Pre-Project Evaluations

for

Cost and Schedule Growth

Cost, Time, and Risk

Evaluating Project Delivery in the Face of Change

Garold D. Oberlender, Ph.D., P.E.

INTRODUCTION

The fear of a cost overrun or a schedule slippage on a project often tops the list of concerns of project managers. Due to the nature of project work, some adjustments are necessary in order to complete the project so it can be used as intended by the owner. At the beginning of a project some of these adjustments are unforeseen and it is the hope of all project managers that sufficient contingency funds are available to handle any additional costs that occur.

Experienced project managers will readily agree that each project is unique and changes are a necessary part of project work, but the full impact of changes are probable not fully understood or appreciated. A single change in a project may cause other changes, influence craft productivity, and impact the cost and/or schedule of the project. These project managers are well aware that adjustments of changes in the scope, budget, or schedule of a project often result in excessive cost overruns, delays in time of completion, and reductions in the quality of the constructed facility.

In recent years, there has been a growing concern regarding the number and magnitude of changes during the construction phase of projects. These concerns have arisen because changes during construction often result in 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 resolving disputes on a particular project or evaluating the effect of changes on craft productivity. Little effort has been given to study multiple projects, to identify those factors that may indicate potential changes in the original planned cost or schedule of a project.

The Construction Industry Institute (CII) formed the Change Order Impact Task Force to study the impacts of changes in projects related to costs and schedules. The CII Task Force began the study in 1989 to identify factors, that can be identified before the start of construction, which are indicators of increased costs and delayed schedules. Data was collected from 106 projects which were reported from 23 CII companies. The sum of the original contract amounts reported from the 106 projects totalled $3.9 billion. This paper presents some of the findings of the Task Force.

During early discussions, members of the Task Force recognized that some additional costs and increases in schedules are unforeseen and are a necessary part of project work. However, the Task Force also suspected there were factors that could be identified early in the project, before construction, that could signal or forewarn the cost and schedule growth of construction contracts. The general feeling was that some projects seem to have characteristics that were indicative of additional costs and delays in completion.

To achieve the purpose and objective of the study, quantitative and qualitative data were collected from completed construction projects. These data were used to develop a series of trend curves which show changes in cost and schedule with respect to the duration of projects. Evaluation of the trend curves provided the basis for identifying factors that are indicators of cost and schedule growth. 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.

The separation between fixed price and cost reimbursable projects was made 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 (fixed scope of work), whereas cost reimbursable contracts are selected when extensive changes during construction are anticipated (the scope of work is not well fixed at the time of contract award). Therefore, cost and schedule growth patterns are considerable different between these two types of pricing methods of construction contracts.

The intent of the Task Force was to identify factors that are early warning signs of potential cost and/or schedule growth and to develop a list of strategies to assist in management of projects. It was the feeling of the Task Force that all parties in a project (owners, designers, and contractors) can improve the cost effectiveness and overall management of a project if they know, in advance, those signs which should be closely monitored in order to control and manage a project.

BACKGROUND OF PROJECTS

A questionnaire was developed by the Task Force to collect data from CII member organizations between November, 1990 and May, 1991. Selection of specific projects was left to the discretion of each respondent to provide a representative sample of successful and problem projects. The CII members 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 study because of the difficulty in analysis of currency exchange rates. Nuclear power and dam facilities were also omitted because of their unique natures.

Of the 106 projects, 42 projects were government projects (forty percent), and 64 projects were private projects (sixty percent). There were 69 projects reported from owners (sixty five percent) and 37 projects were reported from contractors (thirty five percent). Table 1 shows the distribution of projects by facility type. The majority of the projects are from the industrial plant and processing industries.

For this study, the project size is defined as the original contract amount. Figure 1 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.

Projects from 27 states (fifty four percent of the U.S.) were received and studied. States with the most projects were Texas (14 projects), New Jersey (13 projects), New York (12 projects), and California (9 projects).

TABLE - 1

DISTRIBUTION OF FACILITY TYPE

(Source: CII Source Document #91)

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	3	Plastic/Rubber	2
Airport	2	Food Processing	8
Marine	3	Pulp/Paper	7
Manufacturing	6	Other	2

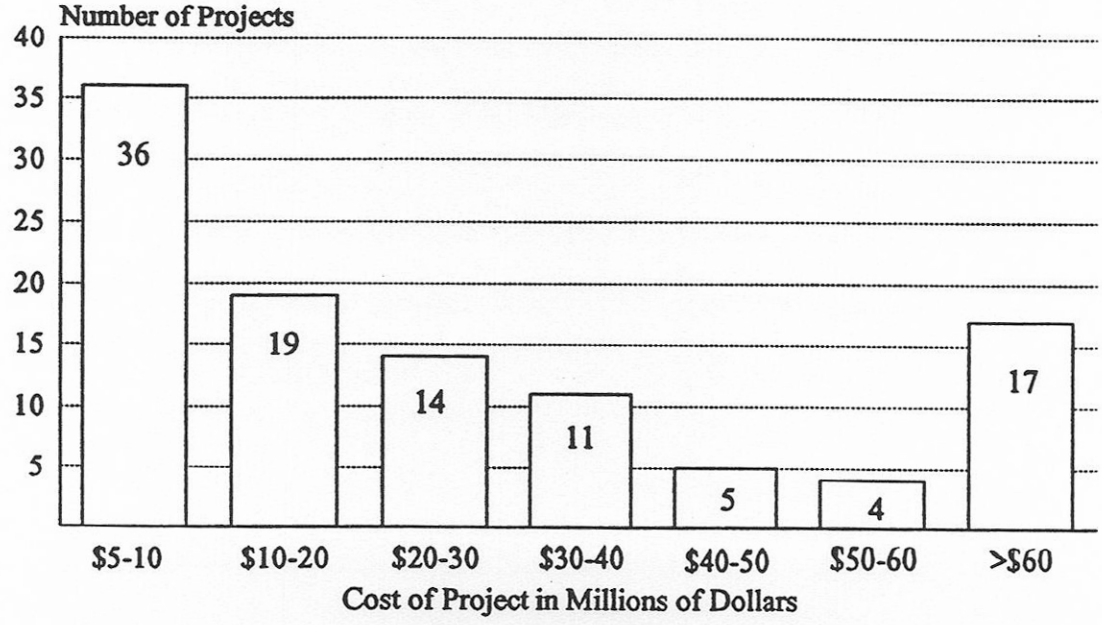

Figure - 1. Distribution of Project Sizes

(Source: CII Source Document #91)

ANALYSIS OF COST AND SCHEDULE GROWTH OF FIXED PRICE PROJECTS

All projects that were administered by a lump sum or unit price format are analyzed in one group as fixed price projects, and those administered as cost reimbursable are analyzed in another group. The distribution of the 106 projects 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.

This section presents the analysis of cost growth and schedule growth for fixed price projects. Analysis of data reported in the project administration section of the questionnaire included execution format, method of bid solicitation, owner type, and origin of contract documents. Analysis of the cost data section of the questionnaire included the number of bidders and money-left-on-the-table (MLOT, defined as the difference between the lowest bid and the next higher bid).

Project Cost Growth Analysis

One of the primary objectives of the Task Force was to analyze cost and schedule growth of projects during construction. Throughout this paper the following equation is used to calculate the cost growth of a project:

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

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 sections of this paper.

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 the above equation, the cost growth is calculated at 25% increments of construction duration (quartiles of construction).

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 study. The intent was not to study any one particular project, but to study multiple projects as a group at the macro level. Figure 2 shows the macro cumulative cost growth curve for all the 71 fixed price projects.

