IDENTIFICATION OF POTENTIAL STRATEGIES, METHODS, AND TOOLS FOR IMPROVING COST ESTIMATING PRACTICES FOR HIGHWAY PROJECTS

A Thesis

by

KELLY E. DONNELL

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

MASTER OF SCIENCE

May 2005

Major Subject: Civil Engineering

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Approved as to style and content by:

Stuart D. Anderson (Chair of Committee)	David Trejo (Member)
Don Smith (Member)	David Rosowsky (Head of Department)

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ABSTRACT

Identification of Potential Strategies, Methods, and Tools for Improving Cost Estimating Practices for Highway Projects. (May 2005)

Kelly E. Donnell, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Stuart D. Anderson

Project cost escalation is a major problem for State Highway Agencies (SHA). This problem is evident in cost estimating procedures that may not promote consistency and accuracy of costs over the project development process. The research proposes that a relationship exists between applying good estimating practices and minimizing cost escalation from the initial planning estimate to the engineer's estimate at final design. The objective of this research is to develop a preliminary list of strategies, methods, and tools for project cost estimation practices aimed at achieving greater consistency and accuracy between the project development phases.

A literature review was conducted that assisted in identifying factors that lead to the cost escalation of projects. The information from the literature was used to discover the core estimating assumptions that are the root causes behind cost escalation and lack of project estimate consistency and accuracy. After the cost escalation factors were determined, interviews with SHAs were conducted that lead to identifying unique and/or innovative approaches that will aid the SHAs in overcoming the cost escalation factors.

The main methodology used to develop a potential list of strategies, methods, and tools was first focused on linking strategies to causes of cost escalation. Global strategies were identified by means of this approach. Methods and tools that would likely be effective in implementing the strategies are therefore directed at mitigating root causes of estimate problems in a focused approach. The strategies, methods, and tools are aligned with the project development phase where they would be implemented. Thus, a preliminary list of strategies, methods, and tools is provided in this study.

To my friends and family

for always supporting me and giving me strength.

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CHAPTER I
INTRODUCTION

A construction project moves through several development phases that can span over many years before it reaches completion. A project begins as an idea that addresses a need. Throughout the life of the project, the initial concept is transformed into reality. During this transition, the project's scope changes and becomes more refined, and as a result, the project cost changes. Estimated project costs often increase over time, and these increases are a major problem for state highway agencies (SHAs) and metropolitan planning organizations (MPOs). News reports of project cost escalation additionally cause the public to lose confidence in the ability of transportation agencies to effectively perform their responsibilities. Cost increases cause a disruption in priority programs where other projects have to be delayed or removed in order to accommodate higher cost estimates. This issue was cited as the number one factor that resulted in changes in statewide highway letting programs (Anderson and Blaschke 2004). Cost increases are present as projects progress from concept in the long-range planning process, are prioritized for programming, and are subject to detailed development prior to construction.

BACKGROUND

This research was conducted under the National Cooperative Highway Research Project (NCHRP) 8-49: *Procedures for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction*, which is funded by the National Academy of Science. From the NCHRP 8-49 problem statement, the National Cooperative Highway Research Program (2004) has identified the problem of cost escalation in the transportation industry and has recognized the need for research into "all aspects of estimation-management and cost-estimation procedures aimed at

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This thesis follows the style of the *Journal of Construction Engineering and Management*.

addressing consistency and accuracy throughout the entire project development process from long-range planning, through priority programming, up to preconstruction engineering and design." The overall objective of NCHRP 8-49 is to develop a guidebook of strategies and practical techniques on highway cost estimating management and project cost estimating procedures aimed at achieving greater consistency and accuracy between long-range transportation planning, priority programming, and preconstruction estimates.

The NCHRP 8-49 project is conducted in two phases with ten tasks being performed. During the first phase of the project, five tasks were accomplished. The intent of the first task was to conduct a state of practice review for the highway cost estimation procedures and cost estimation management during planning, programming, and preconstruction. During the second task, a critical review of cost management and estimation practices was assessed and developed. The purpose of the third task was to identify potential strategies, methods, and tools for improving cost management and estimating practices. The fourth and fifth tasks consisted of creating an outline for the guidebook and preparing an interim report.

The second phase of the NCHRP 8-49 project also has five tasks that have to be performed. The first task in the second phase consists of developing and evaluating the strategies, methods, and tools identified in the first phase. The second task in phase two includes presenting the strategies, methods, and tools to the highway industry. During the third task in phase two, the recommended strategies, methods, and tools will be developed. The fourth task in phase two consists of developing an implementation plan, and the final task includes the preparation of the guidebook.

The research for this thesis was performed during the first phase of the NCHRP project. The researcher recognizes that the cost estimating practices and cost estimating management components interact with one another. Cost estimating practices can be implemented to improve cost escalation, but to ensure that the estimating process continues to operate correctly cost estimating management has to be present through all stages of project development. Therefore, the researcher participated in developing the cost estimating management component of the NCHRP 8-49 project. However, the cost estimating practice component is the focus for this thesis.

Since this research was conducted under the NCHRP 8-49 project, several aspects of the project were defined by the NCHRP problem statement and were therefore used in this research. The first aspect is the use of strategies, methods, and tools. Under the scope of the NCHRP 8-49 project, strategies had to be formulated to address the root causes behind cost escalation. Furthermore, methods and tools had to be defined that are effective during the different phases of the project development process. Therefore, strategies, methods, and tools were used as part of the research framework. The second aspect required by the NCHRP 8-49 problem statement is the use of project development phases. The purpose of the project is to identify cost management and estimating practices that aim at achieving greater consistency and accuracy over the project development phases. Therefore, the project development phases had to be applied to this research to achieve the NCHRP 8-49 goals.

Strategies, Methods, and Tools

The NCHRP 8-49 research problem statement identified the terms strategies, methods, and tools as a basis for conducting research on cost escalation problems and estimating practices. However, no definition of these terms was provided. Therefore, a definition was developed for this research. A strategy can be defined as "*a plan of action intended on accomplishing a specific goal.*" [1] Strategies typically address a specific problem and are often formulated to address a root cause that leads to a problem. For example, a strategy might be to *assess cost impact of unforeseen engineering and constructability complexities*. This strategy would likely address a root cause of cost escalation such as when the scope of a project grows, as more external and internal stakeholders provide input.

[1] From the *American Heritage Dictionary of the English Language*, 4th Edition, 2000.

The strategy is implemented through a method. A method can be defined as "*a means or manner of procedure, especially a regular and systematic way of accomplishing something.*" [2] The method must support the strategy. A method for the strategy described above might be to *use programmatic risk-based cost estimating procedures*. The method is typically applied to early project estimates, as the scope is being defined and detailed, to narrow the range of uncertainty.

A method is then implemented using a tool or technique. A tool can be defined as *"something used in the performance of an operation."* [3] In this case, the operation would be the method. A newly developed tool for the method of programmatic risk-based cost estimates is the *Washington State SHA's Cost Estimating Validation Process* (Molenaar, Diekmann, and Rast 2002). At the core of this tool are systematic peer reviews, risk identification, risk assessment, and risk mitigation employed through software applications using Monte Carlo simulations, influence diagrams, and/or critical path scheduling.

Project Development Phases

Project estimates are made at various times during project development. Different types of estimates will occur during different phases of a project. An estimating technique must fit the information available at the time the estimate is developed. Thus, certain types of estimates are used during project development phases. For example, conceptual estimating is commonly used in planning, programming, and even in the preliminary design phase of a project. A common understanding of the project development phases is critical for any discussion of strategies, methods, and tools used for cost estimating. Each transportation agency has its own terms to describe the phases of this process.

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[2] Ibid.
[3] From the *American Heritage Dictionary of the English Language*, 4th Edition, 2000.

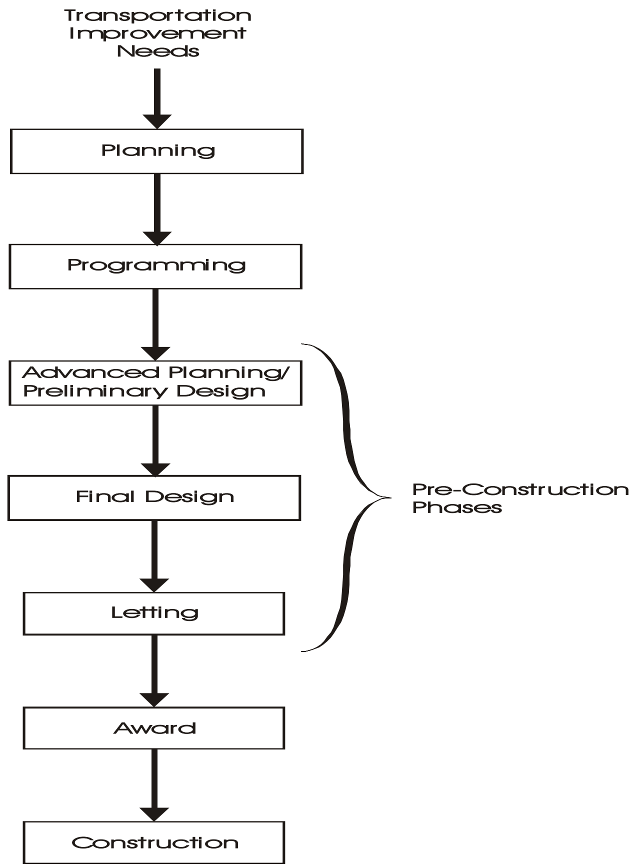

Fig. 1. Typical Project Development Phases for Highway Projects (Anderson and Blaschke 2004)

The NCHRP Synthesis on Statewide Highway Letting Program Management uses the phases shown in Figure 1 and explained in Table 1 to illustrate the interaction between the letting program process and the project development process (Anderson and Blaschke 2004). The project development process identified through the synthesis will be applied during data collection and analysis, so that a standardize approach corresponding to the highway industry is used throughout the study.

Table 1. Project Development Stages and Activities
(Anderson and Fisher 1997)

PROJECT DEVELOPMENT PROCESS PHASES	*TYPICAL ACTIVITIES*
Planning	Purpose and need; improvement or requirement studies; environmental considerations; interagency coordination
Programming	Environmental determination; schematic development; public hearings; ROW plan; project funding authorization
Advanced Planning/ Preliminary Design	ROW development; environmental clearance; design criteria and parameters; surveys/utility locations/drainage; preliminary schematics such as alternative selections; geometric alignments; bridge layouts
Final Design	ROW acquisition; Plans, Specifications, and Estimate (PS&E) development – pavement and bridge design, traffic control plans, utility drawings, hydraulic studies/drainage design, final cost estimates
Letting	Prepare contract documents; advertise for bid; pre-bid conference; receive and analyze bids
Award	Determine lowest responsive bidder; initiate contract
Construction	Mobilization; inspection and materials testing; contract administration; traffic control, bridge, pavement, drainage construction

PROBLEM STATEMENT

Cost escalation or cost increases over the course of project development constitute a major problem in the highway industry. The strategies, methods, and tools and project development phases described previously will be used to study this problem, which is evident in cost estimating procedures that may not promote consistency and accuracy of costs over the project development process. Thus, this thesis proposes that a relationship may exist between applying good estimating practices and minimizing cost escalation from the initial planning estimate to the engineer's estimate at final design. The components of this relationship will be studied for this thesis, and they lead to the following questions.

RESEARCH QUESTIONS

The research problem raises numerous questions that will be addressed during this study. These questions are:

- What are principal causes of cost escalation in SHA projects?
- How do current estimating practices address these causes of cost escalation?
- What new or innovative estimating practices address cost escalation?
- When are these new/innovative estimating practices best applied?
- What preliminary strategies address causes of cost escalation?
- What methods and tools address these strategies?
- When are the preliminary strategies, methods, and tools best applied?

RESEARCH OBJECTIVES

In order to address these research questions, several objectives were developed to examine the cost escalation and cost estimating relationship. The first objective of this research is to identify possible core estimating assumptions that are the root causes behind cost escalation. The second objective is to formulate potential strategies to address root causes at the cost estimation process level. The third objective is to identify estimating methods and tools to implement these strategies. The fourth objective is to consider the impact of project complexity and uncertainty in developing estimating strategies, methods, and tools.

The objectives were accomplished by performing a literature review to understand the problem, including identification of potential key factors influencing cost escalation, and to characterize the current circumstances of SHAs as related to estimating practices. In addition to a literature review, a critical review of current SHA cost estimating practices was developed. In the critical review, a number of approaches were identified that describe cost estimating practices, including innovative or successful approaches, key problems, issues, and deficiencies. Finally, preliminary strategies, methods, and tools were identified that might improve cost estimation procedures based on the different phases of project development and project complexity and lead to minimizing cost escalation.

DELIMITATIONS

This thesis has boundaries that must be identified. The intent of this research was not to collect data for a statistical analysis, but to develop preliminary strategies, methods, and tools based on literature and qualitative information provided by SHAs. Therefore, this project follows a qualitative approach for its research methodology. The information collected from the SHAs does not represent all fifty states; thus it is not known if all states are void in the areas described throughout this thesis. Moreover, the SHAs did not provide detailed information about specific projects but descriptions about the SHAs estimating practices applied to all their projects. After identifying these boundaries, the problem statement was studied.

ORGANIZATION OF THE STUDY

This first chapter provides basic background information concerning the research project. In the remaining chapters of this thesis, the research methodology and results are discussed. Chapter II focuses on the potential factors leading to cost escalation along with methods and tools found during the literature review. Chapter III explains the research methodology followed while conducting the research project. Chapter IV and V describes the details of the data collection and analysis. These chapters focus on the state of practice related to cost estimating practices in the transportation industry, and the critical review of the cost estimating practices. Chapter VI identifies, explains, and justifies the preliminary list of strategies, methods, and tools that are recommended to improve cost estimation in the transportation industry. Finally, Chapter VII provides a summary, conclusions, and recommendations.

CHAPTER II
LITERATURE REVIEW

The literature review for this research project was used to identify potential factors leading to cost escalation in the transportation industry and possible methods and tools that aid in alleviating the cost escalation factors. In order to analyze literature related to the research subject, search engines such as Transportation Research Information Services (TRIS), library resources, and web-based search engines were used. Industry journals and publications from the American Society of Civil Engineers (ASCE) and the Construction Industry Institute (CII) were also reviewed for related subject matter. Key terms used in the literature search include estimating, cost overruns, and construction cost underestimation. Once the literature was gathered, each document was analyzed for information related to cost estimating procedures. The information extracted from the articles was organized according to problems, strategies, methods, and tools based on the research framework.

Most transportation sector estimating literature focuses on cost estimating during the pre-construction phases with very little information available on procedures for estimating cost during the early stages of project development (Schexnayder, Weber, and Fiori 2003). Much of this literature does address problems or issues with cost estimating such as cost escalation.

PREVIOUS WORK

Cost Estimation Issues

The U.S. Department of Transportation's subcommittee on Transportation, Treasury, and Independent Agencies presented a testimony regarding the cost drivers on highway projects to the United States House of Representatives in 2003. Kenneth Mead, the Inspector General, stated "if the efficiency with which the $500 billion invested by the Federal Government and States over the last 6 years had been improved by only 1 percent, an additional $5 billion would be made available - enough to fund 4 of the 17 active major highway projects." During the investigation, Mead discovered that cost increases occurred because costs such as inflation, preliminary engineering, and construction management were not included in the estimate. Another reason for cost escalation and project delays was that SHAs were not able to manage their resources properly to maintain their schedules. In addition, the States' project management practices were not properly administered (Mead 2003).

The General Accounting Office (GAO) performed several audits on how the Federal Highway Administration (FHWA) manages cost inflation on large bridge and highway projects. The GAO (2002) reported a majority of the cost escalation for a project occurs between the initial environmental review estimate and the detailed estimate. The FHWA often approves large projects in segments. As a result, a large public investment has already been made before proceeding segments have been approved. Furthermore, the process that a project must go through to be approved contributes to cost escalation. Initial estimates are completed for an environmental review of the best project alternative. These estimates are not focused on an accurate estimate of total cost, but rather focused on reviewing different design alternatives. Another problem is the FHWA has no statutory requirement to focus on project cost containment (GAO 2002).

Although cost estimating programs have improved due to advances in technology, estimating inaccuracy has remained the same for 70 years. A recent study analyzed the reasons for cost underestimation in public works projects (Flyvbjerg, Holm, and Buhl 2002). The study indicated that projects are 86 percent more likely to be underestimated than overestimated. Furthermore, the actual cost of road projects are on average 20 percent higher than their estimated costs. Flyvbjerg et al. (2002) stated that some promoters and forecasters intentionally deceive the public by claiming a project costs less than it actually will in order to gain support and approval for a project. Many of the estimates that decision makers evaluate do not include important details such as environmental and safety concerns that could result in large cost increases.

Schexnayder et al. (2003) listed numerous reasons for cost estimating issues in their synthesis on project cost estimating. Some of the reasons cited were project scope changes, unforeseen engineering complexities, changes in economic and market conditions, changes in regulatory requirements, and local government pressures. Flyvbjerg et al. (2002) also provided several issues that result in cost underestimation. One issue resulting in underestimation is technical mistakes such as lack of experience or insufficient data. Another explanation for underestimation is economic incentives such as self-interest and public interest. Finally, project promoters and forecasters could underestimate projects for shear political gain and power.

When a project is reviewed for potential inclusion in a SHA's project program, the earlier estimate is not always the most accurate reflection of the project's cost. As a result, underestimated projects that are initiated prevent other projects that are economically feasible from being constructed (Flyvbjerg et al. 2002). Inadequate estimating invariably leads to misallocation of scarce resources. If estimates are consistently high, compared to bid costs and ultimately final costs, fewer projects will be authorized than could have been performed with the resources available, resulting in loss of benefits. If estimates are consistently low, more projects can be authorized than can be fully funded, resulting in project slowdowns, scope changes, performance shortfalls, and generally higher costs and lower benefits. If estimates are consistently neither high nor low, but still inaccurate, the estimated benefit/cost ratios will not be correct and the most beneficial projects may not be authorized, while less beneficial projects are authorized. All of these conditions result in misallocation of funds and a loss in benefits to the public (Flyvbjerg et al. 2002).

Other reasons for cost increases are inaccuracy of the scope and schedule, political pressure to complete a project within a certain budget, and decreasing or extending the project's schedule. Chang (2002) found that the owner was responsible for one-third of cost and time increases; where as the consultant contributed the least to cost and time increases.

Cost Escalation Factors

Construction projects have a long history of cost escalation (General Accounting Office 2003). The potential factors that lead to project cost escalation have been identified through a large number of studies and research projects as described in the literature. The possible factors driving cost escalation of project cost can be divided by project development phases: planning and execution. As defined in this research, planning involves all project development phases prior to bidding including long-range planning, programming, advanced planning/preliminary design, and final design. Execution entails contract bidding, award, project construction, and closeout. For the purpose of this research, only the potential cost escalation factors occurring during the planning phases were studied. However, it should be noted that some of the problems that emerge during project execution, such as unforeseen events or conditions, could be prevented during the planning phases.

The factors that may affect the estimate in each development phase are by nature internal and external. Factors that may contribute to cost escalation and are controllable by the SHA are internal, while factors existing outside the direct control of the SHA are classified as external. This arrangement of factors is shown in Table 2, these factors are numbered for reference only and do not suggest a level of influence. Table 2 has been constructed to provide an over arching summary of the factors that have been identified from many sources and a better understanding of how project estimates are effected. It is important to note that one of the factors points to problems with estimation of labor and material cost, but most of the factors point to “forces” that impact project scope and timing.

Table 2. Potential Factors Causing Cost Escalation of Projects*

	Planning
Internal	1. Bias 2. Delivery/Procurement Approach 3. Project Schedule Changes 4. Engineering and Construction Complexities 5. Scope Changes 6. Poor Estimating (errors and omissions) 7. Inconsistent Application of Contingencies
External	1. Local Government Concerns and Requirements 2. Effects of Inflation 3. Scope Creep 4. Market Conditions

* Note: these factors are numbered for reference only and do not suggest a level of influence.

Planning-Internal

While numerous internal factors may lead to underestimation of project costs at the planning stages seven primary internal factors have been well documented: bias, delivery/procurement approach, project schedule changes, engineering and construction complexities, scope changes, poor estimating, and inconsistent application of contingencies. Each of these factors separately or in combination with others might cause significant project costs increases.

Bias is the demonstrated systematic tendency to be over-optimistic about key project parameters. It is often viewed as the purposeful underestimation of project costs in order to insure a project remains in the construction program. This underestimation of costs can arise from the SHA estimators' or consultant's identification with the agency's goals for maintaining a construction program. The project process in some states is such that the legislature establishes a project budget by legislative act and that budget is based on preliminary cost estimates. Later if the SHA's estimate is higher than the budget, the project may not be let. As a result, engineers and the SHAs feel the pressure to estimate with an optimistic attitude about cost—low (Akinci and Fischer 1998, Condon and Harman 2004, Bruzelius et al. 1998, Flyvbjerg et al. 2002, Hufschmidt and Gerin 1970, Pickrell 1990, Pickrell 1992).

Delivery/Procurement Approach effects the division of risk between the SHA and the constructors. When risk is shifted to a party who is unable to control a specific risk, project cost will likely increase. The decision regarding which project delivery approach, design-bid-build, design-build, or build-operate-transfer, and procurement methodology, low bid, best value, or qualifications based selection effects the transfer of project risks. In addition to the question of risk allocation, lack of experience with a delivery method or procurement approach can also lead to underestimation of project costs. Many SHAs are looking to reduce project schedules in order to quickly deliver much-needed projects to the traveling public, but accelerated schedules are only achievable at a cost. While the end results of applying different procurement approaches should be beneficial, some hard lessons must be learned regarding the proper allocation of risks and what each new method entails, in terms of SHA responsiveness, expectations, and time (Harbuck 2004, New Jersey Department of Transportation 1999, Parsons Brinckerhoff Quade & Douglas, Inc. 2002, SAIC 2002, Weiss 2000).

Project Schedule Changes, particularly extensions, caused by budget constraints or design challenges can cause unanticipated increases in inflation cost effects even when the rate of inflation has been accurately predicted. It is best to think in terms of the time value of money and recognize that there are two components to the issue: 1) the inflation rate and 2) the timing of the expenditures. Many SHAs have a fixed annual or bi-annual budget, and project schedules must often be adjusted to ensure that project funding is available for all projects as needed. Estimators frequently do not know what expenditure timing adjustments will be made and therefore cannot accurately reflect the related cost in the project's estimate (Board on Infrastructure and the Constructed Environment 2003, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Callahan 1998, Hufschmidt and Gerin 1970, "Mass Transit…" 1999, Semple et al. 1994, Touran and Bolster 1994).

