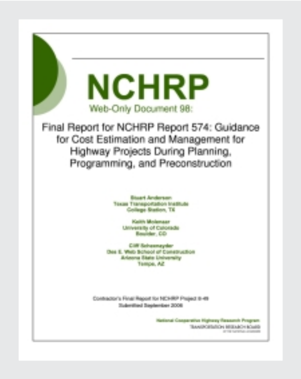

Final Report for NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction

DETAILS

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Note: The Guidebook referred to in this report has been published separately as *NCHRP Report 574*. Readers can read or purchase *NCHRP Report 574* at http://trb.org/news/blurb_detail.asp?id=7271.

SUMMARY

Project cost escalation is a major problem for State Highway Agencies (SHAs). Over the time span between the initiation of a project and the completion of construction many factors influence a project's final costs. 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 developed a Guidebook on highway cost estimation practice and cost estimation management aimed at achieving greater consistency and accuracy between planning, programming and preliminary design, and final design. The Guidebook provides appropriate strategies, methods, and tools to develop, track, and document realistic cost estimates during each phase of the process.

The research was divided into ten tasks spanning equally over two phases. Phase I of the research involved tasks that included an extensive literature review, SHA interviews to assess current practice, a critical review to determine general deficiencies in current practice, and the formulation of strategies, methods, and tools to address cost escalation. The literature review, described in this report, involved researching, gathering, and processing information and literature relevant to cost estimation practice and cost estimation management, but it was found that literature on cost management in the transportation area was virtually nonexistent. As a result, many other sources were examined. The transportation literature more often addresses problems that are frequently associated with larger and more complex projects. To augment the literature analysis, interviews and discussions were conducted with 23 state SHAs to determine current state-of-practice in this area.

The individual factors that lead to the cost escalation of projects were identified through a large number of previous studies and research projects. The current research compiled information from those previous studies and aligned causal factors with project development phases to identify the core estimation assumptions that are the root causes behind cost escalation and lack of project estimate consistency and accuracy. The research team categorized these factors into internal and external influences and mapped them to the various project phases.

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. Eight overarching strategies were identified by means of this approach. By identifying a set of high-level strategies, which focus on the critical causal factors, a strong argument can be made for management action. Methods and tools that would likely be effective in implementing the eight strategies are, therefore, directed at the mitigating root causes of estimation problems in a focused approach. The strategies, methods, and tools are matched to project development phase where they would be implemented. Thus, a preliminary list of strategies, methods, and tools was the major deliverable of Phase I.

Eight strategies are identified as follows:

Management Strategy – Manage the estimation process and cost through all stages of project development;

Scope/Schedule Strategy – Formulate definitive processes for controlling project scope and schedule changes;

Off-prism Strategy – Use proactive methods for engaging those external participants and conditions that can influence project costs;

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

Delivery and Procurement Method Strategy – Apply appropriate delivery methods to better manage cost, as project delivery influences both project risk and cost;

Document Quality Strategy – Promote cost estimate accuracy and consistency through improved project documents;

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

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.

A NCHRP Panel review resulted in a realignment of research tasks for the second phase of the research to achieve an improved end product. Phase II of the research involved tasks including the simultaneous development and recommendation of the strategies, methods, and tools leading to the preparation of a draft Guidebook, which was presented to the industry for critiquing. The research team performed these tasks in an iterative approach to continuously improve the content of the Guidebook based on industry practitioner's comments. The draft Guidebook was developed in parts and critiqued with ten SHAs before a final draft could be completed and presented to the Panel. The comments from each critiquing process were analyzed and significant comments were incorporated into the Guidebook as the critiquing process progressed. The steps followed by the research team in the development of this Guidebook are detailed in this report.

The final draft Guidebook contents are structured around a strategic approach to addressing cost escalation. Eighteen cost escalation factors are identified. Eight strategies are proposed to address these cost escalation factors. Over 30 methods are identified and described to implement the strategies. Finally, over 90 tool applications are presented to support the execution of the methods. The Guidebook strategies, methods, and tools are aligned with three main project development phases: planning; programming and preliminary design; and final design.

A suggested implementation plan is provided. The plan covers implementation by an individual SHA. Ideas for an industrywide implementation effort are also outlined. Ten key principles are provided to successfully implement the results of this research. They are:

Cost Estimation Management

1. ***Make estimation a priority*** by allocating time and staff resources.

2. ***Set a project baseline cost estimate*** during programming or early in preliminary design and manage to it throughout project development.

3. ***Create cost containment mechanisms*** for timely decision making that indicate when projects deviate from the baseline.

4. ***Create estimate transparency*** with disciplined communication of the uncertainty and importance of an estimate.

5. ***Protect estimators*** from internal and external pressures to provide low cost estimates.

Cost Estimation Practice

1. ***Complete every step in the estimation process*** during all phases of project development.

2. ***Document the estimate basis***, assumptions, and back-up calculations thoroughly.

3. ***Identify project risks and uncertainties*** early and use these explicitly identified risks to establish appropriate contingencies.

4. ***Anticipate external cost influences*** and incorporate them into the estimate.

5. ***Perform estimate reviews*** to confirm the estimate is accurate and fully reflects project scope.

The Guidebook is a stand alone volume from this final report.

CHAPTER 1
INTRODUCTION

Project cost escalation is a major problem for Departments of Transportation (DOT). Over the time span between the initiation of a project and the completion of construction many factors influence a project's final costs. This time span is normally several years in duration but for highly complex and technologically challenging projects, project duration can easily exceed 10 years. Over that period, changes to the project scope and its definition can occur. During the early stages of a project, many factors, such as insufficient knowledge about right-of-way costs and project location, environmental mitigation requirements, traffic control requirements, or work-hour restrictions, influence project costs. Moreover, there are other process type factors that often drive project cost estimate increases. These factors can include, for example, unforeseen engineering complexities and constructability issues, changes in economic and market conditions, changes in regulatory requirements, local governmental and stakeholder pressures, and a transformation of community expectations. Some researchers state that there are systemic problems in the estimation process, even to the point that purposeful underestimation of projects is common to gain project funding.[1] The impact of all of these issues is compounded if there is a lack of human resources with appropriate training in cost estimation practice or an institutional lack of cost estimation management processes.

The cited factors create distinct challenges related to development of early project estimates and cost estimation management. These challenges are:

- Difficulty in evaluating the quality and completeness of early project cost estimates;
- Difficulty in describing scope solutions for all issues early in project development;
- Difficulty in identifying major areas of variability and uncertainty in project scope and costs; and
- Difficulty in tracking the cost impact of design development that occurs between major cost estimates.

The primary objective of this research is the development of a Guidebook on highway cost estimation management and project cost estimation practice.

STATEMENT OF PROBLEM

Managing large capital 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. Within the transportation industry, project cost escalation has attracted management and stakeholder attention at federal, state, regional, and local levels. 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

[1] See Flyvbjerg, et al, 2002, Hammer 1976, Hufschmidt and Gerin, 1970, Pickrell 1992

cost estimates. This issue was cited as the number one factor that resulted in changes in statewide highway letting programs (Anderson and Blaschke 2004).

The cost escalation problem is faced by every state highway agency, transit agency, and metropolitan planning organization (MPO) in the country as projects evolve from concept in the long-range planning process, are prioritized for programming, and are subject to detailed development prior to construction. Cost escalation or increases over the course of project development constitutes the major research problem that this project is addressing. This problem is manifested in cost estimation practice and cost estimation management approaches that do not promote consistency and accuracy of cost estimates over the project development process.

This research is not suggesting wholesale changes to the estimation process, but rather it will provide a clear and concise collection of best practices organized into a Guidebook of strategies, methods, and tools that will result in improved cost estimation management.

RESEARCH OBJECTIVE

The transportation industry problem of accurately estimating project cost will be addressed by accomplishing the following main objective:

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

SCOPE OF WORK

The major goals required to address the research problem and meet the research objective are:

1. **How are estimates usually developed and managed?**

   Identify the core estimation assumptions that are the root causes behind cost escalation and the lack of project estimate consistency and accuracy.

2. **What do we need to do to get a valid estimate?**

   Formulate strategies to address root causes at both the: a) cost estimation practice level and b) at the cost estimation management level.

   Define methods and tools that are effective during the different phases of the project development process.

3. **How do we develop a reliable cost estimation and validation process?**

   Consider the impact of project complexity and uncertainty in developing estimation strategies, methods, and tools.

4. **How will the estimation process deliver accuracy and consistency over the project life cycle in a logical and reasonable manner?**

   Document key strategies, methods, and tools in a user-friendly structure and format.

5. **How do we insure that the product is assimilated into industry practice?**

Devise a workable plan to accelerate implementation of the research results in the transportation industry.

These five goals will be met through performing the ten tasks listed below:

Task 1 - Conduct State-of-Practice Review

The main goal of Task 1 is to confirm our understanding of the problem, including all factors influencing cost escalation, and to characterize the current state of DOT practice as related to estimation practices and management of estimates. A three-element framework will be used to generally structure the information collected.

Task 2 - Develop Critical Review of Estimation Practice and Estimation Management

The main goal of Task 2 is to critically review current practices in the area of cost estimation practice and cost estimation management. Strategies for accurate programming estimates and consistent design estimates will be the focus of this task. A number of approaches will be identified that describe cost estimation practice and cost estimation management, including any innovative or successful approaches, key problems, issues, and deficiencies.

Task 3 - Identify Potential Strategies, Methods, and Tools

The main goal of Task 3 is to identify potential strategies, methods, and tools that will improve cost estimation practice and cost estimation management. Based on the framework, these strategies, methods, and tools will be tied to their use in the different phases of project development and project complexity.

Task 4 - Prepare Preliminary Outline of Guidebook

Task 4 has as its main goal the development of an annotated outline for a Guidebook on highway cost estimation practice and project cost estimation management.

Task 5 - Prepare Interim Report

The main goal of Task 5 is to prepare an Interim Report and deliver this report to the Panel for review and discussion of the work plan to complete the project.

Task 6 - Develop and Evaluate Strategies, Methods, and Tools

The main goal of Task 6 is to develop and evaluate in greater detail a range of preliminary strategies, methods, and tools applicable to different project phases and projects of different complexity. This task will develop a set of well-defined strategies, methods, and tools for both cost estimation procedures and management of cost estimates that are applicable across all phases of project development.

Task 7 - Present Strategies, Methods, and Tools to Industry

The goal of Task 7 is to obtain input and feedback from professional practitioners on the preliminary strategies, methods, and tools from Task 6. A final set of strategies, methods, and tools will be identified for inclusion in the Guidebook.

Task 8 - Develop Recommended Strategies, Methods, and Tools

The goal of Task 8 is to develop the recommended strategies, methods, and tools in a format that can structure the content for the Guidebook. A draft Guidebook will then be developed.

Task 9 - Develop Implementation Plan

The main goal of Task 9 is to develop a practical implementation plan to help accelerate the use of the Guidebook in industry.

Task 10 - Prepare Guidebook and Final Report

The main goal of Task 10 is to finalize the Guidebook and prepare the final report.

RESEARCH FRAMEWORK

Successfully achieving the research objective requires a framework from which to conduct the study. The framework provides a basis for the research methodology. In this way, the research is conducted in a systematic and rigorous manner. Thus, the end result and subsequent product will be developed based on a solid research approach but, at the same time, will be described in a manner that is readily applicable to transportation agencies. The framework presented forms the structure behind the data collection, analysis, and results discussed under the tasks covered in this Interim Report.

The overall framework that the research approach will follow includes three main elements:

- Strategies, methods, and tools for project cost estimation practice and cost estimation management linked to;
- Project development phases; and
- Project complexity.

The interaction of these three elements is shown schematically in Figure 1.1. Each element is briefly explained next.

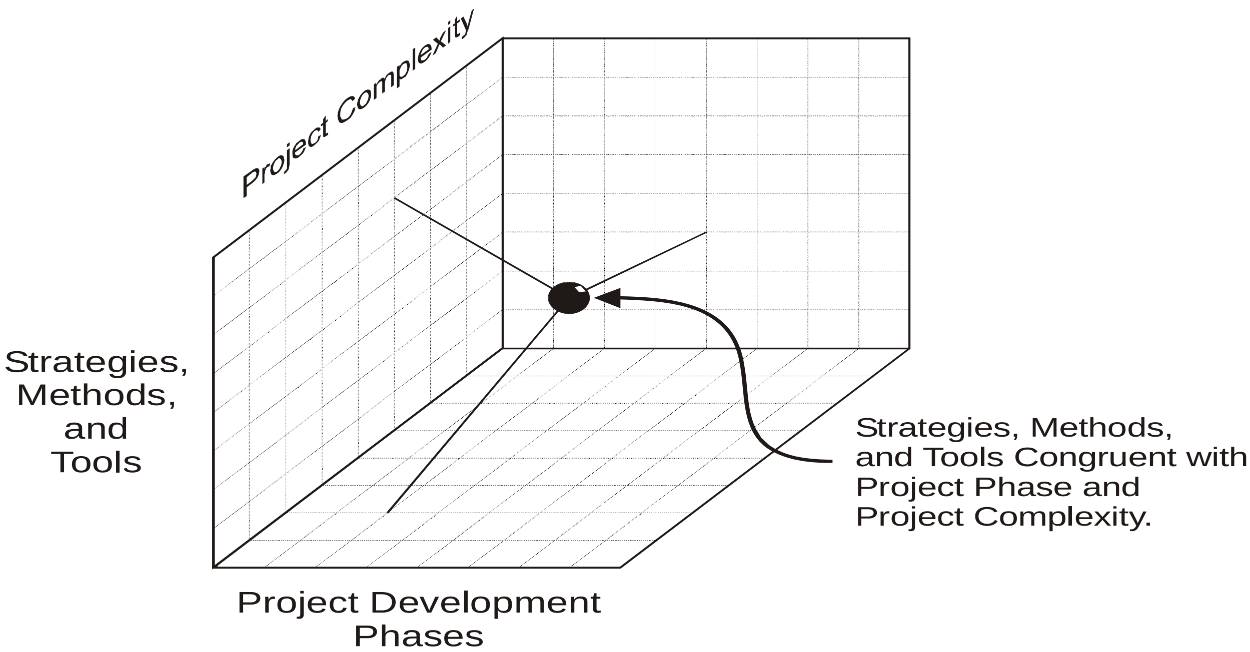

Figure 1.1. Schematic Illustration of Three-Element Interaction

Strategies, Methods, and Tools

A strategy can be defined as "*a plan of action intended on accomplishing a specific goal.*" [2] Strategies typically address a specific problem and are often formulated to address a root cause that leads to a problem. For example, a global strategy might be to **identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks when controlling costs**. 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.

