Analysis of WSDOT Construction Cost Overruns

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16. ABSTRACT

Like any other agency that funds construction projects, the Washington State Department of Transportation (WSDOT) would like to minimize cost overruns on each construction contract that is administered. A study was undertaken to investigate and identify those factors that significantly impact construction cost overruns on WSDOT projects. Cost overruns were measured by the cost overrun rate, which is the percentage of difference between the low bid amount on WSDOT projects and the actual incurred cost on these projects. A total of 433 unit price, competitively bid contracts completed during fiscal years 1985 to 1989 were reviewed. The review involved a statistical analysis of each project, including design, bidding, and construction administration data. Specific factors that were identified to impact construction cost overruns included project size, project type, level of competition (measured by the number of bids and the range of those bids), geographic district, pre-contract engineering, and frequency with which a contractor is awarded WSDOT contracts. The study concluded that construction cost overruns are associated with projects that are more complex or have a large number of bidders. Projects with a high degree of complexity include large projects, new construction projects, bridge projects, and safety improvement projects.

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Final Report

Research Project GC 8719, Task 12
Construction Cost Overruns

ANALYSIS OF WSDOT CONSTRUCTION COST OVERRUNS

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DISCLAIMER

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SUMMARY

Like any other agency that funds construction projects, the Washington State Department of Transportation (WSDOT) would like to minimize cost overruns on each construction contract that is administered. A study was undertaken to investigate and identify those factors that significantly impact construction cost overruns on WSDOT projects. Cost overruns were measured by the cost overrun rate, which is the percentage of difference between the low bid amount on WSDOT projects and the actual incurred cost on these projects. A total of 433 unit price, competitively bid contracts completed during fiscal years 1985 to 1989 were reviewed. The review involved a statistical analysis of each project, including design, bidding, and construction administration data. Specific factors that were identified to impact construction cost overruns included project size, project type, level of competition (measured by the number of bids and the range of those bids), geographic district, pre-contract engineering, and frequency with which a contractor is awarded WSDOT contracts. The study concluded that construction cost overruns are associated with projects that are more complex or have a large number of bidders. Projects with a high degree of complexity include large projects, new construction projects, bridge projects, and safety improvement projects.

Increased cost overruns were noted to occur on larger projects, projects with greater risks, projects with more complexity, projects with larger numbers of bidders, and projects administered by a construction engineering organization with responsibility for larger total dollar volumes of construction.

CONCLUSIONS AND RECOMMENDATIONS

Construction cost overruns experienced on WSDOT construction projects do not appear to be random. Cost overruns are associated with a number of identifiable project variables. Cost overruns are generally highest on larger projects and on projects in which more bidders compete. Other findings show that cost overruns are larger when the construction engineering organization is charged with administering larger total dollar volumes of construction. In addition, cost overruns are higher on projects with greater complexity and those with more inherent risks.

WSDOT personnel should acquire an increased awareness of the sources of construction cost overruns. This may be accomplished through training sessions that included information on construction cost overruns. Training sessions on dispute avoidance and on effective negotiations should also be considered. When feasible, projects should be reduced in scope to decrease cost overruns.

Research efforts should be continued to further define the major sources of construction cost overruns. This may be accomplished through the continuous monitoring of various types of project information. This information should be documented in a standardized format on all WSDOT projects. Furthermore, this information should be subjected to general review and statistical analysis on a regular basis. This analysis may be helpful in indicating the impact that WSDOT actions have on reducing construction cost overruns.

INTRODUCTION

Throughout the construction industry, cost overruns are a critical problem. The changes and claims associated with cost overruns can cripple a project and devastate its budget. No projects are immune; cost overruns can occur on construction projects of all sizes and types in both the private and public sectors.

Construction cost overruns on transportation improvement and highway construction contracts are a primary area of concern within the Washington State Department of Transportation (WSDOT). These cost overruns represent payment of funds that had been unanticipated in the original contract. While the original contract amount, or the engineers' estimates of the contract amount, may include an allowance for contingencies, costs that are in excess of these amounts are considered unanticipated. The payment of these additional funds is especially critical when these funds represent taxpayer dollars. Increased taxpayers awareness of funding for these projects places additional importance on minimizing cost overruns.

The purpose of this study was to identify the causes of construction cost overruns on WSDOT construction projects. If the sources of cost overruns can be identified, then rational procedures can be developed and implemented to reduce them.

The WSDOT awards slightly less than 200 construction contracts per year. Most of these contracts involve unit price bids. The low bid system, which is predominantly used in the public sector, ensures that the lowest responsible bidder is awarded the contract. WSDOT assumes that the lowest bid will result in the lowest cost to the WSDOT. However, many times the final cost incurred on a project exceeds the low bid amount; this is a construction cost overrun.

Cost overruns can occur when changes and claims are made to the original contract. These changes and claims are often the result of unanticipated site conditions, errors or omissions in the contract documents, and the addition of work beyond the scope of the original contract.

LITERATURE REVIEW

Several articles and reports have addressed the topic of construction cost overruns. These provided information on the factors that can influence cost overruns. These factors will be presented as they relate to previous research studies.

PROJECT SIZE

Larger projects have been associated with construction cost overruns. The size of a project, measured by the contract dollar amount, can affect the size and number of changes that occur. Larger projects have an increased number of changes because they have a larger scope than smaller projects. In their study, Diekmann and Nelson found that the size of individual change orders increased predictably when project size increased. (1) In another study, Jahren and Ashe stated that the "cost overrun rate of 1 to 11 percent is more likely to occur on larger projects than smaller ones." (2)

PROJECT TYPE

Projects are generally classified by the type of construction. Information was sought that classified highway construction into specific categories for cost overrun analysis. Specific categories found included large earthwork projects, resurfacing or paving projects, bridge construction projects, and other highway related projects such as traffic control and safety improvements. Of these project types, some are more likely to be associated with cost overruns than others. Certain project types may represent a higher degree risk or be more complex than other types of projects. A project that involves a large amount of excavation work is an example of this; it has a higher degree of risk because of the potential for unforeseen site conditions. Resurfacing or pavement construction projects usually involve modification of an existing roadway. Cost overruns associated with these types of projects may be the result of insufficient site investigation or an over-reliance on as-built plans. Projects that involve ground-related and pavement construction work often involve a significant number of cost overruns. (3)

LEVEL OF COMPETITION

The level of a competition (measured by the number of bidders and the difference between the low bid and the engineer's estimate) has been identified as a factor that influences construction cost overruns. Many times, the level of competition forces contractors to lower their contingencies in order to win a bid. After the bid has been awarded, many owners publish the results of the bidding, which includes the engineer's estimate. At this time, contractors know exactly where they stand in relation to the other bidders and the engineer's estimate. With this information, contractors may become more aggressive in the pursuit of changes and claims in order to recover the difference. (2)

Number of Bidders

One measure of the level of competition is the number of contractors who submit bids on a project. As the number of bidders increase, the low bid amount decreases. As concluded in a report by Rothrock and Repole,

> At the contract level, competition is an extremely critical issue. Based on the data from the 1985 fiscal year, low bids on contracts which received only one or two bid responses, 16 percent of all contracts, were much higher than the engineer's estimate (by an average of 9-10 percent). When the number of bidders ranged from three to five, low bids came in just over the estimate by an average of 1-2 percent. However, on the 28 percent of all contracts that received at least six bids, the low bids averaged 2-4 percent under the estimate. These figures stress the importance of bidding competition in receiving reasonable prices for highway construction work. (4)

In his article, Park noted that the number of bidders did have a significant effect on the low bid, with each bidder decreasing the low bid amount by an average of 2.5 percent (in relation to the engineer's estimate). In other words, a low bid on a project with eight bidders would be approximately 10 percent less than the low bid for the same project if only four contractors had bid. (5)

Difference Between the Low Bid and the Engineer's Estimate

Increasing cost overruns associated with the difference between the low bid and the engineer's estimate can be explained in one of two ways. The first explanation relates to an increased level of competition. In his article, Duck noted that extremely low bids have been the result of an increase in the level of competition, brought about by current poor economic conditions. (6) The second explanation relates to the accuracy of the engineer's estimate. An engineer's estimate is conservative by nature. On average, in 1985 the engineer's estimate was 3.5 percent higher than the contract award price, and almost 80 percent of the construction projects were awarded at prices below the engineer's estimate. (5)

When the low bid is less than the engineer's estimate, the contractor may become more aggressive in pursuing changes and claims. This aggressiveness is reflected in an increased cost overrun rate when the difference between the low bid and engineer's estimate increases. In separate reports by Jahren and Ashe, the difference between the low bid and the engineer's estimate was used to predict the cost overrun rate. (2) (7) In other words, the farther the low bid was below the engineer's estimate, the greater the predicted overrun.

PRE-CONTRACT ENGINEERING EFFORT

Site Investigation

Site investigation is a key element in the pre-contract engineering effort. A thorough site investigation reduces construction cost overruns. In their report, Temple and Stukhart noted that "Problems relating to sub-surface conditions are the number one source of delays, disputes, claims, and cost overruns." (8) In another report, Tyrrell, Lake and Parsons concluded that lack of site investigations and the proper interpretation of site investigation results were associated with cost overruns on highway construction contracts. (3)

Sub-surface site investigations raise the issue of how much is enough. Because these types of investigations are preventive, the savings associated with them are difficult to estimate. However, Temple concluded, "The savings due to better knowledge of site conditions generally outweigh the costs to obtain that information." (8)

Contract Documents

Many potential problems are associated with the contract documents. Proper resolution of these problems in the pre-contract phase of a project minimizes the potential cost overruns associated with these problems. Particular consideration should be given to existing utilities, right-of-way constraints, and drainage patterns during project design. (9)

Many times, problems in the specifications can lead to future construction claims. The practice of modifying old specifications for use on new projects (cut and paste) has been associated with increased construction claims. (10) (11) Conflicts that result from poorly written specifications may also lead to increased cost overruns. Contract specifications should clearly relay information regarding scheduling requirements, time extensions, and differing site conditions. (12) The best way to avoid construction disputes is to make sure that the contract documents accurately reflect the rights and obligations of the parties. (13)

Conflicts or ambiguities in the contract documents often lead to claims or disputes, which, in turn, lead to cost overruns. In his article, Ostrower summarized the rules of interpretation and precedence used by courts to resolve these conflicts and ambiguities. He stated,

> When resolving conflicts or ambiguities in contract documents, courts have their own rules of interpretation and precedence. As a general rule, ambiguities are resolved in favor of the party that did not prepare the wording. Where there are general conflicts with specific language, the specific language will govern. Where there is a direct conflict between plans and specifications, the courts have no rules as to which will prevail but will resolve the ambiguity or conflict in favor of the party that did not prepare the documents. (14)

