as general, prime constructor or as the Construction Manager (CM).
Original Bid/ Budget Amount	- The original bid amount is the initial price the contractor submits to the owner. In cost plus cases the original bid becomes the original budget amount (1st budget agreed upon between owner and contractor).
Owner's Estimate	- The owner's estimate should be on the same basis as the scope of work of the bid documents.
Change Order	- Deviation from the initial project control plan which represent additions, deductions, or deviations to the overall scope of services which have become a part of the contract documents
Variance	- A change, any deviation from the initial project control plan, i.e. original budget and baseline schedule, whether concerning work product, money, materials, manhours, or time.
Ripple Effect	- The cumulative effect of multiple changes on a project's outcome due to their effect on concurrent or subsequent activities, even though the affected activities were not directly involved in the change. This definition applies to either cost or schedule.

GLOSSARY OF TERMS

CII Task Force on Change Order Impacts

Schedule Data

Actual Bid Date (1) - Date on which bids or proposals are finally received/opened.

Assumed Award Date (2) - At the time of "actual bid date" this date is the date which the owner or contractor assumes award will be made.

Actual Award Date (3) - Date that both parties sign contract or a letter of acceptance of an offer is issued.

First Work In Place (4) - The first work that contributes to the first physical reporting of the job.

Planned Completion Date (5) - The anticipated project completion date that was determined at the time of bid.

Original Contract Completion Date (6) - The project completion date that was established at the time of contract award and before any change orders.

Contractually Approved Final Contract Completion Date (7) - The original contractor's completion date adjusted for all time adjustments granted by change orders.

Ripple Effect - The cumulative effect of multiple changes on a project's outcome due to their effect on concurrent and subsequent activities, even though the affected activities were not directly involved in the change. This definition applies to either cost or schedule.

VITA

ALAA A. ZEITOUN

Candidate for the Degree of

Doctor of Philosophy

Thesis: EVALUATION OF COST AND SCHEDULE GROWTH TRENDS DURING CONSTRUCTION

Major Field: Civil Engineering

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Education: Received Bachelor of Science Degree in Civil Engineering from Ain Shams University in June, 1984; received Master of Science Degree in Civil Engineering from Oklahoma State University in May, 1990; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1992.

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