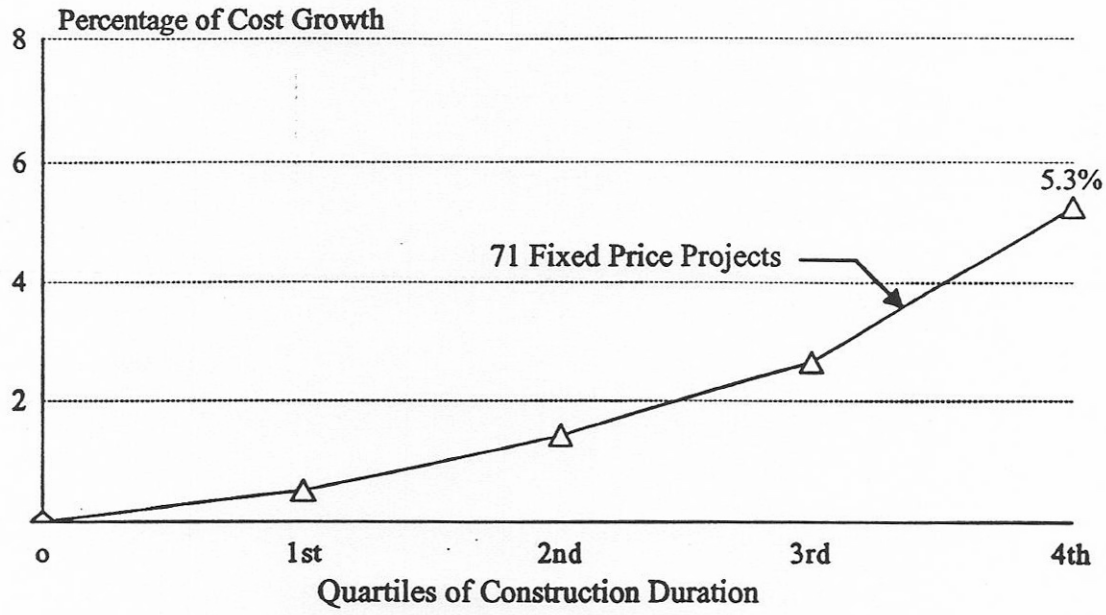

Figure - 2. Cost Growth Trend Curve for All Fixed Price Projects
(Source: CII Source Document #91)

This curve is developed based on 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.

There were also wide variations in the cost growth in each of the quarters of construction duration. This is illustrated by using three projects that had a cost growth at or near the median value of all the 71 fixed price projects. A $26 million project had a uniformly increasing cost growth through each of the quarters of construction duration. However, a $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 were used for statistical testing, because the Task Force was interested in the overall cost growth of projects. 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.

Project Schedule Growth Analysis

Another primary objective of this study was to analyze the schedule growth of construction projects. Schedule growth is defined as the ratio of schedule increase to the original scheduled duration of a project:

$$ScheduleGrowth = \frac{ScheduleIncrease}{OriginalScheduledDuration}$$

For this study, "Schedule Increase" is the difference in time between the original contract completion date and the final mechanical completion, or beneficial occupancy date. The "Original Scheduled Duration" is the difference between the original contract completion date and the actual contract award date. Median values are used for all schedule growth calculations in this study. The median value of schedule growth for all fixed price projects is 9%.

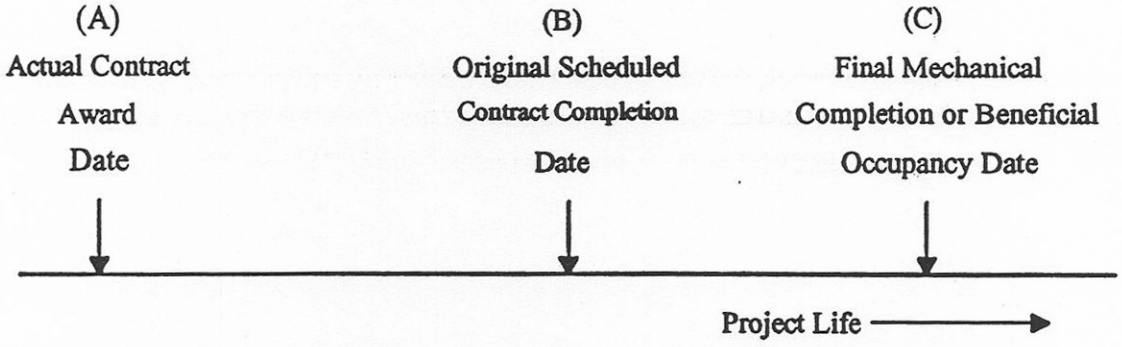

Figure - 3. Major Milestone Dates

$$ScheduleIncrease = (C - B) \qquad OriginalScheduledDuration = (B - A)$$

Factors Related to Cost or Schedule Growth for Fixed Project Projects

Figures 4 through 13 present cost growth trend curves and schedule growth graphs of fixed price projects that were collected by the Task Force. To supplement the results of this study, the Task Force developed a list of strategies to better manage projects that have indicators of cost and schedule growth. These strategies are summarized in the tables that follow each cost and schedule growth figure in this paper. It should be noted the cost and schedule trend curves shown in this report represent the factors that were identified by the Task Force as "indicators", not "causes", of cost or schedule growth of projects.

This study showed that high "Money-Left-On-the-Table" (MLOT) as a factor that is an indicator of high cost and schedule growth of projects. MLOT is the difference between the low bid and the next higher bid. The "Percentage of MLOT" is the ratio of the difference between original low bid and the next higher bid, diivided by the original low bid. Of the reported total 71 fixed price projects, the median value of MLOT was 4.0%, which was used as the benchmark for separating high from low MLOT. Thus, high MLOT is defined as greater than 4.0% and low MLOT is defined as less than 4.0%.

Figures 4 and 5 show the cost and schedule growth trend curves for fixed price projects, sorted by high and low MLOT. As shown in these figures, high MLOT is an indicator of high cost and schedule growth. As previously noted, the cost and schedule trend curves in this report represent "indicators", not "causes", of cost or schedule growth of projects. For example, projects with high money-left-on-the-table (MLOT) reported significantly higher cost growth than projects with low MLOT. Thus, high MLOT was identified as an indicator of cost growth. Additional research is required to determine the cause of high cost growth for projects with high MLOT. Speculative causes may include: misinterpretation of bid documents, non-qualified bidders, unclear plans and specifications, or numerous other causes. Table 2 is a list of strategies developed by the Task Force to better manage projects with high MLOT.

This study showed "Number of Bidders" as a factor that is an indicator of high cost and schedule growth of projects. Of the reported total 71 fixed price projects, the median value of "Number of Bidders" was 5, which was used as the benchmark for separating high from low "Number of Bidders". Thus, high "Number of Bidders" is defined as greater than 5 and low "Number of Bidders" is defined as less that 5.

Figures 6 and 7 show the cost and schedule trend curves for fixed price projects, sorted by "Number of Bidders". Cost and schedule data which were gathered in this study 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 quartile for projects with low "Number of Bidders" is about 2.5 times higher than the value for projects with high "Number of Bidders". The median value of schedule growth for projects with low "Number of Bidders" is 21.5%, almost twice the value for project with high "Number of Bidders". Thus, low "Number of Bidders" is considered as an early warning sign of high cost and schedule growth of projects.

The method of soliciation of bids for each project studied by the Task Force was identified by respondents as either "Open Bidders", where all contractors are invited to submit a bid for the proposed construction work, or "Approved Bidders" where a limited pre-qualified group of contractors is allowed to submit bids.

Figures 8 and 9 show the cost and schedule growth trend curves for fixed price projects, sorted by soliciation of bids. Although the projects with an approved bidders list showed a slight increase in cost growth, compared to an open bidders list, the schedule growth is substantially less than projects awarded by an open bidders list. Projects with open bidders showed a schedule growth of 18%, twice the median value of 9% for all fixed price projects. Table 4 is a list of strategies developed by the Task Force to address high schedule growth on projects solicited by open bidders.

Figures 10 and 11 show cost and schedule growth trend curves of fixed price projects, sorted by the private and government sectors of the industry. Although project data received from government projects showed lower cost growth than the private sector, the schedule growth was substantially higher. As previously discussed, cost growth for this study is based only on approved change orders and does not include claims at the end of the project. Tables 5 and 6 provide project management strategies to address cost and schedule growth in the private and government sectors of the industry.

Figures 12 and 13 show cost and schedule growth trend curves for fixed price projects, sorted by execution formats. The method of contracting created considerable discussion among members of the Task Force. Three methods of execution formats were studied by the Task Force: design/bid/build (D/B/B), design/build (D/B), and construction management (CM). The survey questionnaire did not identify the percent complete of engineering design at the time the CM was assigned to the project. Many members of the Task Force commented on the importance of early involvement of the CM for the success of construction management contracting.