Engineering and Construction Complexities caused by the project's location or purpose can make early design work very challenging and lead to internal coordination errors between project components. Internal coordination errors can include conflicts or problems between the various disciplines involved in the planning and design of a project. Constructability problems that need to be addressed may also be encountered as the project develops. If these issues are not adequately addressed when preparing cost estimates, cost increases are likely to occur (Board on Infrastructure and the Constructed Environment 2003, Bechtel/Parsons Brinckerhoff 2003, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Callahan 1998, Hufschmidt and Gerin 1970, "Mass Transit…" 1999, Touran and Bolster 1994, General Accounting Office 2003, General Accounting Office 1997, General Accounting Office 2002).

Scope Changes, which should be controllable by the SHA, can lead to underestimation of project cost escalation. Such changes may include modifications in project construction limits, alterations in design and/or dimensions of key project items such as roadways, bridges, or tunnels, adjustments in type, size, or location of intersections, as well as other increases in project elements. When these modifications are made, the new elements typically do not have the same associated costs as the previous elements had. If the new elements are more expensive, then the extra costs have to be incorporated into the project's cost estimate (Board on Infrastructure and the Constructed Environment 2003, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Callahan 1998, Chang 2002, Harbuck 2004, Hufschmidt and Gerin 1970, Mackie and Preston 1998, "Mass Transit…" 1999, Merrow et al. 1981, Merrow 1986, Merrow 1988, Semple et al. 1994, Touran and Bolster 1994).

Poor Estimating (errors and omissions) can also lead to underestimation, which subsequently translates into increases in project cost as errors and omissions are uncovered. Estimate documentation must be in a form that can be understood, checked, verified, and corrected. The foundation of a good estimate is the formats, procedures, and processes used to arrive at the cost. Poor estimation includes general errors and omissions from plans and quantities as well as general inadequacies and poor performance in planning and estimating procedures and techniques. Errors can be made not only in the volume of material and services needed for project completion but also in the costs of acquiring such resources (Arditi et al. 1985, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Carr 1989, Chang 2002, Harbuck 2004, Hufschmidt and Gerin 1970, Merrow et al. 1981, Merrow 1986, Merrow 1988, Pickrell 1990, Pickrell 1992).

Inconsistent Application of Contingencies causes confusion as to exactly what is included in the line items of an estimate and what is covered by contingency amounts. Contingency funds are typically meant to cover a variety of possible events and problems that are not specifically identified or to account for a lack of project definition during the preparation of early planning estimates. Misuse and failure to define what costs contingency amounts cover can lead to estimate problems. In many cases, it is assumed that contingency amounts can be used to cover added scope and planners seem to forget that the purpose of the contingency amount in the estimate was lack of design definition. SHAs run into problems when the contingency amounts are applied inappropriately (Noor and Tichacek 2004, Ripley 2004, Association for the Advancement of Cost Engineering International 1997).

Planning-External

External factors that may lead to underestimation of project costs during the planning portion of project development include local government concerns and requirements, effects of inflation, scope creep, and market conditions. Again, it must be recognized that each of these factors can act separately or in combination with others to cause significant project cost increases.

Local Government Concerns and Requirements typically include mitigation of project effects and negotiated scope changes or additions. Actions by the SHA are often required to alleviate perceived negative impacts of construction on the local societal environment as well as the natural environment. Measures may include but are not limited to introducing changes to project design, alignment, and the conduct of construction operations. These steps are often taken to appease the local residents, business owners, and environmental groups. The required accommodation is often unknown during the early stages of project development and therefore is not included in the cost estimates. Since the additional items were not incorporated in the project's initial scope, the project's cost estimate inevitably increases when the items are added. A multitude of examples of "drastic" measures that were taken to accommodate local government and citizen concerns as well as national concerns exist with two of the most notable examples being actions during the Legacy Highway project in Utah and the Big Dig in Massachusetts (Board on Infrastructure and the Constructed Environment 2003, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Callahan 1998, Chang 2002, Daniels 1998, Harbuck 2004, Hudachko 2004, "Legacy…" 2004, Mackie and Preston 1998, "Mass Transit…" 1999, Merrow et al. 1981, Merrow 1986, Merrow 1988, Parsons Brinckerhoff Quade & Douglas, Inc. 2002, Schroeder 2000, Touran and Bolster 1994).

Effects of Inflation is a key factor in the underestimation of costs for many projects. The time value of money can adversely affect projects when: 1) project estimates are not communicated in year-of-construction costs; 2) the forecasted project completion is delayed and therefore the cost is subject to inflation over a longer duration than anticipated; and/or 3) the rate of inflation is greater than anticipated in the estimate. The industry has varying views regarding how inflation should be accounted for in the project estimates and in budgets by funding sources. In the case of projects with short development and construction schedules, the effect of inflation is usually minor; however, projects having long development and construction durations can encounter unanticipated inflationary effects. The results of inflation effects are evident in Boston's Big Dig. The original estimate for this project, which was developed in 1982 and based on the FHWA guidelines in the Interstate Cost Estimate (ICE) manual, excluded inflationary factors. Inflation was a large portion of the cost overruns experienced on the project (Akinci and Fischer 1998, Arditi et al. 1985, Board on Infrastructure and the Constructed Environment 2003, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Hufschmidt and Gerin 1970, Merrow 1988, Pickrell 1990, Pickrell 1992, Touran and Bolster 1994).

Scope Creep is similar to changes in scope; however, these changes are usually the accumulation of minor scope changes. Projects often seem to grow naturally as the project progresses from inception through development to construction. These changes can often be attributed on highway projects to the changing needs or growth of the population in the area to be served. When a project's scope escalates, the additional elements in the scope have to be accounted for in the cost estimate. As a result, a project's cost estimate increases when the scope grows (Akinci and Fischer 1998, Board on Infrastructure and the Constructed Environment 2003, Booz·Allen & Hamilton Inc. and DRI/McGraw-Hill 1995, Callahan 1998, Chang 2002, Harbuck 2004, Hufschmidt and Gerin 1970, Mackie and Preston 1998, "Mass Transit…" 1999, Merrow et al. 1981, Merrow 1986, Merrow 1988, Semple et al. 1994, Touran and Bolster 1994).

Market Conditions or changes in the macro environment can affect the costs of a project, particularly large projects. Often only large contractors or groups of contractors can work or even obtain bonding for a large project. The size of the project affects competition for a project and the number of bids that a SHA receives for the work. Typically, the risks associated with large projects are much greater, for both the owner and contractor, and that affects project costs. Inaccurate assessment of the market conditions can lead to incorrect project cost estimating (Warne and Maryland State Highway Administration 2002).

Current State of Estimating Practice

NCHRP Synthesis, Project 20-07, Task 152, *Best Practices and Guidelines for Project Cost Control Estimating* examined cost estimating methods and tools being used at the various stages of project development within all fifty state SHAs (Schexnayder et al. 2003). The estimating methods for each project development phase are determined by the state agencies' policies. For the conceptual estimate, the majority of the agencies create estimates using historical lane-mile cost averages that are based on similar projects. Contingency and engineering costs are added to the estimates in the form of a percentage of the total project cost.

According to Schexnayder et al. (2003), after a project is programmed, the project moves into the advanced planning/preliminary design phase of project development. During this phase, the project scope is further defined. The most probable type of estimate would be a parametric estimate based on a broad breakdown into key components of the project and parameters such as length of project, width of roadway, or depth of pavement. Other estimating approaches might include using historical unit prices only modified to fit the project complexity and location of the project.

The last project development stage before the project is let for construction is final design, which corresponds with the engineer's estimate. Two methods are used in generating the engineer's estimate: a detailed cost-based estimate or an estimate based on the application of historic bid averages. The detailed estimate is based on specific crews, equipment, production rates, and material costs. Although cost-based estimating can be extremely accurate, this type of estimate requires an extensive amount of time, which SHAs do not always possess. Therefore, they have to rely on less accurate and less reliable methods for estimating their project cost (Ashur and Crockett 1997). This second method is less time consuming, and the method consists of applying historical bid prices to project line items.

Maintaining project cost estimates is a critical issue to solving the problem of project cost escalation and the lack of consistency in cost estimates over the project's life. Schexnayder et al. (2003) revealed that the SHAs are not utilizing consistent or comprehensive strategies to identify, quantify, and mitigate risk, nor are they employing methods and tools for stochastic estimating that are available in other engineering sectors. Therefore, the proposed research will analyze cost estimating practices conducted by SHAs to develop preliminary strategies, methods, and tools.

Strategies, Methods, and Tools

In the article, *Improving Conceptual Estimating Methods Using Historical Cost Data*, Walton and Stevens (1997) discussed Kentucky Transportation Cabinet's tool, KYEstimate. The tool was developed because the original conceptual estimate was used during the life of the project with little changes to it. As a result, scope changes were not considered, and the estimates did not have a high level of accuracy. Furthermore, the rapid decline of experienced district estimators was another issue leading to the development of the tool. The purpose of KYEstimate is to provide estimators with a quick and reliable method for generating conceptual estimates for design, right-of-way, utility relocation, and construction. Another advantage is that the estimator does not need a large amount of experience because the program is user friendly. By using KYEstimate, estimators can also justify their estimates through documentation. The applied method is calculated average total cost and length of past projects that are similar in scope to form a unit cost (cost/kilometer or cost/mile). The historical projects are categorized by fourteen characteristics. This unit cost is then used to calculate new estimates that have similar scopes. KYEstimate is a database that is available in metric and English units. The tool allows the estimator to evaluate historical data, to override data, and to evaluate the user's estimate statistically with historical data. The database can also calculate bridge unit costs and has adjustable inflation factors (Walton and Stevens 1997).

The Virginia Department of Transportation (VDOT) did not have adequate funding to complete the construction projects in their six-year Improvement Program

(Mayes 2003). Many of the initial project costs were underestimated. These early estimates were based on judgment, expertise, and experience. As the project was developed, the estimators did not always use consistent methods to create the estimate. Many of the estimators did not include inflation, environmental issues, or special circumstances. An example of this problem is VDOT's large improvement project, the Mixing Bowl, which experienced many cost and scope changes. In 1994, VDOT estimated the project to cost $241 million. By 2002, the estimate grew to $676.5 million, a 180 percent increase. The reasons for the cost growth were increases in scope, omission of known costs, and unanticipated cost increases. The Mixing Bowl project caused the Virginia Department of Transportation to evaluate their estimating and management process. One of the problems VDOT discovered was that they had difficulty managing information in their large database, which caused inaccurate and incomplete cost estimates. Within the department, each designer had their own method for analyzing VDOT's data and creating estimates (Mayes 2003).

VDOT developed a web-based system that increased their accountability and openness with the public while improving the uniformity and accuracy of the scoping process. The system, Dashboard, provides the SHA with a consistent means to store and access their data throughout the state. Within VDOT's system, the elements of a project such as the description, purpose, need, team, schedule, estimates, documentation, and approvals are displayed on a website. The estimating system has spreadsheets that require the user to enter typical project items. Inflation, construction and preliminary engineering costs, and inspection are automatically computed and included in the project estimate. Dashboard applies two systems, Program Project Management and American Association of State Highway and Transportation Officials' (AASHTO) Trns•port system. The Program Project Management system displays the status of the project from conception to letting. Dashboard's views range from a summary page to details about the project, and the projects can be arranged by state, region, local, or the highway system. Since Dashboard is open for anyone to view, it makes VDOT more responsible to the public for its actions. Dashboard uses red, yellow, and green lights to show the status of a project. Red identifies the project is behind schedule or over budget. Yellow identifies the project is at risk to becoming red, and green identifies the project is on track (Mayes 2003).

Paek (1993) shares lessons he has learned from his experience in the construction field. The strategy addressed is to avoid or minimize the impact of making the same mistakes that have been made in the past. Paek stated that a schedule should never be underestimated and varying production rates should be taken into account. Furthermore, the risk of unfamiliar work should be included and experience gained on similar projects should not be neglected. An important tool in producing accurate estimates is the use of an experienced staff. Being aware of possible cost inflators that occur throughout a project can help to account for these risks upfront, thus minimizing their impact on cost (Paek 1993).

Project Complexity

The transportation literature more often addresses problems that are frequently associated with larger and more complex projects. The FHWA is in the process of creating a set of guidelines for estimating major projects (Capka 2003). Major projects were defined as having cost estimates larger than one billion dollars. The guideline established a set of key principles that a transportation agency should have in order to produce a reasonable estimate.

The guideline identified the main principles as being integrity, contents of a cost estimate, year-of-expenditure dollars, basis of a cost estimate, risk and uncertainty, project delivery phase transitions, team of experts, validation of estimates, revalidation of estimates, and release of estimates and estimating information. The principles state that the cost estimate should accurately reflect all of the projects cost components with proper adjustment for inflation, risk, and uncertainty. The estimators should act honestly, generate estimates using the best information available to them, and apply sound engineering judgment. Furthermore, the different project estimates should be well documented, approved, and undergo periodic reviews throughout project development.

The FHWA guideline also describes the elements that each project estimate should contain, and it includes a checklist to ensure the elements have been considered. Some of the elements identified are preliminary engineering, right-of-way, construction costs, and contingency. In addition to the checklist, FHWA identified areas of cost estimating that should be considered during the earlier stages of cost estimating when the project is not well defined. For example, the guidelines recommend having documentation from the beginning of the project to the end, and it explains that estimating risk should be considered during the initial estimates. The guidelines also state that transportation agencies must integrate quality control and assurance into the estimating procedures.

SUMMARY

Through an extensive literature search, potential cost escalation factors that occur during the planning phases were identified. In addition, the literature provided one example of current cost estimating practices. Although the example provides a synopsis of SHA practices, the researcher found that literature on cost estimating practices in the transportation industry is virtually nonexistent. From the literature, several examples of strategies, methods, and tools used by SHAs and a discussion of project complexity were discovered. After the literature review was completed, a research methodology was conducted to study the research problem, which is explained in the following chapter.

CHAPTER III
RESEARCH METHODOLOGY

This research project will follow the qualitative methodology described in Crabtree and Miller's *Doing Qualitative Research* (1992). The purpose of qualitative methodology is to provide reasonable descriptions and/or explanations, which focus on an activity. A qualitative methodology is appropriate for this research project because the objectives will be met by understanding the problem through identification of potential key factors influencing cost escalation, describing the current cost estimating practices, and explaining potential strategies, methods, and tools, which follow Crabtree and Miller's purpose for applying qualitative methodology. The approach for this research project includes a literature review, a development of framework, data collection, data analysis, results, and validation of results.

METHODOLOGY

Research Framework

In order to achieve the described objectives, a framework was required to conduct the study. The overall framework that the research approach followed included three main elements:

- Identifying strategies, methods, and tools for cost estimation related to:
    - Project development phases and
    - Project complexity.

As previously discussed, the NCHRP 8-49 problem statement requested the identification of strategies, methods, and tools related to project development phases; thus, these two elements were used for this research framework. Project complexity is not part of the NCHRP 8-49 charter, but it is believed to be an important issue that will affect which strategies, methods, and tools can be applied during a specified project development phase. Thus, project complexity is the third element in the research framework. The interaction of these three elements is shown schematically in Figure 2.

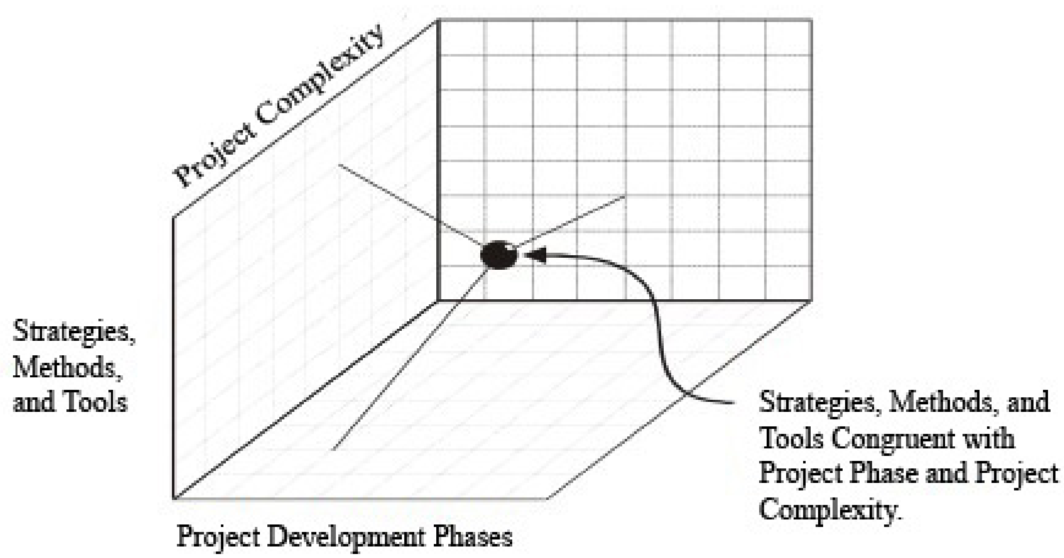

Fig. 2. Schematic Illustration of Three-Element Interaction

Strategies, methods, and tools were the basis for applying good estimating practices to minimize cost escalation. They were developed according to the project development phases because the level of project definition is directly related to the project phases, and therefore affects the estimating procedures applied. Moreover, the project development phases also provide a technique for organizing and analyzing the data.

According to the *NCHRP 20-5: Statewide Highway Letting Program Management* conducted by Anderson and Blaschke (2004), the leading guide to an SHA's estimating development process is their letting program process. Within an agencies letting program, the typical project development phases are planning, programming, advanced planning/preliminary design, final design, letting, award, and construction. Therefore, the first four phases and their definitions described by

Anderson and Blaschke structured the interview process and supplied a methodology for organizing the data. In addition to the project development phase, project complexity should also be considered because projects with more complexity will require different strategies, methods, and tools than less complex projects.

SHAs are not all alike; thus, researchers have to consider the strategies, methods, and tools in terms of their application to small projects, rehabilitation projects, major reconstruction projects, major new construction projects. Special situations such as when an agency uses an innovative contracting method and does not prepare a complete set of plans and specifications must also be considered. Project complexity also relates to the location of a project. For example, a project located in an urban area has to overcome obstacles such as the movement of existing utilities or traffic control that a rural project may not contain. The type of terrain and other environmental issues also affects the project's complexity and ultimately the project's cost. The project complexity element of the framework is important as it may determine when to use what method and tool, and to what extent the method and tool should be implemented. Although project complexity is important, it was not studied in detail because the SHAs did not associate project complexity with each method and tool that they identified. Project complexity will be studied in more detail during phase two of the NCHRP 8-49 project. However, project complexity is discussed throughout this study where it was applicable.

Data Collection

Once the research framework was established, data needed to address the research problem had to be collected. After completing the literature review, it was apparent that the highway industry has little information published concerning early cost estimation of projects. Because of the scarcity of publications on cost estimation procedures in the highway industry, a series of interviews with SHAs were conducted to determine current SHA cost estimating practices. The interviews enabled the acquirement of insightful data directly from the SHAs. After the SHA interviews, other organizations were interviewed to confirm the SHA information.

Interview Protocol

The interview protocol was designed to permit the researcher to obtain SHA information concerning:

- Who is responsible for preparing and approving the estimates at each stage,
- How estimates are prepared and managed,
- Where estimates are prepared, and
- What purpose the estimates serve.

Schexnayder et al.'s (2003) *Project Cost Estimating Synthesis* was the basis for developing the questions for the interview protocol. Similar categories identified in the synthesis on *Statewide Highway Letting Program Management* were applied to the structure of the interview protocol (Anderson and Blaschke 2004). These categories, planning, programming, advanced planning/preliminary design, and final design, reflect typical phases in the project development process. These phases were also outlined and described in the interview package so the definitions of the phases could be aligned with those of the individual SHAs. Under each phase of project development, the questions were further categorized by topic. The subtopics are estimate preparation, estimate review, estimate communication, and cost management.[4] The questions in each section of the interview protocol were similar to allow the interview to be conducted on an individual basis or with a group of SHA personnel representing the different sections with the SHA responsible for each of the project phases. The interview protocol was pretested with two SHAs (Washington State and Florida) to ensure that the questions adequately covered the topic areas. The only change to the protocol was to split long-range planning from programming as the estimates in these two project phases have

[4] Estimate preparation and review are the primary factors for this thesis.

different purposes and frequently different individuals are involved in their preparation. Otherwise, the questions were deemed adequate and comprehensive. The interview protocol is provided in Appendix A.

Interview Process

Interviews were conducted with SHAs and other organizations. Three sources were relied upon to identify appropriate interviewees: 1) participants in the TRB Cost Estimating Workshop[5]; 2) members of the Technical Committee on Cost Estimating which is part of the AASHTO Subcommittee on Design[6]; 3) and contacts established during Schexnayder et al.'s preparation of his synthesis on project cost estimating. A letter that briefly outlined the purpose of the project, provided some background information about the project, and requested a list of individuals who would have appropriate knowledge for the interview was sent to the contacts identified from these three sources (see Appendix B). Initially, the researcher assumed different individuals were involved at each project stage. Therefore, the letter included a form specifically requesting the names of individuals with knowledge of conceptual estimating, preliminary design estimating, and the engineer's estimate. When the responses were collected, the responses revealed this assumption was only partially true. Some SHAs did submit three different names. However, a few SHAs had two people listed for one project phase, and other SHAs listed the same person for several phases. When the interviews were scheduled, each participant from the SHA was contacted, and they were given the option to perform the interview independently or as a group. Many SHAs requested that all representatives of the different project phases be present during the interview, while other SHAs preferred to complete the interview individually.

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[5] TRB AFH35T, Special Task Force, Accelerating Innovation in the Highway Industry, Cost Estimating Workshop, Washington, DC, February 11,2004.

[6] The Technical Committee on Cost Estimating was created in Spring 2002 by the Standing Committee on Highways to provide a focal point for cost estimating issues within AASHTO.

Letters to specific individuals in all fifty states were sent, and 36 states responded. Specific SHAs were selected for interviews based on prior knowledge of their practices from Schexnayder et al. (2003) and judgment based on potential diversity in practice, size, and geographic location. Once responses to the contact letter were received, interviews were coordinated with the SHAs. The interview protocol was sent to the SHAs prior to the interview. When the protocol was sent, the researcher also requested that each SHA send any supplemental information such as estimating procedures or manuals to the researcher prior to the interview. During the interview with the SHA's, the researcher discussed the questions in the interview protocol and recorded the SHA responses.