Section 1-04.2 of the Standard Specifications clearly defines the order of precedence WSDOT uses to resolve discrepancies between contract documents. In the event of a conflict or discrepancy between the Contract Provisions, Contract Plans, Amendments to the Standard Specifications, or the Standard Specifications, the following priority of documents will be used: (1) Contract Provisions; (2) Contract Plans; (3) Amendments to the Standard Specifications, contained in the Contract Provisions; and Standard Specifications. (15)

Construction claims and their associated cost overruns are often caused by delays in the contract. Time extension specifications should clearly define three separate types of extensions: excusable and compensable delays, which include owner caused delays and differing site conditions; non-excusable and non-compensable delays, which are related to contractor problems such as lack of personnel and poor management; and excusable and non-compensable delays, which are related to acts of God, weather, or labor strikes. (12) (11)

Claims that arise as the result of differing site conditions are often difficult and time-consuming to resolve. (16) Specifications that deal with differing site conditions should clearly define the risks and responsibilities of each party. The costs involved with resolving a dispute can outweigh the costs associated with a differing site conditions clause that is fair to both parties. (12)

CONSTRUCTION ENGINEERING EFFORT

Quick Resolution of Changes and Claims

A quick resolution of changes and claims has been suggested as a way to minimize construction cost overruns. (16) (12) (11) In his article, Duck stated that,

> From a strategy standpoint, it is desirable to negotiate each item as it arises and to reach an agreement at that time about the price, rather than permitting an accumulation of charges at the end of the project, since post-construction negotiations tend to favor the contractor in that the full extent of losses may then be known to the contractor. (6)

Quick resolution also means that changes and claims should be resolved at a low level. In their report, Thomas, Hester, and Halligan concluded that

> The higher levels of a claims resolution procedure simply are more likely to award the contractor a larger portion of the claim. (16)

As mentioned above, claims should be resolved at the lowest level possible. Claims should never just be turned over to a legal staff for denial, as this action will harden the position of the "other side" and increase the probability of litigation. (6)

Sometimes the opinion of a neutral third party is useful. Often, the parties involved in the claim are so deeply rooted in their position that they fail to recognize the true entitlement issues. "A third party can recognize the validity of a claim and recommended appropriate settlement." (13)

Project Planning and Management

Project planning and management are key elements to a successful project and the reduction of cost overruns. In their report, Tyrrell, Lake, and Parsons concluded that a significant part of cost overruns on highway construction contracts were associated with a lack of overall project planning and management. Greater attention to project management during the course of the contract could have reduced these cost overruns. (3)

SUMMARY

The information provided in this chapter is a summary of several articles and reports regarding construction cost overruns. As shown in the literature and reported in this chapter, increased cost overruns have been associated with the following factors:

- larger projects, measured by the contract dollar amount, (2) (1)
- projects types that involve ground-related and pavement construction work, (3)
- projects in which the low bid is less than the engineer's estimate, (7) (2)
- projects with an insufficient level of site investigations or poor interpretation of the site investigation results, (3)

- projects with inadequate design considerations given to existing utilities, right-of-way constraints, and drainage patterns, (9)
- projects with "cut and paste" or poorly written specifications, particularly in the areas of scheduling requirements, time extensions, and differing site conditions, (10) (12) (11)
- projects that have no provisions or procedures that encourage quick resolution of changes and claims at the lowest level possible, (16) (12) (11) and
- projects with a lack of overall project planning and management. (3)

RESEARCH METHODOLOGY

This study was conducted to investigate and analyze possible sources of construction cost overruns. Funding for this study was provided by the Washington State Department of Transportation (WSDOT). The WSDOT has a particular interest in this area because of the large number of construction contracts it awards each year. Identification of the probable sources of overruns and a true understanding of them are key elements in preventing construction cost overruns on future WSDOT contracts.

PRELIMINARY DISCUSSIONS

The research effort began with discussions with WSDOT engineers about basic elements of construction cost overruns. These elements had been outlined and presented to them in a research proposal. Discussions were held with engineers in both WSDOT Headquarters and District 1. After the primary focus of the research study had been outlined, information was sought regarding the availability of "in-house" reports that could be used for data retrieval.

DATA RETRIEVAL

After the initial discussion, 25 independent variables were identified. These variables included basic information regarding project factors, design factors, bidding factors, and construction administration factors. These variables are presented and defined below.

Data Variables

1. **Identification Number:** A unique reference number assigned to each project for which information was obtained.
2. **Award Date:** The date when the contract was awarded.
3. **Contract Number:** The contract number assigned to each project.

4. **District**: Regional districts within the WSDOT classified by number and location (shown geographically in Figure 1).

   - District 1 — Seattle
   - District 2 — Wenatchee
   - District 3 — Olympia
   - District 4 — Vancouver
   - District 5 — Yakima
   - District 6 — Spokane

5. **Engineer's Estimate**: WSDOT's estimate of project cost. This amount is published after the bid opening.

6. **Contractor Identification**: The identification number assigned by WSDOT and used by the contractor when bids are submitted.

7. **Low Bid**: The bid amount for which the construction contract is awarded.

8. **Second Low Bid**: The second lowest bid on a project.

9. **Third Low Bid**: The third lowest bid on a project.

10. **Highest Bid**: The highest bid on a project.

11. **Number of Bidders**: The number of bids submitted on a specific project.

12. **Project Type**: Six project types used to classify projects within WSDOT. Reports used in the data retrieval contained these project type classifications for each contract.

    - Type 1 — New Construction. The construction of new roadways. Examples — a new freeway, the addition of new lanes to an existing roadway.
    - Type 2 — Roadway Resurfacing. The resurfacing of existing roadways. Examples — bituminous surface treatment, asphalt paving.

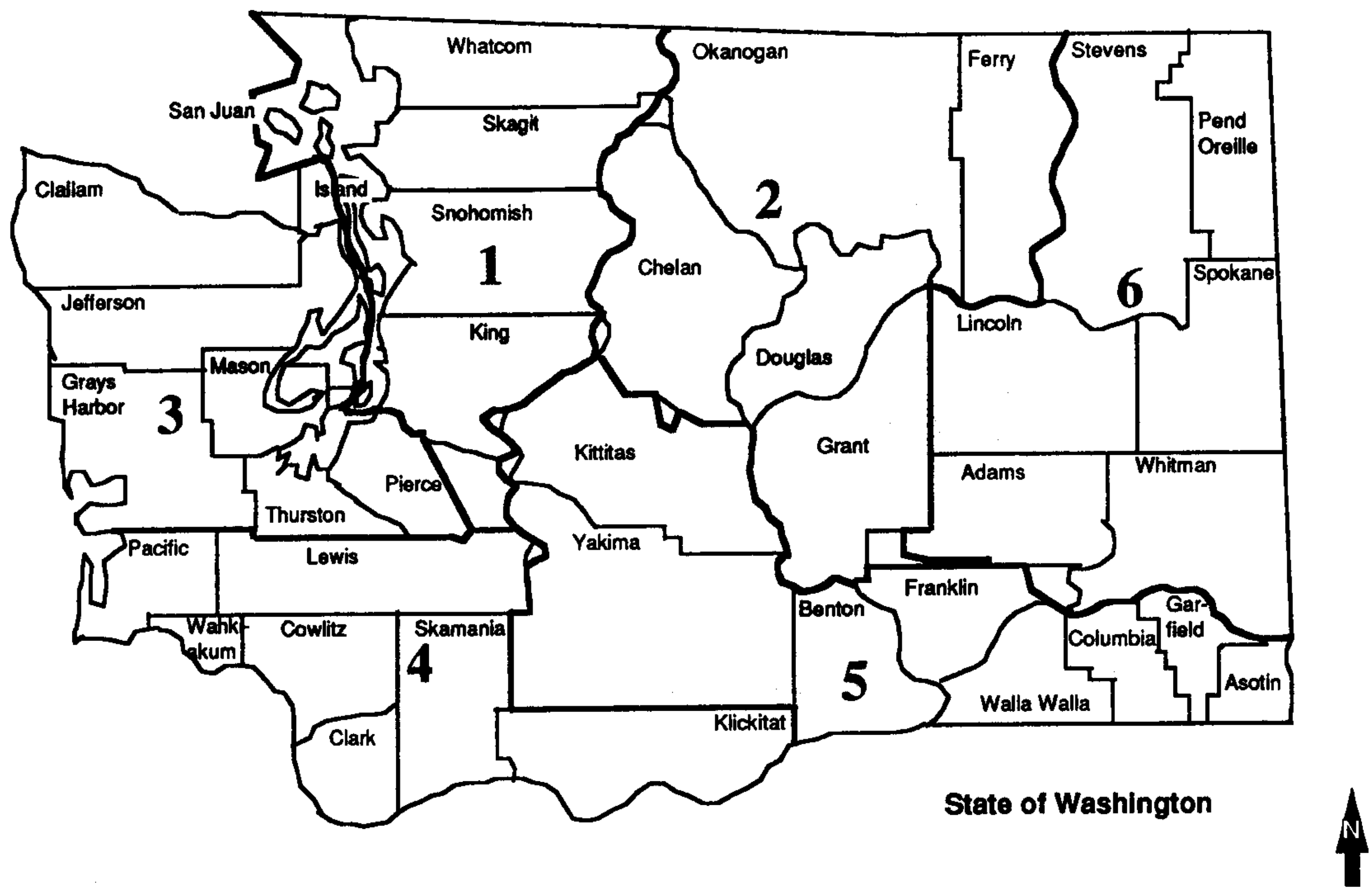

Figure 1. WSDOT Highway Districts

- **Type 3 — Bridge Projects Only**. Projects that involve bridge construction only. Examples — rehabilitation of an existing bridge, construction of a new bridge.
- **Type 4 — Safety Improvement**. Projects that involve safety improvements to existing roadways. Examples — traffic control revision, installing a signal system to an interchange, installing a guardrail, flattening embankment slopes.
- **Type 5 — Landscaping Only**. Projects that involve landscaping only. Examples — erosion control, highway beautification.
- **Type 6 — Unique Projects**. Projects that involve unique construction.

13. **Final Estimate**: The actual incurred cost on a project.

14. **Status**: Current status of the construction project. Status is classified in one of three ways.

    - **Final Completion**. Final Completion is defined under section 1-05.12 of the 1988 Standard Specifications. It states:

      > The Secretary Accepts the completed contract and the items of work shown in the final estimate by signature of the Final Contract Voucher.

    - **Substantial Completion**. Substantial Completion is defined under section 1-08.9 of the 1988 Standard Specification. It states:

      > When the contract work is completed to the extent that the State has full and unrestricted use and benefit of the facilities, both from the operational and safety standpoint, and only minor incidental work,... or repair remains to complete the contract, the Engineer may determine the contract work is substantially complete.

    - **In-Progress**

These definitions were used to determine the status of the contracts used in the database.