In the application of the results of this study, one should not apply the numerical values obtained in this study to a particular project without an understanding of the total conditions related to a particular project. For example, one may interpret the CM contract method as undesirable, compared to D/B/B, when comparing the 12.1% and 2.5% cost growth. However, the schedule growth of fixed price CM projects were reported as significantly lower that D/B/B projects. Thus, for the projects studied it appears that CM projects traded higher costs for decreases in time, compared to D/B/B projects.

High cost growth could be acceptable depending on the project strategy. A CM contract is often selected because the project is unusually complex or because the owner does not have the available expertise to handle the project. The owner may wish to complete the project at the earliest possible date and be willing to accept cost growth to achieve that goal. Considerations must be given to the uniquenesses of each project.

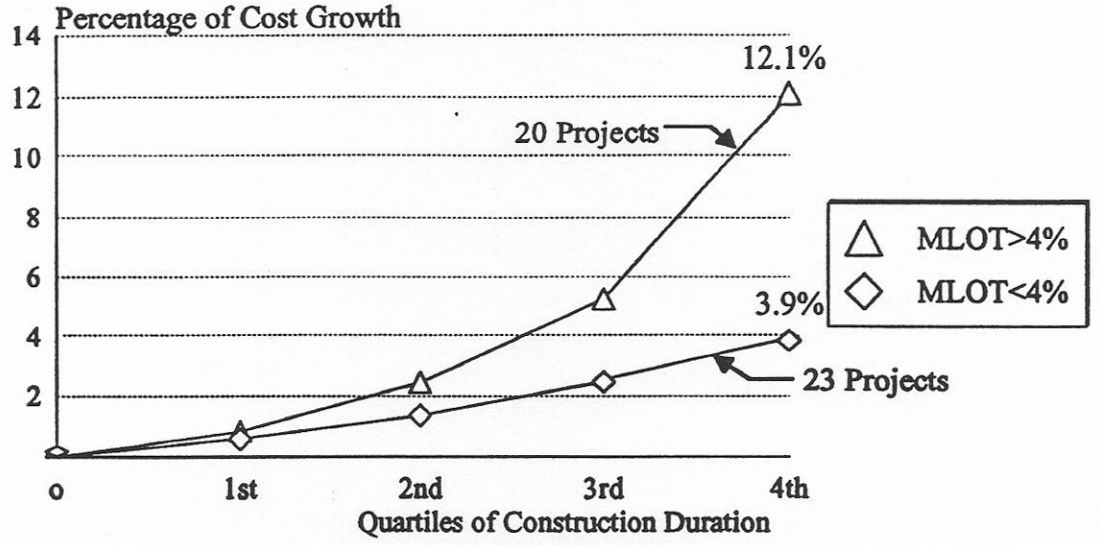

Figure - 4. Cost Growth Trend Curves for Projects with High and Low Money-Left-on-the-Table (MLOT)
(Source: CII Source Document #91)

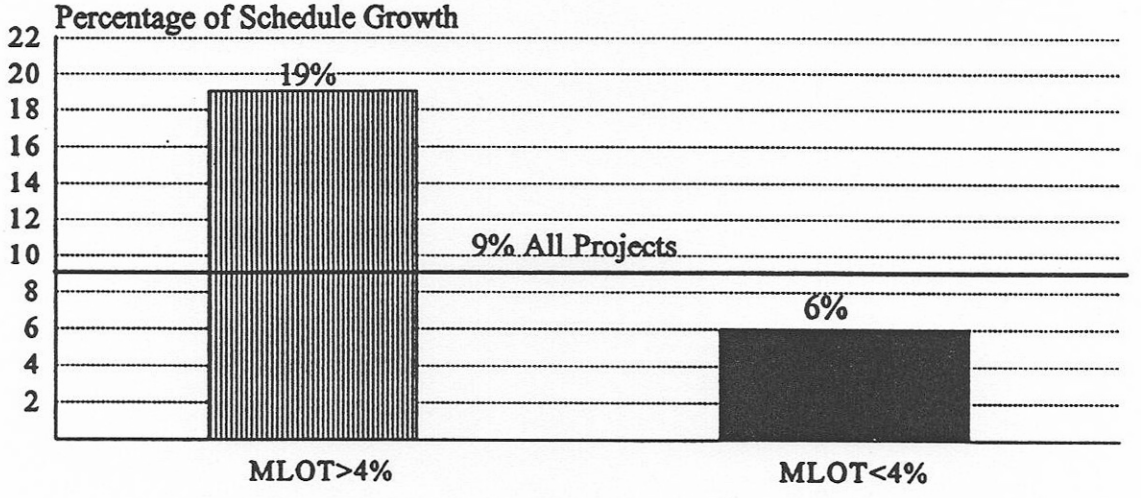

Figure - 5. Schedule Growth Trends for Projects with High and Low MLOT
(Source: CII Source Document #91)

TABLE - 2

PROJECT MANAGEMENT STRATEGIES
(To address high cost and schedule growth on projects with high MLOT)

STRATEGY
Pre-qualify an adequate number of bidders with relevant experience
Prepare interpretable bid documents
Allow sufficient time for bidding
Compare budgeted quantities to bidders quantities
Conduct more extensive pre-award meetings to insure the understanding of all parties
Consider not awarding to low bidder
Offer low bidder the chance to withdraw
When bidders bid different scopes of work resolve the differences
Evaluate bids in detail
Be aware of contractors who are trying to buy the jobs
Set aside contingency funds to deal with high MLOT
Maintain an allowance ($ and time) for more inspection and change management
Review bids' innovative approaches for project execution
Close monitoring of unbalanced pay requests
Strict change control and contract administration
All parties should deal in an open fairness with each other (partnering)

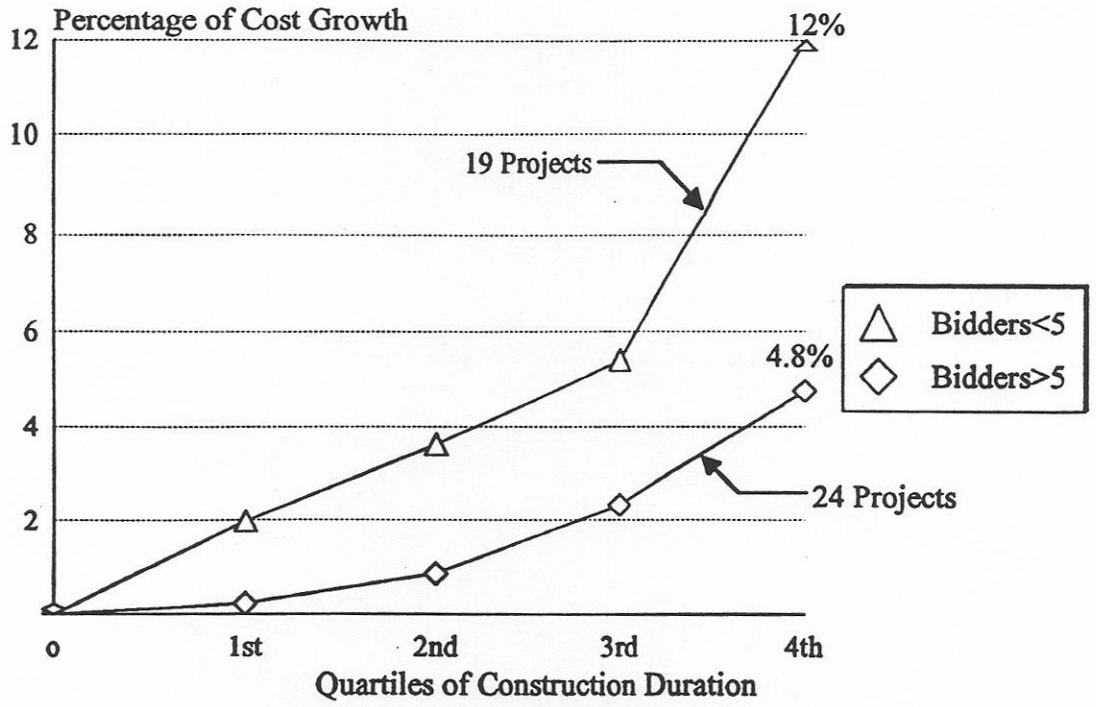

Figure - 6. Cost Growth Trend Curves for Projects with High and Low Number of Bidders

(Source: CII Source Document #91)