Data Analysis

The interviews, along with information from the literature, were used to determine the state of practice. The interviews were also used for the critical review and for the development of the potential strategies, methods, and tools for improving the estimating process. In order to analyze the data collected, factors leading to cost escalation found in the literature were reviewed. After that, the interviews were categorized into the project development phases and then into the topical areas from the interview protocol. States participating in the interview process were grouped according to similar characteristics, such as the type of estimating procedure for long-range planning. The purpose of this characterization was to observe the main approaches used to prepare estimates during the different project development phases so that a state of practice could be developed and documented. For the critical review of the state of practice, factors identified in the literature review were utilized. The potential factors were related to the estimating practices so that unique approaches addressing the factors could be identified. The unique approaches led to the development of preliminary strategies, methods, and tools. The preliminary strategies, methods, and tools, focus on mitigating the potential cost escalation factors by improving cost estimating practices.

SUMMARY

The methodology for this thesis follows a qualitative approach and consists of three main elements: 1) identifying strategies, methods, and tools; 2) project development phases; and 3) project complexity. During the data collection procedure, an interview protocol was used to perform interviews with SHAs. Once the interviews were completed, the information was analyzed to form preliminary strategies, methods, and tools. In Chapter IV, the data collection process is explained in further detail.

CHAPTER IV
DATA COLLECTION

In order to collect data for this study, all fifty states in the United States were contacted; however all fifty states did not respond. Therefore, a range of states that provide an accurate representation of the state of practice were selected. States were selected based on their program size and their geographic location across the United States. A state's program size is dependent on the cost of projects, which includes design and construction costs. The interview process continued until a convergence between the states' estimating procedures had been met, which was measured by the states' using similar estimating practices.

DATA COLLECTION

Twenty state interviews were completed using the interview protocol. Two of the states were used to develop the interview protocol, and two other states were used to test the interview protocol. Minor changes were made to the protocol and then the remaining state of practice interviews were conducted as previously stated in Chapter III. Furthermore, two states sent in written responses to the interview protocol. In addition to the interview methodology, NCHRP 8-49 research members participated in a peer exchange at the Joint Summer Meeting of the Planning, Economics, Environmental, Finance, Freight, and Management Committees held in Park City, Utah in July 2004 as described in the following section. A peer exchange is a group of like-minded professionals that gather to discuss a specific topic, in this case, cost estimating. Representatives from fourteen SHAs participated in the Park City meeting. Upon completion of the data collection process, information was collected from 25 out of 36 states interviewed. As seen in Figure 3, contributions were made by SHAs from across the nation. These SHAs represent a variety of program sizes and diverse attitudes, policies, and issues.

Fig. 3. States Represented

The data collection began at the end of May and continued through August 2004. The interviews were completed in several different ways, but primarily either over the telephone or at the agency's headquarters. During the telephone and onsite interviews, either every project development phase was discussed or only a single phase. The type of interview along with the date it was conducted is listed in Table 3. Agencies that responded to the initial contact letter and were not interviewed were notified, and estimating information such as manuals or guidelines were requested from those agencies.

Table 3. Type and Date of Interview

	State Highway Agency	Interview Date(s)	Type of Interview	Peer Exchange
1	Arizona DOT	January 2004	Interview Development	
2	Arkansas State Highway and Transportation Department	August 24, 2004	Written Response	
3	California DOT	July 23, 2004	Onsite – All Phases	√
4	Connecticut DOT	August 2, 2004	Onsite – All Phases	
5	Florida DOT	May 28, 2004	Onsite – All Phases	√
6	Georgia DOT	July 6, 2004	Telephone – All Phases	
7	Idaho DOT	January 2004	Interview Development	
8	Illinois DOT	July 6, 2004	Telephone – Single Phases	
9	Kentucky Transportation Cabinet	June 14-17, 2004	Telephone – Single Phases	
10	Michigan DOT	July 27-28, 2004		√
11	Minnesota DOT	June 7, 2004	Telephone – All Phases	√
12	Missouri DOT	June 7, 2004	Telephone – All Phases	√
13	Montana DOT	July 27-28, 2004		√
14	Nebraska Department of Roads	June 16 & 18, 2004	Telephone – Single Phases	
15	Nevada DOT	August 24, 2004	Written Response	
16	New York DOT	July 15, 2004	Telephone – All Phases	
17	North Carolina DOT	July 12 & 29, 2004	Telephone – All Phases	√
18	Ohio DOT	July 27-28, 2004		√
19	Pennsylvania DOT	July 8,2004	Telephone – All Phases	√
20	Texas DOT	July 2, 2004	Onsite – Single Phases	
21	Utah DOT	June 1 & 14, 2004	Telephone – Single Phases	√
22	Vermont DOT	July 27-28, 2004		√
23	Virginia DOT	July 12, 2004	Telephone – All Phases	√
24	Washington DOT	May 21, 2004	Onsite – All Phases	√
25	Wisconsin DOT	July 27-28, 2004		√

SHA Interview Process

The interviews with the SHAs began by providing background information about the project, seeking to understand how the agency defines project phases and when in the project development process estimates were prepared. After that, the interviewer proceeded with the questions from the interview protocol. During the interview, the SHA responses were documented as the discussion progressed. Once the interview was complete, the answers recorded from the interview were aligned with the corresponding questions. A general comment section was added to the answered interview protocol so that comments not specifically related to a given question could be retained. In addition, a summary page was written that listed documents acquired from the SHA, and it presented an overview of the SHA's estimating process, the strengths, and the weaknesses identified by the state agency (see Appendix C for an example). Once the interview documentation was complete, it was transmitted to the participating SHA so they could review and clarify their responses. Once the interview process was complete, the researcher analyzed the data collected to form the preliminary strategies, methods, and tools.

Documents Collected

When the interviews were conducted, the researcher requested any documents that the SHAs might have related to their cost estimating procedures and policies. Procedure manuals were obtained that described the steps to prepare an estimate using the SHA's in-house estimating software. The SHAs also provided presentations and documents that describe specific estimating methodology developed by the SHA. Some of the acquired documentation listed typical sections developed by the SHA along with their associated cost per mile factors. Several SHAs supplied spreadsheets that the SHAs use to prepare and document an estimate. The spreadsheets also have inflation rates that are applied to the estimates. One SHA furnished their estimating policies, which included documentation requirements for estimates prepared during each project development phase. Their policies also cover the type of estimating methodology permitted and the approval requirements at each project development phase. Although not every interviewed SHA provided documentation, most SHAs have procedural manuals. These manuals mostly cover estimating during final design for the engineer's estimate.

Utah Park City Peer Exchange

Another source of estimating information was the Park City Peer Exchange in Utah. The NCHRP 8-49 research team participated in a TRB sponsored "Peer Exchange" with the TRB Statewide Multimodal Planning Management Committee. As shown in Table 3, participation involved fourteen SHA representatives and eight representatives from other groups, including FHWA and transportation consultants. A facilitator from NCHRP and facilitator from a transportation consulting firm were also present. The invited guests were given five questions to address prior to the peer exchange. These questions were extracted from the planning section of the interview instrument.

During the "Peer Exchange", the NCHRP 8-49 research team made a brief presentation on the status of the research project. Each participating organization was then asked to discuss their major issues and briefly address the estimating and estimate management question areas relative to project planning and/or programming. The discussion was recorded and summarized into fifteen major issue areas. In addition, eleven strategies for managing the cost estimation process during the planning phase were identified. Key members of the peer exchange group reviewed the research team's summary of the issues and strategies and provided further comment. All but one state agency from the "Peer Exchange" provided written documentation, which was incorporated into the data analysis for this thesis.

Other Organizations

The researcher believes that information pertinent to this project may also be obtained through discussions with organizations other than SHAs. Therefore, contacts were sought with Metropolitan Planning Organizations (MPOs) as well as with other transportation engineering firms. Additionally, contacts were made with non-transportation organizations. An associate director from the Texas Transportation Institute (TTI) assisted the research team in identifying MPO contacts. The researcher contacted several MPOs with the intent of conducting interviews with respect to their cost estimating procedures. The Maricopa Association of Government and the Denver Regional COG were interviewed.

Non-transportation owners who are members of the Rocky Mountain chapter of the Association for the Advancement of Cost Engineering International (AACEI) were also contacted. One interview was successfully completed with a non-transportation organization. Interviews were also coordinated with two major design consultants, Michael Baker Corporation and Carter-Burgess, Inc. The purpose of those interviews was to understand how consultants approach cost estimating practices and to establish the project phases where they are most likely to develop cost estimates, especially prior to the pre-construction phases.

Consultants

A consultant's perspective was obtained on cost estimating procedures. The interview instrument provided the basis for collecting this input. Two major transportation industry design consultants participated in interviews: 1) Carter-Burgess, Inc. and 2) Michael Baker Corporation. Representatives from both of these organizations answered the interview questions from their corporate perspective and involvement in the development and design of transportation projects. The interview information was documented, and the results of the analysis are included in the state of practice.

Coors Brewing Company

In selecting non-transportation organizations to pursue during the course of this study, the researcher decided that the selected organizations should be larger, owner types with capital project experience and large in-house engineering staff. One successful contact was with Coors Brewing Company, based in Golden, Colorado. Coors Brewing Company is a continuously expanding company that operates businesses in brewing, aluminum rigid container sheets, folding carton and flexible packaging, as well as ceramics. Coors is primarily known as a beer brewing company and as such, it requires new facilities and maintenance of facilities involved with grain handling and storage, malting operations and storage, brewing, fermenting, storage of aging beer, and packaging and cold storage warehousing throughout the nation. Additionally, it constructs water collection and treatment facilities, waste treatment, steam generation, refrigeration, electrical systems, office buildings, and distribution warehousing.[7]

The interview process with Coors was similar to the process used with SHAs. Before the interview, contact documents were obtained which provided information regarding the construction program at Coors. Using these documents, the researcher became better acquainted with Coors' project development processes. The interview with the Coors representative was conducted in much the same process as those with the SHAs. The participants discussed the project development phases of the transportation industry and the process of project development followed by Coors. Upon determining that the project development phases are similar in nature, the discussion turned to the interview protocol. Some of the responses were similar to what was gathered from SHAs but many differed and suggested different approaches to dealing with estimate development and control.

[7] Berka, J.H.; Daley, J.C. (1992). "Project Development-An Owner's System." *1992 AACE Transactions*, AACEI, Morgantown, WV., T.1.1-T.1.7.

SUMMARY

The information collected from the sources described in this chapter enabled the researcher to identify the core estimating assumptions that are the root causes behind cost escalation and lack of project estimate consistency and accuracy. By analyzing the collected information, specific estimating practices currently used in each project phase were also identified. Documents provided by some SHAs were also studied, and in many cases, these documents provided additional details of the SHA's current practice. The root causes of cost escalation and the current estimating practices will be used to create preliminary strategies, methods, and tools.

CHAPTER V
RESULTS AND ANALYSIS

The data and information collected through the interviews combined with information from recent literature assisted in identifying reasons for cost growth and estimate inaccuracies. Through the interviews, the problems that arise out of the agencies' weaknesses, which in turn led to the development of factors influencing cost escalation, were determined. The SHAs' cited factors that influence cost growth were matched to similarities found in the literature so that the potential cost escalation factors can be linked with the preliminary strategies, methods, and tools without doing a quantitative assessment. Then, the responses from the SHA interviews were organized according to the project development phase and topical areas: preparation and review.

In order to analyze the data collected from the SHA interviews, an approach similar to an approach described by Crabtree and Miller (1992) was applied. The basic analysis consists of categorizing similar information that corresponds to the initial concerns of the problem. For the purpose of this project, the data were categorized by project development phase so that the analysis remains consistent with the rest of the study. During the interviewing process, the interviews were conducted by project development phase, which allowed the data to be sorted by the phases. Organizing the information by project development phase enabled the phases to be tied to the preliminary strategies, methods, and tools described in Chapter VI.

After grouping the data into project development phases, it was further categorized by topical area, preparation or review, and then by each interview question. The first four questions pertain to estimate preparation, and the last two questions are related to estimate reviews. Once each category and subcategory was established, analysis tables were created.

Each table outlines the project development phase, topical area, and interview question. In the tables, Estimate Procedure corresponds to question one of the interview instrument, which is “describe policies, procedures, techniques, and/or standards used in preparing estimates.” All Project Elements refers to question two of the interview instrument, which is “how does the SHA insure that estimates reflect all elements of project scope as defined at the time estimates are prepared.” Historical Data refers to question three of the interview instrument, which is “what types of historical data do the SHA use as a basis for preparing estimates.” Contingency corresponds to question four of the interview instrument, which is “how are contingency amounts incorporated into the estimate.” Formal Review refers to question five of the interview instrument, which states “is there a formal estimate review within the DOT.” The interview instrument that contain these questions are provided in Appendix A

Under each question, the SHA responses and the number of SHAs that perform the listed responses are recorded. The analysis tables for each project development phase are shown in Tables 4 through 7.

Table 4. SHA Analysis Table for Planning

	Planning	
	Interview Question	**No. of SHAs (Total 18)**
Estimate Preparation	1. Estimate Procedure	
	Cost Per Mile Factors	15
	Not Responsive	3
	2. All Project Elements (Add-on Elements)	
	Percentages	8
	Checklist	3
	Other	4
	Not Responsive	1
	3. Historical Data	
	Database with Past Bids	14
	Other	3
	Not Responsive	1
	4. Contingency	
	Percentage	11
	No Contingency	4
	Risk Analysis	1
	Not Responsive	2
Estimate Review	5. Formal Review	
	No Formal Review	6
	Internally Reviewed by District/Region	6
	Reviewed by MPO	2
	Formal Review	2
	Not Responsive	2

Table 5. SHA Analysis Table for Programming

	Programming	
	Interview Question	**No. of SHAs (Total 18)**
Estimate Preparation	1. Estimate Procedure	
	Parametric Estimating[8]	12
	Volumetric Estimating[9]	1
	Other	3
	Not Responsive	2
	2. All Project Elements (add-on Elements)	
	Percentages	6
	Checklist	4
	Project Estimate File	1
	Included in the Cost per Mile Factor	3
	Other	2
	Not Responsive	2
	3. Historical Data	
	Database with Past Bids	15
	Other	2
	Not Responsive	1
	4. Contingency	
	Percentages	12
	No Contingency	3
	Risk Analysis	1
	Not Responsive	2

[8] Parametric estimating divides the cost estimate into key components of the project and parameters.

[9] Volumetric estimating defines the length-width-depth of a project's pavement component to create a cost estimate.

Table 5. Continued

	Programming	
	Interview Question	**No. of SHAs (Total 18)**
Estimate Review	5. Formal Review	
	No Formal Review	8
	Annual Review	3
	Internally Reviewed by District/Region	2
	Cost Estimate Validation Process	3
	Not Responsive	2
	6. Trigger Additional Review	
	No Trigger	6
	Project Complexity	4
	Cost Increase	3
	Percentage Range	2
	Cost Estimate Validation Process	1
	Not Responsive	2

Table 6. SHA Analysis Table for Advanced Planning/Preliminary Design

	Advanced Planning/Preliminary Design	
	Interview Question	**No. of SHAs (Total 18)**
Estimate Preparation	1. Estimate Procedure	
	Defined Line Items & Percentages	9
	Cost per Mile Factors & Defined Line Items	6
	Not Responsive	3
	2. Frequency of Estimate	
	Project Milestones	7
	Design Change	4
	Annually	3
	Not Responsive	4
	3. All Project Elements (Add-on Elements)	
	Checklist	6
	Percentages	2
	Other	4
	Not Responsive	6
	4. Historical Data	
	Database with Past Bids	16
	Not Responsive	2
	5. Contingency	
	Percentages	13
	No Contingency	2
	Risk Analysis	1
	Not Responsive	2
Estimate Review	6. Formal Review	
	Internally Reviewed by District/Region	9
	Annual Review	2
	Reviewed by Headquarters	2
	No Formal Review	2
	Not Responsive	3
	7. Trigger Additional Review	
	Percentage Range	6
	No Trigger	5
	Cost Increase	2
	Not Responsive	5

Table 7. SHA Analysis Table for Final Design

	Final Design	
	Interview Question	**No. of SHAs (Total 18)**
Estimate Preparation	1. Estimate Procedure	
	Line Item Estimating	11
	Cost Based Estimating	4
	Not Responsive	3
	2. All Project Elements (Add-on Elements)	
	Review Estimate	7
	Contractor's Point of View	2
	Checklist	2
	Other	4
	Not Responsive	3
	3. Historical Data	
	Database with Past Bids	15
	Not Responsive	3
	4. Contingency	
	No Contingency	9
	Percentages	4
	Risk Analysis	1
	Not Responsive	4
Estimate Review	5. Formal Review	
	Review Committee	5
	Compared to Bid	3
	Headquarter Review	3
	Internally Reviewed by District/Region	2
	No Review	2
	Not Responsive	3
	6. Trigger Additional Review	
	No Trigger	6
	Project Complexity	4
	Percentage Range	2
	Other	3
	Not Responsive	3

The tables were completed by reviewing each SHA's response to each question for every project development phase. The method the SHA uses to address each question was documented in the corresponding data analysis table. The SHAs that performed similar methods were categorized together. The methods performed by only one SHA were grouped into an "other" category. Furthermore, the SHAs did not address every question for every project development phase. Therefore, a "not responsive" category is included in the analysis tables. The reason for the no responsive was either the question was not addressed during the initial interview or the SHA did not perform a method for the related question. The SHAs were given the opportunity to review their responses after the interview when the documentation of the interview was completed. The researcher sent the SHA their responses and requested additional feedback such as corrections to the interpretation and to respond to unanswered questions. Six SHAs responded and provided additional feedback. If the SHAs did not initially respond, then the information obtained during the interview was used the way it was recorded.

After the analysis tables were completed, the methods that the majority of the interviewed SHAs perform were characterized as the general cost estimating practices described later in this chapter. The general description represents a state of practice for cost estimating procedures in the highway industry during the project development phases. In the discussion with the SHA practices relevant to cost estimating procedures were identified. The description is general in nature and does not describe a particular approach of any SHA. The general description of the leading methods applied was followed by a more critical explanation of the SHA methods and tools.

The critical review of the interview responses and documentation received from the SHAs was performed. The interview information was used to identify unique and/or innovative approaches that may aid SHAs in overcoming factors that might cause project cost escalation, as identified in Table 2. The unique and/or innovated approaches described in the critical review are used in Chapter VI to create the list of preliminary strategies, methods, and tools. The researcher used literature and interviews to link SHA approaches to potential cost escalation factors that these approaches would address; these approaches are described in the following sections. However, the researcher did not differentiate whether one approach was more effective at quantitatively minimizing cost escalation or even influencing cost escalation. The effectiveness of the approaches will be sought in Phase II of the NCHRP 8-49 research. In general, all factors causing project cost escalation, as noted in the literature and discussed in this report, receive some attention of SHAs; however, not every SHA addresses all of these factors in their entirety. Therefore, the cost estimating practices described in this chapter are a compilation of practices from many transportation agencies, transportation consultants, and a single private non-transportation company.

Once the practices were described, the potential deficiencies in current practice were noted. These deficiencies are discussed under "Summary of Important Issues," the last section of this chapter. The conclusions that were drawn from the literature and the detailed analysis of the interview data are described in the following section.

OVERVIEW OF THE CURRENT COST ESTIMATING PRACTICES

Most SHAs attempt to mitigate the factors leading to cost escalation through their prescribed cost estimating practices. These practices and systems are employed across the spectrum of project development, from the conception of an idea to address a need to the construction of the project. SHAs also have requirements related to planning and programming their projects and eventually committing funds to projects as the target letting date approaches. As a consequence of this requirement, cost estimates must be prepared to support long-range plans, authorized programs, and funds for State Transportation Improvement Programs (STIP). According to FHWA, the long-range plan is required to be at least 20 years (Anderson and Blaschke 2004). The first three years of this long-range plan is typically the STIP. The STIP must be at least three years. A SHA's authorized program varies between four years and twelve years where the first three years are the STIP. In some SHAs, the STIP may be longer than three years and may constitute the authorized program. Other states may have projects that are programmed in later years, that is, beyond the STIP such as, for example, a 10-year authorized program where the first four years are included in the STIP. Those years beyond the authorized program would include up to 20 years or more of projects depending on SHA policies and procedures. The SHA must therefore align their estimating practices to fit within their long-range planning, priority programming, and preconstruction processes.

The organizational structure of a SHA affects the development of the project estimates. An agency's organization determines where the estimate is created, who reviews and approves the estimate, when the estimate is communicated, and the process of how the estimate is prepared. In most cases, the initial project estimate is prepared at a district or region office and that office retains responsibility for project development and creating subsequent estimates. When the project reaches the later stages of development, it is handed over to the region or central office for letting. Although the districts or regions lead the project development process, the region or central office provides the districts with oversight, but this can often be minimal. States with large construction and maintenance programs are extremely decentralized, and their districts perform almost as separate entities. A few states have unique characteristics such as requiring at least one person retain responsibility for the project throughout its duration or having a State Estimator's Office that oversees all project estimates.

The first project development phase is long-range planning. Most of the SHAs interviewed employed conceptual estimating techniques based on cost per mile factors, while a smaller number of SHAs used a typical or similar project to arrive at a planning estimate. If a project has structures, the SHA would use a cost per square foot of bridge deck for this project component. The SHAs use this planning estimate as the stated "order of magnitude cost" of the project when their transportation project needs list is developed.

The estimating procedure for the programming estimate varies among the SHAs. These cost estimates often become the stated project cost included in the agency's authorized program, and in many cases, the program and project costs must be approved for funding at this point by the legislature. Parametric estimating techniques are applied for this estimate based on concept drawings and factors covering significant cost elements in the project scope such as pavements, bridges, and right of way. Parametric estimating divides the cost estimate into key components of the project and parameters that are derived from conceptual drawings.

The advanced planning/preliminary design phase begins when the SHA commits resources to developing design documents for a project. The estimating procedures used during the early project design phase depend on the completeness of the design, that is, percent of design complete. At the early stages of design, estimates are prepared in a manner similar to the programming estimate approaches (parametric based on lane mile factors, bridge deck square foot/yard, or similar projects). As the design becomes more definitive, the estimating procedure evolves from a parametric estimating process to a line item approach. These estimates are often used as the basis for project funds included in the STIP. Preliminary design estimates are typically prepared before each formal design review (30 percent, 60 percent, and 90 percent design reviews are required by many SHAs). The final estimate is the engineer's estimate, which is created when the design is 80 to 100 percent complete. The engineer's estimate is used to evaluate the bid prices submitted by the contractors.

Table 8 summarizes general characteristics of SHA cost estimating practices. These characteristics are further explained in the following sections.