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.*" [3] The procedure must support the strategy. A method for the strategy described above might be to **use programmatic risk-based cost estimation 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."* [4] 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 DOT's **Cost Estimating Validation Process (CEVP)**. 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.

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

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 estimation 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 estimation 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 estimation management and cost estimation practice. Each transportation agency has its own terms to describe the phases of this process. A National Cooperative Highway Research Program Synthesis on Statewide Highway Letting Program Management uses the phases shown in Figure 1.2 and described in Table 1.1 (Anderson and Blaschke 2004). These phases were developed for the Synthesis to illustrate the interaction between the letting program process and the project development process.

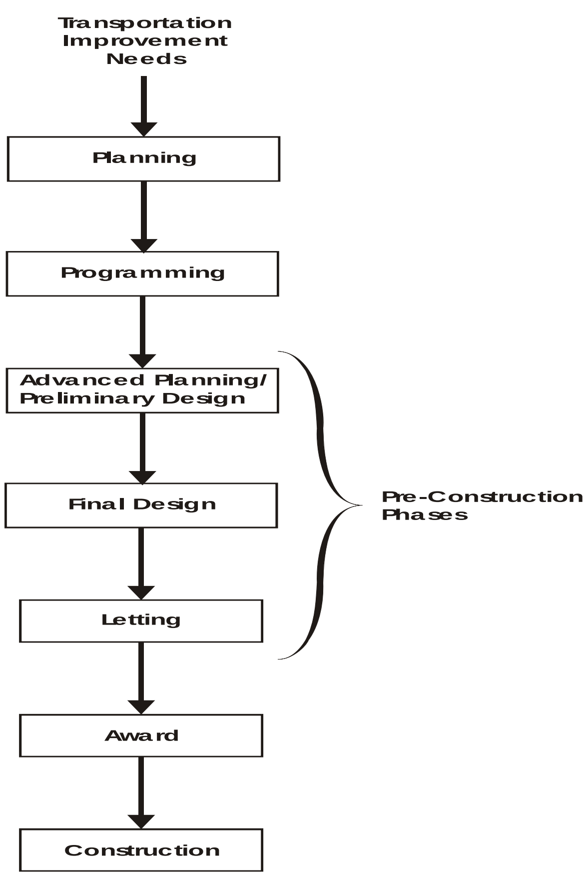

Figure 1.2. Typical Project Development Phases for Highway Projects

Table 1.1. Project Development Stages and Activities (Saag 1999 and 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; 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

Great value results by providing effective cost estimation and estimation-management techniques at the earliest stages in the project development process. Cost engineering research has proven that the ability to influence and manage cost is greatest at the earliest stages in a project. Figure 1.3 illustrates this concept. This concept has been fully endorsed by the Construction Industry Institute ("Pre-Project Planning: Beginning…" 1994).

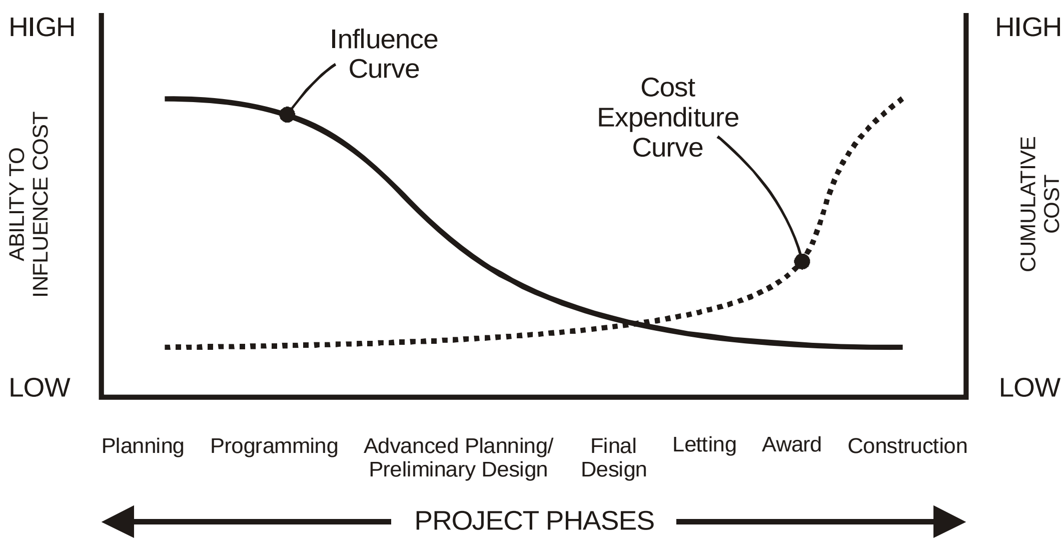

Figure 1.3. Cost/Influence Concept Applied to the Highway Project Development Process (Adapted from "Pre-Project Planning: Beginning…" 1994).

As depicted in Figure 1.3, the ability to influence cost is greatest at the beginning of the project development process and declines as the project nears construction and administration. A project management oversight function definitely has the ability to help manage the process, especially in the area of controlling cost escalation, but it is imperative to examine the problems and solutions for cost management at the planning, programming, and preliminary design stages. To neglect the earliest stages of the project development process would diminish the practical application of this research. Cost estimation practice and cost estimation management strategies and methods must be implemented at the earliest stages of the process – even if the transparency of uncertainty in the engineering and political process is difficult to define and manage.

Project Complexity

Departments of Transportation are not all alike; thus, the research has to consider the strategies, methods, and tools in terms of their application to small projects, rehabilitation projects, major reconstruction projects, major new construction projects, and special situations such as when a DOT uses an innovative contracting method and does not prepare a complete set of plans and specifications. The 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 does not contain. The type of terrain and other environmental issues also affects the project’s scope 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.

REPORT OUTLINE

The Final Report consists of a summary and eight chapters. The summary provides an overview of the entire final report. This first chapter provides basic background information concerning the research project and approach to conducting the research. It outlines the second phase of research which revolved around developing and testing the Guidebook before a final draft was produced. Chapter 2 focuses on the state of practice related to cost estimation practice and cost estimation management techniques in the transportation industry. Comments from the interim report reviews have been included as well. Chapter 3 provides a critical review of the state-of-practice. Chapter 4 identifies a preliminary list of strategies, methods, and tools that are recommended to improve cost estimation practice and cost estimation management in the transportation industry. Chapter 5 provides a short overview of the Interim Report results and how these results impacted the methodology for developing the Guidebook. Chapter 6 outlines the methodology adopted to develop the layout, structure, and content of the Guidebook for cost estimation practice and cost estimation management. Chapter 7 provides a summary of approaches and ideas for implementation of the Guidebook within a state highway agency and across the highway construction industry. Finally, Chapter 8 outlines industry related conclusions on current cost escalation problems and recommendations to address them through this Guidebook.

The research process followed to complete this Final Report is summarized in the roadmap shown in Figure 1.4. The roadmap illustrates basic inputs and outputs of each focus area corresponding to Task’s 1 through 10.

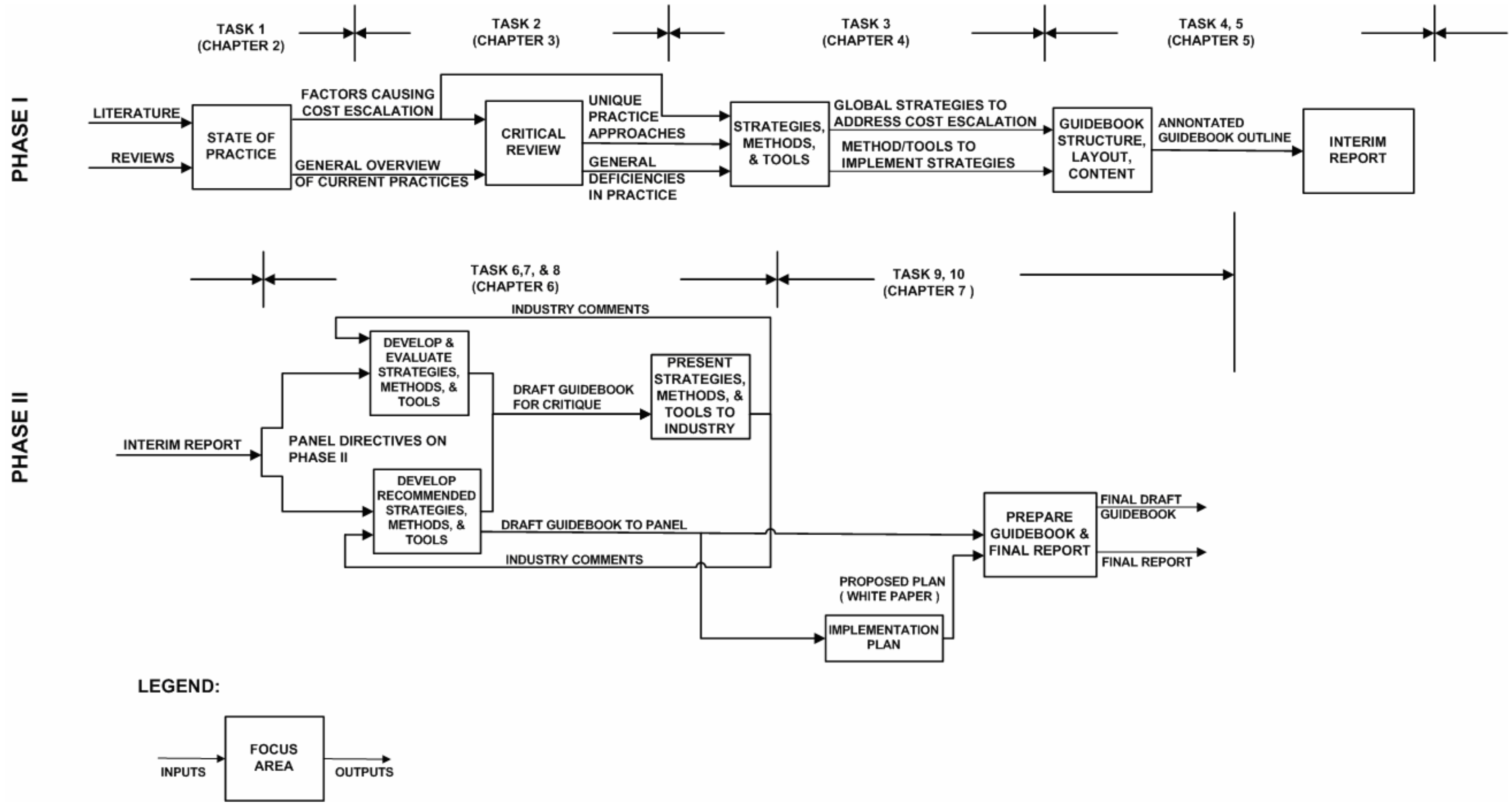

Figure 1.4. Research Roadmap Highlighting Final Report Contents

CHAPTER 2
STATE OF PRACTICE

The objective of Task 1 is to confirm the research team's understanding of the problem, including key factors influencing project cost escalation, and to characterize the current state of Departments of Transportation (DOT) practice as related to cost estimation practice and cost estimation management. Project cost estimation and the management of project cost estimates are critical issues facing state DOTs. The three-element framework of strategies, methods, tools, in combination with project phases, and the impact of project complexity were used to structure the information collected. The team assembled state-of-the-practice estimation information by project development phase so that the final estimation guidelines can present tools to develop, manage (track), and document realistic cost estimates during each phase of a project. Figure 2.1 summarizes the inputs and outputs of this task.

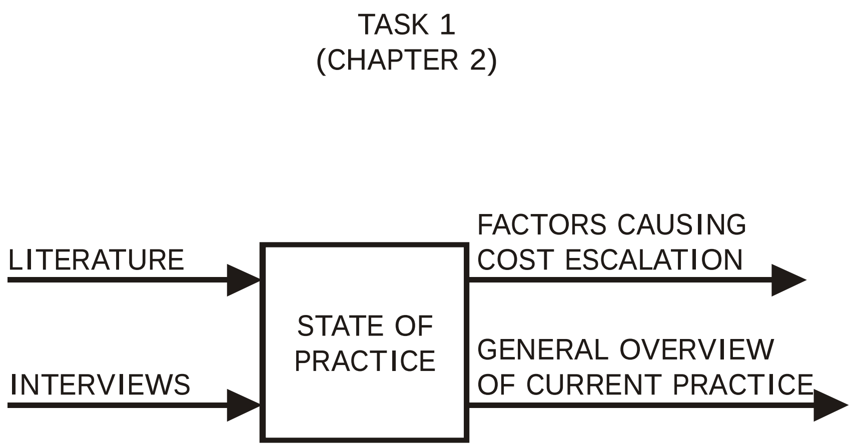

Figure 2.1. State-of-the-Practice Inputs and Outputs

LITERATURE REVIEW AND ANALYSIS

The literature review involved researching, gathering, reading, note taking, and processing information and literature relevant to cost estimation and the management of project estimates. The seeking process consisted of two methodologies. The first method consists of identifying sources through a number of search techniques and searches using keywords that identify areas of significance to the research. The following search engines were used:

The general Internet, including Yahoo, Google, and Hotbot;

Transportation Research Information Services (TRIS);

Academic resources, such as LexisNexis and Engineering Village 2;

Research Institutions, for example the Construction Industry Institute (CII) and Transportation Research Board (TRB);

Societies for journal and conference publications, consisting of the American Society of Civil Engineers (ASCE) and the Association for the Advancement of Cost Engineering International (AACEI); and

Government publications, both federal and state, United States General Accounting Office, and state DOT research departments.