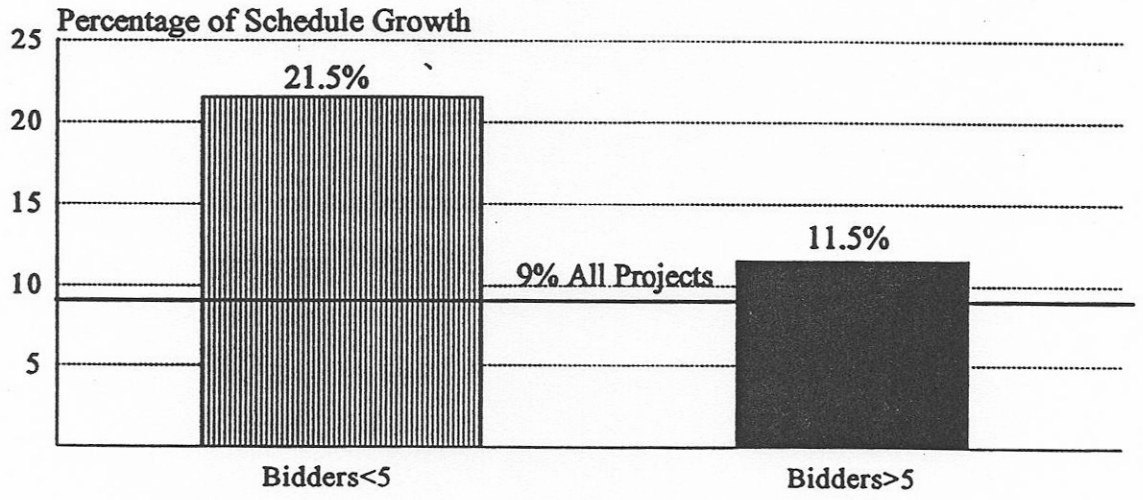

Figure - 7. Schedule Growth Trends for Projects with High and Low Number of Bidders

(Source: CII Source Document #91)

TABLE - 3

PROJECT MANAGEMENT STRATEGIES
(To address high cost and schedule growth on projects with low number of bidders)

STRATEGY
Pre-qualify a larger number of qualified bidders
Develop better package and scope definition to attract more prospective bidders
Issue bid clarifications during the bidding process to all bidders
Owner may consider reimbursing contractor for bid preparation
Insure a better match between the bidders and the type of project
Assure that fixed price format is appropriate for the risk involved
Analyze risk reward from the contractors stand point
Allow proper time to bid the job
Owner may consider purchasing responsibility for high risk project items
Attempt to optimize risk / reward ratio
Consider re-bidding with lessons learned if necessary

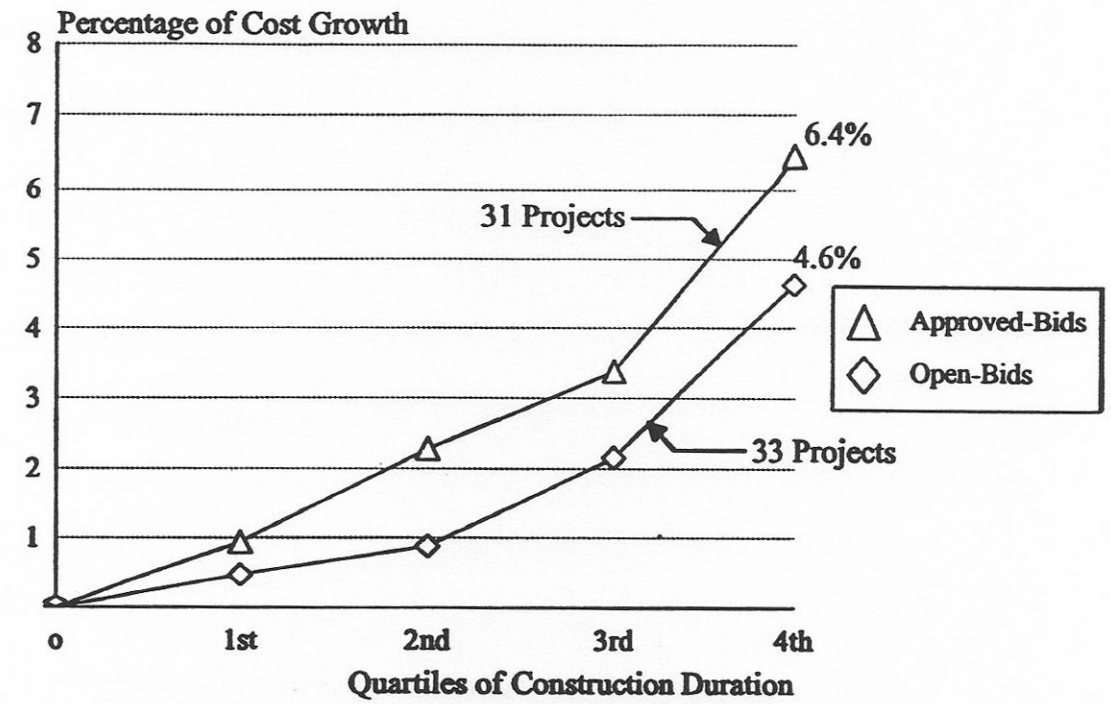

Figure - 8. Cost Growth Trend Curves with Respect to Solicitation of Bids
(Source: CII Source Document #91)

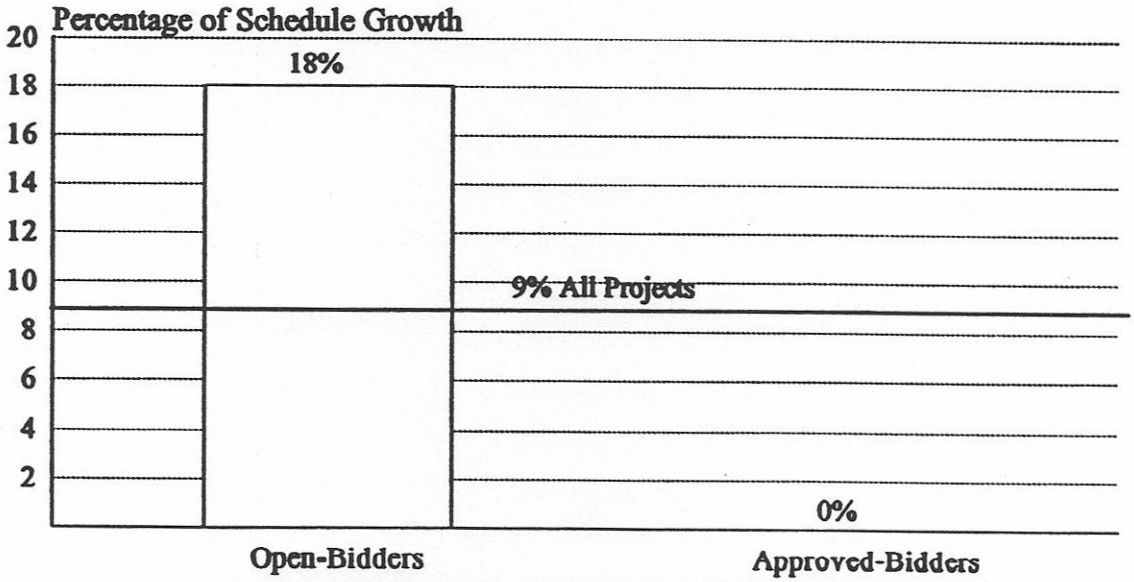

Figure - 9. Schedule Growth Trends with Respect to Solicitation of Bids
(Source: CII Source Document #91)

TABLE - 4

PROJECT MANAGEMENT STRATEGIES
(To address high schedule growth on projects with Open Bids)

STRATEGY
Pre-qualification of bidders to ensure financial and experience reputation
Conduct pre-bid conferences
Good scope definition as it would affect schedule
Have stronger contract clauses which assure schedule compliance
Conduct extensive pre-award meetings
Owner should allow for a realistic project duration and include it in the bid package
Increase oversight and have definite milestones during construction
Limit owner and engineering changes