Table 8. Summary of Cost Estimating Characteristics

Project Development Phase	**Cost Estimating Practices**		
	Estimate Purpose	*Estimate Preparation*	*Estimate Reviews*
Planning (Conceptual Estimate)	Estimated funds needed for long range plan	Cost/Mile & Percentages	Internal Review
Programming (Parametric Estimate)	Estimated funds for project in authorized program	Parametric Estimating	Internal Review
Advanced Planning/Preliminary Design (Parametric and Line Item Estimate)	Estimated funds for project in STIP	Identify Major Cost Line Items	Peer and Team Reviews
Final Design (Detailed Engineer's Estimate)	Estimated construction cost to compare with bids	Completely Line Item	Committee Review

CRITICAL REVIEW OF THE COST ESTIMATING PRACTICES

To review current practices conducted by the SHAs interviewed in the area of cost estimation procedures, a number of unique or innovative approaches to cost estimating are described. A discussion of how current cost estimating approaches do and do not address the identified potential root causes of project cost escalation are also covered in this section. This discussion is organized into the estimates that correspond to the major project development phases. Once the practices are described, the potential deficiencies in current practice are noted. These deficiencies are discussed under "Summary of Important Issues," the last section of this chapter. These unique practice approaches and the general deficiencies in practice are the basis for the preliminary strategies, methods, and tools described in Chapter VI.

When interviewing SHAs, the distinction between programming and advanced planning/preliminary design was not always clear. Further, the estimating procedures employed by the SHAs that were in these two phases were similar. As a result, these two phases have been combined in the discussion to follow and when listing preliminary methods and tools in the next chapter.

Planning Estimates

From the SHA interviews, a summary of the cost estimating practices used during the planning phase is described. The long-range planning estimate is usually the first estimate produced for an identified need, that is, a future project. When the identified need is added as a project to the SHAs' long-range plan, the estimated cost is an important criteria often used to prioritize different needs within the transportation program. Additionally, the purpose of this estimate is to determine funding levels for long-range plans.

The identified need has little definition, which affects the estimating method used to arrive at an estimate of project cost. The main method or approach used for long-range planning estimates is lane mile cost factors. The cost per mile factor is developed using different methods such as historical lane-mile sections or similar projects. The cost is based typically on historical data obtained from the bid prices (not actual project cost), either award or averages of several bidders. The long-range planning estimate is often prepared using only basic computerized tools such as a SHA developed spreadsheet. Many of the spreadsheets used are templates with predetermined formulas and historical data incorporated into the spreadsheet.

Other project elements such as right of way, engineering, environmental, and miscellaneous items are incorporated into the planning estimate as a percentage of the total project cost or as a contingency factor. For example, in the case of preliminary engineering, 0.5 to 8 percent is added depending on project complexity, and the utility cost is 3 percent of the total cost. The estimate may or may not be inflated to the midpoint of the construction year. In most cases, the planning estimate undergoes very little review within the SHA. If the estimate is reviewed, the review is conducted by another person on the estimating team or by an engineer in a district office. However, if the estimate is prepared for a metropolitan planning organization (MPO) it may be reviewed by the MPO during the project selection process for the long-range plan.

The techniques explained above provide a general estimating procedure for the planning phase that is performed by the SHAs interviewed. The following sections describe the unique cost estimating approaches extracted from the SHAs that were interviewed. These approaches are the basis for the methods and tools included in the preliminary strategies, methods, and tool table for the planning phase.

Cost per Mile Factors Using Typical Sections

Cost per Mile Handbook

One unique approach to applying cost per mile factors is developing typical project sections (e.g., pavements) that correspond with the lane-mile cost factors. Using this approach, one SHA created an estimating handbook that has sketches of typical project sections that are used to generate the conceptual estimate. At the planning stage, the pavement thickness, materials, and lane widths are typical values. Depending on the project's standard characteristics, the estimator chooses the corresponding project typical from the handbook. Then, the estimator selects the appropriate cost chart that best fits the anticipated project structure. Cost is still in dollars per a lane mile but it reflects a typical structural section that is identified early in project development. The typical sketches also aid the estimator in deciding on the additional project elements that will be required. The base construction cost, and therefore, the preliminary engineering, civil engineering, inspection, and right-of-way costs are added to this lane mile cost. The right-of-way (ROW) is factored into the estimate as a percentage of the estimated construction cost, and the engineering costs are based on historical ratios of engineering to construction cost. The engineering cost includes preliminary engineering, construction engineering inspection, right-of-way support, and related overhead costs. The factors in this SHA handbook represent present day costs that must be inflated to the project's midpoint of construction. This planning manual has inflation factors that are applied to the planning estimates. The sum of the calculated elements determines the long-range planning estimate's total amount.

This estimating method provides the SHA with a consistent and transparent approach to costing projects. Consistency of approach continues as the project is further developed because the SHA uses an estimating methodology that builds upon the lane mile typical section at each project development phase. The difference between the estimates in each phase is the incorporated level of project detail. Furthermore, the estimate is documented by the systematic preparation of narratives. The approach also has standard project cost components that must be considered for inclusion in the estimate; this helps the estimators avoid the problem of cost item omission.

Cost per Mile Spreadsheet Templates

Two SHAs reported using lane-mile cost factors with typical sections for their planning estimates, but their methods were not consistently used within the SHA as the procedure previously described. One of the SHAs uses three spreadsheet templates specifically for its central, northern, and southern regions. The templates categorize typical projects into rural or urban location, and into new or widening projects. The number of roadway travel lanes and the median type is used to further define each typical section. The spreadsheet templates have columns associated with costs for grading and drainage, base aggregate and pavement, lump sum items (i.e. pavement markings and signs), miscellaneous items, engineering and contingency, total project cost, and total cost per mile. The length of the proposed project is entered into the template and costs for each typical section listed are calculated. This template provides the SHA with different design alternatives along with an estimate for each design so that designs can be compared.

Similarly, another SHA has a cost sheet that lists similar project types and associated cost per mile factors. The cost sheet separates projects into rural and urban with project types listed by the number of roadway travel lanes. From the cost sheet, the estimator chooses the thickness of the pavement and the median type. The cost sheet also refines cost numbers based on work type, reconstruction or new construction. Furthermore, the sheet provides information for estimating the cost of miscellaneous improvements such as signaling. Percentages of the total project cost are used to estimate right-of-way and utility cost. This SHA is in the process of refining their estimating software to include the computerization of planning estimate preparation.

Cost per Mile Factors Using Similar Projects

Several SHAs use information from similar projects that have been fully designed to generate cost per mile factors for long-range planning estimates. One transportation agency identifies similar type projects within the state that are in the programming phase and uses the current average cost per mile estimates from those projects to prepare the conceptual estimates for its planning phase projects. The cost per mile cost data could be obtained from a single programmed project or from a number of similar programmed projects. The key to this estimating practice is using similar projects that have a more defined scope than the project in the long-range planning phase. The planning engineers in the respective districts provide the estimators with the current cost per mile estimate for the programmed projects, which were created using parametric estimating. Thus, the conceptual estimates reflect all project costs elements, including costs for design, utilities, construction, and right-of-way. If the project includes structures, the estimator attempts to separate and remove the structure cost in the programming phase estimates and then estimates the current project's structures separately. Other SHAs develop lane mile factors in a similar manner as the one describe here, but they use costs for projects that have already been let instead of projects still in the programming phase.

Add-on Elements

All SHAs incorporate in one manner or another the cost of “Add-on” elements. These “Add-on” elements often result from local government concerns, environmental issues, and externally imposed requirements. During the long-range planning phase, these issues are added into the estimate as a percentage value based on the total project cost. The percentage either is identified as a separate cost item or is incorporated into other items such as miscellaneous, preliminary engineering, or contingency. Although the SHA’s interviewed apply percentages to account for all project elements not considered in their cost per mile factors, one SHA uses a scoping document to ensure the elements are included in the estimate.

Scoping Document

One SHA creates its long-range planning estimates using costs from similar projects but the agency also uses a scoping document in creating the estimate. The scoping document separates the project costs into five categories related to general roadwork: pavement structural section, roadwork, drainage, specialty items, and traffic items. These major elements are estimated using historical bid averages. Minor items, mobilization, and roadway additions are estimated as percentages of the roadway items. The agency’s structure and right-of-way divisions are responsible for generating estimates for their project elements. Most projects are informally compared to similar existing projects to check for consistency.

Historical Databases

In order to organize and manage the vast amount of information accumulated from past bid data, the SHAs have historical databases that store their estimating or bid data. The databases have mostly line item costs that are not applicable in the planning phase, because of the high level of detail that line item costs require and the variability existing in the planning phase. Although the line item costs are not used to create conceptual estimates, the historical data are used to produce the cost per mile factors that are applied to the estimates in the planning phase.

Contingency

Another characteristic that is unique to each SHA is how they define and apply contingency. Contingency covers a range of issues such as scope changes, scope increase, high-risk elements, and unforeseen site conditions. For every project development phase, the amount of contingency incorporated into an estimate is established by the SHA. The three methods to determine contingency are:

1. Fixed Percentage,
2. Sliding Scale, and
3. Structure/Formal Analysis.

A fixed percentage is a single percentage that is applied to every estimate prepared, and this percentage typically ranges from zero to ten percent. If a transportation agency uses a sliding scale, then they apply a large percentage to the conceptual estimate and decrease the percentage as the project scope is defined. For example, 50 percent is added to the long range planning estimate, 25 percent is added to the programming estimate, and so forth. During the preliminary design phase, the percentage continues to lower until the design is complete, at which time contingency is not included.

The final contingency application is a contingency determined by a structural/formal analysis, such as a Monte Carlo simulation. The state agency performs the risk analysis that identifies the level of risk for each project. Then, the analysis is related to the amount of contingency needed to sufficiently cover the risk. Once the project has entered the final design stage, most agencies do not include any contingency regardless of their methodology.

Estimate Reviews

In the planning phase, the SHAs interviewed do not conduct formal reviews for their conceptual estimates. An internal review within the district or region that the estimate was created is performed on the conceptual estimates. When the initial estimate is completed, the individual who produced the estimate makes certain that all necessary project elements have been considered in the cost estimate. The conceptual estimate is rarely reviewed by someone outside of the project team.

Programming and Advanced Planning/Preliminary Design Estimates

As a project moves into the programming stage of project development, the techniques used to create the cost estimate changes to reflect the availability of additional project information. Programming estimates are produced in a similar manner as the long-range estimates but these estimates are based on more specific definition of project scope. The programming estimate amount often becomes the SHA's cost number included in its authorized program. SHAs typically use cost per mile factors and percentages to create the programming estimate, as was the approach for preparing the planning estimate. However, this estimate is evolving into a parametric estimate and beginning to include defined project items, especially for the major cost items such as paving and structures.

A parametric estimate is an estimate that is based on a broad breakdown into key components of the project and parameters like length of project, width of roadway, or depth of pavement. This information is derived from conceptual drawings. Furthermore, some SHAs use conceptual and parametric estimating software that has been developed by the agency. Other “Add-on” elements, such as local government concerns, environmental issues, and externally imposed requirements, also receive their first recognition as separate costs in this estimate. To produce the programming estimate, historical bid data are often the primary source of cost information. The data utilized may be sorted by statewide and region, or SHA district. Some SHA databases have the capability of being arranged by market area, terrain, and project type. The programming estimates can be created in current year dollars and then inflated to some mid-point of construction time period. Several SHAs have project checklists for standard project elements that list important cost items that must be included in the estimate as it is prepared. After the programming estimate is complete, it does not usually go through a formal review process but typically members of the project team review the estimate internally. If a change has occurred that causes the estimate to increase, then the changes above certain percentages initiate another review of the project within the SHA.

The preliminary design estimate is an amplification of the programming estimate. During the analysis, the researcher discovered that the programming and the preliminary design phases possess many similarities. For many SHAs, programming and preliminary design overlap one another, and the programming estimate is often considered a milestone established within the preliminary design phase. Because of the similarities between the two phases, they were combined for the critical review and for the development of preliminary strategies, methods, and tools.

For the preliminary design estimate, SHAs begin to create increasingly more detailed line item estimates. At this phase, actual design quantities begin to replace previous quantity assumptions. Once the project is in the design phase and the right-of-way limits are set, the right-of-way and utility costs can be refined based on specific design information (e.g., parcels). As the level of design increases, the estimate is further refined. When a project is in the preliminary design phase, the frequency of a project estimate coincides with project milestones or major design changes. A preliminary design estimate is updated when the scope reaches an established design milestone or a significant element in the scope has been identified. During the preliminary design phase, the checklists created in the programming stage are also updated to reflect recently defined project elements. At some point, the preliminary estimate is the basis for funds included in the STIP.

Project estimate preparation can also follow major milestones of project development, such as project initialization, conceptual plan/environmental document completion, preliminary plan completion, right-of-way plan completion, and contract plans completion (PS&E). The difference between each estimate produced during design development is that more line items are identified, as the project scope is refined. At the preliminary design stage, the estimating calculations may be performed using a spreadsheet or in-house computer software. The same historical data used in the programming estimate is applied to the preliminary estimates. The design team is ultimately responsible for the quality and accuracy of the estimates they create.

During the programming phase, most of the SHAs interviewed do not perform a formal review on their estimates. However, for several SHAs, the review process begins to become more formalized as design proceeds and enters into the preliminary design phase. For these SHAs peer and project team reviews, which are often led by the project manager, occur. The project manager approves the estimate, and the district or region often reviews it. The SHA's central office will review the estimate if it has increased beyond specified limits. The cost growth limits that trigger additional reviews or approvals are established by internal SHA policies.

The processes explained above provide a general estimating procedure for the programming and advanced planning/preliminary design phases conducted by the SHAs interviewed. The following sections describe unique cost estimating approaches identified in interviews with SHAs. These approaches are the basis for the methods and tools included in the preliminary strategies, methods, and tool table for the programming and advanced planning/preliminary design phases.

Conceptual and Parametric Estimating

In-house Estimating Software (Long-Range Estimating)

For the programming and preliminary design phase, three SHAs are using computer software to develop conceptual and parametric estimates. For one SHA, the information in their in-house estimating software is recorded in a handbook that is used for the conceptual planning estimate. When the project reaches the programming stage, the SHA's project development group creates different alternatives and then chooses the one that best meets the project's needs. They then use their in-house estimating program to produce the program estimate. A different typical sketch can describe each section of the project. The estimator starts with a preloaded typical sketch and then adjusts it according to the site conditions and project location. The location can be specified by county, market area, or general statewide information can be used. At the programming stage, the estimate becomes more project specific. The SHA tries to perform parametric estimating by identifying the major cost items, such as sound walls, structures, retaining walls, and required clearing. The estimator should visit the project site and decide which work items need to be included in the estimate to reflect specific site conditions. This same program is used to create preliminary design estimates.

Scope of Work Estimating Software

The key to another SHA's estimating software is a complete scope of work. Therefore, the estimate prepared for the programming and preliminary design phases are scope feature driven. The estimating system includes lane mile cost for nine geometric conditions, which are based on the functional classification of the roadway and the terrain. The user must specify in the system when the project will be constructed, and the cost is adjusted according to the entered date. In addition to the lane mile geometric conditions, the cost for the other project items such as structures, demolition of existing structures median barrier, curb and gutter, signals, and crossovers must be estimated and added independently by the estimator. The project manager or the estimator can also add features and costs that were developed outside the system and input these features and costs into the estimate. An example of such an additive would be the additional costs for extensive phasing or for productivity impacts for projects in an urban environment.

The remaining cost elements of a project such as for design, construction engineering, inspection, and right-of-way are drawn from detailed cost models. Design costs are extracted from a curve of historical construction cost versus the value of road design and a separate curve is used for bridge design. Construction Engineering and Inspection (CEI) costs come from a curve based on historical close out cost information. These curves are built into the project cost estimating system. Although the system has right-of-way (ROW) models that are based on the amount of ROW and the current land use, the estimator has the option to apply a cost derived independent of the estimating system. Once the engineering drawings are complete and all quantities are known, the user can chose the Trns•port section of the estimating system to create an estimate, which is described next. This SHA allows the public access to the system's project information creating transparency to the public for the SHA. The openness helps prevent tendencies to create a biased estimate.

AASHTO's Trns•port Software

Computers and estimating software enhance the ability of engineers to manage large data sets that can be used in developing estimates for all types of projects. In the case of SHAs, the most widely used estimating software is Estimator™ by InfoTech. Estimator is a module of Trns•port. Trns•port is owned by Info Tech, Inc. and fully licensed by AASHTO. Using this software, SHAs can prepare parametric or item level project cost estimates. Parametric estimates are based on project work types and their major cost drivers. Item level estimates can be derived either from bid histories or by using cost-based estimating techniques. Cost-based estimates are based on an assumed productivity and the direct cost of material, equipment, and labor.

A survey of SHAs conducted in the fall of 2002 found that the Trns•port Estimator module was being used by 22 SHAs at that time. Historic bid price databases can be created using the BAMS/DDS module of Trns•port. BAMS/DDS is the Decision Support System module of the construction contract information historical database. Another commercially available system used by several SHAs is Bid Tabs by OMAN systems. It is used either as a stand-alone or in conjunction with Trns•port by seven SHAs (Schexnayder et al. 2003).

SHAs' in-house and AASHTO estimating software are tools that assist the SHAs in developing their project estimates. The estimating programs with preloaded templates help the SHA project teams define the project scope, cost, and schedule. The software provides a means to track project development and can assist in project review. Due to software flexibility, the estimator can adjust unit costs or percentages according to the project's complexity. Estimating software also permits the easy inclusion of additional items that are unique to a particular project.

Volumetric Estimating

Another procedure used to create the programming and preliminary design estimate is a volumetric method based upon the pavement component of a project. For this procedure, a length-width-depth (LWD) template has been developed by the SHA for generating programming estimates. Basic project information such as scope of work and the control section are entered into the template. Then the LWD factors for all the roadway items are determined. After that, an LWD cost multiplier is selected from a table and entered into the multiplier box on the template. The estimator must generate the costs for the other project design elements and enter them into the template. The template sums the individual roadway item costs, totals the cost column, and advances that cost to the project total box. The last step is completing a "Project Scope Summary

Form" for the estimate. A project scope summary form provides a summary record of the project scope associated with each project cost estimate that the SHA prepares. The form is set up as a checklist of possible elements that may be included in roadway/bridge construction project.

The LWD cost accounts for all costs associated with building the roadway; it represents the "normal" cost for major items of construction, such as: mobilization, removals and salvage, grading, aggregates, paving and approach panels, by-pass and temporary construction, drainage, concrete items, traffic control, turf/erosion, and miscellaneous. The estimator will collect all the LWD information and separate the information into two portions. The LWD portion is an accumulation of all the roadway parts, and it is used to create a project cost multiplier related to the unit volume consisting of pavement, shoulder, or ramp's length, width, and depth. The project LWD factor is the sum of the volumes (LWD factors) of all the roadway items in the project. The depth of pavement does not include the aggregate base or sub-grade. Depths selected by the agency's Estimate Coordinators are based on historical data and/or as project scopes dictate. The project LWD factor (volume) is multiplied by a LWD cost multiplier that has been developed through historical data and represents different projects with similar type and scope. The SHA created a menu of project types along with a cost multiplier for each type. The SHA also has indicators to follow such as a cost per a square foot of pavement or cost per a lane mile of pavement to check the LWD estimate for reasonableness.

Five specific cost items are not included in the LWD factor roadway cost estimate and must be computed separately. Those five cost items are bridges, signals, noise and retaining walls, traffic management systems, and other abnormal construction items. Other cost items that must be added to the LWD cost are engineering, ROW, and relocation of utilities. A percentage additive item is used to account for project development costs, including engineering, design, and construction costs. About 20 percent of the project cost is typically used for this item. For the ROW cost, the SHA expects that the engineers will layout the project and develop the cost. The engineer assumes a distance from the edge of pavement and that sets the ROW limit. A parcel database from the state's geographic information system allows the estimators to determine which parcels are impacted by the assumed ROW. At this point in project development, any impacted parcel is assumed to be a total take. The County Assessor provides information on the assessed market value for the impacted parcels. A multiplier, specific to the corresponding county, is applied to the parcel value. The cost of the parcels is totaled to obtain the ROW cost estimate. Once all of these project elements have been calculated, they are added together to provide the total planning estimate value.

Identifying Major Cost Items

When a project is in the programming and preliminary design phase, more information about the project scope is developed. Therefore, the estimates created for the project are more specific than the earlier estimates. Many SHAs recognize the fact that about 80 percent of the project cost is in about 20 percent of the project elements. As a result, these SHAs focus on the high cost items while generating an estimate. The SHAs that identify costs for major items use a spreadsheet or in-house software to calculate the total estimate. One SHA's list of major items included surfacing, safety items, structures, and grate and drainage. Another SHA's major items are excavation, embankment, bituminous pavements, portland cement concrete pavements, drainage, curbs and gutters, structural concrete, structural steel, and guide rail. In both cases, these large cost elements are estimated using historical unit costs or cost-based estimating procedures. Once the major items are estimated, the smaller items, such as traffic control, signing, and stripping, are included as percentages or by lane mile factors similar to those used in planning estimates. By applying this estimating approach, the SHAs are considering the project's major cost drivers and the project's complexity. The SHA focuses on the major cost drivers and attempts to develop a precise estimate for those items. Although the minor items are not estimated at the same level of detail as the major items, they are identified and incorporated into the estimate by methods that are more global.

Add-on Elements

During the programming and preliminary design phases of project development, every agency considers "Add-on" elements while developing the project estimate, but at this point in project development, "Add-on" elements are considered separate from direct project line items. Many SHAs have established environmental assessment as a project milestone. Therefore, an estimator must consider any environmental or cultural issues that can affect the cost of the project. If the environmental assessment is not complete, then one SHA has a policy of not assigning funds to the project. Other SHAs perform these "Add-on" element evaluations during their internal estimate reviews. During the reviews, they address issues such as environmental mitigation, public involvement, and context sensitive design issues that might hinder the advancement of the project. Another method used to identity all project elements is performing project scoping.

Project Scoping

Scoping Documents

Many SHAs use "scoping documents" early in the project development process to identify and specify critical design elements. These documents create a baseline scope for the project and any changes in the scope are measured against this baseline-scoping document. Explicitly defining the scope of the project early in the project development phase allows for better scope control and identification of any changes that may translate to changes in project cost and schedule.

One SHA holds a scoping meeting when the project enters the preliminary engineering phase. The meeting brings experts from each phase and discipline together for a field review of the project. The meeting is used to: 1) specify the project limits; 2) identify issues that may affect project elements; 3) agree on the purpose of the project; 4) refine the construction cost estimate; 5) enhance the project schedule; and 6) define the participation of each discipline and establish a contact person. Upon completion of this meeting, a specific document must be completed that distills the decisions and information of the meeting. This document is then distributed to various parties. Prior to signing the final plans for either right-of-way or construction, another form must be completed stating that the project is within the original scope. If it is not within the original scope, documentation concerning deviations must be provided. Another SHA has a Project Scoping Memorandum that is completed by the project manager and submitted to the Design Technical Support Engineer for review and comment. The memorandum summarizes the important information of the project and certifies the scope is as complete as possible at that point in time.