Some representative search terms included:

Estimating;

Cost management;

Cost overruns;

Construction cost underestimation; and

Project controls.

Searches were made with each of these words individually and together with more specific terms such as highway, transportation, infrastructure, design, planning, and construction.

The second method used to seek possible literature of interest was through the references noted in the literature that was examined. Efforts were made to gather the literature of interest through the search engines themselves, as well as through visits to various libraries, through interlibrary loan services, and document request functions. Each document gathered was read and notes taken on any information relevant to the research. Some sources of information found are summaries of a number of research efforts. In cases such as these, endeavors were made to obtain the original source of work rather than the summary. The notes were then filtered and information helpful in achieving the goals set forth in this research extruded.

Over 100 documents have been reviewed and summarized by members of the research team. The documents consist of journal articles, reports, conference proceedings, and other documents (presentations, summaries) in the proportions shown in Figure 2.2. These documents and their abstracts have been uploaded to the controlled project website at: construction.colorado.edu/nchrp8-49.

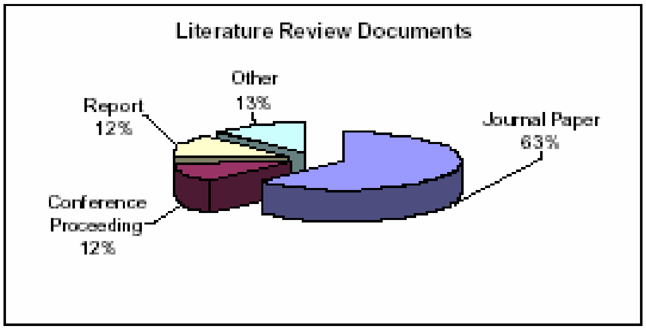

Figure 2.2. Categorization of Articles from Literature Review

The articles on the website have been categorized by their application to project development phase and their relevance to estimation strategies, methods, and tools to allow for quick access by the research team.

The literature was analyzed with attention to cost estimation practice and cost estimation management. Additionally, it was analyzed in relation to the three-element framework and the DOT project development phases presented earlier. This organizational format supports the structure of the white papers for Tasks 1, 2, and 3 and provides supporting evidence for those strategies, methods, and tools identified through the Task 1 interviews and then derived during Task 2 from the critical review of the interview information.

The majority of articles contained in the research team's literature review to create the database of publications are from non-transportation industries, such as journals from the Association for the Advancement of Cost Engineering International (AACE International), the Project Management Institute (PMI), and the American Society of Civil Engineers (ASCE). This literature will be helpful in developing estimation strategies, methods, and tools that are not currently being employed by DOTs. Most transportation sector estimation literature focuses on cost estimation during the pre-construction phases with very little information available on procedures for estimating cost during the early stages of project development (Schexnayder et al 2003). Much of this literature does address problems or issues with cost estimation such as cost escalation. Further, the research team found that literature on cost estimation management practices in transportation is virtually nonexistent.

The transportation literature more often addresses problems that are frequently associated with larger and more complex projects. The Federal Highway Administration (FHWA) is in the process of creating a set of guidelines for estimating major projects (June 2004). Major projects have cost estimates larger than one billion dollars. The draft guideline has established a set of key principles that a transportation agency should have in order to produce a reasonable estimate. The main principles are 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 estimation information. The principles state that the cost estimate should accurately reflect the all 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 through out 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 identifies areas of cost estimation that should be considered during the earlier stages of cost estimation 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 done during the initial estimates. The guidelines also state that transportation agencies must integrate quality control and assurance into the estimation procedures.

STATE DEPARTMENT OF TRANSPORTATION PRACTICE

After completing the literature search, it was apparent that the highway industry has little information published concerning cost estimation and the management of project estimates. Because of the scarcity of publications on cost estimation procedures and management in the highway industry, the research team conducted a series of interviews with state DOTs to determine current DOT cost estimation procedures and estimation management practices. The surveys enabled the research team to acquire insightful data directly from the DOTs. After the DOT interviews, the research team interviewed other organizations to confirm the DOT information.

Interview Protocol

The interview protocol was designed to permit the research team to obtain DOT 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 estimate serves.

The research team used Schexnayder's (2003) *Project Cost Estimating Synthesis,* and Dr. Schexnayder's discussions with Arizona and Idaho's Department of Transportations as a basis for developing the questions for the interview protocol. Then, the research team applied similar categories identified in the synthesis on *Statewide Highway Letting Program Management* (Anderson and Blaschke 2004). The categories, which are 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 team could align definitions of the phases with those of the individual DOTs. Under each phase of project development, the questions were further categorized by topic. The subtopics included: estimate preparation, estimate review, estimate communication, and estimate/cost management. The questions in each section of the interview protocol are similar to allow the interview to be conducted on an individual basis or with a group of DOT personnel representing the different sections within the DOT responsible for each of the project phases. The interview protocol was pretested with two DOTs (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 different purposes and frequently different individuals are involved in their preparation. Otherwise, the questions were deemed adequate and comprehensive. The interview instrument is provided in Appendix A.

Interview Process

The research team conducted interviews with state DOTs and other organizations. The research team relied on three sources 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 AASHTO Subcommittee on Design[6]; and 3) contacts established by Dr. Schexnayder when he prepared the synthesis on project cost estimation. A letter that briefly outlined the purpose of the project, provided some background information about the project, and requested a

[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.

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 research team 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 estimation, preliminary design estimation, and the engineer's estimate. When the team collected the responses, the responses revealed this assumption was only partially true. The team did receive three different names from some of the DOTs. However, a few DOTs had two people listed for one project phase, and other DOTs listed the same person for several phases. When the interviews were scheduled, the research team contacted each participant from the DOT and gave them the option to perform the interview independently or as a group. Many DOTs requested that all representatives of the different project phases be present during the interview, while other DOTs preferred to complete the interview individually.

The research team was able to send letters to specific individuals in all fifty states. The team received responses from 36 states. The research team selected specific DOTs for interviews based on prior knowledge of their practices from Schexnayder (2003) and judgment based on potential diversity in practice, size, and geographic location. Once the research team received responses to the contact letter, interviews were coordinated with the DOTs. The interview instrument was sent to the DOTs prior to the interview. It was also requested that each DOT send any supplemental information such as estimation procedures or manuals to the researchers prior to the interview. During the interview, the team 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 are prepared. After that, the interviewers proceeded with the questions from the interview instrument.

Most of the interview discussions were more topical based than specifically following a question-by-question approach. The topical areas were estimate preparation, estimate reviews, estimate communication, and cost estimation management. At the end of the interview, the interviewers asked the agency to look over the questionnaire to make certain all questions were discussed. Once the interview was complete, the answers recorded from the interview were aligned with the corresponding questions. In addition, a summary page was written that presented an overview of the DOT's estimation process, the strengths, and the weaknesses identified by the state agency (see Appendix C for an example).

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

Data Characteristics

The research team completed 18 formal DOT interviews (Figure 2.3). Two of these interviews 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 addition to the interview methodology, 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. Representatives from 14 DOTs participated in the Park City meeting.

Information was collected from a total of 23 DOTs during Task 1 through interactions between research team members and DOTs. As seen in Figure 2.3 contributions were made by departments from across the nation and representing a variety of program sizes and diverse attitudes, policies, and issues.

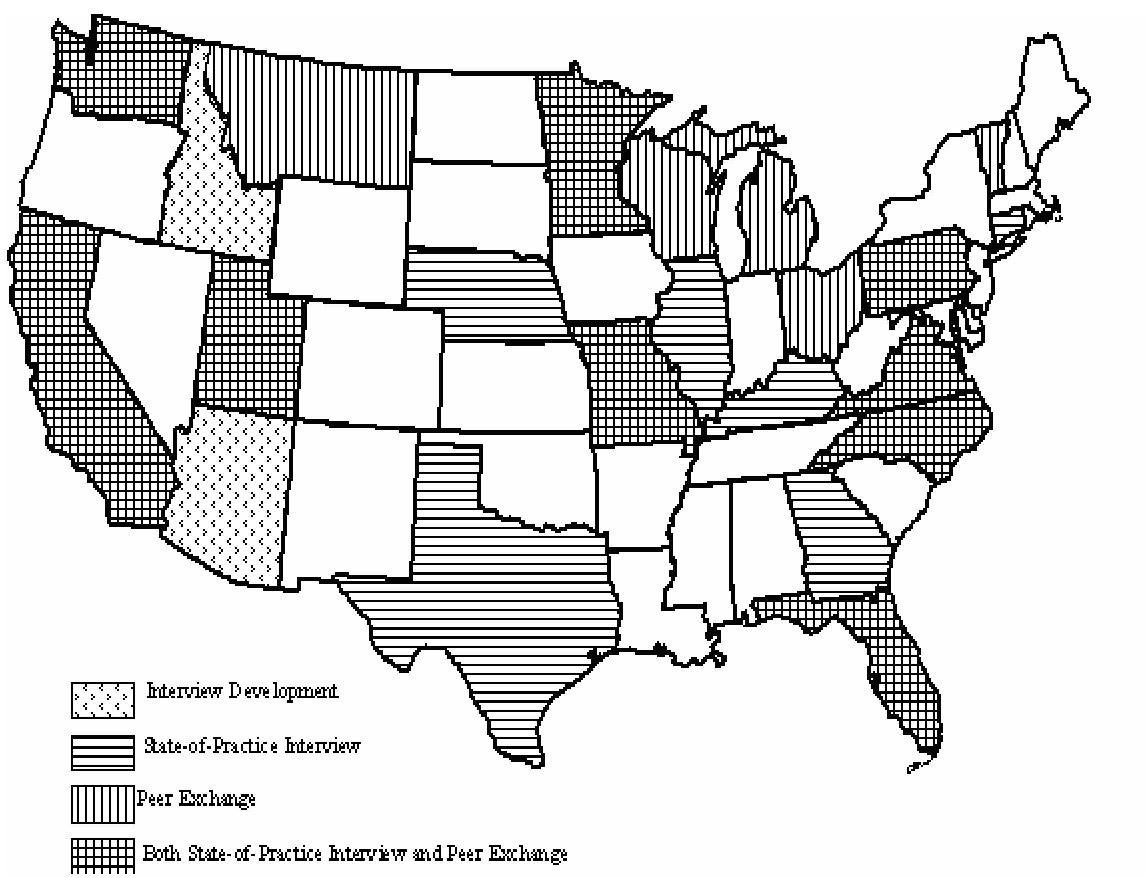

Figure 2.3. States Represented in Task 1

The state-of-practice interviews began at the end of May and continued through August 2004. The team accomplished the interviews 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 2.1. Agencies that responded to the initial contact letter and were not interviewed have been notified that they might be contacted at a later date. The research team also requested estimation information such as manuals or guidelines from those agencies.

Table 2.1. Type and Date of Interview

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

Utah Park City Peer Exchange

In addition to the structured interviews a source of estimation information was the Park City Peer Exchange in Utah. The research team participated in a TRB sponsored "Peer Exchange" with the TRB Statewide Multimodal Planning Management Committee. This "Peer Exchange" occurred on July 27, 2004. The sponsoring committee invited the attendees. Participation involved 14 Department of Transportation representatives and eight representatives from other groups, including the 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. The questions focused on the following areas:

Major issues regarding planning or programming cost estimates

Policies, procedures, techniques, and/or standards used in preparing planning or programming conceptual estimates

Methods to insure the project scope is adequately covered under conceptual estimates

Historical data used in preparing conceptual estimates

Contingency and risk applications in conceptual estimation

During the "Peer Exchange", the 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 five estimation-related questions relative to project planning and/or programming. The discussion was recorded and most of the agencies provided written documentation. The research team summarized the discussion into 15 major issue areas and identified 11 approaches for managing the cost estimation process during the planning phase. Key members of the peer exchange group reviewed the research team's summary of the issues and approaches and provided further comment and confirmation.

A major comment from the Peer Exchange group related to the basic approach DOTs take when developing long-range plans. There appears to be two different types of long-range plans. One type is to prepare a "Policy-based Long Range Plan." The Policy-based Long Range Plan does not identify specific projects and associated cost estimates; it only provides major categories of needs and their priorities. The other type focuses on specific projects to prepare a "Project-based Long Range Plan." This latter type requires cost estimates for projects. The interrelationship between these two types of long-range plans is not clear. Hence, the research team is performing some additional investigation into policy and project based long-range planning in terms of their impact on cost estimation and cost management practices. The primary target of this investigation is DOT Planning Directors. The results obtain from the "Peer Exchange" was considered in the general description of the state-of-practice as well as strategy development.

Other Organizations

The research team feels that information pertinent to this project may also be obtained through discussions with organizations other than state DOTs. Therefore, contacts were sought with MPOs as well as with other transportation-engineering firms. Additionally, contact was made with non-transportation owner organizations.

Metropolitan Planning Organizations

Texas Transportation Institute (TTI), Associate Director, Katie Turnbull, assisted the research team in identifying MPO contacts. The team has contacted several MPOs with the intent of conducting interviews with respect to their cost estimation procedures and cost management practices. At the time of the Interim Report, the team has interviewed the Maricopa Association of Government MPO and the Denver Regional County of Governments (DRCOG).

Consultants

The research team has also obtained information on cost estimation practice and cost estimation management from a transportation consultant's perspective. The interview instrument provided the basis for collecting this input. Two major transportation industry design consultants participated in interviews: 1) Carter-Burgess and 2) Michael Baker. 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.

Non-Transportation Owners

The University of Colorado contacted non-transportation owners who are members of the Rocky Mountain chapter of the Association for the Advancement of Cost Engineering International (AACEI). One interview was successfully complete with a non-transportation organization. In selecting non-transportation organizations to question during the course of this study, the research team 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 sheet, 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 (Berka and Daley 1992).