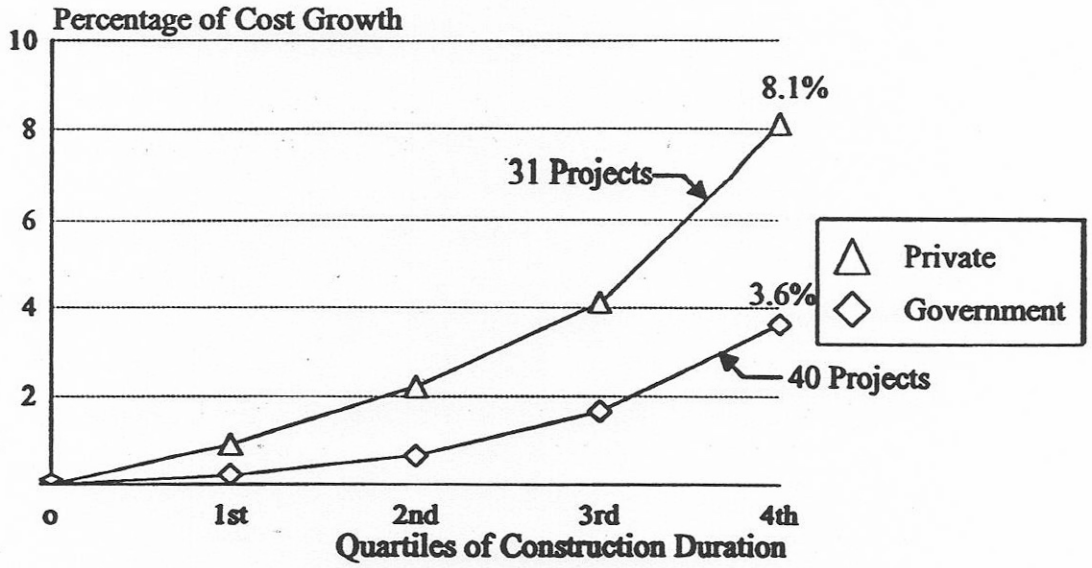

Figure - 10. Cost Growth Trend Curves for Projects with Different Ownership
(Source: CII Source Document #91)

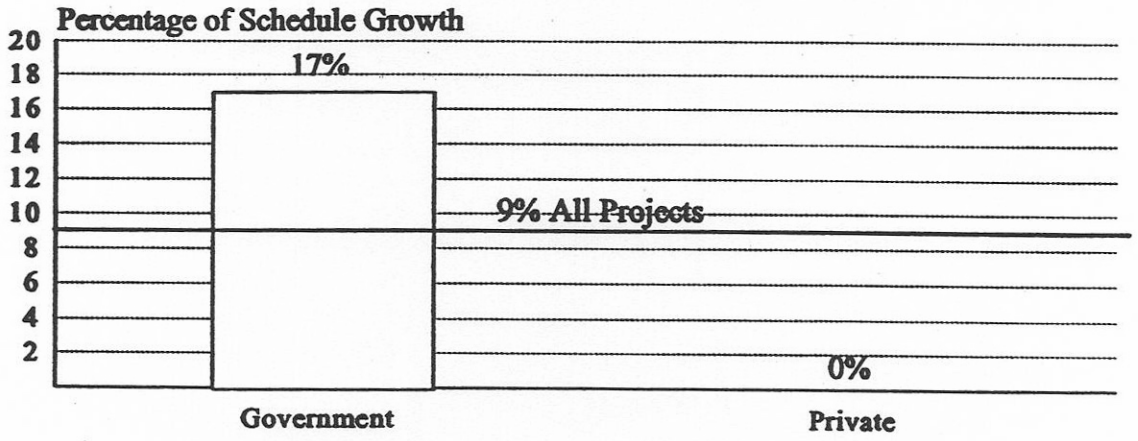

Figure - 11. Schedule Growth Trends for Projects with Different Ownership
(Source: CII Source Document #91)

TABLE - 5

PROJECT MANAGEMENT STRATEGIES
(To address high cost growth and low schedule growth on Private Projects)

STRATEGY
Assure that the right contractual execution format has been selected for project needs
Have a quality engineering job
Give more time for design to complete drawings and specs based on complete scope
Involve users and operators in the scope development process
Perform constructability review early
Use standard proven documents like CSI format
Ensure competent contract administration
Have good open communication
Open up bidders list to get more competition
Freeze design development once construction starts
Don't allow changes unless absolutely necessary
Train project personnel to be knowledgeable of cost growth factors

TABLE - 6

PROJECT MANAGEMENT STRATEGIES
(To address high schedule growth on Government Projects)

STRATEGY
Provide incentives for early completion
Enforce schedule requirements of the contract
Have more contract administration effort
Consider intermediate milestones
When the strategy is to allow schedule growth, owners should reflect this at bid time
When schedule is the driving factor, consider another contractual strategy

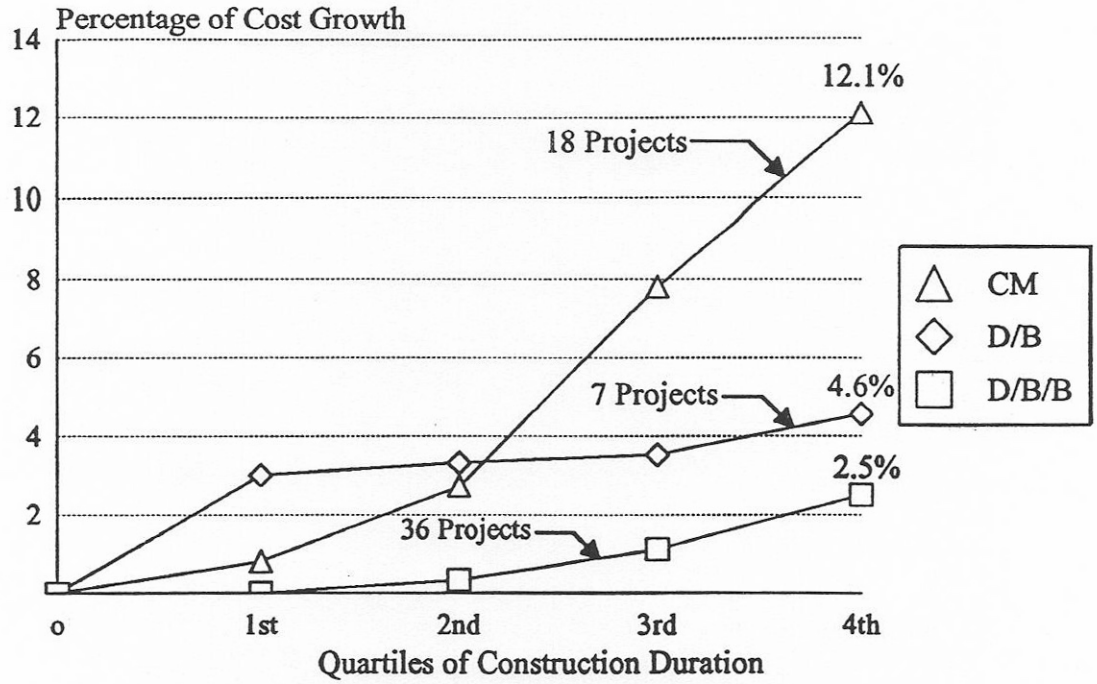

Figure - 12. Cost Growth Trend Curves for Projects which were Administered by Different Execution Formats

(Source: CII Souce Document #91)

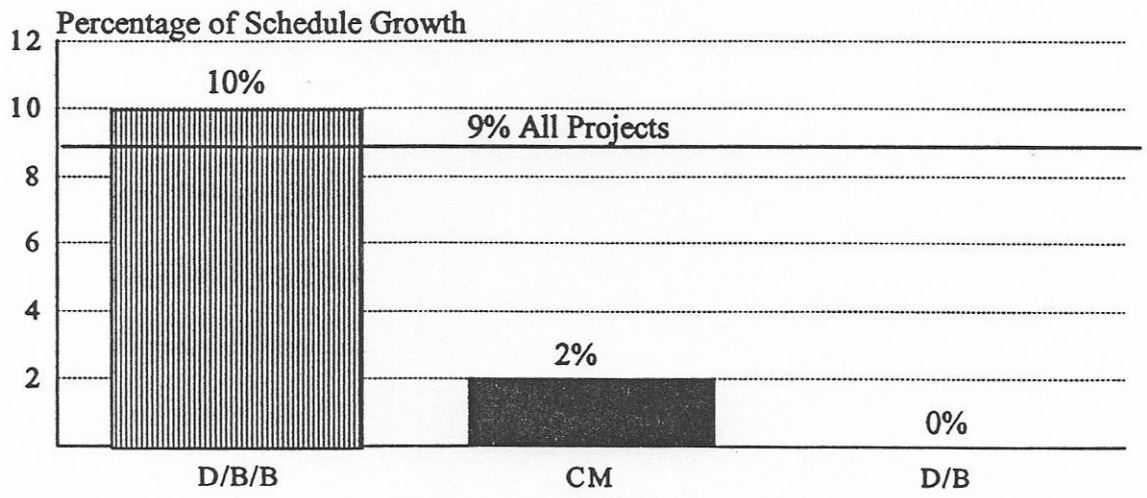

Figure - 13. Schedule Growth Trends for Projects which were Administered by Different Execution Formats