15. **PE Manager**: Pre-contract engineering organization identification number. A pre-contract engineering organization typically consists of the following personnel:

- Project Engineer
- Assistant Project Engineer
- 3-4 Design Team Leaders
- 10 Staff Transportation Engineers
- 10 Staff Transportation Technicians

16. **PE Dollars**: Dollar amount spent during the pre-contract phase of a project. This amount includes site investigation, design, and preparation of contract documents.

17. **PE Hours**: Engineering hours expended during the pre-contract phase of a project. These hours include site investigation, design, and preparation of contract documents.

18. **CE Manager**: Construction engineering organization identification number. A construction engineering organization typically consists of the following personnel:

- Project Engineer
- Assistant Project Engineer
- Office Engineer
- 2-3 Chief Field Engineers
- 10 Staff Transportation Engineers
- 10 Staff Transportation Technicians

19. **CE Hours**: Engineering hours expended during the construction phase of a project. These hours include inspection, quality control, and contract administration.

20. **Planned Working Days:** Number of contract working days set forth in the contract documents for the contract duration.

21. **Revised Working Days:** Revised number of contract working days as adjusted by all change orders.

22. **Actual Working Days:** Number of contract working days expended to complete the construction project.

23. **Claim Amount:** Dollar amount of a formal claim submitted to the WSDOT. A formal claim is defined as a claim submitted using the procedures and requirements given in section 1-09.11 of the 1988 Standard Specifications. For projects awarded before 1988, formal claims are defined as claims filed by contractors in which the cost of construction to WSDOT was increased.

24. **Claim Award:** Dollar amount awarded to the contractor through the formal claims process.

25. **Claim Status:** Current status of formal claims. Claim status is classified in one of the following ways:

    - Active Claim
    - Settled Claim
    - Rejected Claim
    - Trial Judgment
    - Active Lawsuit

The Retrieval Process

Data were needed from all districts in the state. The task of obtaining them could be accomplished either at each District office or at the WSDOT Headquarters office in Olympia. Because of the centralized location of the information, data retrieval was conducted at the Headquarters office. Within Headquarters, data were obtained from four sections, Construction, Workforce Management, Pre-contract Administration, and Plan

Review. Each section maintained statewide contract files, including some computerized information storage, and could easily generate reports of the requested data. These files and reports simplified the data retrieval process.

While most of the data retrieval was conducted at WSDOT Headquarters, some additional data were obtained from the District 1 office in Bellevue. The first report obtained from District 1 was an administrative review of change orders. This report reviewed recent change orders and provided commentary regarding the causes of these changes. This report was at first viewed as a primary source of data. However, since it was generated in District 1, it contained information regarding only District 1 contracts. To be considered a primary source, it would have had to contain comparable data for each district.

When data retrieval was conducted at Headquarters, the first task was to see whether the other districts generated administrative reviews of change orders. Although they did, the content and completeness varied by district. The level of detail of each report, although similar, was not sufficiently consistent to warrant their use as a primary source of data. This finding reinforced the idea that Headquarters files and reports would be the preferred source of data. Data retrieval from Headquarters would yield information that would be more complete and consistent than information gathered district by district.

Other sources from the Headquarters Construction office included the contract files listed in a contract summary report and the Construction Contract Claims Report. The contract summary information included contract number, district, engineer's estimate, bid amount, and final estimate amount. This report was obtained for all contracts that had been completed as of July 1986.

The Construction Contract Claims Report was maintained in a personal computer database system. The formal claims listed in this report were dated from 1977. The data listed in this report included district, contract number, contract title, contractor, award date, acceptance date, claim date, claim amount, status of claim, settlement amount, and date of settlement.

Information obtained from the Workforce Management section included engineering effort in both the pre-contract and construction phases of a project. All of the design and construction administration factors and several of the project factors were obtained from this source. This information was also maintained on a personal computer database.

The pre-contract report was titled "Analysis of PE Expenditures per Contract Award Amount." This report listed district, project engineer organization number, project type, contract number, contract title, contract bid amount, pre-contract engineering expenditures, and pre-contract engineering hours. The data listed in this report dated from July of 1985.

The construction engineering information was listed in the "Statewide Construction Engineering" report. The data included district, project engineer organization number, project type, contract number, planned work days, revised work days, actual work days, contract bid amount, estimated project amount, construction engineering hours, and date of the last estimate. The data listed in this report dated from July of 1987. Note that this report included a few more items of information not retrieved on earlier reports. This precluded some earlier projects from being included in each analysis step.

While the information listed above dealt with "in-house" pre-contract engineering effort, some of the design work is also contracted to private engineering consultant firms. These firms are typically used in the design of larger, more complex projects that require an expanded engineering effort. To ascertain the impacts related to consultant designed projects, information regarding the costs associated with this work was needed. The District 1 Consultant Liaison office was contacted to see whether any data were available. Unfortunately, a review of the report titled "Status of Active Consultant Agreements" revealed that one agreement could represent up to three separate construction contracts. Without a breakdown of the consultant engineering costs per construction contract, this information could not be used as part of the data.

The Headquarters Pre-Contract Administration section provided bidding information. This bidding information was contained on the "Contract Bid History" reports. These reports are published after the opening of bids for each project. The data provided in the report included award date, contract number, contract title, district, engineer's estimate, a description of the work, and the rank, identification, and bid amount for each bidder. The report also identified any bidders whose bids were rejected.

Data regarding the engineer's estimate were requested from the Headquarters Plan Review section. This section reviews all contract documents before the advertisement of bids. A print-out of historical bid data, which are used in determining the engineer's estimate, was obtained. While these data provided useful insights about the methods used to determine the engineer's estimate, the information could not be used for further analysis in this research.

STATISTICAL DATABASE

The personal computer version of a statistical database program, Statistical Package for the Social Sciences (SPSS), Version 3.0, was used to analyze the data. (17) (18) This version of the program permits numerous manipulations and queries of the data to be made. These same efforts on a mainframe computer would have resulted in significantly higher computer costs.

The 25 independent variables listed earlier were obtained for each contract by combining the data found in the various reports. The common variable used to combine the data was the contract number. Once a construction contract has been awarded on a project, WSDOT assigns a contract number to it. All information about the project can be referrenced by this number. This numbering system for projects has simplified the task of retrieving data from several sources.

All data for each project were coded and entered in numerical form. Non-numerical values were converted to numerical input for analysis. An example of this process is the variable "status." As shown earlier, this variable separated contracts into those that had achieved final completion, those that had achieved substantial completion, or those classified as "in-progress." The numerical codes describing these three phases were assigned the values 1, 2, and 3, respectively.

After the data had been numerically coded, they were put into the computer database. The results of this coding and input yielded 433 valid cases. Each case represented one contract or project.

WSDOT estimates that it awards slightly less than 200 contracts per year. Since the data represented cases dating from July of 1985, obviously many more projects were available for analysis than were used. Some projects were excluded from the database because they did not meet the conditions of final or substantial completion. These criteria were necessary because cost overrun rates, as defined in this study, had to be measured, and only contracts that had met some form of completion had these rates. Other contracts excluded from the study's database included bridge painting, facilities construction and renovation, and marine vessel and terminal construction. These exclusions were established to keep the research focused and measurable.

Once the data had been put into the database, they were tested to ensure that they were free from input errors. The SPSS command called "Frequencies" was run for each variable to look for obvious errors in the database. This command listed all values for each variable. This listing was used to determine whether any of these values were atypical and needed to be reviewed or corrected. Since few errors were detected by this procedure, data entry was assumed to have been accomplished with reasonable accuracy.

After the data had been input, tested, and corrected, additional data variables were computed from the original independent variables. These computed variables consisted of both dependent and independent variables.

The computed dependent variables represented the overrun rates and are listed below.

Computed Dependent Variables

1. **Overruns of Low Bid Amount**: The percentage of difference between the low bid and the final estimate.
2. **Overruns of the Engineers Estimate**: The percentage of difference between the engineer's estimate and the final estimate.
3. **Overruns in Working Days**: The percentage of difference between planned working days and actual working days.

The rates based on the low bid amount and the engineer's estimate are both defined as cost overrun rates. While both measures of the cost overrun rate are related, the term "cost overrun rate," as used in this study, describes the overrun rate based on the low bid. This measure of the cost overrun rate is also used within the WSDOT. WSDOT does not commonly use the cost overrun rate based on the engineer's estimate to measure overruns; it was developed for this study to draw comparisons.

The overrun rate based on working days is only used to measure working day overrun rates and is not related to cost overrun rates. Revised working days are not used to compute the working day overrun rate. The data for this independent variable were not available in enough cases to warrant its use in this computation.

The first four computed independent variables were developed as factors that might represent the level of competition. The remaining computed independent variables were developed to address pre-contract and construction engineering factors. These nine computed independent variables are presented and defined below.

Computed Independent Variables

1. **Range of Bids**: The percentage of difference between the low bid and the high bid.
2. **Low Bid to Engineers Estimate**: The percentage of difference between the low bid and the engineer's estimate.
3. **Low Bid to Second Bid**: The percentage of difference between the low bid and the second bid.
4. **Low Bid to Third Bid**: The percentage of difference between the low bid and the third bid.
5. **PE Dollars to Low Bid**: The ratio of pre-contract engineering dollars to the low bid amount.
6. **PE Hours to Low Bid**: The ratio of pre-contract engineering hours to the low bid amount.
7. **PE Dollars to Engineers Estimate**: The ratio of pre-contract engineering dollars to the engineer's estimate.
8. **PE Hours to Engineers Estimate**: The ratio of pre-contract engineering hours to the engineer's estimate.
9. **CE Hours to Final Estimate**: The ratio of construction engineering hours to the final estimate.

The next step was to stratify the data on the basis of project size, project type, and district. As shown in Table 1, project size was classified into five groups. Since project size had not been classified within the WSDOT and since no obvious break points were identified in the data, project size groups were developed solely for this research. These groups were based primarily on the researchers' best judgment, with an attempt to distribute the cases somewhat evenly among the groups.

The data, stratified on the basis of project type, can be seen in Table 2. Project type is determined within the WSDOT. As mentioned earlier, project type was identified on a number of reports used in the data retrieval process.

Geographic District was used to classify data for Tables 1 and 2.

To determine whether an increase in number of projects awarded to a contractor affected the cost overrun rate, the frequency for contractor identification was examined. The number of projects was set at a value of ten or greater. In other words, all contractors who were awarded ten or more projects were identified for further analysis.