Estimating Checklist

Some SHAs use estimating checklists to develop the project's scope and to ensure an estimate includes important items that frequently occur in projects. Checklist can help prevent the failure to include project items that might be needed, but are not yet designed at the time the estimate is completed. The level of detail in a checklist mirrors the detail of the estimate at any given level of project development. In the early phases of project development for example, checklists may be extremely simple; they then become more complex as the project advances through the development phases to correlate with more detailed scope definition. One example checklist, used by a SHA during early project programming, includes the following:

Functional/Preliminary Estimate List:

1. Clearing and Grubbing (acr. or ha.)
2. Earthwork (cy or m^3) - unclassified, borrow, undercut, etc.
3. Fine Grading (sy or m^2)
4. Drainage (per mile or kilometer)

5. Paving (ton or mtn, w/ pavement design, or sy/m^2 without)
6. Stabilization (sy or m^2)
7. Shoulder Drains (lf or meter)
8. Curb & Gutter (lf or meter)
9. Guardrail (lf or meter)
10. Anchor Units (each-type)
11. Fencing (mile or kilometer)
12. Interchange Signing (type and location)
13. Traffic Control (TCP) (per mile or kilometer)
14. Thermo and Markers (per mile or kilometer)
15. Utilities (lf or meters)
16. Erosion Control (acres or hectares)
17. Traffic Signals (each and location)
18. Retaining Walls / Noise Walls (sf or m^2, with avg. height)
19. Bridges (individual location)
20. RC Box Culverts (individual location)
21. Railroad Crossing (each-with or without gates)

The estimating checklists are also used during project reviews to make certain all necessary project items have been included in the estimate.

Document Estimate Basis and Assumptions

Project Estimate File

One SHA requires their engineers to create a project estimate file that holds all documents pertaining to a specific project. The purpose of this requirement is to ensure that each project has a well-documented and easily retrievable history of the assumptions, methods, and procedures used to estimate the right-of-way and construction costs associated with the specific scope of work identified for the project. Having this information contained in one location and separated from other project documentation helps ensure that the estimate information is readily accessible from a known location and uncluttered with other project information.

At a minimum, the project estimate file contains any assumptions that have been made, the current project scope, maps, photos, as-built plans, functional classification, design criteria, and a copy of or reference to the cost data used to support the estimate. This basic information has to be included in each project estimate file regardless of the stage of project development. A sheet is placed in the front of each estimate file so that the project manger can record the date and current project milestone or project development stage each time the project estimate is changed, updated, or reviewed. A signature line is also included to document the project manager's review of the estimate file.

Depending on the level of project development that has occurred on the project, the amount and type of documentation contained in the project estimate file varies. Information used to develop the project specific cost per mile factors or generic factors that are applied are well documented and added to the project estimate file. This information may consist of items such as estimate software, bid tabulation data from similar projects, unit bid price books, or some other reputable resource. Additionally any deviations from the generic cost per mile factors, that are determined to be warranted by the estimator, must have well documented reasons included in the project estimate file.

Variations of the miscellaneous and utility cost percentages are also documented in the project estimate file. Some projects that are not complex and have a small scope of work may warrant the inclusion of a cost adjustment factor to compensate for the short project development time and project uncertainties. These cost adjustment factors are well documented in the project estimate file and have a reproducible basis.

Copies of all pertinent information related to the project estimate, as well as all documentation of the quantities and unit costs used, are included in the project estimate file. All estimate data sheets include the date of preparation and the estimator's name. In addition, any project scope change approval letters required are also retained in the project estimate file. The project estimate file includes all cost estimates prepared for the project up to and including the completed final estimate.

Contingency

As explained in the planning section, each SHA addresses contingency differently, with 1) a fixed percentage, 2) a sliding scale, or 3) a structural/formal analysis being the most common approaches. Although most interviewed SHAs factor contingency into their estimates, only one SHA performs a detailed risk analysis, using a tool developed by the agency. When this SHA creates an estimate, they remove all contingencies from the line items. Then, the SHA develops a base cost and schedule that represents performance of the project according to the plan. After that, cost risks, schedule risks, and opportunities are identified and evaluated. The SHA combines the base cost and the risk/opportunity assessment and then applies critical path methodology and Monte Carlo simulation to generate ranges for expected project cost and schedule. The methodology also generates related probabilities for the predicted cost and schedule ranges. Through this risk analysis tool, the SHA has created a method for applying contingency factors that are based on an in-depth analysis of possible events and the probability of the event’s occurrence. By performing this analysis, the SHA recognizes potential project problems early in the project development process and this enables the SHA to respond proactively to the identified events.

Estimate Reviews

For reviewing a programming or preliminary design estimate, one SHA conducts peer reviews. The project manager and the design team review the design and comment on any discrepancies or problems. The designers of the specialty items such as retaining walls and structures make certain their features are accurately represented in the design and estimate. By reviewing the estimates, the SHAs can detect possible errors or omissions. SHAs also use reviews to identify discrepancies in the estimate that are the result of bias that lead to underestimation of project cost. Another SHA stressed the importance of gathering the individuals responsible for all the different aspects of the project such as right-of-way, structures, and surveying so that their input could be utilized to develop a realistic estimate. This SHA also explained that involving all disciplines early in the project development process is important to the project's final outcome.

Reviews are conducted when the project reaches pre-established milestones. However, a project's estimate value or complexity can prompt additional reviews. The typical review trigger for the SHAs interviewed is percent ranges established through the agencies' policies. If a cost estimate exceeds its programmed amount by a certain percentage, then an additional review of the project is conducted. Another trigger used by the interviewed SHAs is project complexity. This trigger assigns levels of complexity to projects. For example, one SHA uses descriptive tables that define project complexity; these tables are explained in the next section. If a project were a standard project with no extraordinary characteristics, then it would be considered non-complex and will not have any additional reviews. However, an abnormal project would be considered complex, and it would have more reviews than a non-complex project.

Recognition of Project Complexity

Project complexity should be addressed early in the project development process so that appropriate cost estimating methods are conducted. One SHA created three tables that describe project complexity. The SHA defines three categories for project complexity: non-complex (minor) projects, moderately complex projects, and most complex (major) projects. For each table, the projects are categorized by project elements: roadway, traffic control, structures, right-of-way, utilities, environmental, and stakeholders. Within each section, the type of projects and criteria are listed. For example, non-complex projects for roadways are maintenance betterment projects, moderately complex projects for roadways are minor roadway relocations, and most complex projects for roadways are new highways. The five other project elements have similar lists. For the stakeholder section, the SHA describes non-complex projects as those that have no public controversy issues. Moderately complex projects moderately involve the public and public officials due to non-controversial project types, and general communication about project progress is required. The most complex projects are controversial and high profile projects, and major coordination among numerous stakeholders is required. The project complexity tables provide a statewide definition of project complexity that ensures projects of similar complexity are subject to the same reviews and attention. These definitions allow for a common language between SHA employees to aid in communication regarding projects. This type of definition insures that estimates reflect appropriate levels of complexity.

Final Design Estimates

Once a project has entered the final design phase, the project's scope should be completely developed, and therefore, all project elements can be estimated with precision. This higher level of project knowledge enables SHAs to create a detailed estimate. Furthermore, estimating software is typically used to assist the SHA in producing the final design or engineer's estimate.

Although previous estimates are prepared by the SHAs' district or regional office, the final or engineer's estimate is typically completed by the SHA's central office. When the project's design is ready for advertisement, it is sent to the central office, and a detailed estimate is prepared by the headquarters' staff. A few SHAs generate the engineer's estimate within the district or region and then send it to the central office for review prior to letting. The final design estimate is typically reviewed by the SHA's headquarters.

The engineer's estimate is the final estimate before a project is advertised and it is used to judge the contractors' bids. This estimate is performed using complete plans, specifications, and other project information. Estimating software such as AASHTO's Trns•port software or an in-house program is used to generate the engineer's estimate. There are basically three approaches used to develop the final line item (pre-bid) engineer's estimate (*Contract* 2001).

- The use of historical data from recently awarded contracts is the most common approach. Under this approach, bid data are summarized and adjusted for project conditions (i.e., project location, size, quantities, etc.) and the general market conditions. However, this method is the most susceptible to outside factors such as inflated bid prices from contracts with little or no competition (*Contract* 2001).

- The detailed estimate approach based on specific crews, equipment, production rates, and material costs (also termed cost-based estimating). Cost-based estimating is similar to the way a construction contractor would estimate a project. This approach requires the estimator to have a good working knowledge of construction methods and equipment. While adjustments for current market conditions may be required, this approach typically produces an accurate estimate and is useful in estimating unique items of work where there is insufficient bid history (*Contract* 2001).

- The third approach combines the use of historical bid data with actual cost development. Most projects contain a small number of items that together comprise a significant portion of the total cost. These major contract items may include portland cement concrete pavement, structural concrete, structural steel, asphalt concrete pavement, embankment, or other specialty items. Prices for these items are estimated using the detailed approach and adjusted for specific project conditions. The remaining items are estimated based on historical prices and adjusted as appropriate for the specific project (*Contract* 2001).

If the design team prepares the engineer's estimate, then it undergoes a district or regional review and more than likely a central office review. Some estimates are reviewed by estimating committees that are composed of personnel that have specific knowledge about different aspects of a project and ranges of experience. If the agency's central office prepares the engineer's estimate, then they also review the estimate.

In many states, the engineer's estimate is not released to the public before the letting. What is allowable concerning release of the SHA's estimates is usually defined by state statute and, in many cases, out of the SHA's control. Once the bids have been submitted to the SHA, the agency uses estimating software to compare the engineer's estimate with the bids. By law or internal rules, SHA's require the bids to fall within a certain range of their engineer's estimate, or they will not award the contract. After the bids have been compared to the SHA's estimate, the total amount of the SHA estimate is usually released to the public; however, most SHA's do not release the detail item prices of their estimate.

The processes explained above provide general estimating procedures for the final design phase conducted by the SHAs interviewed. The following sections describe the unique cost estimating approaches obtained from the SHAs that were interviewed. These approaches are the basis for the methods and tools included in the preliminary strategies, methods, and tool table for the final design phase.

Estimating Software

Often SHAs use estimating software to calculate the engineer's estimate. The software is either a program that has been developed within the agency or the Estimator module from AASHTO's Trns•port software. A few SHAs use a combination of their in-house software and the AASHTO programs. The SHAs that have AASHTO's Trns•port use one or several different modules of the software, such as the Cost Estimation System (CES), the Proposal and Estimates System (PES), or the Estimator module. The CES enables the user to prepare parametric and cost-based estimates. The CES module has the ability to store historical labor, equipment, material, and crew data. Detailed project information can also be entered into the program. If a SHA uses the PES, they can enter project data into the program and prepare conceptual to detailed estimates. Within PES, the SHA can use multiple funding units and differing percentages for engineering and contingency. AASHTO's Estimator module allows the user to apply several different estimating methods such as estimates based on historical bid data, historical cost data, reference tables, or a collection of price derivations. All the data used to generate an estimate such as crew wages, equipment and material costs, production rates, and historical cost data are stored in Estimator.

Historical Bid Price Databases

Along with estimating software, SHAs have extensive databases of their accumulated historical bid data. All of the possible items that would be used in a project are set in these databases and each item is tied to a specific specification. A staff unit at the SHA's headquarters often manages the database, with the districts and regions having online access to the information.

SHAs vary as to the period of time historical data are retained in their databases and how far back price data should be considered to determine average prices used in estimates. Typical look back periods are 1 year, 18 months, or two years for use in calculating averages. Nine SHAs retain data for as long as records exist (Schexnayder et al. 2003). Estimators can examine and use this data for items that are not frequently encountered or items that have seasonal price swings as an averaging of data obscures seasonal pricing. The bid averages shown in the database are calculated several ways:

- Low bid only - 20 SHAs
- Low and second bid - 1 SHA
- Three lowest bids - 15 SHAs
- All bids (but may exclude single bids that are very high or low) - 11 SHAs
- All bids except high and low - 2 SHAs
- Bid analysis to determine a reasonable bid amount for each line item - 1 SHA (Schexnayder et al. 2003).

By the use of different sorting criteria, the line item cost data can be analyzed under different protocols. The line item cost data can be sorted by district, county, region, and state. In addition, the data are also categorized by project type, market area, location, and terrain. Within the historical database, the users can view the bid average for a particular item or they can view all the unit prices so the user can select a price that corresponds to their estimated quantities. One SHA database has an item price menu, and the user can view different item criteria, such as a date range, region and county prices, only awarded prices, all bid prices, specifications in English or Metric units, funding, quantity range, similar projects, or contractor's bid. Finally, bid prices are also used to support in-house programs like the long-range estimating approach.

The Trns•port modules discussed earlier have the ability to store historical bid information and use the data in estimate preparation. The Trns•port CES program uses historical data and regression models. The regression models take into account specific criteria such as quantity, season, market area, and date. The regression curves help the estimator know how reliable their unit cost is based on the number of criteria it meets. For example, if the regression curves show that 4 out of 6 categories apply to the unit cost used, then the estimator can be certain the unit cost has less variability. The Trns•port BAMS/DSS program also analyzes historical bid information. Within this database, the SHA can view contract and vendor information and analyze the market. The program also assists the SHA in analyzing bids, specifically in searching for unbalanced bidding. BAMS/DSS can assess historical bid prices and estimates and can evaluate the difference between the awarded and final costs and quantities of a specific project.

The databases allow the SHAs to systematically utilize the large amounts of price information they have collected over time. By using the large databases, estimators can select the most appropriate unit costs for their project enabling them to consider unique project characteristics. If the same database is accessible throughout the state, then the individuals developing the project estimate can apply data that they would otherwise not have available to them. The large databases help prevent estimators from relying on data that is not relevant to a specific project.

Contingency

When the project is in the final design phase all project elements have been fully developed with estimates associated to each line item. Therefore, most SHAs interviewed do not include contingency. The few SHAs that do incorporate contingency into their final estimate add a percentage of the total project cost. The contingency percentage is small ranging from three to four percent. One SHA interviewed performs a risk analysis to compute the amount of contingency added to their estimate. The risk analysis is the Monte Carlo simulation explained in the previous contingency section.

Estimate Review

The review of the project estimate at final design can vary from no review, to an in-house/peer review, to a formal committee review. The less formal review can include another estimator in the state estimating office or design division, who examines the estimate before the project is bid. The final review may only check to make sure that no items were omitted. This review is typically based on experience or a formal check system. In many cases during the final design phase, SHAs have more formal estimate reviews that require the estimate be presented to a committee. The committee can consist of a number of people including department heads and field personnel representing the state construction engineer, FHWA personnel, the contract administration engineer, the state maintenance engineer, and/or the project/field engineer. The committee may ask for more information regarding elements of the estimate. The committee then votes regarding approval of the estimate.

Once the project enters the final design phase, most of the SHAs interviewed do not use triggers to prompt additional reviews. However, four SHAs consider project complexity, and two SHAs apply percent ranges to elicit further reviews. These triggers are established by the agencies' estimating policies.

SUMMARY OF IMPORTANT ISSUES

Cost estimating practices described by the SHAs attempt to alleviate many causes of cost escalation. However, it appears that no single SHA has estimating systems in place that address all factors causing cost escalation, which the agencies must address in establishing the cost of their projects. The important issues were selected by reviewing the SHA information and the cost escalation factors found in the literature. The important issues are based on the limited sample collected during the interview process. If one or no SHA that was interviewed addressed a cost escalation factor that was identified in the literature as an area that needs consideration, then the estimating practice was selected as an important issue. For example, the literature stated that a cost escalation factor is engineering and construction complexities, but only one SHA that was interviewed has an estimating approach that formally documents project complexity. Therefore, project complexity was identified as an important issue. These issues include contingency and uncertainty, risk-based estimating, time value of money, estimate reviews, estimate documentation, and project complexity.

Contingency and Uncertainty

Contingency is typically applied to SHA cost estimates but its application must still be considered a deficiency. It was found that in most SHAs the application of a contingency to an estimate is so loosely defined that typically there is no consistent application of contingency. The SHAs are aware that potential issues exist for each project and therefore incorporate contingency. However, they very often fail to define the specific aspects contingency dollars are supposed to cover.

To a large extent, the problem is the result of the fact that contingency means what the estimator says that it means. As a result, issues that should not be a part of contingency consume the contingency budget leaving no funds for its intended purpose. By definition contingency is meant to cover: 1) an event that may occur but that is not likely or intended or 2) a possibility that must be prepared against, the condition being dependent on chance. Often the amount of contingency added to an estimate is dependent on engineering judgment rather than an analytical approach causing inconsistent application of contingency.

Risk-based Estimating

Risk-based estimating is used by one transportation agency. Range estimates and risk charters are common practice in other industries, but the highway sector is just beginning to apply these techniques. A risk charter is a list of identified risks that may be encountered during the life of the project. The charter may address the likelihood of the risk, the cost and schedule implications of the risk, and mitigation technique suggestions, as well as identifying which risks can have the largest impacts on the project. The goal of the risk charter is to reduce the number of risks on the list to as few as possible by mitigation strategies or project design changes.

The SHAs who are applying risk-based estimating approaches have found it to be successful in communicating the true nature of project costs at the planning and preliminary design phase. These SHAs have also found it useful in managing the project development and design process.

Time Value of Money

Many SHAs inflate their estimates to the prospective date of construction by applying a factor that reflects the current economic situation. However, SHAs do not usually consider the impact of a schedule change on inflation. Prolonging the schedule will increase the cost of construction. For example, a million dollar project that has been postponed for one year would experience an additional $30,000 in cost if the current inflation factor were 3 percent. If the estimates are periodically reviewed the schedule must also be considered. The SHA might then consider the impact of time changes and incorporated additional costs into the estimate. However, many agencies do not have a regular formal estimate review process.

Estimate Reviews

Most of the SHAs have informal reviews that are conducted by the project team. Frequently, the individual preparing the estimate is responsible for the quality of the estimate. As a result, the SHAs rely on the individual's judgment to impartially review the estimate. Although the final project estimate is reviewed before letting, periodic reviews and approval are seldom required during the project's development. Reviews typically occur after the project's cost has increased or a major scope change has occurred. A few SHAs have requirements that an estimate (the project's estimated cost) must remain within an established range. If the estimated cost goes outside the range, additional reviews and approvals are needed. The informality of the review process leads to projects advancing to the next stage without serious cost reviews.

Estimate Documentation

Proper estimate documentation is another common deficiency that causes accountability issues. Unless a SHA has to request additional funding, the reasons that cause a project cost increase or a scope change is not recorded and therefore not traceable. Many SHAs lack consistent estimating procedures between their districts. Many SHAs do not have standardized estimating procedures and they allow the districts to use whatever approach the districts deem suitable. Management cannot properly correct a problem if they do not know how an estimate was prepared or what changes were made during project development.

Project Complexity

Most of the SHAs do not adequately consider project complexity when they create a cost estimate. They describe project complexity by preservation projects, medium sized to large rehabilitation and reconstruction (mid-range) projects, and large mega projects (greater than $100 million). Project complexity is also characterized by the project's anticipated cost. For example, one SHA divides their projects into smaller maintenance projects estimated to be less than 5 million dollars, widening projects ranging from 20 to 30 million dollars, and large projects ranging from 60 to 80 million dollars.

SHAs do not consider projects such as preservation projects to be a significant issue in cost estimating because the SHA typically has a good idea of the project elements and quantities associated with preservation projects. For the mid-range projects, SHAs do not have a consistent estimating procedure. SHAs consider project characteristics such as the project's location, but additional costs included to reflect project complexity are dependent on the estimator's judgment and experience. If a project is more complex than the SHA's standard projects, then the SHA might include additional contingency. During a project review, some SHAs consider complexity by requiring more approval signatures than a less complex project, but the impact a highly complex project has on the cost estimate is not considered.

For large or mega projects, SHAs are forced to consider project complexity. SHAs conduct constructability reviews, value engineering reviews, and evaluate several alternative design concepts for mega projects. Due to the complexity of the mega projects, SHAs have to perform some conceptual development before they can select an appropriate alternative and cost for that alternative. One SHA has developed separate policies for major projects and minor projects. For major projects, this SHA requires a draft scoping memorandum, a final scoping memorandum, more approval signatures, and extensive environmental documents.

SUMMARY

This chapter has compiled the interview data into analysis tables and provided an overview of the highway cost estimation practices. Additionally, a critical review of the current cost estimation procedures was discussed, which described a number of unique or innovative approaches. This analysis was derived through in depth interviews with SHAs, MPOs, transportation consultants, and non-transportation owners. Finally, possible issues and deficiencies in current practice were identified. Strategies to address these and other issues are presented in Chapter VI, including proposed methods and tools to implement strategies to overcome these issues and deficiencies. It should be noted that no correlation between the issues and strategies have been identified.

CHAPTER VI
PRELIMINARY STRATEGIES, METHODS, AND TOOLS FOR COST ESTIMATING PRACTICES

Once the data was collected and analyzed a list of preliminary strategies, methods, and tools that may improve cost estimation procedures was identified. These strategies, methods, and tools are tied to their use in the different phases of project development.

The main methodology used to develop the preliminary list of strategies, methods, and tools was to first focus on possible causes of cost escalation and potential strategies that would address these causes. Creating this linkage between possible causes of cost escalation and strategies was based on literature, an assessment of current practice, and general deficiencies found in reviewing the unique practice approaches. Five overarching or global strategies related to cost estimating practices were identified and then described. Three other strategies were developed for the NCHRP 8-49 project that specifically addresses cost estimating management, but for the purpose of this study, they were not discussed. The researcher believes that identifying a set of high-level strategies provides a stronger support base for promoting management action on implementing these strategies.

Once the strategies were developed, the methods and tools that would likely be effective in implementing the global strategies were identified. These methods and tools are those described in the previous chapter as unique practice approaches. In some instances, methods and tools were based on literature and other industry practices, especially in support of the general deficiencies. The strategies, methods, and tools were then placed in the project development phase where they are most likely implemented. Thus, a preliminary list of strategies, methods, and tools was formed.

COST ESTIMATING STRATEGIES

If SHAs are to produce accurate estimates, they must have solid management plans in place that address estimate practices and consideration of project risk and complexity. The estimators who assemble the cost information must rely on the expertise and input from many individuals both within and outside the SHA if they are to develop an accurate project estimate. Preparation of accurate estimates is, therefore, the responsibility of many different divisions in the SHA and does not rest solely upon the estimators.

The project development process consists of a series of incremental actions that often occur over a period of years (see Figure 1). As the project is developed:

1) Initial estimates are prepared based on preliminary and incomplete information as to scope and structural features, and with an absence of definite environmental and geotechnical information. These estimates are not necessarily designed to be reliable predictors of a project's final cost. These initial cost estimates are more useful in determining funding levels needed for long-range capital programs. Some SHAs stated during the interviews that the expectation for these early estimates is in the plus or minus 40 percent range.