(Source: CII Source Document #91)

TABLE - 7

PROJECT MANAGEMENT STRATEGIES
(To address high cost growth and low schedule growth on CM Projects)

STRATEGY
Involve construction manager in the early planning stages
Award the construction management contract before the design engineering contract
Develop an effective team approach to management of the project
Involve the owners operating department in the design review
Implement one project control and reporting system for the project
Owner and construction manager should develop a joint project execution plan
Develop a sensitive mechanism for solving disputes of multi parties
Master schedule should give all participants a fair share of time for execution
Use when the project is schedule driven

ANALYSIS OF COST AND SCHEDULE GROWTH OF

COST REIMBURSABLE PROJECTS

This section presents cost growth trend curves and cost growth graphs 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. Factors analyzed from the project administration section of the questionnaire included driving factor, execution format, and distribution of work.

The definition of cost growth for cost reimbursable projects is defined as the sum of all change orders divided by the original contract amount, the same definition of cost growth used in fixed price projects. As discussed in the cost growth analysis of the preceding section of this publication, 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 median cost growth for all cost reimbursable projects was 6.8%. The cost growth trend curve for all of the cost reimbursable projects is shown in Figure 14.

Schedule growth is defined as the increase in time which was required to complete the project beyond the original anticipated completion date of the project, the same definition used for fixed price projects, reference Figure 3. For the 35 cost reimbursable projects, the median schedule growth was 7.5%.

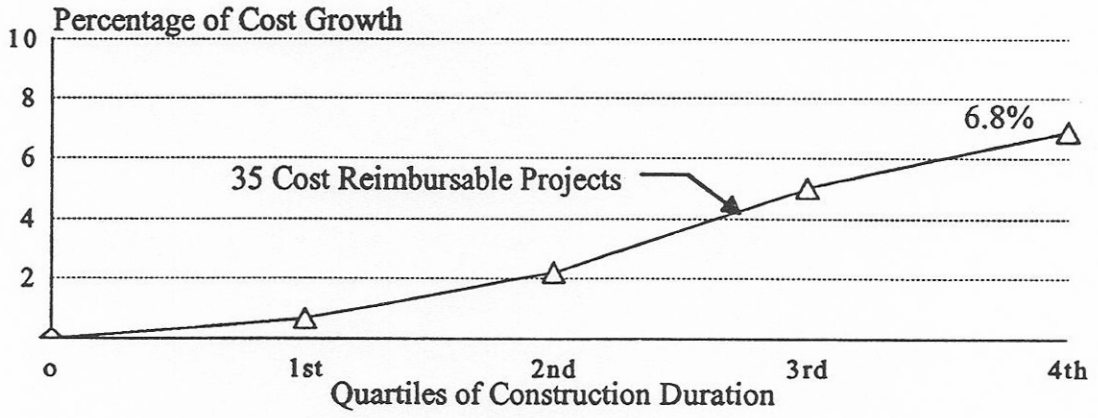

Figure - 14. Cost Growth Trend Curve for All Cost Reimbursable Projects
(Source: CII Source Document #91)

Factors Related to Cost or Schedule Growth

for Cost Reimburseable Projects

The remainder of this section presents cost growth trend curves and schedule growth graphs of cost reimbursable projects from data collected by the Task Force. Similar to fixed price projects, the Task Force developed a list of strategies to better manage projects that have indicators of cost and schedule growth. These strategies are summarized in the table that follow each of the cost and schedule growth trend curves.

From the data collected, members of the Task Force identified three factors related to cost or schedule growth of cost reimbursable projects: primary driving factor, execution format, and distribution of work. Figures 15 through 19 show the cost and schedule growth trend curves for these factors.

Respondents to the data collection questionnaire were asked to rank the primary driving factor of each project as either quality, cost, or schedule. Although the driving factor is a subjective term and may vary for different contracting parties in a project, members of the Task Force suspected the driving factor might impact the cost and schedule of a project. The data which were collected in this study indicate that when "quality" was the driving factor on projects, those projects experienced low cost and schedule growth. When "schedule" was the driving factor, projects experienced high cost growth. When "cost" was the driving factor, projects tend to experience high schedule growth. The cost growth trend curves in Figure 15 illustrate the relative different cost growth for each of the driving factors.

As previously discussed, caution should be exercised in the interpretation of the cost growth trend curves. For example, one may interpret that quality as a driving factor will produce the least cost for a project because Figure 15 only shows the cost increase is low for projects that were reported with quality as a driving factor. However, this cost increase is based upon the original contract amount. The original cost of a quality driven project may be higher than a cost driven or a schedule driven project. The conclusion of the Task Force is that quality driven projects most likely had more up-front planning, better developed design drawings, and better understanding of the project needs and objectives. Thus, the amount of changes during construction was less than cost or schedule driven projects.

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 with quality as the primary driving factor, the median value of schedule growth is 4.5%, about half the corresponding value for projects driven by schedule (9%) and about a third the value for projects driven by cost (15%), reference Figure 16.

Figures 17 and 18 show cost and schedule growth trend curves for cost reimbursable projects, sorted by execution format. Projects with the CM execution format indicated a high cost and schedule growth when used for cost reimbursable projects. However, many owner organizations select a cost reimbursable CM contract with the intent to adjust scope and make changes in a project. This allows more control in the development of a project than the rigid requirements of a fixed price contract where all of the design must be completed before the start of construction.

As one member of the Task Force stated, "That's the way I do business, it's my contracting strategy. If I were using fixed price contracts my projects would be more costly and take more time, CM gives me flexibility and options that I don't have in other methods of contract execution formats".

As noted earlier in this paper, cost growth in this study was based on the amount of changes orders during construction, divided by the original contract amount. For CM projects, the "program or project budget", the total amount of money the owner had set aside for the project was unknown. In CM contracts, the owner sometimes will sign a contract for construction that is less than the anticipated amount that will be required to complete the project to the satisfaction of the owner. The difference in the "program budget" and the "contract amount" is then used to make adjustments in the project during construction to suit the owner. Thus, cost growth may be anticipated as a planned strategy of the owner to adjust the project as needed.

Figure 19 shows the schedule growth curve for cost reimbursable projects, sorted by distribution of work. The distribution of the construction work indicated a lower schedule growth for projects that used direct hire workers, compared to projects that used subcontract labor. Members of the Task Force felt that 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 to decrease this problem.

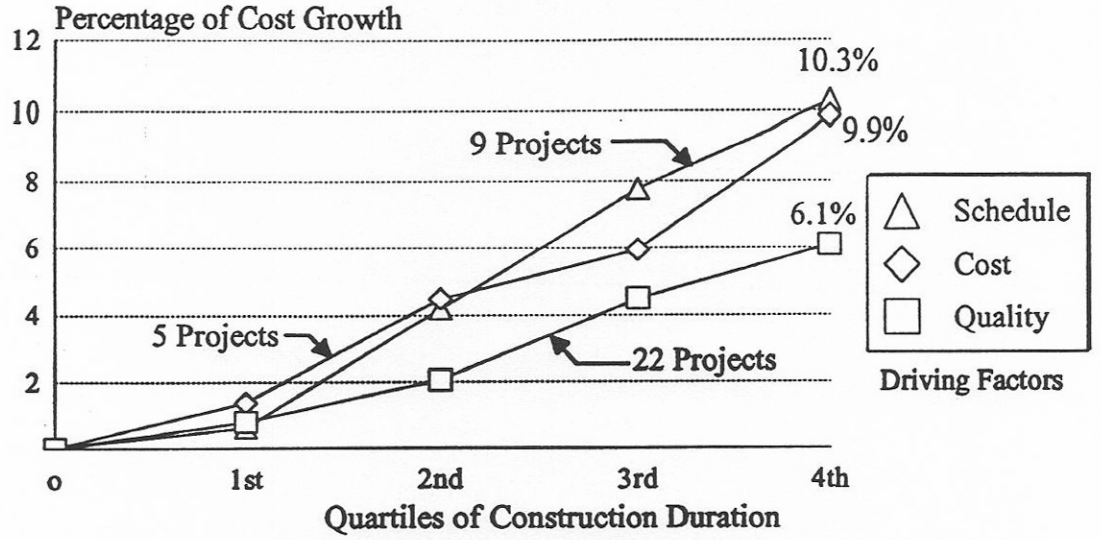

Figure - 15. Cost Growth Trend Curves for Projects with Different Driving Factors
(Source: CII Source Document #91)