The interview process with Coors was similar to the process used with DOTs. Before the interview, contact documents were obtained that provided information regarding the construction program at Coors. Using these documents, the research team became better acquainted with Coors project development processes. 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 state-of-practice survey instrument. The research team gained significant insight from the Coors interview. Some of the responses were similar to what was gathered from DOTs and but many differed and suggested different approaches to dealing with estimate development and control.

Data Analysis

The data collected from all of sources enabled the research team to identify the core estimation assumptions that are the root causes behind cost escalation and lack of project estimate consistency and accuracy. The team was also able to identify specific estimation practices and cost estimation management approaches currently used or maybe more importantly not being used during each project phase. The data recorded during the interviews was analyzed by citing common practices approaches used by DOTs in the database. Documents provided by some DOTs were also studied. In many cases, these documents provided additional details of a DOTs current practice.

The research team convened in College Station, Texas and spent two days analyzing the data. First, the team reviewed the factors leading to cost escalation. Through the interviews, the team was also able to determine problems that arise out of the agencies' weaknesses, which in turn led to the development of factors influencing cost escalation. The factors were further proven through correlation with the information found in the literature review.

The research team organized the information and characterized the state of practice as revealed by the interview data. The information was separated into project development phases and topical areas: preparation, review, communication, and management. Once the data was organized, the team developed trial approaches that described the state of practice. The conclusions that were drawn from the literature review and analysis of the interview data are described in the following section.

CHARACTERISTICS OF THE STATE OF PRACTICE

The state of practice is described first by identifying factors that lead to cost escalation. This discussion is followed by a discussion of DOT identified practices relevant to cost estimation procedures and cost management approaches. The description is general in nature and does not describe a particular approach of any DOT.

Cost Escalation Factors

Construction projects have a long history of cost escalation. (Federal-Aid 2003, Flyvbjerg 2002) The 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 factors driving cost escalation of project cost can be divided by project development phases: planning, and execution. As defined here 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.

The factors that affect the estimate in each development phase are by nature internal and external. Factors that contribute to cost escalation and are controllable by the DOT are internal, while factors existing outside the direct control of the DOT are classified as external. This arrangement of factors is shown in Table 2.2, these factors are numbered for reference only and do not suggest a level of influence. Table 2.2 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 2.2. Factors Causing Cost Escalation of Projects*

	Planning	Execution
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	1. Inconsistent application of Contingencies 2. Faulty Execution 3. Ambiguous Contract Provisions 4. Contract Document Conflicts
External	1. Local Government Concerns and Requirements 2. Effects of Inflation 3. Scope Creep 4. Market Conditions	1. Local Government Concerns and Requirements 2. Unforeseen Events 3. Unforeseen Conditions 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 can 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 estimation, and inconsistent application of contingencies. Each of these factors separately or in combination with others can 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 DOT 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 department's estimate is higher than the budget, the project may not be let. As a result, engineers and the DOTs feel the pressure to estimate with an optimistic attitude about cost - (Akinci 1998, Condon 2004 Bruzelius1998, Flyvbjerg 2002, Hufschmidt 1970, Pickrell 1990, Pickrell 1992).

Delivery/Procurement Approach effects the division of risk between the DOT and the constructors, and 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 DOTs 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 DOT responsiveness, expectations, and time (Harbuck 2004, New Jersey 1999, Parsons 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 DOTs 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 (Board 2003, Booz·Allen 1995, Callahan 1998, Hufschmidt 1970, Mass 1999, Semple 1994, Touran 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 addressed, cost increases are likely to occur (Board 2003, The Big Dig 2003, Booz·Allen 1995, Callahan 1998, Hufschmidt 1970, Mass 1999, Touran 1994, Federal-Aid 2003, Transportation Infrastructure 1997, Transportation Infrastructure 2002).

Scope Changes, which should be controllable by the DOT, 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 (Board 2003, Booz·Allen 1995, Callahan 1998, Chang 2002, Harbuck 2004, Hufschmidt 1970, Mackie 1998, Mass 1999, Merrow 1981, Merrow 1986, Merrow 1988, Semple 1994, Touran 1994).

Poor Estimation (errors and omissions) can also lead to underestimation, which subsequently translates into increases in project cost as errors and omissions are uncovered. Estimation 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 estimation 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 1985, Booz·Allen

1995, Carr 1989, Chang 2002, Harbuck 2004, Hufschmidt 1970, Merrow 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 estimation 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. DOTs run into problems when the contingency amounts are applied inappropriately (Noor 2004, Ripley 2004, Association 1997).

Planning—External

External factors that can 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 costs increases.

Local Government Concerns and Requirements typically include mitigation of project effects and negotiated scope changes or additions. Actions by the DOT 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. There are a multitude of examples of “drastic” measures that were taken to accommodate local government and citizen concerns as well as national concerns with two of the most notable examples being actions during the Legacy Highway project in Utah and the Big Dig in Massachusetts (Board 2003, Booz·Allen 1995, Callahan 1998, Chang 2002, Daniels 1998, Harbuck 2004, Hudachko 2004, Legacy 2004, Mackie 1998, Mass 1999, Merrow 1981, Merrow 1986, Merrow 1988, Parsons 2002, Schroeder 2000, Touran 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 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 is a large portion of the cost overruns experienced on the project (Akinci 1998, Arditi 1985, Board 2003, Booz·Allen 1995, Hufschmidt 1970, Merrow 1988, Pickrell 1990, Pickrell 1992, Touran 1994).

Scope Creep is similar to changes in scope; however, these changes are usually the accumulation of minor scope changes. Projects seem to often 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 (Akinci 1998, Board 2003, Booz·Allen 1995, Callahan 1998, Chang 2002, Harbuck 2004, Hufschmidt 1970, Mackie 1998, Mass 1999, Merrow 1981, Merrow 1986, Merrow 1988, Semple 1994, Touran 1994).

Market Conditions or changes in the macroenvironment 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 DOT receives for the work. Typically, the risks associated with large projects are much greater, both for the owner and contractor, and that affects project costs. Inaccurate assessment of the market conditions can lead to incorrect project cost estimation (Summary of Independent Review 2002, Woodrow 2002).

Execution—Internal

Although this study focuses on developing better practices for early estimates, cost growth occurring during the construction of a project cannot be ignored and must be planned for during project development. Internal factors that lead to the underestimation of project costs during the execution of a project stem from poor project management and design documents. More specifically, these factors can include inconsistent application of contingency, faulty execution, ambiguous contract provisions, and contract document conflicts.

Inconsistent Application of Contingency can be both an internal factor contributing to underestimation during the planning stage and a contributor to cost overruns during the execution of the project. During the project execution contingency funds, instead of being applied to their dedicated purpose are inappropriately applied to construction overruns and then not available for their intended purpose (Noor 2004, Ripley 2004).

Faulty Execution by the DOT in managing a project is one factor that can lead to project cost overruns. This factor can include the inability of the DOTs representatives to make timely decisions or actions, to provide information relative to the project, and failure to appreciate construction difficulties cause by coordination of connecting work or work responsibilities (Board 2003, Callahan 1998, Chang 2002, Merrow 1981, Merrow 1986, Touran 1994).

Ambiguous Contract Provisions dilute responsibility and cause misunderstanding between the DOT and project constructors. Providing too little information in the project documents can lead to cost overruns during the execution of the project. When the core assumptions underlying an estimate are confused by ambiguous contract provisions forecast accuracy cannot be achieved (Callahan 1998, Chang 2002, Department 1994, Harbuck 2004, Mackie 1998, Measuring 1998, Tilley 1997, Touran 1994).

Contract Document Conflicts lead to errors and confusion while bidding and later during project execution they cause change orders and rework. (Callahan 1998, Chang 2002, Department 1994, Harbuck 2004, Mackie 1998, Measuring 1998, Tilley 1997, Touran 1994)

Execution—External

External factors that lead to the underestimation of project costs during the execution of a project stem from those items that are primarily out of the control of the highway agencies. External factors in the project execution stage include local government concerns and requirements, unforeseen events, unforeseen conditions, and market conditions.

Local Government Concerns and Requirements can affect the project costs during the execution phase. Similar to the effects during the planning phase, mitigation actions imposed by the local government, neighborhoods, and businesses as well as local and national environmental groups during the construction of a project can extend the project duration affecting inflation allowances or add direct cost. By not anticipating these changes, DOTs can be plagued by project cost increases (Board 2003, Booz·Allen 1995, Callahan 1998, Chang 2002, Hall 1980, Mackie 1998, Mass 1999, Merrow 1981, Merrow 1986, Merrow 1988, Pearl 1994, Sawyer 1951-52, Summary of Independent Review 2002, Touran 1994, Woodrow 2002).

Unforeseen Events are unanticipated and typically not controllable by the DOT, occurrences such as floods, hurricanes, tornadoes, or other weather related incidents. Typically these are called "acts of god." These acts can bring construction to a standstill and have been known to destroy work creating the need for extensive rework or repair. Events controlled by third parties that are also unforeseen include terrorism, strikes, and changes in financial or commodity markets. These actions can have devastating results on projects and on project costs (Akinci 1998, Arditi 1985, Callahan 1998, Chang 2002, Hufschmidt 1970, Merrow 1981, Merrow 1986, Merrow 1988, Semple 1994, Touran 1994).

Unforeseen Conditions are notorious for causing cost overruns. Unknown soil conditions can effect excavation, compaction, and structure foundations. Contaminated soils may be present. Utilities are often present that are not described or described incorrectly on the drawings. There are a multitude of problems that are simply unknown during the planning stage and which can increase project cost when they become apparent during construction (Akinci 1998, Arditi 1985, Callahan 1998, Harbuck 2004, Hufschmidt 1970, Merrow 1981, Merrow 1986, Merrow 1988, Semple 1994, Touran 1994, Transportation 1999).

Market Conditions affect the project costs during the execution phase similar to the effects during the planning phase. Changing market conditions during the construction of a project that reduces the number of bidders, affects the labor force, and other related elements can disrupt the project schedule and budget (Board 2003, Booz·Allen 1995, Callahan 1998, Chang 2002, Hall 1980, Mackie 1998, Mass 1999, Merrow 1981, Merrow 1986, Merrow 1988, Pearl 1994, Sawyer 1951-52, Summary of Independent Review 2002, Touran 1994, Woodrow 2002).

Current Practice in Cost Estimation Practice and Cost Estimation Management

Departments of Transportation attempt to mitigate the factors leading to cost escalation through their prescribed cost estimation practice and cost estimation management systems. These practices and systems are employed across the spectrum of project development, from the conception of an idea to address a need to construction of the project. DOTs 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, requirements the long-range plan must 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 DOT's authorized program varies between four years and twelve years where the first three years are the STIP. In some DOTs, 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, 10-year authorized program where the first four years are included the STIP. Those years beyond the authorized program would include up to 20 years or more of projects depending on DOT policies and procedures. The DOT must therefore align their estimation practices and cost management systems to fit within their long-range planning, priority programming, and preconstruction processes.

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

The estimation procedure for the programming estimate varies among the DOTs. These cost estimates often become the stated project cost included in the department's authorized program, and in many cases the program and project costs must be approved for funding at this point by the legislature. Parametric estimation techniques are used 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.

The advanced planning/preliminary design phase begins when the DOT commits resources to developing design documents for a project. The estimation 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 estimation approaches (parametric based on lane mile factors, bridge deck square foot/yard, or similar projects). As the design becomes more definitive, the estimation procedure evolves from a parametric estimation 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%, 60%, and 90% design reviews are required by many DOTs). 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 2.3 summarizes general characteristics of state DOT cost estimation practice and cost estimation management characteristics. These characteristics are further explained in the following sections.

Table 2.3. Summary of Cost Estimation Practice and Cost Estimation Management Characteristics

Project Development Phase	Cost Estimation Practice			Cost Estimation Management	
	Estimate Purpose	Estimate Preparation	Estimate Reviews	Estimate Communication	Cost Management
Planning (Conceptual Estimate)	Estimated funds needed for long range plan	Cost/Mile & Percentages	Internal Review or MPO Review	Point or Range	Promote Transparency and Integrity
Programming (Parametric Estimate)	Estimated funds for project in authorized program	Cost/Mile, Percentages, & Defined Line Items	Internal Review	Point	Checklist & Tracking System
Advanced Planning/Preliminary Design (Parametric and Line-Item Estimate)	Estimated funds for project in STIP	Defined Line Items & Percentages	Peer and Team Reviews	Point	Management Accountability & Scope Control
Final Design (Detailed Engineer's Estimate)	Estimated construction cost to compare with bids	Completely Line Item	Committee Review	Point	Checks within Estimating Software

Cost Estimation Practice

The initial project phase, planning, identifies the need for a project. This need has little definition, which affects the estimation 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, similar projects, or volumetric factors. The cost is based typically on historical data derived 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, a Department developed Excel spreadsheet. Many of the spreadsheets used are templates with predetermined formulas and historical data incorporated into the spreadsheet. The DOTs also have a cost per mile document that lists project types, such as a four-lane roadway in a rural area, and the cost that corresponds with the project type. A few DOTs have developed typical and/or standardized sections that correspond to a cost per mile section.

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 construction year. In most cases, the planning estimate undergoes very little review within the Department. If the estimate is reviewed, the review is conducted by another person on the estimation team or by an engineer in a district office. However, if the estimate was prepared for a metropolitan planning organization (MPO) it may be reviewed by the MPO during the project selection process for the long-range plan.

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 DOT's cost number included in its authorized program. DOTs 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 DOTs use conceptual and parametric estimation software that has been developed by the department. Other "Add-on" elements, such as local government concerns, environmental issues, and externally imposed requirements, also receive their first recognition in this estimate. To produce the programming estimate, historical bid data is often the primary source of cost information. The data utilized may be sorted by state, region, or DOT district. Some DOT 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. 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 DOT.