To determine whether the number of projects designed and developed by a particular pre-contract engineering organization affected the cost overrun rate, the frequency for this variable was examined. To determine whether the number of projects administered by a particular construction engineering organization affected the cost

TABLE 1. NUMBER OF PROJECTS
Classified by Project Size and by District

District	Location	Under $250,000	$250,000 to $500,000	$500,000 to $1,000,000	$1,000,000 to $2,500,000	Over $2,500,000	Total
1	Seattle	51	26	26	26	20	149
2	Wenatchee	9	6	12	7	1	35
3	Olympia	21	9	24	19	12	85
4	Vancouver	5	11	15	15	3	49
5	Yakima	18	15	10	9	7	59
6	Spokane	10	10	13	18	5	56
Total		114	77	100	94	48	433

TABLE 2. NUMBER OF PROJECTS
Classified by Project Type and by District

District	Location	New Construction	Roadway Surfacing	Bridge Only	Safety Improvements	Landscape and Unique	Total
1	Seattle	51	50	10	35	3	149
2	Wenatchee	4	23	3	4	1	35
3	Olympia	31	28	14	11	1	85
4	Vancouver	5	26	13	4	1	49
5	Yakima	13	22	8	14	2	59
6	Spokane	7	32	10	6	1	56
Total		111	181	58	74	9	433

administered by a particular construction engineering organization affected the cost overrun rate, the frequency for this variable was also examined. The number of projects was again set at ten or more for both of these variables. This number of projects was determined from the researchers' best judgment.

HYPOTHESIS

The data variables that were defined in this chapter were to test the hypothesis statements listed below.

- The project size of a contract, measured in dollars, affects the construction cost overrun rate.
- The type of project, as classified by the WSDOT, affects the construction cost overrun rate.
- The level of competition, measured by the number of bidders affects the construction cost overrun rate.
- The geographic location of a project, classified by regional districts within the WSDOT, affects the construction cost overrun rate.
- The level of pre-contract engineering effort, measured in dollars and hours, affects the construction cost overrun rate.
- The level of construction engineering effort, measured in hours, affects the construction cost overrun rate.
- The frequency with which a contractor is awarded WSDOT contracts, affects the construction cost overrun rate.

DATA ANALYSIS

Statistical analysis was conducted to determine the relationships that existed among the various dependent variables and the measures of cost overruns. This analysis included computer generated histograms and statistical calculations of mean, median, mode, and standard deviation for the cost overrun rate. The distribution of the data was non-parametric; therefore, the median, which represents the middle value of the sample, was used to represent the overrun rate. This analysis was run for each dependent variable within each project size classification.

After this analysis had been completed, a Pearson's Correlation Test was run for each dependent variable measured against each independent variable. This test was used to identify the relationships that might affect the overrun rate. Relationships that had a one-tailed statistical significance of less than 0.05 involving at least five valid cases were identified. These correlations were then put into a separate database to facilitate the sorting and comparison of similar relationships. Additional analysis was performed on cases in which the percentage of difference between the low bid and the final estimate was positive, i.e., the low bid exceeded the final estimate. Further analysis was performed on cases in which the low bid was less than the engineers' estimate.

Once the relationships had been identified, regression plots were developed with the SPSS program. These plots were developed to provide a visual analysis of the relationships and to help evaluate the strength of each relationship. The regression equations developed from these plots were also used to calculate predicted cost overrun rates.

With a number of relationships between overruns and independent variables identified, these relationships needed to be presented in a statement format. This format was based on the hypothesis statements mentioned earlier in this chapter. Conclusions for each of these results were then developed, along with recommendations. These results, conclusions, and recommendations are detailed in the following chapters.

Before these recommendations could be implemented, presentation to WSDOT officials was essential to obtain necessary feedback and comments regarding feasibility. To obtain this feedback, presentations were given to WSDOT officials from both District 1 and Headquarters.

RESULTS

The results of the data analysis are focused on various factors associated with construction cost overruns. These factors are grouped into seven general categories. The categories include project size, project type, level of competition (measured by number of bids), geographic district, pre-contract engineering effort, construction engineering effort, and frequency with which a contractor is awarded WSDOT contracts. Within each of these general categories, significant findings are discussed, followed by specific conclusions.

A total of 433 projects were reviewed and analyzed for this study. These projects were classified by size and type. Project size was determined by the low bid or award amount. Five different classifications, ranging from projects under $250,000 to projects over $2,500,000, were used. Project type was classified into six groups. These classifications, which WSDOT currently uses, included New Construction, Resurfacing, Bridge Construction, Safety Improvement, Landscaping, and Unique Construction.

The median cost overrun rate based on the low bid amount (unless otherwise noted) was used to define cost overruns for this study. The non-parametric distribution of the cost overrun rate made the use of the median value applicable.

PROJECT SIZE

The median cost overrun rate for all projects in the sample was 4.0 percent. Further analysis revealed that the cost overrun rate was related to project size (see Table 3 and Figures 2, 3, and 4). The median cost overrun rate for projects greater than $2.5 million was 8.4 percent, while smaller projects, less than $250,000, had a median cost overrun rate of 1.5 percent.

Another finding was that when the project size was greater than $1 million, cost overrun rates increased when the number of formal claims increased. This finding makes sense because formal claims have been previously identified as a factor that increases the

TABLE 3. CONSTRUCTION COST OVERRUNS
Classified by Project Size

Project Size	Cases	Mean	Standard Deviation	Median	Correlation Coefficient	Level of Significancc (1-Tailed)
Under $250,000	114	5.49%	2.41%	1.50%	.0996	.146
$250,000-$500,000	77	4.55%	1.15%	3.99%	.0509	.330
$500,000-$1,000,000	100	4.68%	1.16%	4.56%	-.1594	.057
$1,000,000-$2,500,000	93	6.17%	1.05%	4.06%	-.0025	.491
Over $2,500,000	48	10.43%	1.61%	8.40%	-.0039	.489
All	432	5.83%	0.78%	4.01%	.0564	.121

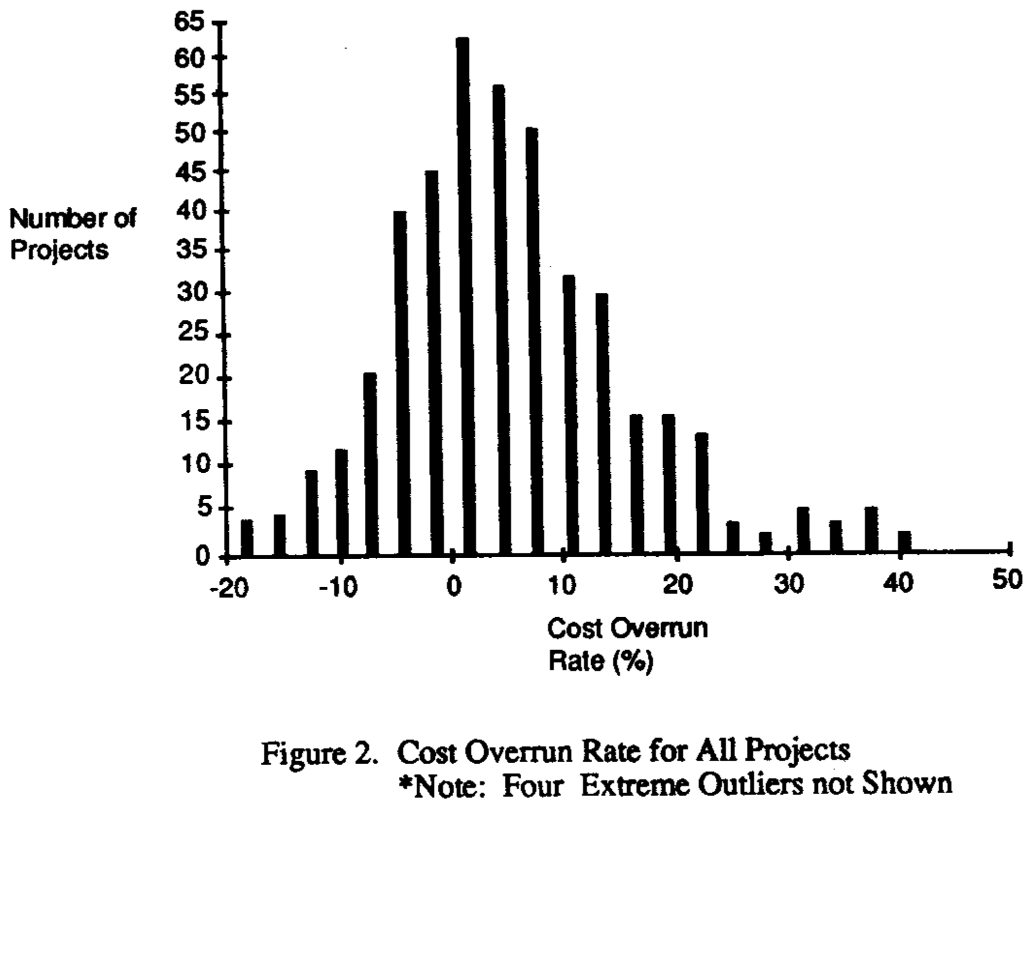

Figure 2. Cost Overrun Rate for All Projects
*Note: Four Extreme Outliers not Shown

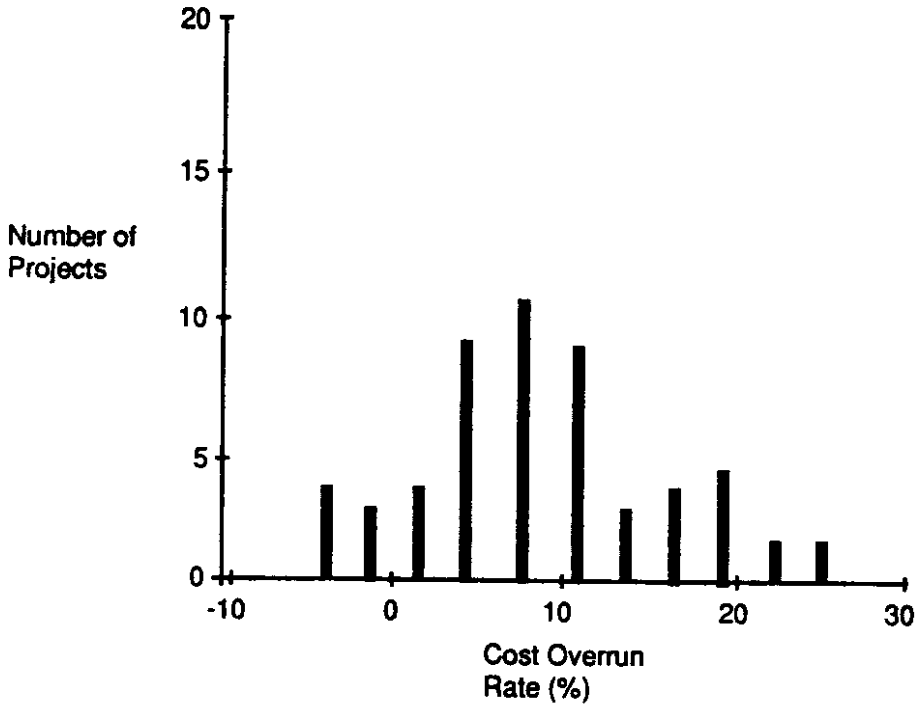

Figure 3. Cost Overrun Rate When the Low Bid is Greater than $2,500,000
* Note: Extreme Outliers not Shown