2) Initial estimates are modified to reflect development of plans (design) and specifications. As the project scope is better defined and when the environmental impact statement is completed, risk factors will still exist but they can be defined and should be mitigated if possible by the design or by contracting strategies.

3) Add-on elements that are often considered beyond the control of the SHAs affect a project's cost and the development of a project cost estimate. Some of these factors include community driven scope modifications, schedule changes that impact time value of money assumptions (inflation) and property values, and possibly even political mandates or pressures.

4) Final project cost is only known when all construction work is completed and all change orders and claims are settled. The cost of a project is not established when bids are received.

SHAs can develop strategies to produce accurate and consistent cost/schedule estimates that address all of the major factors influencing project cost and cause cost escalation. SHAs can also clearly explain the purposes and precision of estimates prepared during each stage of project development. The statement has been made in many forums that "initial cost estimates are not reliable" (General Accounting Office 1997). SHA management has the responsibility to explicitly state the assumptions upon which an estimate is based and the purpose of the estimate. The purpose of many early estimates is not so much to be an exact predictor of future project cost but to provide gross cost numbers at the same level of specificity for evaluating project alternatives. This evaluation is often necessary, as part of the environmental review, but the actual cost of environmental mitigation cannot be estimated with any level of precision until site testing is completed for the final design.

Based on the review of literature concerning project cost estimating and from the interviews it is clear that global strategies exist that can affect the accuracy and consistency of project estimates and costs. Five strategies were identified. The definition of a strategy from Chapter I, "*a plan of action intended on accomplishing a specific goal,*" is used as the basis for developing short statements about each global strategy as follows:

1) **Estimate Quality Strategy** – Use qualified personnel and uniform approaches to achieve improved estimate accuracy;

2) **Document Quality Strategy** – Promote cost estimates accuracy and consistency through improved project documentation;

3) **Risk Strategy** – Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed;

4) **Off-prism Strategy** – Use proactive methods for engaging those external participants and conditions that can influence project costs; and
5) **Integrity Strategy –** Insure checks and balances are in place to maintain estimate accuracy and minimize the impact of outside pressures that can cause optimistic biases in estimates.

These five global strategies address the factors presented in Table 2 that might cause cost escalation on SHA projects and within their capital programs. The interviews with SHAs identified many specific methods and tools that are currently being used to address most of these strategies. At the same time, it was also clear that no single SHA has a comprehensive approach for addressing all of these strategies. The strategies must be developed so that they provide an approach that spans the project development phases from the initial planning estimate to the engineer's estimate at final design. The following discussion focuses on the overarching strategies but also presents major sub-strategies that can be addressed through specific methods and tools. Methods and tools frequently will impact more than one strategy.

Estimate Quality Strategy

Use qualified personnel and uniform approaches to achieve improved estimate accuracy. Significant differences exist among the estimating practices of individual SHAs. It appears that the estimating practices of many SHA are often determined solely by the experience of the personnel in charge of estimating, usually the head of the estimating section or the chief of design. Because SHAs do not share bidding and pricing information with their neighboring SHAs, some potentially valuable insights are lost. It seems that the SHAs would benefit from collaborative discussions of bidding trends, habits of bidders that are in common bidder pools, and potentially on estimating practices for large projects.

Estimate quality is a key strategy to mitigating cost escalation factors. Creating a quality estimate means all aspects that could affect the accuracy of an estimate have been considered and properly reflected in the cost estimate. In addition to typical project elements, other aspects include cost escalation factors such as project schedule changes, effects of inflation, engineering and construction complexities, and market conditions. Potential project schedule changes should be considered when generating an estimate because schedule changes will affect indirect costs on a project that have to be paid regardless of progress. Furthermore, prolonging a project past its scheduled completion date causes the project to be subjected to inflation costs over a longer duration then anticipated, thus increasing the total project cost.

Engineering and construction complexities change the dynamics of the cost estimate because projects that are more complex typically have a higher cost associated with them. Large projects affect market conditions because many contractors do not have adequate resources to complete the project. A higher demand for these resources causes prices to increase creating higher project costs. Because complex projects are costly, they tend to consume a large part of the SHA's budget and therefore the estimates should be carefully prepared so that the SHA resourcefully distributes its limited funds.

The estimate quality strategy also improves poor estimating, which can lead to cost underestimation. An example of poor estimating is errors and omissions, which are usually the result of inadequate estimate procedures and reviews. Another characteristic of poor estimating is inconsistent application of contingency. Assuming the cost of errors and omissions is included in contingency when it is not could reduce the contingency. Therefore, fewer contingencies would be left if it were needed for its intended purpose causing the project cost to overrun.

Many of the unique practices discussed are being used by a limited number of SHAs. Some of the practices are derived from studies of contractor estimating procedures. To describe the estimate quality strategy in more detail, three sub-sets were established: Estimate Procedures, Scope Creep, and Estimate Reviews, and they are discussed in the following sections.

Estimating Procedures

Estimate documentation should be in a form that can be understood, checked, verified, and corrected (Carr 1989). The foundation of a good estimate is the processes, procedures, and formats used to arrive at the cost. Most SHAs do not currently have a published estimating procedure for early estimating. SHAs would benefit greatly by producing their own guidelines of standard processes, procedures, and formats to be used by both SHA estimators and design consultants retained for estimating purposes. This guidance document should be specifically written for those responsible for preparing the State's estimates.

In preparing an estimating manual, members of these states heavy/highway construction industry can be asked to share with the agency their knowledge of production rates, estimating techniques, and factors that increase project risk. Advice from local contractors can specifically be sought in regard to factors that they consider important cost drivers. Some considerations that are often made by contractors include (*Estimating Guidelines* 1989):

- Is this a labor-intensive project (Schexnayder 2001)?
- Does the project depend heavily on certain pieces of equipment?
- Is there a danger of material price increases due to shortages of key materials?
- What is the cash flow of the project?

The availability of an easy to use guide that prescribes the standard estimate format for the SHA will greatly assist estimators in preparing estimates in less time, as many of their questions can be addressed simply by reading the manual and following standard procedures. The benefits of standardized procedures clearly explained in a manual should outweigh the cost of initial production and periodic updates. In order to reduce production costs and make changes less expensively, the manual could be published and maintained electronically.

Scope Creep

Scope and schedule strategies are also important at the operation level. The loss of scope control, particularly during engineering, ranks as a leading factor driving divergence of estimated project cost. This can be the result of a few major changes to the scope or by successive minor changes, often referred to as scope creep. The relationship between poor scope definition and scope changes is clear. A poorly defined project scope early in project development does not provide a clear baseline for estimating cost and then managing the project. There must be clear guidelines within the SHA as to scope change authority and for notification of management about the impacts of scope changes. As an example, in 1982 the initial cost estimate for the Boston Central Artery/Tunnel Project (CA/T) was $2.6 billion. That estimate was based on a preliminary concept that covered only a small fraction of what was eventually built. Features built but not anticipated in 1982 include: rebuilding of the Dewey Square Tunnels; new interchanges at Logan Airport; Fort Point Channel work; tunnel roofs for South and East Boston; and temporary ramps and supporting structures. The direct cost for those scope changes alone was $2.7 billion. Environmental compliance and mitigation requirements added another $3 billion (Bechtel/Parsons Brinckerhoff 2003).

Estimate Reviews

The FHWA document *Guidelines on Preparing Engineer's Estimates, Bid Reviews and Evaluation* (2004) discusses the need to review project bids; "A multi-disciplined review committee should be used to analyze the bids received so that the various perspectives within the contracting agency are represented and are provided with technical and managerial input." However, this document fails to directly call attention to the fact that review processes can validate the quality of the SHA estimate. Only in Attachment A – "Review of Engineer's Estimate Preparation" is there any recognition of the fact that SHA estimates should be reviewed, and Attachment A is strictly directed at the engineer's estimates. A very effective tool for establishing the reliability of cost estimates is to subject them to review and verification by independent experts. The depth of such reviews should be dictated by the complexity of the project and in most cases need only be directed to the major items of work. Establishment of an estimate review process, for all estimates from initial conceptual to the final engineer's estimate, is an effective method for validating estimate basis and assumptions, and establishing estimate reliability.

Document Quality Strategy

Promote cost estimate accuracy and consistency through improved project documents. Contract documents must be clear and unambiguous as to what must be constructed and to what standard. The documents must clearly state the responsibilities of all parties; contractors, the SHA, and third parties. It is critical that all parties involved understand third party involvement in the project construction process.

The design and documentation process has a major influence on the overall performance and efficiency of construction projects and on estimating the cost of the work. Designers provide the graphic and written representations that allow contractors and subcontractors to transform concepts and ideas into physical reality. How well this transformation occurs will depend largely on the quality of the design and documentation provided. Inadequate design and documentation leads directly to contractors including their own contingency dollars in bids, to construction delays, and to rework—contributing to increases in project schedule and cost (Tilley 1997).

A CII study found that design deficiencies are responsible for approximately half of all construction contract modifications (Burati, Farrington, and Ledbetter 1992). Therefore, a Quality Assurance Program for ensuring the quality of the project documents is an important strategy in controlling project cost and in achieving estimate accuracy. Document quality assurance begins at project conception and runs through all development stages and into construction. Document quality affects project cost first at the bidding stage and during construction when conflicts are discovered and change orders must be issued. Therefore, document quality needs to be given careful consideration during all phases of project development. It has been recommended that owners have tools in place to assess and control:

- Timeliness of documents (designs) – When designs are not completed in a timely manner (as scheduled) the project is delayed and inflation cost is increased.
- Accuracy – Errors, conflicts, and inconsistencies cause bidder confusion and add to perceived project risk.
- Completeness – When information is lacking, the result is possibly project delay or doubts by bidders as to exactly what is required (how do I price the work).
- Coordination – Design disciplines must be coordinated if the final result is to be efficiently constructed.
- Conformance – The design must meet the requirements of performance standards and statutory regulations.

The document quality strategy addresses several cost escalation factors: 1) engineering and construction complexity, 2) poor estimates, and 3) inconsistent application of contingency. By properly documenting a project's complexity, engineers that design and estimate a project are able to relay critical information to their managers and to contractors. The managers and contractors can approach the project in a manner that is suitable to the project's complexity. Furthermore, quality documentation allows for people associated with the project to be able to read the documents and clearly understand the project's characteristics.

Proper documentation is also important in producing an accurate estimate. If the plans and specifications are difficult to comprehend, then an estimator might have trouble calculating quantities, selecting the required material, and applying suitable costs, which all lead to poor cost estimates. The document quality not only affects the current estimate but it also affects the estimates submitted by bidders because the bidders will base their estimates on the documentation they have received from the SHA.

One deficiency discovered during the data analysis process is the application of contingency. Many SHAs include contingency but do not fully comprehend its purpose. By clearly documenting the SHA's purpose of contingency, the aspects that contingency covers, and how to apply contingency the estimators can properly incorporate contingency into an estimate. The elements not included in contingency can also be added to the estimate as a separate item. Documenting the purpose of contingency prevents designers and estimators from assuming all additional costs are included in contingency.

Risk Strategy

Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed. The actual cost of a project is subject to many variables, which can and will significantly influence the range of probable projected costs. The Census Bureau does not present a single forecast population growth; it offers projections based on different assumptions of fertility, mortality, and migration rates. In the case of SHA project estimates, any one cost number represents only one possible result based on multiple variables and assumptions. These variables are not all directly controllable or absolutely quantifiable. Therefore, cost estimating and the validation process must consider probabilities in assessing cost.

The risk strategy deals with cost escalation factors that influence the project's risks. The engineering and construction complexities affect the risk of a project because the more complex a project becomes the higher the uncertainty, which leads to greater costs. A large amount of risk also exists in market conditions because this factor is not predictable. The probability that changing market conditions arise during the project's development is directly reflected in the project's cost.

As potential risks arise through either government concerns and requirements or further project development, the scope is inevitably affected, which could lead to scope changes and additional costs. The additional costs are typically included in contingency.

However, inconsistent applications of contingency could diminish the contingency before it can be applied to the elements it was intended to cover.

Furthermore, the delivery and procurement approach selected for a project allocates the risks to participating members. Depending on the approach, the risks could be placed on the contractor or the SHA. Whoever is responsible for the risk is also responsible for additional costs that could arise from the risks. As a result, these additional costs will influence the contractor's bid prices.

Four key functions that comprise the risk management process are: 1) planning; 2) assessment; 3) handling; and 4) monitoring. The overriding objective of the risk management process is to identify potential project risks and implement actions that will mitigate the impact of the identified risks. Risk planning is the process of developing an interactive strategy for identifying and tracking risks and performing continuous risk assessments to determine how risks have changed. Risk planning is iterative. All projects having significant complexity should be required to develop a risk management plan. In order to establish accurate scope, schedule, and cost estimates for a project, all risks can be assessed as to potential cost and schedule impacts. For each identified risk, a risk handling strategy can ensure that the necessary mitigation actions are developed and implemented. Risk monitoring involves tracking risk-handling strategies, identifying new risks, and re-evaluating changes to previous risks and their impact on project cost.

Risk management is concerned with future events, whose outcome is unknown, and how to deal with those uncertainties by identifying and examining a range of possible outcomes. The objective is not to avoid risks but to understand and control them. Understanding the risks inherent with each potential project alternative is important to controlling cost and developing estimates that reflect the cost of accepted risks. The project team, not solely the estimator, can conduct a comprehensive risk analysis for all major projects. The purpose of such analyses is first to identify risks by likelihood of occurrence and consequences, and secondly to devise methodologies and strategies for avoiding or managing the risks. Risks must be defined to a level that an individual comprehends the causes and potential impacts.

Managers can continuously update risk assessments and modify their management strategies accordingly. A successful risk management program:

- Must be a planned and structured process, integral to the acquisition process;
- Have continual re-assessment of project and associated risks;
- Have metrics to monitor effectiveness of risk handling strategies; and,
- Require approval of accepted risks at the appropriate decision level.

The overriding objective of the risk management process is to identify potential project risks and implement actions that will mitigate the impact of the identified risks. Early risk identification and analyses should be "built-in" to the project development process. An event's probability of occurrence and consequences/impacts may change as the project development proceeds and additional information becomes available. Therefore, project managers and estimators must re-evaluate known risks on a periodic basis and examine the project for new risks.

A risk assessment should consider:

- *Requirements Definitio*n. The sensitivity of the project to scope uncertainty.
- *Environment, Safety, and Health.* The impacts that the project has or will have on the environment directly when completed and during construction (noise, lights, dust).
- *Design.* The ability of the contractor to achieve the project's engineering objectives based on the available technology and equipment.
- *Technology.* The degree to which the technology proposed for the project has been demonstrated as capable of meeting project objectives.
- *Logistics.* The ability to construct the project within the confines of the site based on the design and required support resources.

- *Concurrency.* The sensitivity of the project to the uncertainty resulting from adjacent or overlapping work or activities.
- *Capability of Contractor.* The resources of the contracting community to build the project. Some projects require specific experience, resources, and knowledge to be accomplished successfully.
- *Management Capability***.** The degree to which a qualified management team can be placed on the project by the SHA or to which the SHA can sufficiently staff the project.
- *Funding and Budget Management.* The sensitivity that the project has funding and budget changes.
- *Schedule.* The adequacy of the time allocated for performing the development and construction of the project. This factor includes the effects of programmatic schedule decisions, the inherent errors in the schedule estimating technique used, and external physical constraints.
- *Stakeholder, Legal, and Regulatory.* The sensitivity and degree to which these areas will impact the planning, performance, scope, schedule, and cost of the project.

Risk assessments can be deliberately performed prior to each phase of project development. For each identified risk, a risk handling strategy is formulated to ensure that the necessary actions are being developed and implemented. The method chosen to handle a risk is specific to that risk. There are no universal mitigation strategies except attempting to buy one's way out of the problem. Handling strategies are intended to either avoid the event or to mitigate (minimize the impact) the event. Risk mitigation can be an active endeavor continually performed during project development and the estimators must know what risk mitigation strategies are being applied.

Off-prism Strategy

Use proactive methods for engaging those external participants and conditions that can influence project costs. In the case of construction projects, engineers focus on technical solutions with little attention to community interest or concerns, the off-prism items. This focus has been changing in some cases where SHAs are experimenting with context sensitive design and construction (*A Guide to Best Practices for Achieving Context Sensitive Solutions* 2002, Werkmeister and Hancher 2001). However, technical alternatives are frequently discussed at early stages of project development before community outreach efforts are undertaken. Concerns related to the external effects of projects are not addressed until later in the project cycle. Such an approach can "… lead to project changes at a stage when such changes are particularly costly (Bruzelius et al. 1998)." "Lack of public involvement also tends to generate a situation in which those groups who feel concern about the project… are inclined to act destructively… (Bruzelius et al. 1998)."

Operationally, every project is executed in the context of a particular political, economic, and cultural environment. Since the early 1970s, researchers who have studied the issue of actual project cost exceeding estimated cost have pointed to time lags and external factors as being significant cost overrun drivers. Merewitz (1973) stated, "The most significant fact is that the longer the project continues the greater is there likely to be cost overruns." Delay creates greater time opportunity for increases in scope. Studies of the estimates prepared by the Corps of Engineers, the Tennessee Valley Authority (TVA), and the Bureau of Reclamation found that exogenous—*off-prism*—factors caused large cost increases (Hufschmidt and Gerin 1970). In the case of the TVA, 80 percent of the deviations could be characterized as exogenous.

The macro environment can affect cost growth in two ways: 1) by being unknown to some degree to estimators and managers; and 2) by changes in the environment. Unlike other aspects of project planning and estimating, understanding the macro environment, the off-prism items, has never been standardized as a part of project estimating. It is therefore important to develop early stage planning processes that focus on community concerns, requirements, and other off-prism issues.

The intent of the off-prism strategy is to have SHAs consider add-on elements or additional items that are not traditionally considered in a cost estimate. Local government concerns and market conditions are examples of add-on elements that cause cost escalation. When project development is initiated, the SHA should discuss concerns about the project with government officials so that potential problems and desires are addressed early when the project's scope is defined and when the project's cost can be influenced. Addressing government concerns early in project development enables the SHA to consider the concerns and incorporate related costs into the project's estimate. In addition, changing market conditions are inevitable and are difficult to define. However, recognizing their existence and providing associated costs allows the SHA to create an estimate that is more closely related to the actual project conditions than if the elements were not included. Considering the off-prism items should alleviate scope creep and scope changes that would otherwise occur as the off-prism items start to impact the project's development and ultimately the project's cost estimate.

Integrity Strategy

Insure checks and balances are in place to maintain estimate accuracy and minimize the impact of outside pressures that can cause optimistic biases in estimates. The potential for conceptual estimate error (on the low side) can result from pressure by project sponsors who seek the approval of their projects (CII Cost/Schedule Controls Task Force 1986). Conceptual estimating is an art, not a science. Clever people do not want to do it because in many SHAs it is a dead-end job and there is recognition of the pressures that can be brought to bear if estimators produce high estimates. In developing a conceptual estimate, judgment replaces straightforward material takeoffs and costing, therefore it is difficult to justify estimates quantitatively. Some SHA estimators expressed such frustrations during conversations with the research team.

The integrity strategy is one that SHAs can apply to their organization if bias tendencies and pressure from local government officials exists. Applying the integrity strategy enables the SHAs to implement a system that prevents bias actions because the estimators are not influenced by the political pressure that would hinder intentional underestimation. The intent of the integrity strategy is not to take accountability away from the estimators but to give the estimators an opportunity to accurately reflect the project's cost.

If SHAs truly want accurate project estimates, especially in the case of large complex projects, they must have management structures in place that shield estimators for external and internal pressures to produce a low project estimate. As part of such a structure, it is necessary to elevate the status of senior estimators and to provide them with the tools to defend their cost numbers. To produce accurate conceptual estimates SHAs need to enhance their cost databases and document factors that affect project cost. Just keeping a database of historical bid tabs is not sufficient to proving the necessary data for estimating; the data must be analyzed to provide information.

The five strategies presented in this chapter are intended to address the possible cost escalation factors identified in Chapter II. Table 9 illustrates the link between the global strategies and potential cost escalation factors, as described in previous sections. As the table shows, some of the strategies overlap cost escalation factors that they intend to mitigate.

Table 9. Link Between Strategies and Cost Escalation Factors

				Global Strategies				
				Estimate Quality	Document Quality	Risk	Off-Prism Issues	Integrity
Cost Escalation Factors	Planning	Internal	Bias					√
			Delivery/Procurement Approach			√		
			Project Schedule Changes	√				
			Engineering and Construction Complexities	√	√	√		
			Scope Changes			√	√	
			Poor Estimating	√	√			
			Inconsistent Application of Contingencies	√	√	√		
		External	Local Government Concerns and Requirements			√	√	√
			Effects of Inflation	√				
			Scope Creep				√	
			Market Conditions	√		√	√	

SUMMARY

Engineering skill and judgment invested in project planning is obscure to the general public, legislators, community leaders, and the media. Over-budget projects are easy for the public to understand. Nevertheless, who wants to appreciate the fine points of route alignment, difficult geotechnical conditions, wetlands mitigation analysis or community desires for a signature structure? SHAs need strategic approaches to cost estimating that:

- Avoid false precision – a big problem is created by early optimism.
- Relate contingency to the layman's everyday experiences with uncertainty.
- Invest in continuous and transparent QA/QC of estimating processes.

PRELIMINARY STRATEGIES, METHODS, AND TOOLS

Strategies for estimating practices must be applied across the continuum of project development phases. The definitions identified in Chapter I guided the description of a particular method and tool that supports the implementation of the global strategies. A method is described as "*a means or manner of procedure, especially a regular and systematic way of accomplishing something.*" Tools, on the other hand, are used to perform a method, as the definition of a tool suggests, *"something used in the performance of an operation [method]."* The methods and tools were aligned with the strategies based on their description in Chapter V and the potential cost escalation factors that the strategies are meant to mitigate. Figure 4 illustrates an example of selecting the appropriate strategy, method, and tool for a given cost escalation factor.