The preliminary design estimate is an amplification of the programming estimate. For this estimate, DOTs 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 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. A preliminary design estimate is updated when the scope reaches established design milestone or a significant element in the scope has been identified. 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 estimation 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. However, the review process begins to become more formalized as design proceeds. 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 Department'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 DOT policies.

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. Estimation 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 estimation). This 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 estimation 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.

Project Complexity

Most DOTs 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 DOT 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. DOTs do not consider projects such as preservation projects to be a significant issue in cost estimation, because the DOT typically has a good idea of the project elements and quantities associated with preservation projects. For the mid-range projects, DOTs do not have a consistent estimation procedure. DOTs 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. For large or mega projects, DOTs are forced to consider project complexity. DOTs conduct constructability reviews, value engineering reviews, and evaluate several alternative design concepts for mega projects. Due to the complexity of the mega projects, DOTs have to perform some conceptual development before they can select an appropriate alternative and cost for that alternative. One DOT has developed separate policies for major projects and minor projects. For major projects, this DOT requires a draft scoping memorandum, a final scoping memorandum, more approval signatures, and extensive environmental documents.

Cost Estimation Management

Scope creep and major scope changes are significant factors that drive project cost increases. Managing the scope and schedule of a project is an essential element in alleviating cost escalation. To control and overcome these problems, project scope and schedule must be communicated and managed. In order to manage a project's scope and schedule, therefore cost, departments attempt to promote transparency by identifying major issues contiguous to the project and project uncertainties. When long-range planning estimates are created, most states do not have regulations requiring the estimates to be approved by the legislature. The long-range estimates are simply communicated to higher Department management as a single number dollar amount. Only occasionally is the estimate communicated as a cost range, which typically is result from the performance of a risk analysis.

During the programming phase, the project is often included in an authorized program with the project estimate. The project is usually assigned a tracking or project number. The project may or may not be included in the STIP at this point. Since the programmed estimate is often the first estimate entered into the tracking system, future estimates are compared to the baseline estimate. Departments have project checklists for standard project elements. These checklists call the planner's attention to important cost items like pavement, right-of-way, demolition, traffic control, utilities, and engineering. As an estimate is prepared, the estimator makes certain that the costs of the listed items have been included in the project estimate. The project cost is further managed by the use of a risk charter. 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. 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.

If the project was not added to the STIP during the programming phase, then it is included during the preliminary design phase. The estimate in the STIP is a single number, and it is open to public awareness. Therefore, management is held accountable for the estimate in the STIP. This accountability causes management to increase control over scope modifications. During the preliminary design phase, the project estimates and checklists created in the programming stage are being updated to reflect recently defined project elements. The scope and estimate is monitored with checklists and red flags caused by changes.

Release of the DOT's Engineer's Estimate

In many States, the engineer's estimate is not released to the public before the letting. What is allowable concerning release of the DOT's estimates is usually defined by State statute and, in many cases, out of the DOT's control. Once the bids have been submitted to the DOT, the department uses estimation software to compare the engineer's estimate with the bids. By Law or internal rules DOT'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 DOT's estimate, the total amount of the DOT estimate is usually released to the publicly, most DOT's however, do not release the detail item prices of their estimate.

Overall Estimation Characteristics

The organizational structure of a state DOT affects the development of the project estimates. A department'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 life or having a State Estimator's Office that oversees all project estimates.

The organization of the DOT also affects how historical cost data is managed. Some agencies have separate databases for each district. However, most DOTs have created a central database that can be accessed by all districts within the state. To generate unit-price data departments systematically compile bid data from past project lettings. These data are broken down by bid line item. The database users can sort the historical bid process by state, region, or district averages. Furthermore, users have the ability to organize the data by market area, terrain, or project type.

Another characteristic that is unique for each DOT 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 DOT. The three methods to determine contingency are listed below:

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 the set percentage could range 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% is added to the long rang planning estimate, and then 25% is added to the programming estimate. 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.

CONCLUSIONS

This chapter has described the state of practice in highway cost estimation practice and cost estimation management. The research team arrived at this state-of-the-practice review through an exhaustive literature review and in depth interviews with DOTs, MPOs, transportation consultants, and non-transportation owners. Additionally, the team has defined the factors that cause cost escalation and summarized them into 18 total internal and external factors that occur during the project planning and execution phases. Chapter 3 will provide a critical review of the state of practice through an analysis of how the current DOT cost estimation practices and management relate to the factors that cause cost escalation.

CHAPTER 3
CRITICAL REVIEW OF THE STATE OF PRACTICE

The main goal of Task 2 is to review current practices in the area of cost estimation practice and cost estimation management. Numerous unique or innovative approaches to cost estimation practice and cost estimation management are described. A discussion of how current cost estimation practice and cost estimation management approaches do and do not address the identified potential root causes of project cost escalation are also covered in this chapter. Finally, important issues and more specifically deficiencies in current practice are identified. Figure 3.1 summarizes the inputs and outputs of this task.

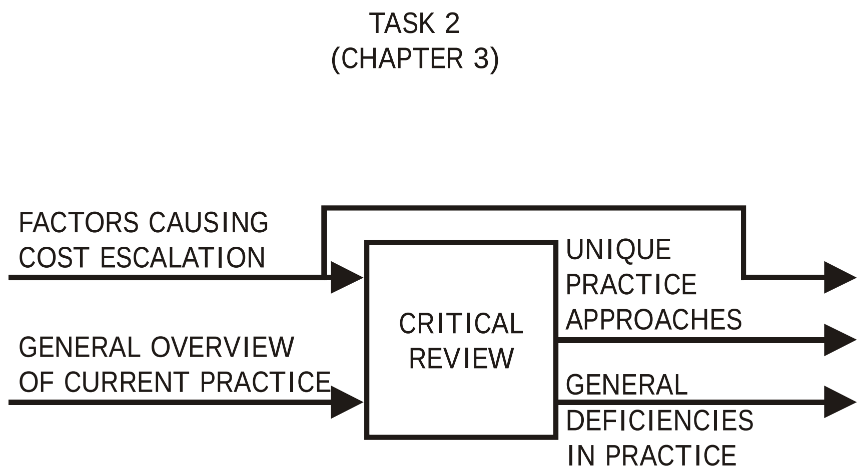

Figure 3.1. Critical Review Inputs and Outputs

METHODOLOGY

The research methodology followed for Task 2 builds upon Task 1 findings. The data and information collected through the interviews, combined with results of an exhaustive literature review, assisted the team in identifying reasons for cost growth and estimate inaccuracies. A detailed data analysis meeting took place in College Station, Texas, where the team performed a critical examination of the information collected for the state of practice. The Task 2 interview data was analyzed according to project development phases. The research team reviewed the interview data and identified unique and/or innovative approaches that will aid the Departments of Transportation in overcoming factors that cause project cost escalation, as identified in Table 2.2. The research team used literature, interviews, and experience to link the better DOT approaches to cost escalation factors these approaches would address. However, the research team did not have sufficient information about each approach presented in this chapter to measure the effectiveness of the approaches in addressing cost escalation. Further, the team did not gather effectiveness information directly during the interview process. Our intent is to address these issues in Phase II of the research, and more specifically, through Task’s 6 and 7.

In general, all those factors causing project cost escalation, as noted in the literature and discussed in this report, receive some attention by DOTs; however, not every DOT addresses all of these factors in their entirety. Therefore, the cost estimation practice and cost estimation management techniques described in this chapter are a compilation of the better practices from many transportation agencies, transportation consultants, and a single private non-transportation company.

A discussion of current practices follows. This discussion is organized into categories of: 1) cost estimation practice; and 2) cost estimation management. These categories are further organized into the estimates that correspond to the major project development phases. Each of the practices listed in Table 3.1 below is discussed. Once the practices are described, the research team noted potential deficiencies in current practice. 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 strategies, methods, and tools described in Chapter 4.

Table 3.1. Current Cost Estimation Practice and Cost Estimation Management

Project Development Phase	Cost Estimation Practice	Cost Estimation Management
Planning Estimates	• Applying Cost-per-Mile Factors Using Typical Sections • Applying Cost-per-Mile Factors Using Similar Projects • Order of Magnitude Estimates • Add-on elements	• Communication • Conceptual Estimating Software • Red Flag Items • Recognition of Project Complexity
Programming and Preliminary Design Estimates	• Identifying Major Cost Items • Conceptual and Parametric Estimating • Volumetric Estimating • Risk Analysis • Add-on elements • Estimate Reviews	• Scoping Documents • Communication • Public Involvement • Conceptual/Parametric Estimating Software • Definitive Management Plan • Risk Charter • Estimating Checklist • Design Value Engineering • Design to Cost • Management of ROW, Utilities and Environ. Issues • State Estimating Departments • Cradle to Grave Estimators • Year of Construction Costs • Scope Change Form • Cost Containment Table • Gated Process • Create Project Baseline • Estimate Manual • Estimator Training • Estimation Scorecard
Final Design Estimates	• Estimating Software • Historical Bid Price Databases	• Estimation and Management Software • Estimate Review

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

COST ESTIMATON PRACTICE

Planning Estimates

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 DOTs' 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. As described in the state of practice, the typical method used to prepare planning estimates is historical lane-mile cost averages.

Applying Cost-per-Mile Factors Using Typical Sections

Cost-per-Mile Estimation 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 DOT created an estimation handbook, which 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 numbers. 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 proposed typical section, 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 the DOT handbook represent present day costs, which must be inflated to the project's midpoint of construction. The planning manual has inflation factors that are applied to the planning estimates. The calculated elements are summed to arrive at the long-range planning estimate's total amount.

This estimation method provides the DOT with a consistent and transparent approach to costing projects. Consistency of approach continues as the project is further developed because the DOT uses an estimation 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 DOTs reported using lane-mile cost factors with typical sections for their planning estimates, but their methods were not as consistently used within the DOT as the procedure previously described. One of the DOTs uses three Excel 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 Excel 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 DOT with different design alternatives along with an estimate for each design so that designs can be compared.

Similarly, another DOT 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 are used to estimate right-of-way and utility cost. This DOT is in the process of refining their estimation software to include the computerization of planning estimate preparation.

Applying Cost-per-Mile Factors Using Similar Projects

Several DOTs 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 planning engineers in the respective districts provide the estimators with the current cost per mile estimate for the programmed projects. 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 tries to segregate and remove the structure cost in the programming phase estimates and then estimates the current project's structures separately. Other DOTs develop lane-mile factors in a similar manner as the one describe, but they use costs for projects that have already been let instead of projects still in the programming phase.

Scoping Document

One DOT creates its long-range planning estimates using costs from similar projects, but they also use 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 Department'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.

Order of Magnitude Estimation

Early in project development, estimates are often done very quickly with only limited project definition, and expected cost is communicated as an order of magnitude estimate. One DOT expresses the long-range planning estimate as an order of magnitude estimate so those who see the estimate are aware of the limited scope definition that was used to prepare the estimate. These estimates should only be used for the very initial feasibility studies. Order of magnitude estimates are far from exact, and only represent an indication as to a degree of expected project cost. The plus or minus 40% confidence range typically associated with these estimates reflects the lack of definite project information (Merrow, Phillips, and Myers 1981), however one DOT reported a 45% confidence range.

Add-On Elements

All DOTs incorporate in one manner or another affects of "Add-on" elements have on project cost. 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.

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. During the critical analysis of the state of practice, the research team discovered that the programming and the preliminary design phases possess many similarities. For many DOTs, 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.

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 DOTs recognize the fact that about 80% of the project cost is in about 20% of the project elements. As a result, these DOTs focus on the high cost items while generating an estimate. The DOTs that identify costs for major items use a spreadsheet or in-house software to calculate the total estimate. One DOT's list of major items included surfacing, safety items, structures, and grate and drainage. Another DOT's major items are: excavation, embankment, bituminous pavements, Portland cement concrete pavements, drainage, curbs and gutters, structural concrete, structural steel, and guard rail. In both cases, these large cost elements are estimated using historical unit costs or cost-based estimation procedures. Once the major items are estimated, the smaller items, such as traffic control, signing, and striping, are included as percentages or by lane-mile factors similar to those used in planning estimates. By applying this estimation approach, the DOTs are considering the project's major cost drivers and the project's complexity. The DOT 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.

Conceptual and Parametric Estimation

In-House Estimation Software (long-range estimation)

For the programming and preliminary design phase, a few DOTs are using computer software to develop conceptual and parametric estimates. For one DOT, the information in their in-house estimation software is recorded in a handbook that is used for the conceptual planning estimate. When the project reaches the programming stage, the DOT's project development group creates different alternatives and then chooses the one that best meets the project's needs. Then they use their in-house estimation program to produce the program estimate. Each section of the project can be described by a different typical sketch. The estimator starts with a preloaded typical 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 DOT tries to perform parametric estimation 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 Estimation Software

The key to another DOT's estimation software is a complete scope of work. Therefore, the estimate prepared for the programming and preliminary design phases are scope feature driven. The estimation 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 those 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 estimation 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 estimation system. Once the engineering drawings are complete and all quantities are known, the user can chose the Trns•port section of the estimation system to create an estimate. This DOT allows the public access to the system's project information creating transparency for the DOT. The openness helps prevent tendencies to create a biased estimate.

AASHTO's Trns•port Software

Computers and estimation 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 DOTs the most widely used estimation 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 DOTs 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 estimation techniques. Cost-based estimates are based on an assumed productivity and the direct cost of material, equipment and labor.

A survey of DOTs conducted in the fall of 2002 found that the Trns•port Estimator module was being used by 22 DOTs 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 that is used by several DOTs is "Bid Tabs" by OMAN systems. It is used either as a stand-alone or in conjunction with "Trns•port" by seven DOTs (Schexnayder et. al. 2003).

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

Volumetric Estimation

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 DOT for generating planning 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 for 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.