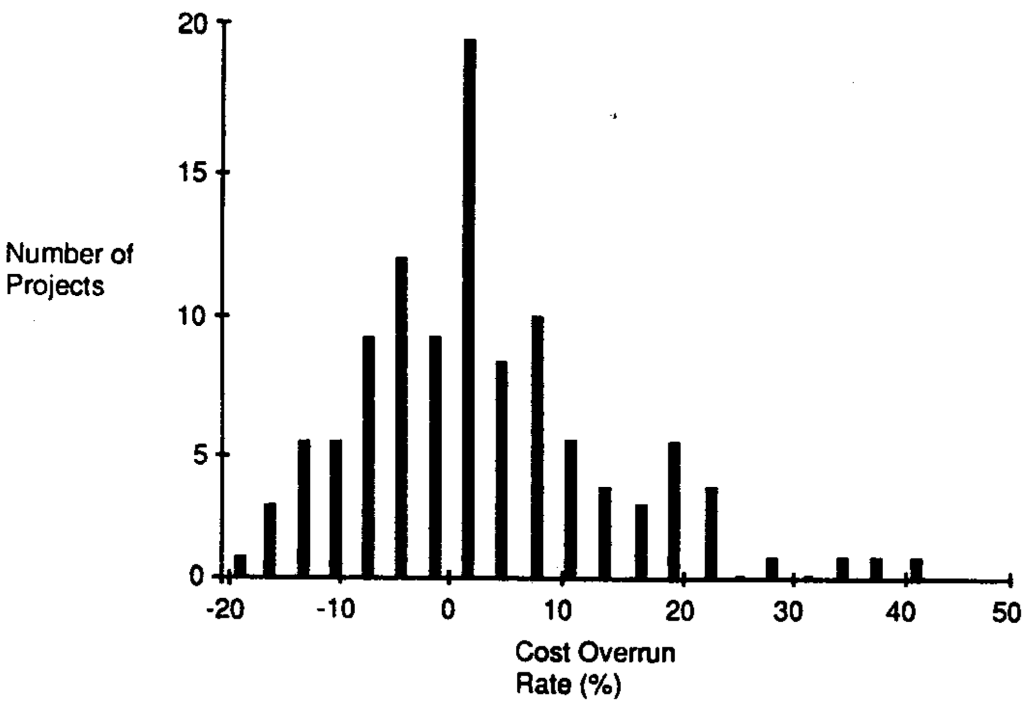

Figure 4. Cost Overrun Rate When the Low Bid is Less than $2,500,000
*Note: Extreme Outliers not Shown

cost overrun rate, and the number of formal claims submitted on larger projects is substantially higher than those submitted on smaller projects (see Figure 5).

A related finding was that when the project size was greater than $2.5 million, working day overrun rates increased when the number of formal claims increased (see Table 4).

PROJECT TYPE

In general, the costs of charges constituted approximately 80 percent of the overrun amounts which claims were responsible for. The results showed that increased cost overrun rates attributable to increased formal claims were more likely to occur on new construction and bridge construction projects (see Figure 6). The study also found that increased cost overruns were correlated with safety improvement projects (see Table 5).

New construction, bridge construction, and safety improvement projects are generally complex. Again, the complexity of a project is related to cost overruns. Complexity may contribute to the cost overruns common for these types of projects. While the level of expertise of WSDOT personnel was not directly assessed in this study, discrepancies in the plans in relation to site conditions will generally result in changes and may potentially lead to claims, both of which increase the cost overrun rate.

While technology contributes to complexity, safety improvement projects also require a substantial amount of electrical and utility work. Since most of this electrical work is underground, actual conditions may not match those represented in the plans. These discrepancies, primarily associated with unknown subsurface conditions, often require changes in the contract and may lead to situations in which the contractor submits a claim. These changes and claims can increase the cost overrun rate.

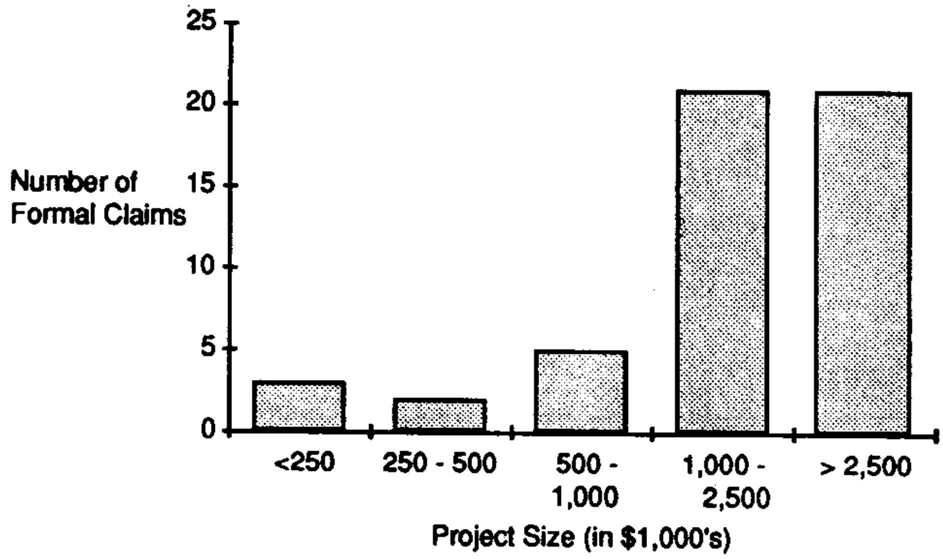

Figure 5. Number of Formal Claims, Classified by Project Size

TABLE 4. NUMBER OF FORMAL CLAIMS
Classified by Project Size and Working Day Overrun Rate*

Working Day Overrun Rate	Under $250,000	$250,000 to $500,000	$500,000 to $1,000,000	$1,000,000 to $2,500,000	Over $2,500,000	Total
Under -10%	0	0	1	1	4	6
-10% to 0%	0	0	0	5	2	7
0% to 10%	0	0	0	0	3	3
Over 10%	0	1	1	7	11	20
Total	0	1	2	13	20	36

*Data are restricted to only those projects with formal claims. (Data also excludes projects for which duration data were not available.)

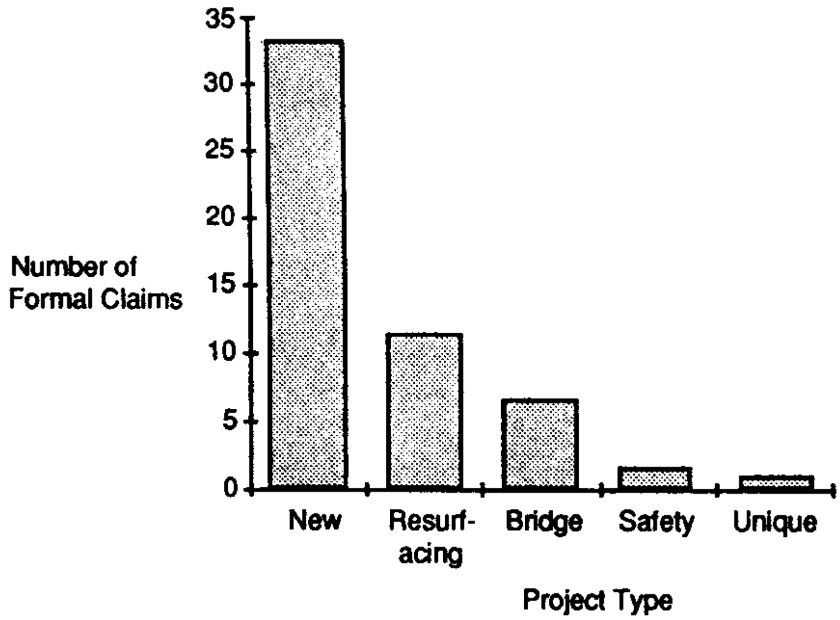

Figure 6. Number of Formal Claims, Classified by Project Type

TABLE 5. CONSTRUCTION COST OVERRUNS
Classified by Project Type

Project Type	Cases	Mean	Standard Deviation	Median	Correlation Coefficient	Level of Significance (1-Tailed)
New construction	110	9.23%	1.22%	5.89%	.0394	.341
Resurfacing	181	3.90%	0.80%	3.00%	.0825	.135
Bridge only	58	8.20%	4.24%	1.80%	.0699	.301
Safety improvement	74	2.98%	1.25%	1.76%	.3000	.005
Landscaping	4*	—	—	—	—	—
Unique	5*	—	—	—	—	—

*Not enough valid cases to analyze data.

LEVEL OF COMPETITION

The results showed that competition can be measured to some extent by the number of bidders on any given project.

A related measure of competition is the difference between the low bid and the engineer's estimate. For most cases (305 out of 433 projects), the low bid was less than the engineer's estimate. The percentage of difference between the low bid and the engineer's estimate increased as the number of bidders increased (see Table 6). The number of bidders did not appear to be related to the size or type of project.

Analysis showed that as the number of bidders increased, the cost overrun rate based on the engineer's estimate decreased, while the cost overrun rate based on the low bid amount increased (see Figure 7). In other words, more bidders decrease the bid amount; and a lower bid amount decreases the cost overrun rate based on the engineer's estimate and increases the cost overrun rate based on the low bid.

This result indicates that cost overrun rates are influenced by the number of bidders. In most cases, if the number of bidders increased, the cost overrun rate based on the low bid also increased. This cost overrun, however, did not usually cause the final estimate to surpass the original engineer's estimate. Figure 8 shows that the median engineer's estimate was 7 percent above the median low bid amount. This figure also shows that when the number of bidders was greater than six, the predicted overrun exceeded the engineer's estimate. However, only 12 percent of the projects received more than six bids.

GEOGRAPHIC DISTRICT

The results showed that the median cost overrun rate was highest in District 4 (see Table 7). The results also showed that districts 1 and 3 had the highest dollar amount of formal claims per construction dollar (see Figure 9).