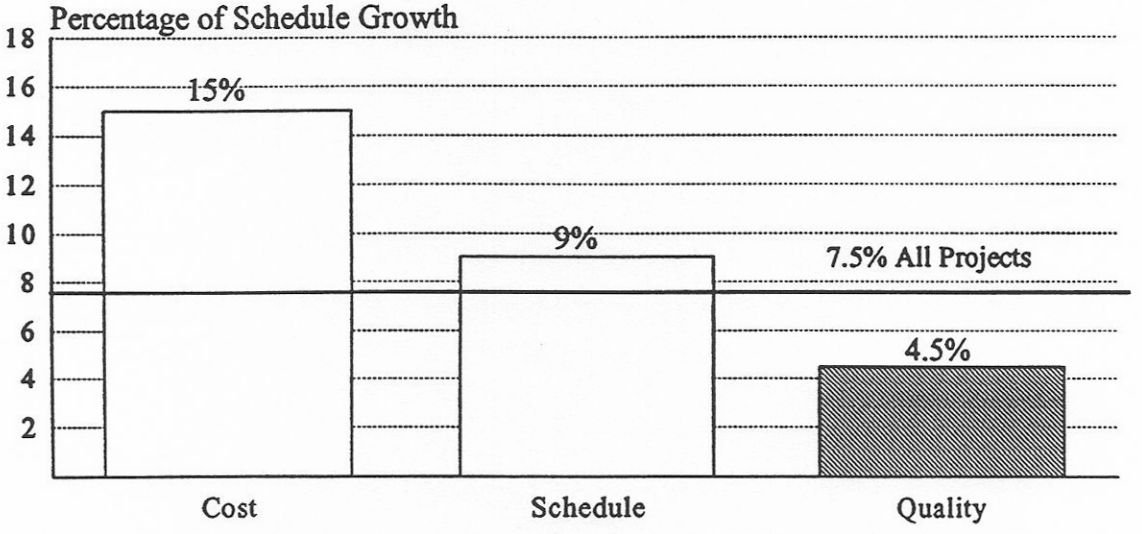

Figure - 16. Schedule Growth Trends for Projects with Different Driving Factors
(Source: CII Source Document #91)

PROJECT MANAGEMENT STRATEGIES
(To address low cost and schedule growth on projects with Quality as the Driving Factor)

STRATEGY
Quality as a driving factor prevents surprises, but doesn't necessarily guarantee least cost or least time
Good project management principles are essential when quality is the driving factor: - Prepare better scope definition which results in fewer changes - Know what you want to design before you start - Get the right management attention - More reviews early in the job during the engineering phase - Good planning on the front end - Better engineering by taking enough time and using CAD - Reasonable scheduling which allows proper quality checking - Use more experienced personnel - Implement constructability - Get everyone bought into the objectives - Get customer involvement as well as operation and maintenance people - Have good open communication - Pay attention to details - Focus on the factors which organize the project

TABLE - 9

PROJECT MANAGEMENT STRATEGIES
(To address high cost and schedule growth on projects with Cost as the Driving Factor)

STRATEGY
Referral of engineering costs to construction is false economy
Careful attention to construction cost during early design
When cost is the driving factor, schedule extensions indirectly affect cost
Pre-planning and constructability input
Use of better scope eliminates unnecessary schedule growth
Careful attention to construction during evaluation of design alternatives
Owner should fix the fee so that the contractor would want to get off the job early
Evaluate the cost of time extension versus indirect costs
Incentives for the contractor for cost efficiency and/or schedule compliance
Just because cost is the driving factor, don't ignore schedule
Adopt no changes philosophy

TABLE - 10

PROJECT MANAGEMENT STRATEGIES
(To address high cost and schedule growth on projects with Schedule as Driving Factor)

STRATEGY
Complete scope and design of segments prior to the phased construction releases
Use an open and detailed cost estimate of worst case to keep on schedule
Evaluate cost impacts versus economic benefits
Reward for finishing on cost
Put better people on the project
Develop a realistic completion date
Relax the penalty clause
Careful attention to the impacts caused by a change

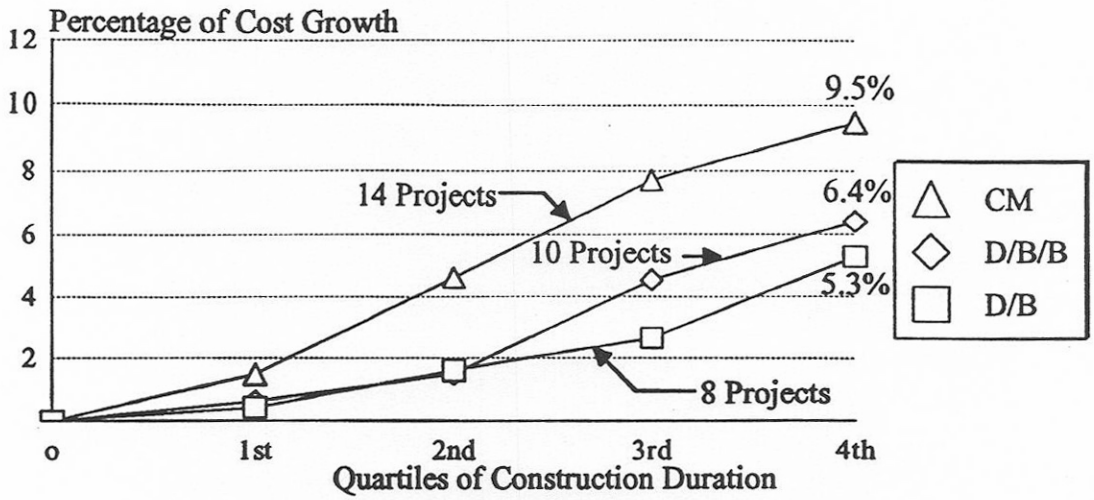

Figure 17. Cost Growth Trend Curves for Projects which were Administered by Different Execution Formats

(Source: CII Source Document #91)

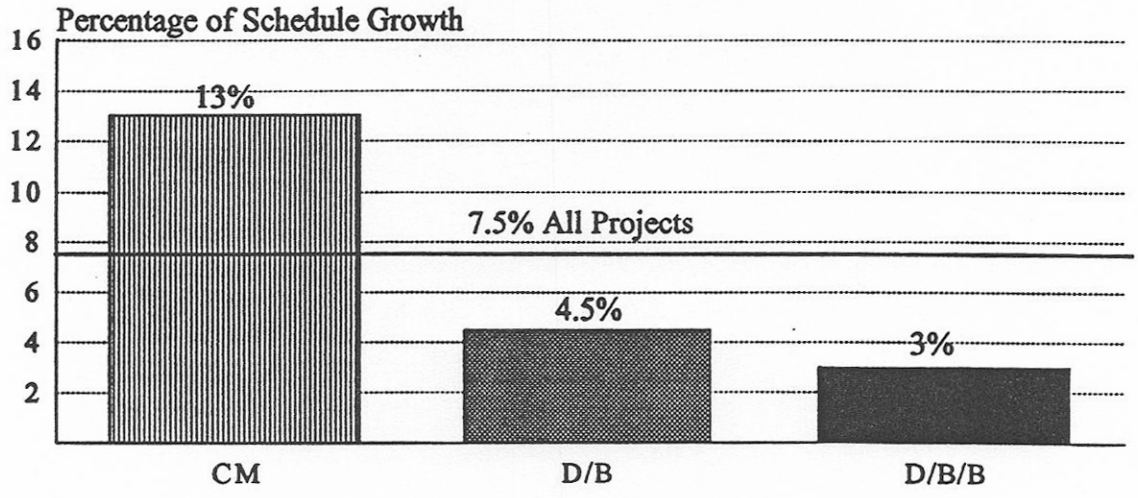

Figure - 18. Schedule growth Trends for Projects which were Administered by Different Execution Formats