The Length-Width-Depth 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 break the information up 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 department'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 DOT created a menu of project types along with a cost multiplier for each type. The department 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, right-of-way, and relocation of utilities. A percentage additive item is used to account for project development costs, including engineering, design, and construction costs. About 20% of the project cost is typically used for this item. For the right-of-way (ROW) cost, the DOT 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 right-of-way limit. A parcel database from the state's geographic information system allows the estimators to determine which parcels are impacted by the assumed right-of-way. 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 right-of-way cost estimate. Once all of these project elements have been calculated, they are added together to provide the total planning estimate value.

Risk Analysis

As described in Chapter 2, State of Practice, each DOT 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 DOTs factor contingency into their estimates, only one DOT performs a detailed risk analysis, using a tool developed by the department. When this DOT creates an estimate, they remove all contingencies from the line items. Then, the DOT 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 DOT 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 DOT 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 DOT recognizes potential project problems early in project development process and this enables the Department to respond proactively to the identified events.

Add-On Elements

During the programming and preliminary design phases of project development, every department 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 DOTs 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 DOT has a policy of not assigning funds to the project. Other DOTs perform these "Add-on" elements 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.

Estimate Reviews

For reviewing a programming or preliminary design estimate, one DOT 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 DOTs can detect possible errors or omissions. DOTs also use reviews to identify discrepancies in the estimate that are the result of bias that lead to underestimation of project cost. Another DOT 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. The DOT also explained that involving all disciplines early in the project development process is important to the project's final outcome.

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 DOTs to create a detailed estimate. Furthermore, estimation and management software is typically used to assist the DOT in producing the final design or engineer's estimate.

Although previous estimates are prepared by the DOTs' district or regional office, the final or engineer's estimate is typically completed by the DOT'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. The final estimate is produced using the bid items and plan quantities derived from the completed plans and specifications. Then, applicable historical unit cost data that has been adjusted to reflect current year costs is applied to the quantities. A few DOTs generate the engineer's estimate within the district or region and then sent it to the central office for review prior to the letting.

Estimation Software

Often DOTs use estimation software to calculate the engineer's estimate. The software is either a program that has been developed within the department or the Estimator module from AASHTO's Trns•port software. A few DOTs use a combination of their in-house software and the AASHTO programs. The DOTs 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 Cost Estimation System 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 DOT uses the Proposal and Estimates System, they can enter project data into the program and prepare conceptual to detailed estimates. Within PES, the DOT can use multiple funding units and differing percentages for engineering and contingency. AASHTO's Estimator module allows the user to use several different estimation 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 is stored in Estimator.

Historical Bid Price Databases

Along with estimation software, DOTs 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 DOT's headquarters often manages the database, with the districts and regions having on line access to the information.

Departments vary as to the period of time historical data is 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 averages. Nine DOTs 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 is calculated several ways:

Low bid only - 20 DOTs

Low and second bid - 1 DOT

Three lowest bids - 15 DOTs

All bids (but may exclude single bids that are very high or low) - 11 DOTs

All bids except high and low - 2 DOTs

Bid analysis to determine a reasonable bid amount for each line item - 1 DOT (Schexnayder et. al. 2003).

By the using 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 is 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 DOT 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 estimation 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 is precise. The Trns•port BAMS/DSS program also analyzes historical bid information. Within this database, the DOT can view contract and vendor information and analyze the market. The program also assists the DOT in analyzing bids, specifically in searching for unbalanced bidding. BAMS/DSS can assess historical bid prices and estimates, and it can evaluate the difference between the awarded and final costs and quantities of a specific project.

The databases allow the DOTs 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.

COST ESTIMATION MANAGEMENT

Cost estimation management should occur continuously throughout the project development process. Some efforts are exclusive to a particular stage of development, while others are pervasive throughout the process. The three phases of 1) planning, 2) programming and advanced planning/preliminary design, and 3) final design can require the application of different cost management methods due to the level of project information that is available and the manner in which the estimate must be communicated. From the DOT interviews, it was discovered that a variety of cost estimation management methods are being utilized by DOTs. This section of the report examines the different cost and schedule management methods used by the DOTs. A number of ideas that were found in the non-DOT interviews are also discussed.

Planning Phase

Communication

How estimate precision is communicated is important, particularly during the earliest stages of project development.

Communication of Importance - Every project estimate is important as cost is integral to project scope, and together cost and scope drive many of the project team’s design decisions. Additionally, the estimated costs that are presented to stakeholders outside of the project team can have many positive and negative implications to the project and to the DOT. All team members must understand the importance of cost estimation if costs are to be managed appropriately. Many projects have been misrepresented, in terms of scope and cost, early in their development because of a lack of understanding that estimates must indicate the “total cost” of the project, as it is known at the time the estimate is completed. To maintain creditability with stakeholders it is important to “tell the public the truth” about project cost and identify the precision of estimate values.

Communication of Uncertainty - Projects are not well defined in the early stages of their development. Identification and communication of the project’s early stage uncertainty and the fact that unknowns can impact scope and costs will help in managing project expectations. The unknown elements of a project estimate can be communicated as cost ranges rather than as point values. The wider the range of values obviously the greater the number of unknowns or specific information about the identified unknown. Communication of the uncertainty can aid in communicating the need to better define the unknown elements and perhaps the need to seek ways to mitigate the unknown aspects of the project by engineering and construction approaches. This process of communicating project cost uncertainty can begin in any stage and continue throughout project development.

Conceptual Estimation Software

When estimation software is used for developing the estimate rather than a simple spreadsheet, the software often has associated cost management tools. The research team was provided examples of both commercially available software and software developed within particular DOTs that had the capability of enhancing project cost management efforts. Examples of this would be estimation software, which required that certain items be entered, checked off, dated, and/or approved before the project development could progress to the next stage of development. Such requirements ensure that all cost related aspects of the project have been properly addressed, limiting later scope changes, and to the practice of inconsistently apply contingency. Many software packages have the capability of highlighting costs that are out of prescribed ranges, thereby prompting the DOT to check the accuracy of an estimate. Estimation software can also be used to track item costs as the project moves from one development phase to another. This feature helps to control total project costs. Currently DOTs do not use any sophisticated estimation software at the planning stage of project development. The majority of DOTs use simple spreadsheets at this project development level. Two DOTs are planning to expand their current in-house software packages used to estimate and manage project costs at the earlier stages of project development.

Red Flag Items

Items that can potentially impact project cost in a significant way are sometimes identified—red flagged—by DOTs early in the planning process. Many DOTs develop a list of these impacting items, based primarily on engineering judgment. The red flagging of items may not involve any formal risk analysis of these factors. In the case of a DOT having a repair project of an urban interstate bridge that crosses over a commercial rail line and a light rail transit line, the red flag item list may include such things as coordination with railway, maintaining open tracks for the light rail, coordination with the light rail entity, and maintaining sufficient traffic over the bridge for the daily commuter traffic.

Recognition of Project Complexity

Project complexity should be addressed early in the project development process so that appropriate cost estimation methods are conducted and the project can be properly managed. One DOT has created three tables that describe project complexity. The DOT 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 DOT 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 DOT employees to aid in communication regarding projects. This type of definition insures that estimates reflect appropriate levels of complexity.

Programming and Preliminary Design

Scoping Documents

Many DOTs 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. When used correctly, this document can be an effective cost management method addressing many cost overrun factors including scope changes, project schedule changes, and engineering and construction complexities. Explicitly defining the scope of the project early in the project development phase allows for better scope control and identification of any changes, which may translate to changes in project cost and schedule.

One DOT 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 DOT 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.

Communication

Communication of Uncertainty - The identification and communication of the uncertainty and of project scope and cost unknowns helps in managing project cost in the Programming and Preliminary Design phase just as for the planning phase. As the project moves from programming through preliminary design, the amount of uncertainty in the estimate should diminish. Good cost management techniques communicate specifically how the design process has removed the uncertainty.

Communication between Departments within the DOT - Communication between internal DOT departments is imperative throughout project development given the complexity and number of people involved in even the simplest project. One DOT mentioned that communications must be open between all departments, and all departments must be active in the project development process, even during the earliest stage of the development phase.

Public Involvement

Public involvement is an essential cost management tool. Public involvement in environmental planning and project scoping is commonplace in highway design, but the public is not often sufficiently involved in project cost development. Conducting public workshops with a focus on cost can help to manage and communicate cost impacts more effectively. Communicating the precision of an estimate, prepared at a particular point in project development, is essential to limiting local government concerns and requirements (Construction Industry Institute 1994).

Conceptual/Parametric Estimation Software

Similar to in the planning phase, estimation software can serve as a comprehensive cost management tool. At this stage, some DOTs still use spreadsheets to prepare estimates and manage costs. However, conceptual/parametric estimation software packages can serve as useful cost management tools in this phase. Some DOTs have developed their own software, and AASHTO Trns•port software is available. These programs provide management with the ability to compare the original estimates with any future estimate.

Definitive Management Plan

From the *FHWA Major (Mega) Projects Lessons Learned* (2003) document, it is recommended that a Project Management Plan be developed during the early stages of every major project. The purpose of the plan is to clearly define roles, responsibilities, processes, and activities, which will result in the project being completed on time, within budget, with the highest degree of quality, and in a safe manner. "The Scope of Work should be clearly defined in the Plan, along with change order and claims controls and other cost containment strategies to be used throughout the life of the project. Upper management buy-in from all sponsoring agencies should also be included in the form of a signature page."

Risk Charter

A risk charter is similar to a list of red flag items. It is a list of identified risks that may be encountered during the life of the project. However, a risk charter is typically based on a more scientific assessment of risk, rather than simple engineering judgment. 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 by project design changes. This method may be more effective than simply listing the potential problem areas, as with the red flagging of items, since it seeks to successfully eliminate the number of risk items.

Estimation Checklist

Some DOTs use estimation checklists 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 should mirror 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 definition of scope. One example checklist, used by a DOT 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)

Design Value Engineering

Value engineering (VE) is used throughout the construction industry (SAVE International 2004). Within DOTs, VE is used to increase the project deliverables within the limited funds available for a project. By breaking the project into components, reviewing the function, and formulating solutions and developing recommendations for improvements, one DOT has shown an increase in constructability, a minimization of ROW and/or environmental impacts, and a compression of construction schedules. Another DOT requires VE of all highway projects greater than $25 million.

Design to Cost

This is a technique that is used often in commercial development or manufacturing where a project must produce a product that will in essence pay for itself within a specified duration. A DOT can think of this as the matching of fuel tax revenue stream to the construction program; a processes used by some MPOs. In the private sector, a project must not only make a profit for the company but must also meet a minimum rate of return to be considered viable.[7] The steps in this process require the company to set a target cost of the product, which includes the costs to make the product and the gross profit margin. Then the project team must evaluate the design alternatives and their costs. The design cost estimate and the target cost of the project are compared. If the estimated cost during design exceeds the target cost of the project, then one or both need to be re-evaluated before continuing with project development (Burman 1998). One DOT mentioned using an approach similar to this process. Rather than estimating the target cost, the DOT looks at the economic benefits generated by the highway's construction. In essence, the DOT cannot spend more on the road than the incoming revenue stream for its funding sources.

Management of ROW, Utilities, and Environmental Issues

The costs of various project items that are included in the estimate must be managed in different ways. One DOT specifically breaks out the various elements of an estimate in an effort to manage the costs of these elements more closely. The first tier of element definition is:

PE

Final design

ROW

Utility

Construction

A study phase as needed.

Another DOT uses in-house software to manage the costs of various components. A checklist within the system requires each item to be entered by the project or task manager. In this system, ROW is completed by a ROW person in the district who can use their own numbers for the estimate or the model numbers based on the amount of ROW and current land use. The manager of the project must be careful that the level of definition for each element is consistent throughout the estimate. One DOT has a ROW division, which produces extremely straightforward and accurate estimates. This DOT has a training program for the ROW appraisers.

[7] Interview with Coors Brewing Company, July 30, 2004.

State Estimation Department

Numerous DOTs develop their project estimates at the central office. Locating estimation knowledge in one location provides the estimators with the ability to focus solely on estimation and maintenance of the cost databases that support estimate preparation. Through the use of one standardized process, DOTs can ensure estimate consistency.

Cradle to Grave Estimators

Maintaining the same estimator throughout all phases of project development allows that person to become intimate with the project scope and any unique characteristics impacting the project. This connectivity can increase estimate preparation efficiency as the estimator has historical knowledge about the project. In the case of one DOT that uses the same estimator from the start of project development through the final estimate, the projects are estimated at the local level. By keeping estimate preparation responsibility at the local level there is the advantage that the people doing the estimate understand the local situation and the political climate. Disadvantages of this system are that estimates are not always consistent throughout the state and estimation knowledge and costs data tends to be local.

Year of Construction Costs

Project cost estimates can be priced in current dollars or in year of construction dollars (cost inflated to the expected midpoint of construction date). The advantage of using year of construction cost is that it will more accurately reflect the cost of the project when it is complete and the communication of estimate is more credible. The disadvantages of using future costs are that it is difficult to compare current project costs with other projects in the STIP and inflated costs are not always accurate due to variances in inflation rates, market forces, and actual dates of construction.

Scope Change Form

Requiring completion of a scope change form for each change to the project permits tracking of scope changes as well the effects that the changes have on the project cost and schedule. Requiring scope change approval is extremely effective in managing project changes. The use of a form creates a discipline and awareness of the cost impact of scope changes. By notifying project team members in a timely manner of scope changes and their impact on project costs and schedule, appropriate actions can be taken to mitigate the impact of the change to the project and to other projects in the program. Several DOTs mentioned very rigorous scope change systems requiring certain forms be completed and approvals from or notification of specified personnel, if a scope change is made.

Cost Containment Table

The Cost Containment Form shown in Table 3.2 requires updating at each predetermined project milestone. At each project milestone point where this form is used the estimate must be broken down by specified items. The form has space available for scope definition as well as comments. A change in an estimate category is evident when completing the form and this allows for immediate investigation and notation of explanations. This effort to manage project costs continues from the programming and advanced planning/preliminary design stage through final design until the project letting.