TABLE 6. PERCENTAGE OF DIFFERENCE BETWEEN THE LOW BID AND THE ENGINEER'S ESTIMATE
Classified by the Number of Bidders

Number of Bidders	Cases	Average Percentage of Difference Between the Low Bid and the Engineer's Estimate
1	13	3.58%
2	81	-2.15%
3	101	-3.60%
4	95	-1.49%
5	50	-7.31%
6	30	-9.70%
7	14	-5.02%
8	18	-15.09%
10	7	-11.64%
>10	11	-16.10%

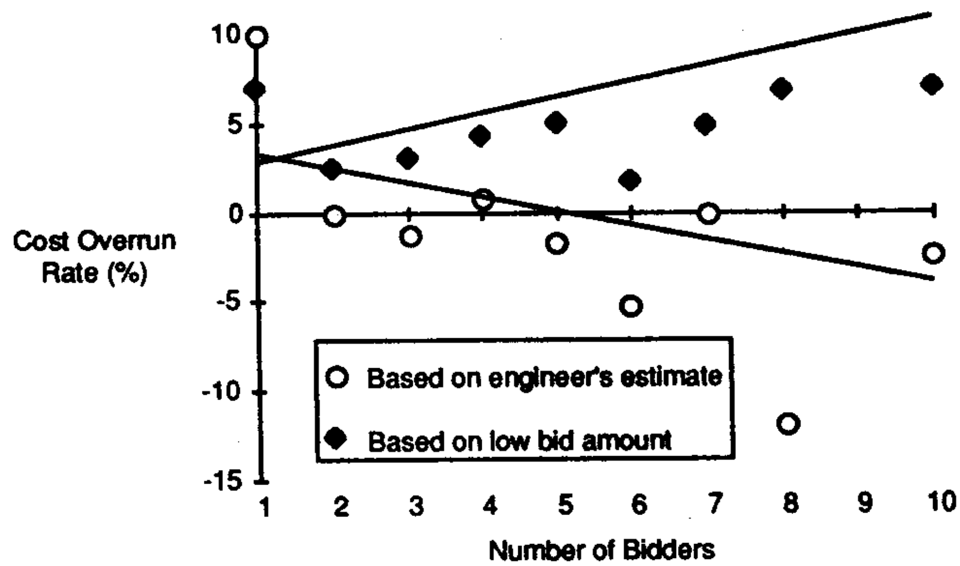

Figure 7. Median Cost Overrun Rates, Measured Against Number of Bidders

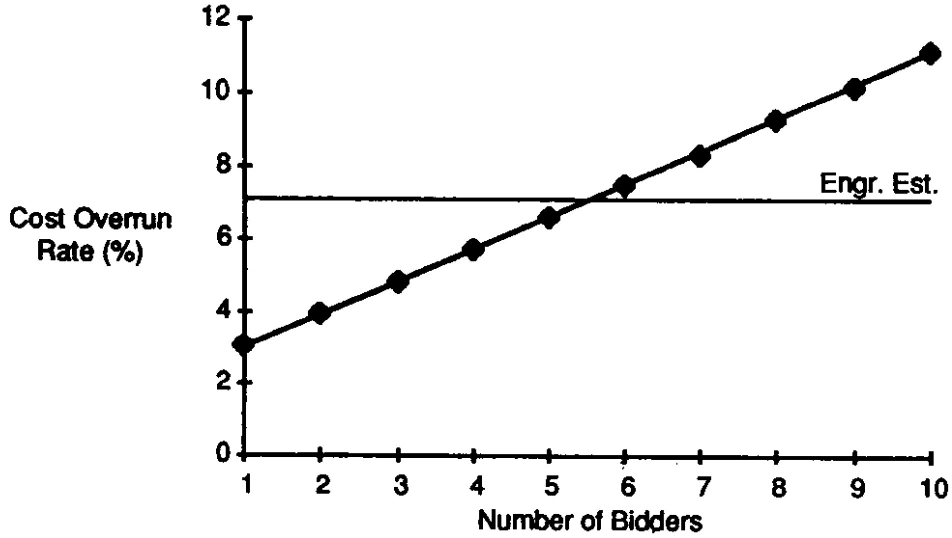

Figure 8. Predicted Cost Overrun Rates, Measured Against Number of Bidders

TABLE 7. CONSTRUCTION COST OVERRUNS Classified by District

District	Location	Cases	Mean	Standard Deviation	Median	Correlation Coefficient	Level of Significance (1-Tailed)
1	Seattle	149	6.14%	1.04%	5.15%	.0732	.188
2	Wenatchee	35	1.93%	1.55%	-1.02%	.0174	.460
3	Olympia	84	4.64%	1.38%	2.01%	.2076	.029
4	Vancouver	49	8.20%	1.40%	8.47%	.0346	.407
5	Yakima	59	6.35%	1.40%	4.67%	.1479	.132
6	Spokane	56	6.61%	4.43%	2.60%	-.0824	.273

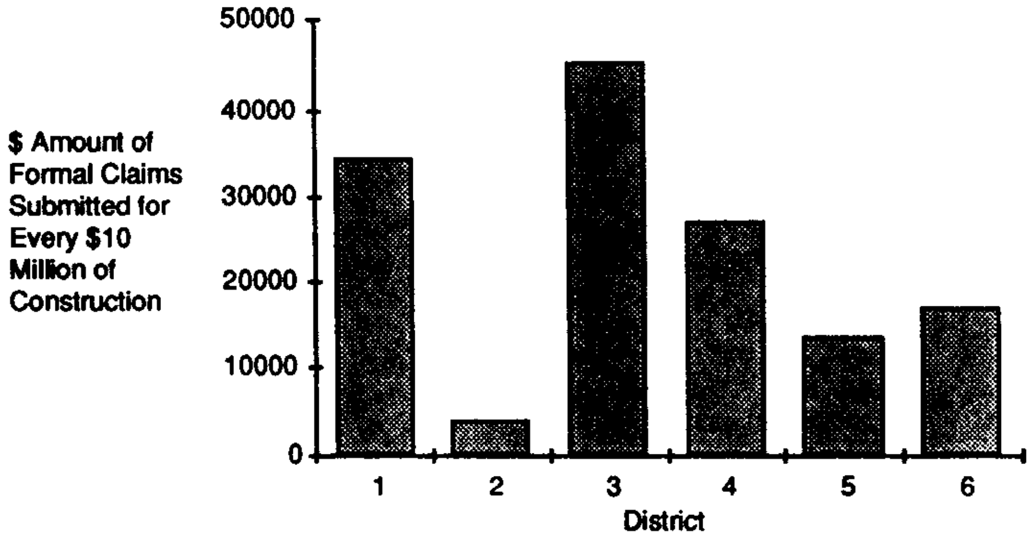

Figure 9. Dollar Amount of Formal Claims per Construction Dollar, Classified by District

PRE-CONTRACT ENGINEERING

The cost overrun rate was examined in relation to pre-contract engineering costs expressed as a percentage of the low bid amount. Analysis found that cost overrun rates tend to increase when the ratio of pre-contract engineering dollars to low bid amount increased (see Figure 10). With the wide distribution of points noted on the figure, the relationship can only be considered a tenuous one, i.e., a few outlying points may be influencing the analysis. It should also be noted that project complexity was ignored in this portion of the analysis.

CONSTRUCTION ENGINEERING

Analysis determined that cost overrun rates increased as the construction engineering hours increased. This may be understandable if it is recognized that more construction engineering will be required on more complex projects. Thus, cost overruns may not be influenced by the engineering hours spent but rather by the complexity of the project for which the engineering effort is required. Further analysis of the data showed no effect on the overrun rate if the engineering hours were expressed as a percentage of

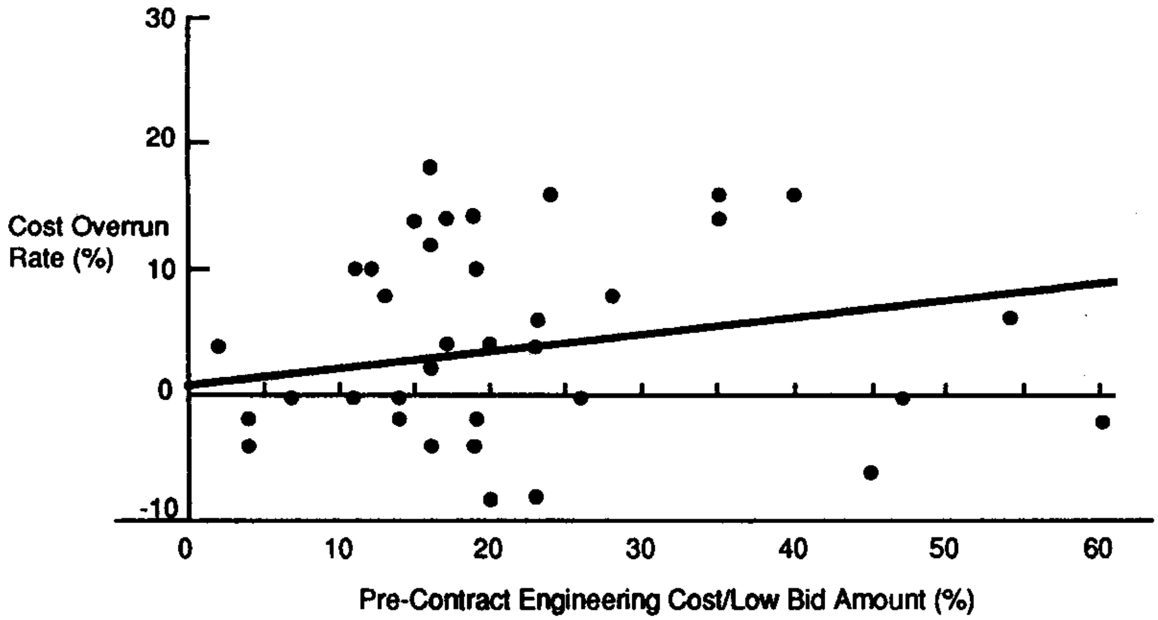

Figure 10. Scatter Plot of Cost Overrun Rates,
Classified by PE$/Low Bid Amount

the total project cost. Another finding was that the median cost overrun rates increased when the construction engineering organization administered fewer than ten projects during the time frame of this study (see Table 8). This should not be construed to mean that greater effectiveness in minimizing cost overruns is realized when more projects are undertaken. Organizations with fewer projects to administer may be the same ones that administer larger and more complex projects. This in itself could explain the difference in cost overrun rates. In addition, if an organization administers only a few small projects, fewer resources will probably be made available to that organization. This would also explain this relationship. A related finding showed that the median cost overrun rates increased when the construction dollar volume administered by a construction engineering organization was greater than $10 million (see Table 9). Since larger projects are typically more complex, it is understandable that overrun rates would be higher in organizations responsible for larger projects.

TABLE 8. MEDIAN COST OVERRUN RATES
Classified by Construction Engineering Organization Frequency

Number of Projects Administered by Construction Engineering Organization During Study	Median Cost Overrun Rate
Projects < 10	6.20%
Projections >= 10	4.05%

TABLE 9. MEDIAN COST OVERRUN RATES
Classified by Construction Engineering Contract Dollar Volume

Dollar Volume Administered by Construction Engineering Organization During Study	Median Cost Overrun Rate
Dollar Volume <= $10,000,000	3.48%
Dollar Volume > $10,000,000	5.05%

CONTRACTOR FAMILIARITY WITH WSDOT

No significant findings were related to contractor familiarity with the WSDOT. The number of projects that a contractor had been awarded by the WSDOT did not increase or decrease the cost overrun rates. While some WSDOT personnel contend that certain contractors are more inclined to file claims and ask for added compensation, the data did not support this conclusion. Some "familiar" contractors filed few claims, and some "familiar" contractors filed many claims. Certainly, there are specific contractors who have a reputation for filing many claims. However, when they were grouped with other "familiar" contractors, no relationship with cost overruns was noted.