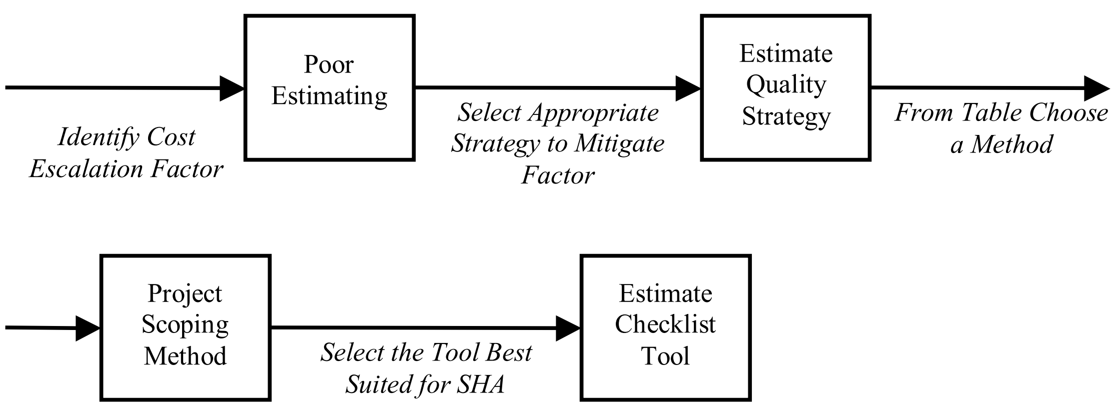

Fig. 4. Strategy, Method, and Tool Example

In this example, the estimate quality strategy addresses the cost escalation factor, poor estimating. Poor estimating consists of errors and omissions. Therefore, a method that can mitigate this factor is project scoping, which attempts to fully define the project's elements. A tool used to implement the method is an estimate checklist that contains project elements that might be included in a cost estimate.

Specific methods and tools that support implementation of the global strategies are shown in the following tables. The methods and tools displayed in these tables are based on those presented in Chapter V, only linked to specific strategies they support. The names of the methods and tools in each table correspond to the section titles in Chapter V so that the description can be easily located. As shown in these tables some methods have more than one tool that can be used to perform the method. In addition, the same method and tool can be applied in more than one project phase and strategy. The use of the method and tool may change slightly to fit cost estimating requirements for that particular phase or strategy. Finally, the tables indicate where a strategy may currently have only a small number of applicable methods and tools or none at all. In addition, project complexity affects the selection of the methods and tools used. For example, cost per lane mile estimating is not a suitable method to estimate an extremely complex project because the method does not provide enough detail for estimating a complex project. Furthermore, the strategies, methods, and tools in the tables are a preliminary list, and the effectiveness of the methods and tools was not considered in this research.

Planning Phase Strategies, Methods, and Tools

Current methods and tools being used by SHAs in support of planning phase estimating are shown in Table 10. The table shows that under the estimate quality strategy, the SHAs have several methods and tools that can be utilized. While some SHAs are beginning to deal with the impact of off-prism cost and schedule drivers by the use of context sensitive design, very few are engaging all of the other external influences. During the interview process, there were no reports of SHAs having structured processes for looking at integrity methods as they might influence cost estimating, which is exhibited by their absence in the planning table. Methods and tools will need to be developed to handle the integrity strategy so that the potential cost escalation factors linked to this strategy can be mitigated.

Table 10. Planning Phase Strategies, Methods, and Tools

	Planning	
Strategy	Method	Tool
1. Estimate Quality	Cost/Mile Factors Using Typical Sections	Cost/Mile Handbook
		Cost/Mile Spreadsheet Templates
	Cost/Mile Factors Using Similar Projects	Scoping Document
	Project Scoping	Estimate Checklist
		Scoping Document
	Recognition of Project Complexity	Complexity Definition
2. Document Quality	Document Estimate Basis and Assumptions	Project Estimate File
3. Risk	Contingency	Cost Estimate Validation Process - Estimate Ranges
		Contingency - Fixed Percentage
		Contingency - Sliding Scale
4. Off-Prism Issues	Add-on Elements	Percentage of Total Project Cost
5. Integrity		

Programming and Preliminary Design Phase Strategies, Methods, and Tools

Current methods and tools being used by SHAs in support of programming and preliminary design phase estimating are shown in Table 11. Again, the estimate quality strategy has numerous methods and tools that can be applied during the programming and preliminary design phase. In the area of estimate integrity, methods and tools were identified, but these methods and tools were not specifically intended to address the strategic issues of estimating integrity. However, they were included under the integrity strategy because they could serve to monitor estimate integrity. More tools and methods need to be developed to handle the off-prism issues that impact project cost and for achieving document quality.

Table 11. Programming and Advanced Planning/Preliminary Design Phase Strategies, Methods, and Tools

	Programming & Advanced Planning / Preliminary Design	
Strategy	Method	Tool
1. Estimate Quality	Identifying Major Cost Items	Spreadsheet Template (6-Page Estimate)
		In-house Estimating Software (Long Range Estimating)
	Volumetric Estimating	LWD Template
	Parametric Estimating	In-house Estimating Software (Long Range Estimating)
		Scope of Work Estimating Software
		AASHTO's Trns•port Software
	Project Scoping	Estimate Checklist
		Scoping Document
	Internal Estimate Reviews	In-house/Peer
		Formal Committee
		Estimate Checklist
	External Estimate Reviews	Expert Team
2. Document Quality	Internal Estimate Reviews	In-house/Peer
		Formal Committee
	External Estimate Reviews	Expert Team
	Document Estimate Basis and Assumptions	Project Estimate File
3. Risk	Contingency	Cost Estimate Validation Process - Estimate Ranges
		Contingency - Fixed Percentage
		Contingency - Sliding Scale
4. Off-Prism Issues	Add-on Elements	Environment Assessment
		Add-on Element Evaluation
5. Integrity	Internal Estimate Reviews	In-house/Peer
		Formal Committee
	External Estimate Reviews	Expert Team
	Validate Costs	Estimating Software
	Verify Scope Completeness	Estimate Checklist
	Consistent Estimate Processes	FHWA Mega Project Estimating Guidelines

Final Design Phase Strategies, Methods, and Tools

Current methods and tools being used by SHAs in support of final design phase estimating are shown in Table 12. The table shows that there is a notable lack of methods to address off-prism issues and for achieving document quality.

Table 12. Final Design Phase Strategies, Methods, and Tools

	Final Design	
Strategy	Method	Tool
1. Estimate Quality	Detailed Line Item Cost Estimates	In-house Estimating Software
		Historical Bid Price Databases
		AASHTO's Trns•port Software
	Cost Based Estimates	Estimating Spreadsheets
	Internal Estimate Reviews	In-house/Peer
		Formal Committee
	External Estimate Reviews	Expert Team
2. Document Quality	Document Estimate Basis and Assumptions	Project Estimate File
3. Risk	Contingency	Cost Estimate Validation Process - Estimate Ranges
		Contingency - Fixed Percentage
		Contingency - Sliding Scale
4. Off-Prism Issues	Contingency	Cost Estimate Validation Process - Estimate Ranges
		Contingency - Fixed Percentage
		Contingency - Sliding Scale
5. Integrity	Internal Estimate Reviews	In-house/Peer
		Formal Committee
	External Estimate Reviews	Expert Team

REVIEW OF RESULTS

In order to ensure the validity of the results, experts from the American Association of State Highway and Transportation Officials (AASHTO) Cost Estimating Task Force evaluated the results. The Technical Committee on Cost Estimating was created by the Standing Committee on Highways through the Subcommittee of Design to provide a focal point for cost estimating issues with AASHTO. At the validation meeting, fifteen members from the Task Force were present, and each member represented a different SHA. The meeting started with each member giving a short synopsis of the issues they are facing in their states.

Many SHA members discussed concerns that matched the strategies presented in this research. Market influences and intentional underestimation are some of the issues the SHAs are facing. They also stated that scope and risk are problems. The members cited two scoping dilemmas: 1) missing items and 2) additional items being added to the scope. The problems SHAs have to deal with closely correspond to those cost escalation factors discussed in this research. One member stated that SHAs are thinking about the issues presented but they do not have an executable method to address the issues during long-range planning, programming, and preliminary design/advanced planning, giving an indication that the results from the NCHRP 8-49 project could be useful to the SHAs.

After the task force explained the issues existing within their states, the researcher gave a brief presentation on the methodology used to collect and analyze the data. Then, each member was provided with a handout that contained the strategies with their definitions and the three strategies, methods, and tool tables shown previously in this chapter. The task force was given time to review the handout, and then a discussion about the results was conducted. The discussion was organized in the same manner as the rest of the research, by project development phase. Each strategy and the methods and tools that were aligned with the strategy were reviewed.

Once the discussion was completed, the task force had one recommendation, which was to add the method, cost based estimating, to the estimate quality strategy.

Although cost based estimating was discussed in Chapter V, it was not distinguished as a separate method. Therefore, per the task force's recommendation, cost based estimating was added to the final design table under estimate quality. With the exception of the one recommendation, the Task Force came to a consensus that the preliminary strategies, methods, and tools describing cost estimating practices were appropriate to begin testing. During phase two of the NCHRP 8-49 project, the preliminary strategies, methods, and tools will be confirmed.

CHAPTER VII
CONCLUSION

The following chapter provides a brief summary of the research presented, conclusions that were drawn from the study, and recommendations for future research concerning the study.

SUMMARY

Cost escalation is a major issue that the highway industry faces. From the initiation of a project to the completion of construction, many factors influence a project's final cost. Managing large expenditure construction projects requires the coordination of a multitude of human, organizational, technical, and natural resources. Quite often, the engineering and construction complexities of such projects are overshadowed by economic, societal, and political challenges. This research examines the reasons that may attribute to cost escalation and cost estimating practices that might address the cost escalation problem. In order to address this research problem, many questions were raised, and several objectives were established to address the research questions.

The first question considered the principal causes of cost escalation in SHA projects and the question was addressed by the objective of identifying possible root causes behind cost escalation. This objective was met by conducting an extensive literature review that was used to identify potential cost escalation factors. The literature review, described in this report, involved researching, gathering, and processing information and literature relevant to cost estimation practices. From the literature, possible cost escalation factors were identified and discussed. The next three questions requested the identification of current estimating practices including innovative practices that address cost escalation factors and when these approaches are implemented. To investigate these questions, interviews with SHAs were conducted. Through the interviews, cost estimating practices were identified and used to support the strategies developed. The last three questions asked what potential strategies address the discovered cost escalation factors, and what methods and tools can be used to implement these strategies. The intent of the second objective was to address these questions and this objective involved formulating preliminary strategies that address the root causes at the cost estimating process level. The second objective was achieved by reviewing the cost escalation factors and linking strategies to possible causes of cost escalation. The final objective was to create a list of preliminary strategies, methods, and tools that can be used to generate project cost estimates during the development phases. This objective was met by utilizing the data collected during the interview process. During the data analysis, unique and/or innovative cost estimating approaches were aligned with the appropriate strategies to form three tables. A strategies, methods, and tools table was created for each project development phase: planning, programming and advanced planning/preliminary design, and final design.

CONCLUSIONS

The individual factors that may lead to the cost escalation of projects have been identified through a large number of previous studies and research projects found in the literature. The current research compiled information from those previous studies and aligned causal factors with project development phases to identify possible core estimating assumptions that are the root causes behind cost escalation and lack of project estimate consistency and accuracy. These factors were categorized into internal and external influences.

Although numerous causes can lead to underestimation of project costs while preparing planning and design estimates, seven primary internal causes or factors have been well documented: bias, delivery/procurement approach, project schedule changes, engineering and construction complexities, scope changes, poor estimating, and inconsistent application of contingencies. Similarly, external factors may lead to underestimation of project costs. The primary external factors are local government concerns and requirements, effects of inflation, scope creep, and market conditions. According to the literature, these internal and external factors can cause significant project cost increases individually or in combination.

From the data collected, it was possible to identify unique and/or innovative approaches that may aid the SHAs in overcoming the factors that cause project cost escalation. The research linked cost escalation factors found in the literature to identified SHA approaches, which may addresses specific escalation factors. In general, all of those possible factors causing project cost escalation, as noted in the literature and discussed in this report, receive some attention by SHAs; however, no SHA addresses all of the factors.

Five overarching or global strategies were produced. They are:

1) **Estimate Quality Strategy** – Use qualified personnel and uniform approaches to achieve improved estimate accuracy;
2) **Document Quality Strategy** – Promote cost estimates accuracy and consistency through improved project documents;
3) **Risk Strategy** – Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed;
4) **Off-prism Strategy** – Use proactive methods for engaging those external participants and conditions that can influence project costs; and
5) **Integrity Strategy** – Insure checks and balances are in place to maintain estimate accuracy and minimize the impact of outside pressures that can cause optimistic biases in estimates.

Methods and tools that would likely be effective in implementing the global strategies are directed at mitigating root causes of estimate problems in a focused approach. The preliminary strategies, methods, and tools are also matched to project development phase where they would likely be implemented. Some of the methods that were revealed include identifying major cost items, project scoping, and cost based estimating. To support the methods, several tools were also identified, and they include tools such as a project estimate file, estimating software, and estimating checklists. The overall purpose of this research was to find a way to mitigate cost escalation factors that is pertinent to the highway industry. From the information included in this thesis, the researcher found that the highway industry has a large task to overcome the cost estimating problems. In other words, the preliminary strategies, methods, and tools presented in this thesis may assist in alleviating the cost escalation issues, but further research should be conducted to find an appropriate technique to implement the strategies, methods, and tools in an applicable manner.

RECOMMENDATIONS FOR FUTURE RESEARCH

For this research project, a list of preliminary strategies, methods, and tools were produced. Since this list was only preliminary, their effectiveness to mitigate cost escalation was not addressed. Therefore, this research could be implemented to validate the effectiveness of the results. The NCHRP 8-49 project that was conducted in conjunction with this research study intends to perform such a task. The NCHRP 8-49 project plans to collect additional information to better understand the methods and tools presented in this research study. The research team plans to develop a ranking system that ranks how effective the methods and tools are at mitigating the cost escalation factors in the highway industry. In addition, the NCHRP project will addressed project complexity in more depth than was performed in this study. The final result for the NCHRP 8-49 project will be a guidebook that contains recommended strategies, methods, and tools that can be used by SHA personnel.

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APPENDIX A
INTERVIEW PROTOCOL

Texas Transportation Institute

MEMORANDUM
January 14, 2005

TO: Survey Participant

FROM: Stu Anderson
Principal Investigator

SUBJECT: NCHRP 8-49 Interview Questionnaire

Thank you for participating in the NCHRP 8-49 Research Project concerning procedures for cost estimation and management for highway projects during planning, programming, and preconstruction. We have enclosed some brief background information about the research project along with the questionnaire we plan to discuss with you during our phone interview. A research team member will call you on the day and time agreed upon to conduct the interview. Please review the questionnaire prior to the interview to become acquainted with the nature of the questions that we will be discussing. If you would like any additional information, you may visit our website at http://construction.colorado.edu/nchrp8-49/Desktop.aspx.

If you have any questions, please contact me by telephone at 979-845-2407 or by email at s-anderson5@tamu.edu.

Background

The Texas Transportation Institute (TTI) is conducting an NCHRP project (8-49) entitled "Procedures for Estimating and Management for Highway Projects During Planning, Programming, and Preconstruction." The research team consists of Dr. Stuart Anderson (Principal Investigator), Dr. Keith Molenaar (Co-Principal Investigator), Dr. Cliff Schexnayder (Consultant), as well as an industry review and implementation team. This project focuses on the cost escalation problem that every state highway agency, transit agency, and metropolitan planning organization faces. This problem is manifested in cost management approaches and cost estimate processes that often do not promote consistency and accuracy of costs over the project development process. The transportation industry problem of accurately estimating project cost will be addressed by accomplishing the following main objective:

> *Develop a guidebook on highway cost estimating management and project cost estimating procedures aimed at achieving greater consistency and accuracy between long-range transportation planning, priority programming, and preconstruction estimates.*

Because the study scope requires the research team to consider estimating procedures and management methods during various phases of project development, we have developed an interview instrument that addresses the following general issue areas:

1. How conceptual estimates are prepared for long range-planning and priority programming;
2. How advanced planning/preliminary design estimates are prepared;
3. Procedures for preparing engineer's estimates; and
4. Methods for managing cost estimates between project development phases.

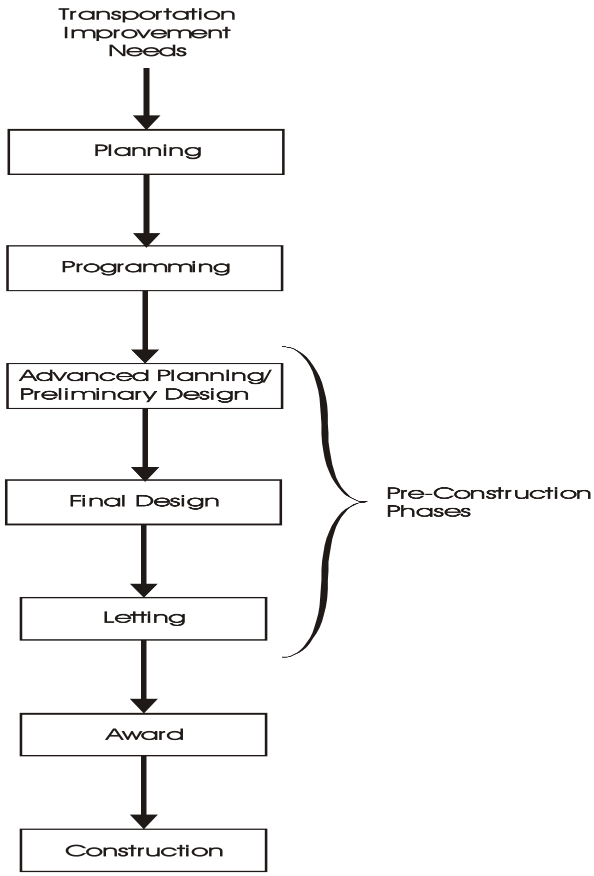
The task will focus on two separate but interrelated areas: 1) cost estimation management; and 2) cost estimation procedures. The team will assemble "state of practice" estimating information by project development phase so that the final guidelines will present tools to develop, track (manage), and document realistic cost estimates during each phase of a project. For the purpose of this research project, we have defined the different project phases shown in Figure 1 and further described in Table 1.

Instructions

We have enclosed a questionnaire with sections relevant to the first four project phases and types of cost estimates typically prepared in these project phases (see Figure 1). This survey will be conducted via telephone and based on a short interview questionnaire. A NCHRP 8-49 project member will contact you to set up an interview time. During the interview, all persons representing your state agency may be present for a group interview, or each person can be interviewed individually. The telephone interview will last approximately 30 minutes to an hour depending on the number of individuals involved in the discussion. The questionnaire to be discussed has been attached for review prior to the telephone interview. Please note that not all the questions will apply to every individual. The research team would also appreciate receiving any supplemental information regarding the DOT's estimating methods and tools such as computer programs and guidelines.

Table 1. Project Development Stages and Activities

PROJECT DEVELOPMENT PROCESS PHASES	TYPICAL ACTIVITIES
Planning	Purpose and need; improvement or requirement studies; environmental considerations; interagency coordination
Programming	Environmental determination; schematic development; public hearings; ROW plan; project funding authorization
Advanced Planning/ Preliminary Design	ROW development; environmental clearance; design criteria and parameters; surveys/utility locations/drainage; preliminary schematics such as alternative selections; geometric alignments; bridge layouts
Final Design	ROW acquisition; PS&E development – pavement and bridge design, traffic control plans, utility drawings, hydraulic studies/drainage design, final cost estimates
Letting	Prepare contract documents; advertise for bid; pre-bid conference; receive and analyze bids
Award	Determine lowest responsive bidder; initiate contract
Construction	Mobilization; inspection and materials testing; contract administration; traffic control, bridge, pavement, drainage construction



ESTIMATE TYPE

Conceptual

Conceptual

Preliminary Design – Parametric, Others

Detailed Engineer's Estimate

Source: *NCHRP Synthesis 33-09 "Statewide Highway Letting Program Management" Stuart D. Anderson and Byron C. Blaschke January 2004*

Figure 1 – Typical Project Development Phases for Highway Projects

- For further information regarding this project please visit our website at http://construction.colorado.edu/nchrp8-49/Desktop.aspx

Conceptual Estimates (Long-Range Planning):

Contact:

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing *long range planning conceptual estimates*? If these policies, procedures, techniques, and/or standards are formally documented (written), can you provide us with a copy or a website location where we can obtain a copy?

2. How do you insure that conceptual estimates reflect all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time conceptual estimates are prepared?

3. What types of historical data do you use as a basis for preparing conceptual estimates? How is this data adjusted for time (schedule), location, and other project specific conditions?

4. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

Estimate Reviews

5. Is there a formal estimate review within the DOT?

Estimate Communication

6. Is there a systematic program that is used to standardize estimating procedures and train those responsible for assembling the estimates?

7. Who approves the *long range planning conceptual estimate*? Once approved, is the *planning conceptual estimate* communicated to executive management and/or the public as a point estimate (one number) or as a range of values with an indication of reliability?

Cost Estimating Management

8. Are there established cost-reporting mechanisms to control changes resulting from project scope development and schedule after *long range planning conceptual cost estimates* are prepared? If so, please describe these mechanisms.

Conceptual Estimates (Programming):

Contact:

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing *programming conceptual estimates*? If these policies, procedures, techniques, and/or standards are formally documented (written), can you provide us with a copy or a website location where we can obtain a copy?

2. How do you insure that conceptual estimates reflect all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time conceptual estimates are prepared?

3. What types of historical data do you use as a basis for preparing conceptual estimates? How is this data adjusted for time (schedule), location, and other project specific conditions?

4. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

Estimate Reviews

5. Is there a formal estimate review within the DOT? If yes, go to 5a. If no, go to 5b.

5a. Is there a set of formalized and institutionalized procedures for conducting such reviews? What are the milestones for these reviews? What personnel outside of those responsible for preparing the estimate are involved in the review?

5b. How does your DOT verify an estimate?

6. Does project value or project complexity trigger additional reviews? If so, what are these trigger values?

Estimate Communication

7. Is there a systematic program that is used to standardize estimating procedures and train those responsible for assembling the estimates?

8. What formal mechanisms are used for capturing and transferring knowledge about cost estimating techniques?

9. Who approves the *programming conceptual estimate*? Once approved, is the *programming conceptual estimate* communicated to executive management and/or the public as a point estimate (one number) or as a range of values with an indication of reliability?

Cost Estimating Management

10. Are cost differences between *long range planning conceptual cost estimates* and *programming conceptual cost estimates* reconciled? If so, how is reconciliation performed?

11. Are there established cost-reporting mechanisms to control changes resulting from project scope development and schedule after *programming conceptual cost estimates* prepared? If so, please describe these mechanisms.

12. What triggers an update of an estimate during the long-range planning and programming process? Are estimates updated on a periodic basis, when design major changes occur, or through some other triggering mechanism?

Preliminary Design Estimates (Advanced Planning/Prelim Design):

Contact:

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing *advanced planning/preliminary design estimates*? If these policies, procedures, techniques, and/or standards are formally documented (written) can you provide us with a copy or a website location where we can obtain a copy?

2. How frequent are estimates prepared (or updated) during *advanced planning/preliminary design estimates*? What is the percent design completion when each of these estimates is prepared? What triggers the update of an estimate (i.e. a set periodic basis, when design changes occur, or through some other triggering mechanism)?