Table 3.2. Cost Containment Form used by One DOT

Cost Containment Table						
District:	Program Yr:					
County:	Project:					
	Short Title:					
Cost Containment	**Milestone Estimate**					
Cost Breakdown	Program Amount (PMC approved amount) $	E&E Scoping Field View $	30% (Design Field View) $	75% (After Final Design Field View) $	95% (Engineer's Estimate) $	Bid Amount $
Engineering:						
Preliminary Engineering						
Final						
Design						
R/W						
Utilities						
Construction						
Total Cost:						
Scope						
Comments						

Gated Process

In essence, a cost containment spreadsheet, such as the Form shown in Table 3.2 which was discussed previously, creates a gated development process because projects cannot move from one milestone to the next without approval of the Cost Containment Form. One non-transportation source communicated that they use a gated process, which is extremely formalized. Before a project can continue in the development process the project team must hold a meeting in which the Construction Industry Institute's Project Definition Rating Index (PDRI 1997) must be completed. The PDRI scores a project's level of scope definition as compared to a historic data on scope definition. The project must achieve a maximum score before the project can continue. If the project does not obtain the maximum score then the project is returned to the previous phase for more definition. The PDRI requires that the project be scored in of the following areas;

Basis of Project Decision

a. Manufacturing Objective

b. Business Objective

c. Basic Data Research and Development

d. Project Scope

e. Value Engineering

Front End Definition

Site Information

Process/Mechanical

Equipment Scope

Civil, Structural, and Architectural

Infrastructure

Instrument and Electrical

Execution Approach

Procurement Strategy

Deliverables

Project Control

Project Execution Plan

Create Project Baseline

All DOTs need to establish a baseline scope and estimate for their projects. The project baseline scope and estimate is used to measure performance throughout project development and construction. This baseline may be created at different points by different DOTs but the purpose is the same; it defines the moment when an identified need becomes a "real" project and is budgeted. Some DOTs establish a baseline estimate early in the project development process, during long range planning, where other DOTs set the base line when the project is programmed or at 35% design.

Estimation Manual

The creation of a DOT specific estimation manual helps to ensure consistency in estimate preparation. Some DOTs have estimation manuals that pertain to estimates starting at the earliest phases of project development, while other DOT manuals do not indicate how estimates should be prepared until the later phases of project development. A few DOTs do not have any type of formal estimation manual. The estimation manuals that are available vary considerably in depth and quality of provided information. The manuals for several DOTs are very general while others provide great detail regarding preparation and content of the estimate.

Estimator Training

Very few states offer formal training to their estimators. Many states noted that the training that takes place must either be requested or occurs on the job. The formalized training that is present by DOTs does not necessarily address all portions of the estimate preparation. One DOT mentioned that there is formal training for ROW estimators, while there is no formal training for the personnel that estimate the remainder of the project. Other DOTs have training courses that teach the estimators how to use the software and expose the participants to details and issues that they should consider when creating cost estimates.

Estimation Scorecard

Estimation scorecards can be used to measure the success of project development processes. These scorecards are developed early in the project development process. Scorecards are most commonly used when consultants are preparing the project design and estimate. They indicate the measures that will be used at project completion to evaluate success. Once the project is completed the consultants fees can be based off of target values designated during project development and the achieved values measured after project completion. A set of scorecards is developed for each project, one for execution and another for benefit. The elements of the execution scorecard for determining project success are cost, schedule, and quality/performance. The benefit scorecard elements are defined based on the project. Each scorecard element is measured as either above target, on target, or below target. Early identification of the project success measures ensures that there is no miscommunication regarding functionality and physical structure of the completed project. This helps to clearly align defined project scope with expectations thereby limiting scope changes.

Final Design

Estimation and Management Software

Similar or the same software used during the earlier project development phases is used for preparing the final estimate, and again it can also be used to manage project cost. Commercially available software is capable of this function as well as DOT developed software. Currently many DOTs use the Trns•port modules at this level, even if in-house programs were used in the previous phases.

Estimate Review

The review of project estimate at this stage can vary from none, to an in-house/peer review, to a formal committee review. The less formal review can include another estimator in the state estimation office or design division, who examines the estimate before the project is bid. This review may only check to make sure that no items were missed. This review is typically based on experience or a formal check system. In many cases during this phase, DOTs have more formal estimate reviews, which 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, Federal Highway Administration, 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.

SUMMARY OF IMPORTANT ISSUES

Cost estimation practices and management techniques describe by the DOTs to the research team attempt to alleviate many causes of cost escalation. However, it appears that no single DOT has cost estimation practice and cost estimation management systems in place that address all factors causing cost escalation that Departments must address in establishing and managing the cost of their projects.

Contingency and Uncertainty

Contingency is typically applied to DOT cost estimates but its application must still be considered a deficiency. It was found that in most DOTs the application of a contingency to an estimate is so loosely defined that typically there is no consistent application of contingency. The DOTs 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 Estimation and Management

Risk-based estimation and management is used by only a small number of transportation agencies. Range estimates and risk charters are common practice in the other industries, but the highway sector is just beginning to apply these techniques. The DOTs who are applying a risk-based estimation approach have found it to be successful in communicating the true nature of project costs at the planning and preliminary design phase. These DOTs have also found it useful in managing the project development and design process.

Time Value of Money

Many DOTs inflate their estimates to the prospective date of construction by applying a factor that reflects the current economic situation. However, DOTs 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, then the DOT might consider the impact of time changes and incorporated it into the estimate. However, many departments do not have a regular formal estimate review process.

Scope Control

The issue of scope control is paramount to managing project costs. DOTs are attempting to use a variety of methods and tools to control scope changes[8] and scope growth, but their use is not widespread and it is far from standard practice. Scoping documents are being used in the project development process to identify and specify critical design elements. Definitive management

[8] By Arizona law (A.R. S. 28-6353) if there is a material scope change for freeways in Phoenix the change must be approved by the Maricopa Association of Governments.

plans are being recommended on major projects. Cost containment tables are being used to identify when a project's scope has grown, but these tables may not indicate growth until significant growth has occurred.

Project Baseline and Gated Process

A system of cost validation points must be established if a project is to remain on budget. Few DOTs have a process, which is gated based upon estimated cost. A gated process begins with a standard point in design in which a project estimate baseline is created. Some DOTs establish a baseline estimate early in the project development process, during long range planning, where other DOTs set the base line when the project is programmed or at 35% design. However, many do not have a standard point for setting a project baseline at all. Upon establishment of the project estimate baseline, a gated process involves the validation of scope, schedule and cost at critical points during the project development process. A project should not be allowed to move to the next phase of development unless all scope, schedule and cost constraints have been established.

Estimate Reviews

Most of the DOTs 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 DOTs 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 DOTs have requirements that an estimate (the project's estimated cost) must remain within an established range. If the estimated cost goes outside the range, then additional reviews and approvals are needed. The informality of the review process leads to projects advancing to the next stage without serious cost reviews.

Estimator Qualifications

The reliance on estimators who lack sufficient experience is another deficiency that DOTs must overcome. When an experienced estimator retires or moves to another job that estimator's knowledge is lost. This dependency hinders the DOTs' because they rarely have a training program for new estimators or an estimation procedure documented (a Manual) with sufficient detail for an inexperienced individual to follow.

Estimation Documentation

Proper estimation documentation is another common deficiency, which causes accountability issues. Unless a DOT 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 DOTs lack consistent estimation procedures between their districts. Many DOTs do not have standardized estimation 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.

Communication

The DOTs also lack coordination and communication between the disciplines participating in the development of the project's scope and estimate. The supporting groups, who feed information into the primary estimate, do not play an active role in the project's development until the project reaches the preliminary design phase. In addition, the individual who is compiling the estimate is often not certain the other groups have properly accounted for their project elements.

Project Complexity

Most of the DOTs do not adequately consider project complexity when they create a cost estimate. If a project is more complex than the DOT's standard projects, then the DOT might include additional contingency. During a project review, some DOTs 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.

CONCLUSIONS

This chapter critically reviewed current practices in the area of cost estimation practice and cost estimation management. A number of unique or innovative approaches to cost estimation practice and cost estimation management were described. A discussion of how current cost estimation practice and cost estimation management approaches do and do not address the identified potential root causes of project cost escalation was also provided. Finally, important issues and more specifically deficiencies in current practice are identified. Strategies to address these and other issues are presented in Chapter 4, including proposed methods and tools to implement the strategies.

CHAPTER 4
STRATEGIES, METHODS, AND TOOLS

The main goal of Task 3 is to identify potential strategies, methods, and tools that will improve cost estimation management and cost estimation practice. The deliverable of this task is a set of strategies, methods, and tools. Based on our framework, these strategies, methods, and tools will be tied to their use in the different phases of project development and project complexity. Figure 4.1 highlights the basic inputs and outputs of Task 4.

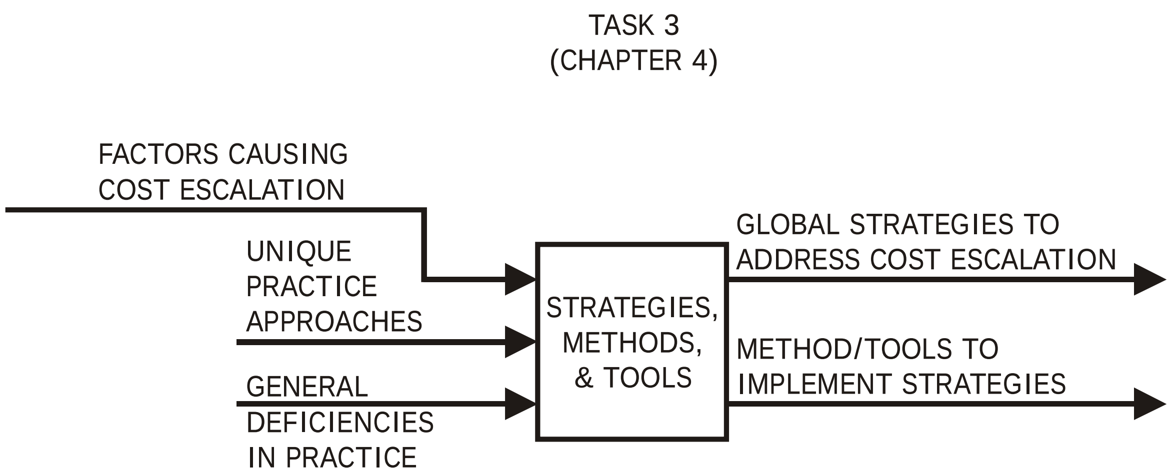

Figure 4.1. Strategies, Methods, and Tools Inputs and Outputs

METHODOLOGY

The main methodology used to develop the potential list of strategies, methods, and tools was to first focus on causes of cost escalation and potential strategies that would address these causes. Creating this linkage between causes of cost escalation and strategies was based on literature, an assessment of current practice, and general deficiencies found in reviewing unique practice approaches. Eight overarching or global strategies were identified and then described. The research team believes that identifying a set of high-level strategies provides a stronger support base for promoting management action on implementing these strategies. The research team then identified the methods and tools that would likely be effective in implementing the global strategies. 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 created. Complete descriptions and application of the methods and tools will be developed in Phase II of this research.

COST ESTIMATION PRACTICE AND COST ESTIMATION MANAGEMENT STRATEGIES

If DOTs are to produce accurate estimates, they DOT must have solid management plans in place that address the management of estimates, 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 DOT if they are to develop an accurate project estimate. Preparation of accurate estimates is, therefore, the responsibility of many different divisions in the DOT 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 1.2). As the project is developed:

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 costs. These initial cost estimates are more useful in determining funding levels needed for long-range capital programs. Some DOT's stated during the interviews that the expectation for these early estimates is in the plus or minus 40 percent range.

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.

Add-on elements that are often considered beyond the control of the DOTs 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.

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.

DOTs 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. DOTs 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" (*Transportation Infrastructure Managing the Costs of Large-dollar Highway Projects* 1997). DOT 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 the purpose of evaluating project alternatives. This 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 estimation and from the interviews it is clear that there exist global strategies that can affect the accuracy and consistency of project estimates and costs. Eight strategies were identified. The definition of a strategy from Chapter 1, "*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:

Management Strategy – Manage the estimation process and costs through all stages of project development;

Scope/Schedule Strategy – Formulate definitive processes for controlling scope and schedule changes;

Off-prism Strategy – Use proactive methods for engaging those external participants and conditions that can influence project costs;

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

Delivery and Procurement Method Strategy – Apply appropriate delivery methods to better manage cost, as project delivery influences both project risk and cost;

Document Quality Strategy – Promote cost estimates accuracy and consistency through improved project documents;

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

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 eight global strategies address the factors presented in Table 2.2 that cause cost escalation on DOT projects and within their capital programs. Table 4.1 illustrates the link between the global strategies and cost escalation factors.

Table 4.1. Link Between Strategies and Cost Escalation Factors

Cost Escalation Factors			Management	Scope/ Schedule	Off-Prism Issues	Risk	Delivery/ Procurement Methods	Document Quality	Estimate Quality	Integrity
			Global Strategies							
Planning	Internal	Bias								√
Planning	Internal	Delivery/Procurement Approach	√			√	√			
Planning	Internal	Project Schedule Changes		√					√	
Planning	Internal	Engineering and Construction Complexities				√	√	√	√	
Planning	Internal	Scope Changes	√	√	√	√				
Planning	Internal	Poor Estimation						√	√	
Planning	Internal	Inconsistent Application of Contingencies	√			√		√	√	
Planning	External	Local Government Concerns and Requirements	√		√	√				√
Planning	External	Effects of Inflation		√					√	
Planning	External	Scope Creep		√	√					
Planning	External	Market Conditions			√	√			√	
Execution	Internal	Inconsistent application of Contingencies	√			√		√	√	
Execution	Internal	Faulty Execution	√				√			
Execution	Internal	Ambiguous Contract Provisions					√	√		
Execution	Internal	Contract Document Conflicts						√		
Execution	External	Local Government Concerns and Requirements	√		√	√				
Execution	External	Unforeseen Events			√	√				
Execution	External	Unforeseen Conditions			√	√				
Execution	External	Market Conditions			√	√				

The interviews with DOTs 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 DOT has a comprehensive approach for addressing all of these strategies. The strategies must be developed so that they provide an approach that spans those 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. It should also be noted that the global strategies could be further separated into sub-strategies in management and operational categories. For example, the Scope/Schedule, Off-Prism, Risk, and Estimate Quality strategies have management sub-strategies, which overlap very closely with parts of the global Management Strategy. Where possible, these operational sub-strategies are discussed separately within each global strategy description.