RESULT OF MULTIPLE REGRESSION ANALYSIS

The final stage of the analysis consisted of a multiple regression analysis in which all the foregoing variables were included. By conducting a stepwise analysis, the researchers were able to remove all variables from the equation that did not significantly contribute to explaining the cost overrun rate. The most significant variable that explains the overrun rate was found to be the relative difference between the low bid amount and the high bid amount. That is, the cost overrun rate increases as the difference between the highest received bid and the low bid increases. This variable was found to be related to the number of bidders, i.e., the relative difference between the high and low bid increases with an increase in the number of bidders. Another variable of importance was the relative amount of engineering costs borne by the project. Projects with higher engineering costs, those projects presumed to be more complex, had higher cost overruns. To a lesser degree, greater cost overruns were associated with larger sized projects.

SUMMARY

The objective of this research was to identify factors that influence construction cost overruns. Data analysis was performed to test theories concerning factors that influence these overruns. The results of the data analysis identified several of these factors. In summary, increased cost overruns were associated with the following factors:

- projects greater than $2,500,000,
- increased formal claims submitted by the contractor,
- safety improvement projects,
- projects with a high degree of complexity,
- formal claims on new construction projects,
- formal claims on bridge construction projects,
- increased competition measured by the number of bids, and
- an increased construction dollar volume administered by a construction engineering organization.

CONCLUSIONS

The conclusions related to the variables of interest are presented in the same manner or order in which they appear in the results section. Conclusions are intuitive statements that emerge from the correlation analysis. In some cases, the conclusions are tempered with experience and/or comments made by WSDOT personnel. Additional study may be necessary to substantiate some conclusions.

PROJECT SIZE

The results indicate that higher cost overrun rates are associated with larger projects. An explanation for this relationship is that larger projects are more complex. Complex projects require increased engineering effort in both the pre-contract and construction phases. Even when projects are merely increased in size, complexity is added simply by the increase in administration tasks required. In many cases, the increase in staffing is in a larger proportion than the increase in size. Despite this additional effort, cost overrun rates tend to be higher on these projects.

The results also showed that increased cost overrun rates caused by formal claims are more common on larger projects. The high percentage of formal claims occurring within the two largest project size classifications reinforced this conclusion.

A related finding in the results was that working day overrun rates caused by formal claims are more likely to occur when the project size is greater than $2,500,000. Working day overruns can be attributed to delays in completing the contract. These delays are more apparent on larger projects because changes tend to be larger and more complex and take more time and effort to estimate, to negotiate with the contractor, and to have approved. Formal claims submitted by the contractor may be attributable to the impacts associated with these delays.

There is a strong sense among WSDOT personnel that the cost of claims goes up if the dispute is not resolved quickly.

This led to the conclusion that a quick resolution of these changes, at the lowest level possible, would minimize these delays and the associated cost overruns.

While formal claims were identified with increased cost overruns and working day overruns, the number of formal claims submitted was relatively low in relation to the number of projects awarded. As stated previously, the WSDOT awards approximately 200 construction contracts a year. Out of these projects, about 10 percent involve the submittal of at least one formal claim. This ratio is relatively small and should be considered in relation to other factors affecting construction cost overruns.

PROJECT TYPE

The cost overruns resulting from formal claims on new construction projects may be related to project size. As defined in the previous chapter, "new construction" projects are generally large and complex.

The cost overruns resulting from formal claims on bridge projects may also be a function of project size instead of project type. Bridge projects in this category are large projects. They also tend to be complex. So once again, project size and complexity seem to surface as possible causes of cost overruns.

Another explanation for these cost overruns may be related to unforeseen site conditions. Unforeseen site conditions are most common on large excavation projects. When contractors encounter unforeseen conditions on large roadway excavation projects, they can easily move to another area and continue other work activities while the problems are resolved. However, when a similar problem is encountered on bridge projects, the contractors may not have this option. Bridge projects have tighter schedules, and with the restricted options and specific sequence of the work required, problems can quickly translate into delays. The impacts associated with these delays on bridge projects may be the true cause of these formal claims and their associated cost overruns.

LEVEL OF COMPETITION

These relationships reflect traditional assumptions regarding the low bid contract system for procuring goods and services. This system is predominantly used in the public sector. As competition increases (measured by the number of bids), the low bid decreases and the agency procures contracts at a lower price. While competition causes the low bid to decrease, overruns increase. In other words, as competition forces contractors to "leave more on the table" and lower their contingencies to win a bid, they may feel a strong compulsion to try to recover this difference. Some contractors may try to recover this difference through the aggressive pursuit of changes and claims.

If the low bid on a project is below the engineer's estimate, the sum difference may be regarded as an amount that has been committed to the project but for which no direct claim exists. Since this sum exists in the minds of contractors, they may have a strong inclination to try to justify their claim to such amounts. Likewise, WSDOT personnel may be more inclined to accept a request for additional sums if the cumulative result on the project is still within the engineers' original estimate. When costs do not exceed the engineer's estimate, a greater emphasis may be placed on keeping the project on schedule and disputes at a minimum. At the same time, changes in the project scope may be made with greater ease if the cumulative effect is within the engineer's original estimate. Naturally, if the amounts requested exceed the engineer's estimate, the agency may be more reluctant to accept requests for additional funds.

For most cases, cost overruns do not raise the final contract amount above the original engineer's estimate. This is a significant conclusion. Since the engineer's estimate is based on historical information, it may be conservative; however, it should be considered a fair representation of the project costs. If the engineer's estimate is considered a fair representation of project costs, cost overruns that raise the final project costs up to or below the engineer's estimate should not always be viewed negatively.

The final conclusion is that increased competition is desirable. While this competition decreases the low bid and influences cost overruns, in many cases, these overruns should be considered within acceptable limits. When the difference between the low bid and engineer's estimate is used to avoid delays and provide a better product, these benefits make the cost overruns appear even more acceptable.

GEOGRAPHIC DISTRICT

The higher dollar amount of formal claims per construction dollar found in districts 1 and 3 appears to be associated with the increased number of larger projects found in those districts. While the analysis tried to determine the factor or factors influencing the number of claims in District 4, no clear explanation was discovered.

PRE-CONTRACT ENGINEERING

Cost overruns were not expected to increase when the ratio of pre-contract engineering dollars to low bid amount increased. Usually, increased engineering effort equates with decreased cost overruns. Thus increased pre-contract engineering effort should produce a "cleaner" set of contract documents, and a clean set of contract documents should be less vulnerable to cost overruns. Because this assumption appears correct, other factors may have produced the cost overrun result.

One explanation of this result may be based on the complexity of a project. As discussed earlier, complex projects, which require additional engineering, are subject to cost overruns. In other words, the complexity is such a driving force that additional engineering cannot overcome the potential for cost overruns.

Another explanation of this result may be associated with the number of bidders. An increased level of pre-contract engineering may produce a "cleaner" set of contract documents. Contractors may be more willing to submit bids on a project that is clearly defined in the contract documents. Therefore, a project whose contract documents have been improved by an increased level of pre-contract engineering may receive more bids.

As concluded earlier in this chapter, an increased number of bidders increases the cost overrun rate.

A third explanation of this phenomenon may be "scope creep" or "design by committee." These phrases describe a process in which a project is revised and redesigned, and each revision includes additional features outside the scope of the original project. In some cases, because of funding limitations, availabilities, or windows of opportunity, a project may be designed, set aside, redesigned, and finally advertised for bids.

CONSTRUCTION ENGINEERING

The first finding relating engineering hours to the overrun rates appears to be a function of project size, as opposed to construction engineering. For larger projects, an increase in the total number of construction engineering hours is needed. Furthermore, results showing construction engineering as a ratio to final project costs did not reflect any significant findings. In other words, a higher ratio of construction engineering hours to final project costs did not increase or decrease cost overruns.

The second finding was that cost overrun rates increase when a project office administers a fewer number of projects simultaneously. WSDOT management attempts to equitably and consistently distribute the dollar volume of construction contracts among district project offices. This procedure maintains consistent staffing levels for each office. A fewer number of projects means that these projects are usually larger in size. Therefore, this increased cost overrun rate is a function of project size, not the number of projects administered.

The third finding reconfirms the result that increased cost overruns are associated with the administration of larger volumes of construction. A higher construction dollar volume typically represents an increased number of larger and more complex projects.

CONTRACTOR FAMILIARITY WITH WSDOT

A contractor's familiarity and working relationship with the WSDOT is different for each contractor. Increased cost overrun rates associated with an individual contractor's tendency to submit formal claims were observed on a case by case basis. However, when classified into groups based on the number of contracts they were awarded, no direct relationship was observed between contractor familiarity and construction cost overruns.

SUMMARY

This study analyzed information about many projects. In addition, it considered numerous variables. The multiple regression analysis disclosed that the relative difference between the high bid and the low bid explained the most about the cost overrun rate. Because the correlation analysis showed that several other variables are related to the cost overrun rate, it can be concluded that several variables must be interrelated. It can also be concluded that cost overrun rates are quite complex and cannot be modelled easily. Most importantly, it must be noted that cost overruns on WSDOT projects tend to be relatively modest, averaging about 5 percent of the contract award amounts.

RECOMMENDATIONS

The investigation and identification of factors that influence construction cost overruns were the primary objectives of this study. These factors were described in the previous chapter. Proper identification of the factors will provide the WSDOT with essential information for recognizing situations and conditions that influence construction cost overruns.

WSDOT can utilize the recommendations in this chapter to help minimize construction cost overruns.

INCREASED AWARENESS OF COST OVERRUN FACTORS

The WSDOT should become more aware of the factors that influence construction cost overruns. Unfortunately, for some of the factors identified, no obvious solutions exist. Without a practical solution available, an increased awareness of these factors is the next best alternative. Project size, project type, and level of competition are all factors that warrant WSDOT's increased awareness.

The project demonstrated that larger projects experience higher cost overruns. Increased awareness of project size and its relation to cost overruns could help alert WSDOT engineers that cost overruns (from increased formal claims and other sources) are more likely to occur on these projects. Consideration might be given to reducing the scope of individual contracts by breaking projects into smaller bid packages. Since the number of formal claims filed is associated with the cost overrun rate, claims handling must be efficient and effective. Training in dispute avoidance might be appropriate. Additional study needs to be devoted to the source of cost overruns on such projects.