3. How do you insure that *advanced planning/preliminary design estimates* reflect all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time *advanced planning/preliminary design estimates* are prepared?

4. What types of historical data do you use as a basis for preparing *advanced planning/preliminary design estimates*? How is this data adjusted for time (schedule), location, and other project specific conditions?

5. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

Estimate Reviews

6. Is there a formal estimate review within the DOT? If so, go to 7a. If no, got to 7b.

7a. Is there a set of formalized and institutionalized procedures for conducting such reviews? What personnel outside of those responsible for preparing the estimate are involved in the review?

7b. How does your DOT verify an estimate?

8. Does project value or project complexity trigger additional reviews? If so, what are these trigger values?

Estimate Communication

9. Who approves the *advanced planning/preliminary design estimates*? Once approved, is the *advanced planning/preliminary design estimates* communicated to executive management and/or the public as a point estimate (one number) or as a range of values with an indication of reliability?

Cost Estimating Management

10. Are there established cost-reporting mechanisms to control changes resulting from project design development and schedule after *advanced planning/preliminary design estimates* are prepared? If so, please describe these mechanisms.

11. Is there a reporting system for managing changes that provides traceable and visibility for all changes?

12. Is there an established reporting system that provides the necessary data to each level of management to track the cost, schedule, and scope of a project?

13. Are cost changes between different *advanced planning estimates/preliminary design estimates* reconciled, as these estimates are prepared? If so, how is reconciliation performed?

Engineer's Estimate (at Final Design (PS&E Completion)):

Contact:

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing the *Engineer's estimate*? If these policies, procedures, techniques, and/or standards are formally documented (written) can you provide us with a copy or a website location where we can obtain a copy?

2. How do you insure that the *Engineer's estimate* reflects all elements of project scope (e.g., related to construction administration, construction, etc.) as defined at the time the *Engineer's estimate* is prepared?

3. What types of historical data do you use as a basis for preparing the *Engineer's estimate*? How is this data adjusted for time (schedule), location, and other project specific conditions

4. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

Estimate Reviews

5. Is there a formal estimate review within the DOT? If yes, go to 5a. If no, go to 5b.

5a. Is there a set of formalized and institutionalized procedures for conducting such reviews?

5b. How does your DOT verify an estimate?

6. Does project value or project complexity trigger additional reviews? If so, what are these trigger values?

Cost Estimating Management

7. Are cost differences between *advanced planning/preliminary design estimate* and the *Engineer's estimate* reconciled? If so, how is reconciliation performed?

APPENDIX B
CONTACT LETTER

Date 2004

Name
Address

Dear Name:

The Texas Transportation Institute (TTI), under the AASHTO-sponsored National Cooperative Highway Research Program, is conducting Project 8-49, "Procedures for Cost Estimation and Management for Highway Projects During Planning, Programming and Preconstruction." The objective of this research is *to develop a guidebook on highway cost estimating management and project cost estimating procedures aimed at achieving greater consistency and accuracy between long-range transportation planning, priority programming, and preconstruction estimates*. This work is being conducted by TTI in collaboration with Dr. Keith Molennar of the University of Colorado, and Dr. Cliff Schexnayder, Consultant and formerly with Arizona State University.

Because the study scope requires the research team to consider estimating procedures and management methods during various phases of project development, we are seeking your help in identifying, for your State Highway Agency (SHA), a point of contact individual or individuals who are knowledgeable about:

5. How conceptual estimates are prepared for long range-planning and priority programming;
6. How advanced planning/preliminary design estimates are prepared;
7. The procedures for preparing engineer's estimates; and
8. Methods for managing cost estimates between project development phases

We would like to contact the appropriate individual(s) directly over the telephone or via e-mail to arrange appropriate telephone interviews. The interview will be for the purpose of understanding scope definition and estimating procedures currently in use by your SHA and to obtain copies of policy and procedure documents. Our focus is to assemble state of practice estimating information and to understand what factors cause estimating accuracy problems. We would also like to gain an understanding of how cost estimates are managed as the scope of a project is developed.

You participated in the TRB sponsored workshop on Cost Estimating. As your may recall, I made a short presentation on the 8-49 research project at this workshop. We selected your name because of your interest in this subject. We think that different individuals may be involved in different types of estimates at different times in a project. Please use the attached form to provide a contact person or persons that you believe can help us with this research. My contact information by telephone is 979-845-2407 or by email at s-anderson5@tamu.edu.

We hope that you will be able to help us with this request and look forward to working with your department on this important project.

NCHRP Project 8-49 Procedures for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction

Please return this page via fax, email or mail to:

Stu Anderson, Ph.D., P.E.
Manager, Construction Program
Texas Transportation Institute
3135 TAMU
College Station, TX 77843-3135
Fax: 979-845-6554 Email: s-anderson5@tamu.edu

Conceptual Estimating Contact (long-range planning and programming)

Name: ____________________
Agency: ____________________
Department: ____________________
Address: ____________________
____
City, State Zip ____________________
Phone: ____________________
Fax: ____________________
Email:

Preliminary Design Estimating Contact

Name: ____________________
Agency: ____________________
Department: ____________________
Address: ____________________
____
City, State Zip ____________________
Phone: ____________________
Fax: ____________________
Email:

Pre-Bid Design Estimating Contact (Engineer's Estimate)

Name: ____________________
Agency: ____________________
Department: ____________________
Address: ____________________
____
City, State Zip ____________________
Phone: ____________________
Fax: ____________________
Email: ____________________

APPENDIX C
EXAMPLE INTERVIEW DOCUMENTATION

Department of Transportation
Date of Interview

Particpants

Documentation Provided

- Policy Analysis and Program Evaluation Handbook
- Long Range Estimate Program Manual
- Link to the department's external website

Interview Summary

Strengths of the DOT

- The DOT has a State Estimator that oversees the estimating policies and procedures and reviews the estimates once they are programmed.
- The DOT uses the same estimating program to generate their estimates from conception to the final estimate. This consistency enables the department to have a standardized method for estimating.
- The DOT also requires their estimators to participate in a training session that teaches them how to use their computer software, and they have estimating manuals that explain the estimating procedure.
- The estimating program provides the department with a scope tracking system that documents all changes, and they require justification of the changes.
- The department has an extensive historical database that sorts data by location, project type, etc.

Weaknesses of the DOT

- For long-range planning, the department does not include contingency and does not have a written procedure for reviews.
- The DOT does not compare the estimates from the different project phases.
- The DOT does not perform a risk analysis when they apply contingency.

Overview of Project Development Phases

The Department of Transportation has seven districts and the Turnpike. The DOT's planning phase begins when a project is identified for their 2010 or 2020 plan. The department's State Transportation Improvement Program (STIP) is three years long. The preliminary design estimate starts at 0% design and is updated at 30% design, 60% design, and 90% design. At 100% design, the estimate moves into the engineer's estimate.

General Comments

- *The Department of Transportation gave the research team a copy of their Policy Analysis and Program Evaluation Handbook and their Long Range Estimate Program Manual.*

- *The DOT has a State Estimates Office that reviews the estimates and attempts to make improvements in their estimating procedures. The districts produce the estimate, conduct* *internal reviews, and update the estimate. The project manager relays project changes to the estimators as soon as they discover them.*

- *The DOT develops a planning estimate for the projects in their long-range plan by using historical cost per a mile data. During the programming stage, the scope of the project is developed and a conceptual typical section is used in the estimate. At 0% design, the project enters the advanced planning and preliminary design phase. For the preliminary design estimate, the available details are used to create the estimates along with typical sections where design has not been completed. An estimate is produced at 0%, 15%, 30%, and 90% during this stage. The project estimate is inputted into the long range estimate program from programming up to the engineer's estimate. The engineer's estimate is conducted using the 100% design details, and the estimate details are transferred from the LRE program to Trns•port.*

Conceptual Estimates (Long-Range Planning):

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing *long range planning conceptual estimates*? If these policies, procedures, techniques, and/or standards are formally documented (written), can you provide us with a copy or a website location where we can obtain a copy?

The purpose of the planning estimate is to determine a list of potential projects for the Department of Transportation (DOT) that goes into their 2010 and 2020 plans. The Districts use cost per a mile data from the DOT Policy Analysis and Program Evaluation Handbook. The handbook's Table of Contents lists various project types. Depending on the project type, the estimator chooses the corresponding project typical from the handbook. Then, the estimator chooses the appropriate cost chart that would best fit the estimated project. The cost listed is dollars per a lane mile for the chosen typical. The right-of-way (ROW) is a percentage of the estimated construction cost, and the engineering costs are based on a ratio of engineering to construction cost. The engineering cost includes preliminary engineering, construction engineering inspection, right-of-way support, and related overhead costs.

The Turnpike Enterprise has a general consultant that produces an estimate at the conceptual stage using DOT data. They also apply their knowledge to the estimate. After the general consultant creates the conceptual estimate, the Turnpike Enterprise reviews the estimate to ensure the correct areas are covered. Usually, the DOT personnel act as an administrator overseeing the consultants for the turnpike.

2. How do you insure that conceptual estimates reflect all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time conceptual estimates are prepared?

The Long Range Estimate (LRE) manual has several typical sketches that are used to create the conceptual estimate. The typical sketches help the DOT decide on what additional elements are needed. At the planning stage, the pavement thickness, materials, lane widths, etc. are typical numbers. Once the project reaches the programming stage, more information should be known about the project so that the pavement thickness can be adjusted to the desired size and so on. The base cost is the construction cost, and therefore, the preliminary engineering, civil engineering, inspection, and right-of-way costs must be added.

3. What types of historical data do you use as a basis for preparing conceptual estimates? How is this data adjusted for time (schedule), location, and other project specific conditions?

The data used for conceptual estimating comes from the Long Range Estimate program created by DOT. The LRE data represents present day costs that are inflated to the letting year. The planning manual has inflation factors that are applied to the planning estimate. The unit price data is updated every six months. The high and low bids from across the state are thrown out, and the remaining bids are averaged creating DOT's historical data base.

4. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

The districts do not include contingency in their long-range planning estimate.

The Turnpike Enterprise includes scope creep in their planning estimate to cover any unknown costs and is a percentage (25%) of the estimated cost. As the project becomes more defined, the scope creep decreases.

Estimate Reviews

5. Is there a formal estimate review within the DOT?

The review is based on complexity of the project, and does not follow any written procedures. An estimate will not be programmed until the estimate goes through their turnpike department.

Estimate Communication

6. Is there a systematic program that is used to standardize estimating procedures and train those responsible for assembling the estimates?

The LRE program is used by each district and the Turnpike Enterprise. All estimators are required to go through a LRE training session.

7. Who approves the *long range planning conceptual estimate*? Once approved, is the *planning conceptual estimate* communicated to executive management and/or the public as a point estimate (one number) or as a range of values with an indication of reliability?

For the districts, the planning estimate is reviewed by the person creating the estimate.

A general consultant prepares a planning estimate, which is then reviewed by the Turnpike Enterprise.

The planning estimate is released to the local MPO's so that they know how much the project will cost. However, the legislators are not notified unless they have a particular reason to be interested.

Cost Estimating Management

8. Are there established cost-reporting mechanisms to control changes resulting from project scope development and schedule after *long range planning conceptual cost estimates* are prepared? If so, please describe these mechanisms.

Not discussed.

Conceptual Estimates (Programming):

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing *programming conceptual estimates*? If these policies, procedures, techniques, and/or standards are formally documented (written), can you provide us with a copy or a website location where we can obtain a copy?

The project development group creates different alternatives and then chooses the best one that meets the community's needs. Then they use the LRE Program to produce the program estimate. Each section of the project can be broken up into different typical sketches. The estimator starts with a preloaded typical and then adjusts it according to the site conditions and location. The location can be divided by county, market area, or statewide.

2. How do you insure that conceptual estimates reflect all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time conceptual estimates are prepared?

At the programming stage, the estimate is becoming project specific. The DOT tries to identify the large cost items, such as sound walls, incorporated structures, retaining walls, and clearing work. The estimator can visit the site and decide what extensive work items need to be included in order to match the cost with site conditions.

3. What types of historical data do you use as a basis for preparing conceptual estimates? How is this data adjusted for time (schedule), location, and other project specific conditions?

The same historical data from the LRE program that is used for planning is also used for programming. The LRE system has unit costs based on county, market area, and statewide. The estimator also has the ability to change the unit price if they found another source. Season and work conditions also affect the unit cost.

4. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

The further the project is defined, then the scope creep can be reduced. The estimators try to include any known items. The districts add 20% to their programming estimate.

For the turnpike, excess construction work due to accessibility is included in contingency.

Estimate Reviews

5. Is there a formal estimate review within the DOT? If yes, go to 5a. If no, go to 5b.

Yes, there is a formal estimate review within the DOT.

5a. Is there a set of formalized and institutionalized procedures for conducting such reviews? What are the milestones for these reviews? What personnel outside of those responsible for preparing the estimate are involved in the review?

The State Estimates Office reviews the estimates in the work program that are over $500,000, all bridges, and long term estimates once a year.

~~5b. How does your DOT verify an estimate?~~

6. Does project value or project complexity trigger additional reviews? If so, what are these trigger values?

The State Estimates Office makes sure the estimate in the LRE is close to what is programmed so that it is reasonable. The indicators of scope are which typical was used and what costs were used. The LRE program has reports that show if the estimate is outside the default quantities. If the estimate is more than 15% outside of the default than the line item is flagged. If the line items are the same but have different costs, then the LRE program will identify the differences.

Estimate Communication

7. Is there a systematic program that is used to standardize estimating procedures and train those responsible for assembling the estimates?

Each district and the Turnpike Enterprise use the LRE program. All estimators are required to go through a LRE training session.

8. What formal mechanisms are used for capturing and transferring knowledge about cost estimating techniques?

The DOT has an internal website that allows the estimators through out the state to post information about each project, which can then be accessed by other DOT personnel. Any updates or changes made to the estimate, when the changes were made, and why they were made are inputted and tracked at the website. The type of estimate conducted is also documented.

9. Who approves the *programming conceptual estimate*? Once approved, is the *programming conceptual estimate* communicated to executive management and/or the public as a point estimate (one number) or as a range of values with an indication of reliability?

The State Estimates Office approves the programming conceptual estimate. The estimate is public information, and legislators will see the number. The DOT meets with the legislators and present their budget for work in the year.

Cost Estimating Management

10. Are cost differences between *long range planning conceptual cost estimates* and *programming conceptual cost estimates* reconciled? If so, how is reconciliation performed?

The District does not go back and compare the programming estimate with the planning estimate.

The Turnpike Enterprise does go back to the planning estimate and compares it to the programming estimate. They track every change that occurs from project inception so that they know why the costs might be different.

11. Are there established cost-reporting mechanisms to control changes resulting from project scope development and schedule after *programming conceptual cost estimates* prepared? If so, please describe these mechanisms.

The LRE program has a scope tracking system. However, the planning estimates do not have project numbers attached to it. Therefore, the programming estimate initiates the tracking of the estimate. Again, the Turnpike Enterprise does track changes in the project (#10).

12. What triggers an update of an estimate during the long-range planning and programming process? Are estimates updated on a periodic basis, when design major changes occur, or through some other triggering mechanism?

The estimator has to justify all changes. If the estimate is increasing, they must explain the reason why. The estimator has to fill out a form that the project manager and his supervisor have to sign. Then, the change is updated in the work program. DOT has the ability to put old and new estimates together and compare them.

Preliminary Design Estimates (Advanced Planning/Prelim Design):

Estimate Preparation

1. Describe policies, procedures, techniques, and/or standards used in preparing *advanced planning/preliminary design estimates*? If these policies, procedures, techniques, and/or standards are formally documented (written) can you provide us with a copy or a website location where we can obtain a copy?

The Department of Transportation continues to use the LRE program for their Preliminary Design Estimate.

2. How frequent are estimates prepared (or updated) during *advanced planning/preliminary design estimates*? What is the percent design completion when each of these estimates is prepared? What triggers the update of an estimate (i.e. a set periodic basis, when design changes occur, or through some other triggering mechanism)?

The Preliminary Design Estimate also called the Scoping Estimate by the DOT, starts at 0% design. The estimates are updated at 30% design, 60% design, and 90% design. At 100% design, the estimate moves into the engineer's estimate. Before the engineer's estimate occurs, an authorization estimate is also conducted for federal aid purposes. The 100% estimate is for budgeting purposes and is prepared about three months before letting.

3. How do you insure that *advanced planning/preliminary design estimates* reflect all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time *advanced planning/preliminary design estimates* are prepared?

The difference between each estimate created at this stage is that more pay items are identified as the scope becomes more defined. The plans that are developed at each estimate helps further define the cost. At 0% design, the estimate could have about 100 line items. The number does not increase much, but the quantities become more defined. The estimators work with the project manager to ensure items are not overlooked. The estimates do not include utility costs, except transmission lines and rail lines.

4. What types of historical data do you use as a basis for preparing *advanced planning/preliminary design estimates*? How is this data adjusted for time (schedule), location, and other project specific conditions?

The same historical data from the LRE program that is used for planning and programming is also used for advanced planning/preliminary design estimates. The LRE system has unit costs based on county, market area, and statewide. The estimator also has the ability to change the unit price if they found another source. Season and work conditions also affect the unit cost.

5. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

A risk analysis is not conducted. As the project becomes more defined, the contingency is reduced. The districts include an "initial contingency," which is for unforeseen changes in construction. This contingency is a non-bid item, and it is 5% of the cost for projects less than a million dollars. For projects over a million dollars and less than 5 million dollars, the initial contingency is $50,000, and for projects 5 to 15 million dollars, it is 1% of the cost or a maximum of $150,000.

For the turnpike, a standard percentage of 25% is applied to the estimate during Phase I (30% Design). A 20% contingency is applied during Phase II (60% Design), and a 15% contingency is applied to the estimate during Phase III (90% Design). During Phase IV (100% design), a 5% contingency is added to the estimate. Risk assessments are done on specific line items.

<u>Estimate Reviews</u>

6. Is there a formal estimate review within the DOT? If so, go to 7a. If no, got to 7b.

Yes, there is a formal estimate review within the DOT.

7a. Is there a set of formalized and institutionalized procedures for conducting such reviews? What personnel outside of those responsible for preparing the estimate are involved in the review?

The DOT does not review each estimate from 0 to 90 percent of the design. The district is still observing cost and changes, and they continue to notify the project manager of any changes. The program value is not changed unless it is more than 10% of the cost or one million dollars over the previous estimate.

For the turnpike, the program value is adjusted based on assessment, and all changes are documented on their website. The estimates are still reviewed by their office.

The project manager also reviews the estimate, and if they find items that need to be added then they will inform the estimating team.

7b. How does your DOT verify an estimate?

8. Does project value or project complexity trigger additional reviews? If so, what are these trigger values?

The LRE program has reports that show if the estimate is outside the default quantities. If the estimate is more than 15% outside of the default than the line item is flagged. If the line items are the same but have different costs, then the LRE program will identify the differences.

Estimate Communication

9. Who approves the *advanced planning/preliminary design estimates*? Once approved, is the *advanced planning/preliminary design estimates* communicated to executive management and/or the public as a point estimate (one number) or as a range of values with an indication of reliability?

The advanced planning/preliminary design estimates are approved within the district. Then they are communicated at a state level.

Cost Estimating Management

10. Are there established cost-reporting mechanisms to control changes resulting from project design development and schedule after *advanced planning/preliminary design estimates* are prepared? If so, please describe these mechanisms.

If any changes have occurred after scoping the project, then they have to be signed off on by a production director or secretary of transportation.

11. Is there a reporting system for managing changes that provides traceable and visibility for all changes?

All changes are documented and are traceable through their website and the LRE program.

12. Is there an established reporting system that provides the necessary data to each level of management to track the cost, schedule, and scope of a project?

LRE has reports and their website. The LRE program has the ability to produce several reports that can be sorted different ways. A report can be created that compares the default estimate to any changes made to the estimate. The program also has a check system that identifies costs or quantities that are out of tolerance.

13. Are cost changes between different *advanced planning estimates/preliminary design estimates* reconciled, as these estimates are prepared? If so, how is reconciliation performed?

The District does not go back and compare the advanced planning estimates/preliminary design estimates.

The Turnpike Enterprise does go back to the each advanced planning estimate/preliminary design estimate and compares it to the previous estimate. They track every change that occurs from project inception so that they know why the costs might be different.

Engineer's Estimate (at Final Design (PS&E Completion)):

<u>Estimate Preparation</u>

1. Describe policies, procedures, techniques, and/or standards used in preparing the *Engineer's estimate*? If these policies, procedures, techniques, and/or standards are formally documented (written) can you provide us with a copy or a website location where we can obtain a copy?

The Engineer's Estimate is the official estimate, and the bids are compared against this estimate. The estimate is usually prepared a month before letting. At this stage, the estimators shift from the LRE program to Trns●port (PES and CES). The Proposal and Estimates System (PES) is where DOT manages their projects so that the projects can be transferred to the Cost Estimation System. The Cost Estimation System (CES) is where the estimators do their unit pricing.

2. How do you insure that the *Engineer's estimate* reflects all elements of project scope (e.g., related to design, construction administration, construction, right of way, environmental, etc.) as defined at the time the *Engineer's estimate* is prepared?

The estimator works with the project manager to ensure that all elements are covered.

3. What types of historical data do you use as a basis for preparing the *Engineer's estimate*? How is this data adjusted for time (schedule), location, and other project specific conditions.

The CES program uses historical data and regression models. The regression models take into account quantity, season, market area, and date. Inflation is not included because they use present day costs. Regression curves help the estimator know how reliable their unit cost is. For example, if the regression curves show that 4 out of 6 categories apply to the unit cost used, then the estimator can be fairly certain the unit cost is precise.

4. How are contingency amounts incorporated into the estimate? Are contingency amounts based on total estimated cost, identified project risks, or some other variables?

The only contingency is the "initial contingency" that was discussed in the Preliminary Design Estimate.

Estimate Reviews

5. Is there a formal estimate review within the DOT? If yes, go to 5a. If no, go to 5b.

Yes, there is a formal estimate review within the DOT.

5a. Is there a set of formalized and institutionalized procedures for conducting such reviews?

The districts do an internal review, and a quality assurance team, which is comprised of senior project managers, reviews the estimate. All disciplines look at the plans to insure that all items are covered in the estimate. Then the State Estimates Office reviews the estimate to make certain that items are included, but they do not usually look at unit prices.

The Turnpike conducts their own review.

5b. How does your DOT verify an estimate?

6. Does project value or project complexity trigger additional reviews? If so, what are these trigger values?

Cost Estimating Management

7. Are cost differences between *advanced planning/preliminary design estimate* and the *Engineer's estimate* reconciled? If so, how is reconciliation performed?

Once the project's estimate is entered into Trns•port's CES, it becomes confidential.

VITA

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