(Source: CII Source Document #91)

TABLE - 11

PROJECT MANAGEMENT STRATEGIES
(To address high cost and schedule growth on CM Projects)
(Source: CII Source Document #91)

STRATEGY
Have realistic milestones built into the project plan
Include constructability
CM and contractors shouldn't be selected based on price only
Involve construction manager in the early planning stages
Award the construction management contract before the design engineering contract
Develop an effective team approach to management of the project
Involve the owners operating department in the design review
Implement one project control and reporting system for the project
Owner and construction manager should develop a joint project execution plan
Develop a sensitive mechanism for solving disputes of multi parties
Master schedule should give all participants a fair share of time for execution

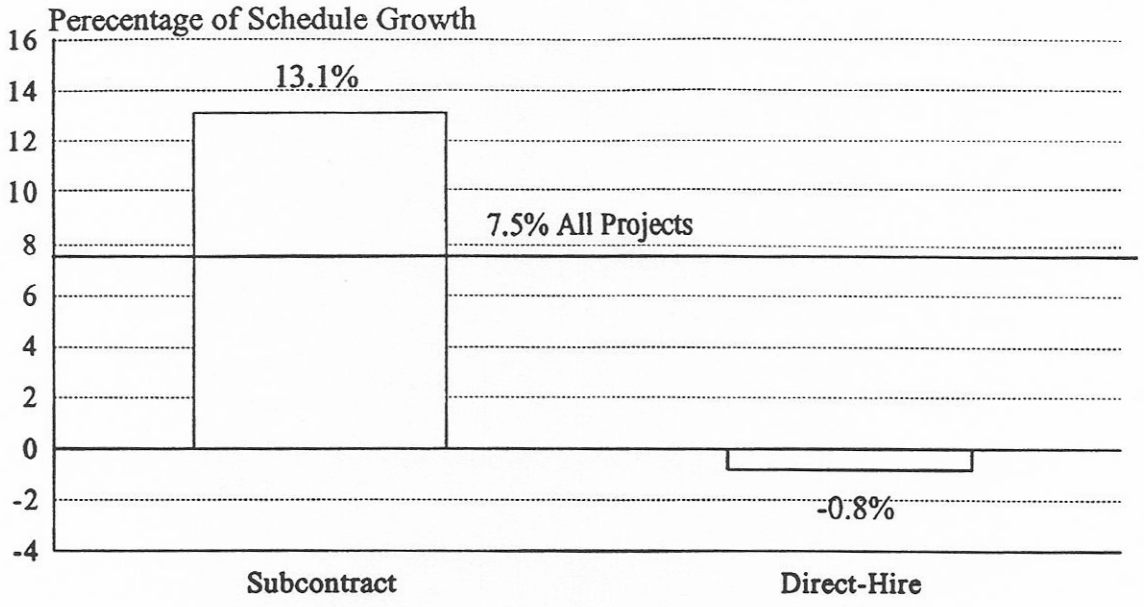

Figure - 19. Schedule Trends for Projects with Different Work Distribution

TABLE - 12
PROJECT MANAGEMENT STRATEGIES
(To address high schedule growth on projects with Subcontracting)

STRATEGY
Direct hire of the work provides better schedule control due to ability to absorb changes
Limit the amount of subcontracting
Effective management of the subcontractors interfaces and clear scopes of work
Don't subcontract more than a certain percentage of the work
Obtain commitment to the schedule prior to awarding contract
Supervise the subcontractors closely
Schedule has to reflect the engineering effort
Direct hire allows early start of construction activities when changes are approved
Consider the use of incentives

SUMMARY AND CONCLUSIONS

The impact of project changes on the cost and schedule of a project is complex and influenced by numerous interrelated factors. As previously stated, the objective of the Task Force was to perform a macro trend analysis to identify signs, that are known prior to the start of construction, which are indicators of cost and schedule growth in projects.

The separation of fixed price and cost reimbursable projects was a key element in the analysis of the project data, due to the major differences in the contracting strategy of the two pricing formats. Table 13 provides a summary of the quantitative values obtained from the trend analysis of fixed price projects. Table 14 provides the values for cost reimbursable projects.

These tables show the values that are significantly different from the baseline median value of cost and schedule growth of all projects. For the 71 fixed price projects, 5.3% is the baseline for cost growth and 9.0% is the baseline for schedule growth. The baseline cost growth for the 35 cost reimbursable projects is 6.8%, and 7.5% for schedule growth.

This research has identified several factors that are early warning signals of cost and/or schedule growth of projects during construction. 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.

Fixed Price Projects

For fixed price projects, the early warning signs are in the categories of money-left-on-the-table, number of bidders, execution format, and bid solicitation.

For fixed price projects that have high money-left-on-the-table (MLOT), the study indicated high cost and schedule growth. Thus, 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.

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 bidding competition and encourage a thorough evaluation of bid documents. Several bids can help the owner detect possible mistakes in a bid so that the contract can be awarded 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, but a low schedule growth, for fixed price projects which were handled by the construction management execution format.

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

The data collected in this study indicates that government type owners can expect a higher schedule growth and perhaps a lesser cost growth than the private type owners.

Cost Reimbursable Projects

For cost reimbursable projects the early warning signs 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. Better scope definition results in fewer changes and less rework during construction. Enough time should be spent on the right design, planning, and constructability at the front-end of a project.

The construction management execution format has indicated a high cost and schedule growth when used for cost reimbursable projects. The data collected in this study did not provide the percent complete of design at the time the owner selected the CM. The general consensus of the Task Force was that the CM should be brought onboard at the earliest possible date, before starting design, to realize the benefit of CM contracting. This is necessary because the CM format of contrating is often selected by the owner to take full advantage of the experience of the CM firm in review of design alternatives and developing the contracting strategy for construction. There are many forms of CM contracting which complicates the understanding and application of construction management.

Using direct hire, rather than subcontracting, indicated a low schedule growth. 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.

Closing

The information in this publication is intended to help improve the management and cost effectiveness of construction projects. As previously stated, this study identified early warning signs that are "indicators", not "assurances" or "causes" of cost and/or schedule growth. For example, every project with high Money-Left-on-the-Table (MLOT) did not show high cost growth. Thus, there is no assurance that a particular project with high MLOT will have high cost growth. However, the study did show a definite pattern or trend of high cost growth for the projects that had high MLOT. Also, it should not be construed that high MLOT is the cause of high cost growth. As previously discussed, high MLOT is likely caused by errors in bids, misunderstanding of contract documents, etc. The same principles should apply to other factors that are identified in this study as indicators of cost and/or schedule growth. Considerations must be given to the uniquenesses of each project.

TABLE - 13

FIXED PRICE FINDINGS
(Source: CII Source Document #91)

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%.

*** These values did not pass the statistical testing.

TABLE - 14

COST REIMBURSABLE FINDINGS
(Source: CII Source Document #91)

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%.
*** These values did not pass the statistical testing.

Garold D. Oberlender, Ph.D, P.E.
Professor of Civil Engineering
Oklahoma State University

Biographical Information

Garold D. Oberlender is a civil engineering professor and coordinator of the graduate program in construction engineering and project management at Oklahoma State University. He holds the B.S., M.S., and Ph.D degrees in civil engineering. He is the author of two McGraw-Hill books, **Project Management for Engineering and Construction**, and co-author of **Estimating Construction Costs**, with R. L. Peurifoy. For the past four years, Dr. Oberlender has been the corresponding editor for the construction division of ASCENEWS, the monthly publication of the American Society of Civil Engineers. Currently he is chairman-elect of the Professional Engineers in Construction practice division of the National Society of Professional Engineers. He has interests in numerous aspects of the management of engineering and construction projects and has conducted the Project Management for Engineers lecture series for NSPE since 1990. His technical specialities include team building and the integration process of linking design functions to construction implementation. He recently was an invited key speaker at the International Project Management Symposium in Cairo, cosponsored by INTERNET of Europe and the Management Engineering Society of Egypt.