New construction and bridge construction projects are more likely to experience construction cost overruns from increased formal claims. Increased awareness of this potential could result in greater emphasis on claims prevention and dispute resolution for these types of projects. Further study into the sources of cost overruns on these projects may provide further insights on how to minimize cost overruns.

The low bid system WSDOT uses to procure construction contracts is not likely to change, and the resulting level of competition brought about by this system will also continue. Therefore, awareness that increased competition (measured by the number of bidders) is associated with higher cost overruns is important. Information regarding the current level of competition for WSDOT contracts could be provided to the districts, who could use this information to possibly anticipate and prepare for additional requests for funds. While this procedure would not guarantee a decreased cost overrun rate, it would increase the awareness of the number of bidders and their affect on the rate.

The administrative review of changes report, which is submitted district by district, is an example of increased awareness within the WSDOT regarding changes and their affects on cost overruns. This report reviews changes and identifies the factors that cause them. Standardization of and increased emphasis on this report is recommended. Identification of the factors associated with changes on a consistent, statewide basis will provide the documentation necessary for the WSDOT to isolate and prevent or minimize the factors. During the past year, some standardization has been achieved with the implementation of a computer database system that records and identifies the factors that cause change orders. This system was developed by the Headquarters Construction office. Continued use and application of this system is also recommended.

The WSDOT strives for consistency in all phases of its operations. From the standardization of designs to the administration of construction contracts, consistency among project offices and geographic districts is essential. In fact, consistency is so vital that one of the primary functions of WSDOT Headquarters is to maintain consistency among offices and districts throughout the state. While consistency is critical, certain projects might require increased awareness or added emphasis on factors that influence cost overruns. This greater awareness could be useful in minimizing cost overruns, but care would have to be taken to avoid compromising consistency.

STATISTICAL DATABASE USED TO ANALYZE COST OVERRUN FACTORS

Development of a historical database similar to the one in this study could be useful for monitoring the factors that influence cost overruns. Historical information could be obtained from the same sources to accomplish this. From this database, the WSDOT could identify the influencing factors and the specific projects that might be more likely to experience cost overruns. Such a long term monitoring effort would provide information on the impact of various remedies or actions that were implemented to reduce cost overruns.

The reduction of the cost overrun rate for certain districts, pre-contract engineering organizations, and construction engineering organizations could be identified with this database. Analysis of these specific districts and organizations could provide information about the techniques or procedures they used to reduce the cost overrun rate. This information could then be applied to all areas within the WSDOT to minimize construction cost overruns.

This database could also be used as a management tool to provide information to assist WSDOT engineers in making engineering decisions. Statistical information based on historical data could aid these engineers in the planning, pre-contract, and construction phases of a project. Statistical information provides insight to trends and relationships on similar projects, but decisions should not be made on this information alone. There is no substitute for the expertise of the engineers who make these decisions. Therefore, this information should be used as a reference to aid the engineers in the decision making process.

An example is included to illustrate the benefits of using this database as a management tool. Suppose a safety improvement project was in the preliminary stages of project development, and a decision was needed regarding the number of pre-contract engineering dollars that should be allocated for the design of this project. To aid in this decision, the Project Development Engineer would request information from this database. Information regarding the project type, project size, and district would be used to generate a report that contained statistical information regarding similar projects. This report might contain information about pre-contract engineering dollars used on similar projects and the corresponding cost overruns that were experienced. In this instance, the information could be used to help the Project Development Engineer determine the optimal number of pre-contract engineering dollars to allocate toward the design of the project. For such decisions, the uniqueness of projects would also have to be recognized so that the database could be used as an aid rather than an absolute guide.

Implementation of a statistical database would also provide the WSDOT with an additional resource for future research in construction cost overruns. While this study identified the factors that influence cost overruns, in-depth analysis beyond the scope of this study would be beneficial. Specifically, analysis not covered in this study might include the effects of different subcontractors on the cost overrun rate, cost overruns associated with consultant designed projects, the effects of changes to certain specifications, and the effects of changing policies and procedures within the WSDOT.

Some of the reports used to obtain information in this study were relatively new (19). The newness or restricted availability of these reports limited the size of the database (433 valid cases). Future research would incorporate more information, which would increase the number of valid cases in the database and provide information with a higher degree of accuracy.

QUICK RESOLUTION OF CHANGES AND CLAIMS

Comments by WSDOT personnel indicated that quick resolution of changes and claims at the lowest level possible can reduce cost overruns. Implementation of policies or procedures that emphasize quick resolution would be a positive step in reducing construction cost overruns. Two suggested policies that reflect the concept of quick resolution of changes and claims at the lowest level possible are listed below.

1.	Train WSDOT personnel to assume the responsibility granted to the districts to efficiently resolve changes and claims.

Modification of the change order checklist should allow increased change order approval authority at the district and project engineer level. While this change in delegation may reduce claims and disputes, care should be taken in order to avoid compromising consistency between the districts.

To resolve these claims and disputes at the district level, increased education and training in the areas of claims management, negotiation, and resolution are needed. A course entitled "Construction Claims" is already being offered to WSDOT engineers. This course, along with actual experience in this area, should improve the efficiency of WSDOT in handling claims and disputes.

2.	Improve response time for issues that require Headquarters approval.

The introduction of facsimile machines and computer modems has given the WSDOT tools to improve its response time for construction related approvals. However, even with these tools, response time still needs improvement. This study demonstrated that delays on WSDOT's larger projects have been associated with increased formal claims. In some cases, these delays have been associated with the submittal and approval process. Many improvements have already been implemented in this area. Technical advisors are assigned to bridge projects. Direct submittal of drawings has been implemented in the bridge division. Some project offices have implemented a computer database system that tracks all required submittals and approvals. This system has been especially useful on larger projects. Examples of these submittals include material approvals, material certifications, change orders, and shop drawings. Efforts should be expanded to continue emphasis on response time for issues that require headquarters approval.

Currently, the WSDOT Headquarters Materials division publishes and distributes statewide via computer modem the "Record of Materials" for each project. This record establishes required levels of material sampling and testing. A similar system should be implemented for all types of project submittals. This system would help monitor and track response time to minimize delays. Another system the WSDOT has developed is the "Construction Contract Information System." This system monitors and makes available to the individual project offices, via computer modem, current construction contract information. Access to this information will help reduce the response time for critical and time sensitive approvals.

INCREASE LEVEL OF EXPERTISE ON COMPLEX PROJECTS

One conclusion of this study was that the design and administration of complex projects is associated with construction cost overruns. As mentioned previously, increased complexity on a project is associated with larger projects, new construction, and safety improvement projects. An examination could be conducted to determine the extent to which shortcomings exist among WSDOT personnel in their ability to properly administer complex construction projects. The staffing criteria should also be studied for such projects. An increased level of expertise may be needed to minimize cost overruns associated with them. Enhancing the level of expertise of WSDOT engineers can be brought about by increasing education and training in these areas.

Implementation of a fellowship program to encourage WSDOT engineers to receive their Master's degree is a vital step towards improving the level of expertise. This program would give WSDOT engineers an opportunity for intensive study in the area of construction, transportation, and traffic engineering. In fact, WSDOT management has just recommited itself to and improved its existing program.

Training programs should be established for engineers and technicians who cannot enter the formal Master's program. To enhance and develop these training programs, the WSDOT could enlist the engineers who have completed the Master's degree program. This would ensure that the WSDOT training programs would continually receive current information in these areas. It would also help distribute the information gained by those engineers to the various WSDOT employees.

SUMMARY

The recommendations outlined above represent ideas that could reduce construction cost overruns. Some of these recommendations are currently being implemented for reasons that may or may not be associated with cost overruns. The findings of this study have shown that improvement in the areas discussed will minimize these cost overruns. Therefore, continued support of the programs already established, with an added emphasis on minimizing construction cost overruns, is recommended. In addition, the review and implementation of the remaining proposed ideas and suggestions is also recommended.

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REFERENCES

1. Diekmann, J. E., and Nelson, M. G., "Construction Claims: Frequency and Severity," Journal of Construction Engineering and Management, Vol. 111, No. 1, March, 1985, pp. 74 - 81.

2. Jahren, C. T., and Ashe, A. M., "Predictors of Cost Overrun Rates," Journal of Construction Engineering and Management, Vol. 116, No. 3, September, 1990.

3. Tyrrell, A. P., Lake, L. M., and Parsons, A. W., An Investigation of the Extra Costs Arising on Highway Contracts, Report No. 814, Transport and Road Research Laboratory, 1983.

4. Rothrock, T. P., and Repole, W., Construction Cost Estimation and Bid Evaluation Report, Report No. FHWA/PA-86/008+83-25, Gainesville, Florida: Info Tech Inc., 1986.

5. Park, W. R., "How Accurate are Engineers' Estimates?," Consulting Engineer, Vol. 66, April, 1986, P. 72.

6. Duck, D. J., "Negotiating Construction Claims," Journal of the American Water Works Association, Vol. 76, No. 2, February, 1984, pp. 39 - 41.

7. Ashe, A. M., "Predictors of Change Order Rates on Public Works Construction Contracts," research report presented to the University of Washington in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering, 1988.

8. Temple, M. W. B., and Stukhart, G., "Cost Effectiveness of Geotechnical Investigations," Journal of Management in Engineering, Vol. 3, No. 1, January, 1987, pp. 8 - 19.

9. King, R., "Designing Plans for Constructibility," Journal of Construction Engineering and Management, Vol. 113, No. 1, March, 1987, pp. 1 - 5.

10. Kagan, H. A., "How Designers can Avoid Construction Claims," Journal of Professional Issues in Engineering, Vol. 111, No. 3, July, 1985, pp. 100 - 107.

11. Wilson, R. L., "Prevention and Resolution of Construction Claims," Journal of the Construction Division, ASCE, Vol. 108, No. CO3, September, 1982, pp. 390 - 405.

12. Prather, G. M., "An Owner's Guide to Claims Prevention," Public Works, Vol. 115, July, 1984, pp. 51 - 53.

13. Callahan, M. T., "Deter Construction Claims by Anticipating Problems," American City and County, Vol. 98, September, 1983, pp. 48 - 50.

14. Ostrower, D. A., "Conflicts in Contract Documents," Consulting - Specifying Engineer, Vol. 1, June, 1987, pp. 29 - 34.

15. Washington State Department of Transportation, Standard Specifications for Road, Bridge, and Municipal Construction, 1988.

16. Thomas, H. R., Hester, T. H., and Halligan, D. W., "Managing Unforeseen Site Conditions," Journal of Construction Engineering and Management, Vol. 113, No. 2, June, 1987, pp. 273 - 287.

17. Frude, N., "A Guide to SPSS/PC+," Springer, New York, 1987.

18. Norusis, M. J., The SPSS Guide to Data Analysis for SPSS/PC+, SPSS Inc., Chicago, 1988.

19. Statewide Construction Engineering Report, 1987.