Management Strategy

Manage the estimation process and costs through all stages of project development. At the highest level within the DOT, DOT leadership can advance cost management strategies that foster and support estimate accuracy and consistency through all phases of project development. The DOT leadership has the responsibility to publicly explain how the project development processes works and most importantly ensure that cost estimation practice and cost estimation management processes are transparent. Therefore, the DOT must be able to produce accurate estimates. Personnel must be trained and there must be established processes and critical reviews of all estimates to achieve accurate estimate results. Currently, 40 DOTs use only on-the-job training (OJT) to train their estimators. Twenty-six DOTs have no published standard estimation procedures (Schexnayder 2003). Senior management must take a more active role in advancing strategies to increase estimator knowledge and consistency in estimates through management sub-strategies of organizational leadership and operational sub-strategies of estimator training and development of estimation procedures.

Organizational Leadership

Senior DOT management should view itself as investors, developers, and strategists. Management has the responsibility to provide project staff members with the resources to effectively perform their jobs, including gathering sufficient project information so that reliable estimates of cost and schedule can be developed. Senior management can: 1) create an environment for success; 2) insure that appropriate oversight processes are established and functioning; and 3) position the right people for the tasks.

Estimate Communication

The manner in which project estimates and estimate precision is communicated is imperative, particularly during the earliest stages of project development. Internally, senior management must convey the importance of a project estimate and the fact that cost is integral to project scope. Together cost and scope should drive many of the project team's design decisions if cost is to be managed successfully. Communication of cost uncertainty is also important internally. Identification and communication of the project's early stage uncertainty and the fact that unknowns can impact scope and costs will help in managing project expectations. The unknown elements of a project estimate can be communicated as cost ranges rather than as point values.

Externally, these issues of estimate importance and estimate uncertainty are possibly even more critical to project success. To maintain creditability with stakeholders it is important to "tell the public the truth" about project cost and identify the precision of estimate values. Transparency in estimate communication is sometimes difficult because external stakeholders often want "one number" before an accurate estimate can be made by even the best estimators and engineers, but transparency of costs will be best over the duration of a project. Management of project cost through proper communication has implications on the other global strategies of Scope/Schedule, Off-prism, Risk, Delivery, Estimate Quality, and particularly the Integrity Strategy.

Estimator Training

DOT projects are becoming increasingly complex, both in design features and contracting procedures. As a consequence, producing an accurate estimate requires individuals with extensive experience and expertise. DOTs must increase the knowledge, skills, and abilities of their employees and provide a cadre of well-trained professional estimators if they want to achieve estimate accuracy and quality. There could be a set of minimum core competencies for which all estimators are provided training. An important component of management's estimation strategy must be providing comprehensive and rigorous training in project cost estimation and scheduling to their estimation staff.

Estimation Procedures

Estimation documentation must 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 DOTs do not currently have a published estimation procedure for early estimation. DOTs would benefit greatly by producing their own guidelines of standard processes, procedures, and formats to be used by both DOT estimators and design consultants retained for estimation purposes. This guidance document should be specifically written for those responsible for preparing the State's estimates.

In preparing an estimation manual, members of the States heavy/highway construction industry can be asked to share with the department their knowledge of production rates, estimation techniques, and factors that increase project risk. Advice from local contractors can specifically be sought in regard to factors that they consider to be 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 DOT, 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/Schedule Control Strategy

Formulate definitive processes for controlling scope and schedule changes. Scope control ensures that project changes are identified, evaluated, coordinated, controlled, reviewed, approved, and documented in a manner that best serves the defined need. Projects often take years to move through the development process. As the time frame is extended there are more opportunities for external and internal parties to suggest changes in scope. Additionally, if the schedule is extended there will be cost impacts resulting from increases in land costs and effects from inflation. The cost effect of a change depends on the point in time when it is introduced. Early in project development, before estimates are prepared, a change in scope does not cause significant problems. Later scope changes, during engineering design and construction, have ripple effects and later changes can increase project cost exponentially.

Scope Control

Scope control is a management responsibility. Specific management methods and tools, all of which can be include in the management plan for scope control, are: 1) commitment to change control; 2) a defined point in the project development process when management freezes the design; and 3) a requirement of formal justification of changes (every change must be justified and reviewed by supervisors and affected parties).

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 DOT 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.

Design to Budget

In order to ensure that designers are aware of how scope changes will affect project cost, it is advantageous to require submittal of a cost estimate along with each design submittal. When large differences between the conceptual estimate and the design estimate are reported (>10%), approval could be required from the supervisory level or higher before design proceeds to ensure sufficient funds will be available for construction. If estimated project cost exceeds the existing budget, then changes will have to be made to reduce the overall project cost. This issue may require project scope reduction. Another scope control method is design to budget, which forces designers to be constantly aware of the cost implications of their design decisions.

Gated Process

Some DOTs are delaying the incorporation of projects into the STIP until scope is clearly defined and there is sufficient data for developing an accurate cost estimate and projection of project schedule, including the time to fully design the project. Each DOT can use methods and tools, which will:

Serve to anticipate and predict scope changes

Evaluate the impacts of scope changes

Identify and control the consequences of scope changes

Prevent unauthorized or unintended deviations to scope

Ensure that each scope change is evaluated, and reviewed and approved at the proper management level.

Time Value of Money

The scope/schedule strategy must also directly address inflation. While the rate of inflation is uncontrollable, it is usually a foreseeable factor. Inflation engendered by the Vietnam War greatly affected the BART system's cost. The original estimates provided for 3 percent per annum inflation, but the actual rate was 6.5 percent (Hall 1980). Many indexes are available that can aid the estimator in establishing inflation adjustments to an estimate. However, often the problem is not that an inflation rate was not incorporated into the estimate but that the project schedule has slipped and the time duration to midpoint of construction is much longer resulting in greater inflationary effects.

Inflation's effect must be accounted for both in terms of a rate and a time interval; it is a time value of money issue with the inflation rate being only the interest component. The lengthening of construction schedules will cause inflation to be a significant cost growth factor. The National Academy report (2003) on the CA/T project stated; "… the CA/T project management team indicated that about half of the cost growth was caused by inflation (the original estimates were in 1982 dollars, as required by FHWA) and that a portion of this could be attributed to the extended schedule." Exposing capital outlays to a more prolonged period of inflation contributed to the cost overruns experienced.

The effects of inflation must be addressed early. How inflation is treated in the estimate must be clearly stated. The FHWA recommends the cost estimates be prepared in year-of-expenditure dollars, inflated to the midpoint of construction, with some allowance for schedule slippage taken into account. Reporting the costs in year-of-expenditure dollars will greatly reduce the media and public perception of "cost growth."

Off-Prism Strategy

Use proactive methods for engaging those external participants and conditions that can influence project costs. In the case of most 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 DOTs 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, Flyvbjerg, and Rothergatter 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 (Merewitz 1973)." 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 macroenvironment 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 estimation, understanding the macroenvironment, the *off-prism* items, has never been standardized as a part of project estimation. It is therefore important to develop early stage planning processes that focus on community concerns, requirements, and other *off-prism* issues.

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 DOT 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 estimation and the validation process must consider probabilities in assessing cost.

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. There should be a requirement to develop a risk management plan for all projects having significant complexity. 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, there can be a risk handling strategy to 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 is 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 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 DOT or to which the DOT 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 estimation 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 your 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.

Delivery and Procurement Method Strategy

Apply appropriate delivery methods to better manage cost, as project delivery influences both project risk and cost. Delivery and procurement involves the process by which a construction project is comprehensively designed and constructed for an owner including project scope definition and determination of project size, organization and selection of engineers, constructors and various consultants, and determination of the contract types used to allocate risk and define payment. Open communication with the construction industry from initial project planning to contract award is the cornerstone for a successful project. Procurement documents tailored to project requirements improves source selection by focusing efforts on those features critical to a successful construction process.

A project delivery and procurement strategy can be structured to achieve project stability of project costs by minimizing technical, schedule, and cost risks. The strategy involves the process of identifying and describing requirements and determining the best method for meeting those requirements. The approach should address *market conditions* (Summary of Independent Review Committee Findings Regarding the Woodrow Wilson Bridge Superstructure Contract 2002, Woodrow Wilson Bridge Project Bridge Superstructure Contract 2002), effective use of competition (encourage competition), and performance based contracting opportunities. Projects may require multiple contracts. Specific contracting methods should be tailored based on the size, risks, and complexity of the project. Documentation of the method should describe: 1) the key technical and performance parameters for the project; 2) funding profile that distributes the costs by fiscal year; 3) identify sources of funds, including those from outside sources; 4) discuss lifecycle costs; and 5) identify key milestone dates in the project development and contracting process (Chapter 5 Definition Phase 2003). In the case of major or complex projects there must be methods and tools in place that will:

Formalize roles and responsibilities;

Provide a roadmap to project completion;

Define process and strategy for each major project element—how you get to each milestone;

Insure executive endorsement of the process;

Rigorous industry outreach, (pre-bid plan availability at 60 percent design (Zanetell 2004), industry review meeting[9]);

Provides opportunities for small and disadvantages businesses; and,

Work to keep communications channels open.

Determination of Contract Type

Specific contract planning should be appropriate and proportionate to the complexity and dollar value of the project. The major types of contracts and incentives proposed should be based on an overall view of major project risk. Fixed-price type contracts are often not appropriate for complex projects where there is a high degree of uncertainty in the execution or DOT requirements. Fixed-price is appropriate where the level of risk permits realistic pricing and an equitable allocation of the risk consequences between the parties.

Communication

Early exchanges of information about future projects among the construction industry and other parties interested in the project can identify and resolve concerns regarding the procurement method and the work. Information concerning proposed contract type, terms and conditions, and schedules; and performance requirements provide feed back about the project and help to insure bidding competition.

The purpose of exchanging information is to improve the understanding of DOT requirements and industry capabilities, thereby allowing potential presenters to judge whether or how they can satisfy the DOT's requirements, and enhancing the DOT's ability to obtain construction, at reasonable prices, and increase efficiency in proposal preparation, proposal evaluation, negotiation, and contract award.

Some methods to promote competition and project feed back before bidding are:

Industry or small business conferences

Market research

Presolicitation notices

Requests for information

Pre-solicitation or pre-proposal conferences

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[9] Nevada Department of Transportation, I-580 Freeway Extension Contractor Review Meeting, August 26, 2004.

Site visits

Effects of Large Projects

Funding and staffing issues are driving DOTs towards larger projects and these large projects are creating well documented problems with cost growth. FHWA has distributed information on lessons learned from major (Mega) projects. An important point that should be considered in addition to inflation is a project's *economic impact on the local economy*. Cost estimates should consider the economic impact of major projects on the local geographical area. For example, material suppliers that would normally compete with one another may be "forced" to team together to meet the demand of a major project. Extremely large construction packages also have the potential to reduce the number of contractors that have the capability of bidding on the project, and may need to be broken up into smaller contracts to attract additional competition. Bid options (simultaneous procurements of similar scopes with options to award) should also be considered for potential cost savings resulting from economies of scale and reduced mobilization. A value analysis should be performed on the project to determine the most economical and advantageous way of packaging the contracts for advertisement.

Large complex projects have characteristics that make them extremely challenging to estimate and which estimators should always consider when reviewing costs assumptions. These include:

Large projects stretch available resources to the limit ─ labor, material, management skill, and information systems

Large projects have a high profile with political subdivisions and the public

Large projects are very noticeable by regulators

Large projects are unusually long duration projects and there is less likelihood of maintaining continuity of management

Document Quality Strategy

Promote cost estimates 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 DOT, 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, which 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 Construction Industry Institute 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 consider 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 adds 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.

Estimate Quality Strategy

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

Many of the unique practices discussed are being used by a limited number of DOTs. Some of the practices are derived from studies of contractor estimation procedures. In addition to management sub-strategies of Estimator Training and Estimation Procedure previously discussed in the global Management Strategy, a discussion of two additional operational strategies of Estimation Documentation and Estimate Reviews follows.

Estimation Documentation

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

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 the quality of the DOT estimate can be validated by review processes. Only in Attachment A – "Review of Engineer's Estimate Preparation" is there any recognition of the fact that DOT estimates should be reviewed and Attachment A is strictly directed at Engineer's Estimates. A very effective management 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.

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 (Scope Definition Control 1986). Conceptual estimation is an art, not a science. Clever people do not want to do it because in many departments 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 DOT estimators expressed such frustrations during conversations with the research team.

If DOTs 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 DOTs need to *enhance their cost databases* and document factors that effect project cost. Just keeping a database of historical bid tabs is not sufficient to proving the necessary data for estimation; the data must be analyzed to provide information.

Summary

Engineering skill and judgment invested in project planning is obscure to the general public, legislators, community opinion leaders, and the media. Cost busts are easy for the public to understand. But who wants to appreciate the fine points of route alignment, difficult geotechnical conditions, wetlands mitigation analysis or community desires for a signature structure?

Departments need strategic approaches to cost estimation practice and cost estimation management 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 estimation processes.

PRELIMINARY STRATEGIES, METHODS, AND TOOLS

Strategies for cost estimation practice and cost estimation management must be applied across the continuum of project development phases. Specific methods and tools that support implementation of the global strategies are shown in Tables 4.3, 4.4, and 4.5. The methods and tools shown in these tables are based primarily on those presented in Chapter 3, only linked to specific strategies they support. There are several methods and tools that are not presented in Chapter 3 but are indicated in these tables. These methods and tools were identified in later interviews after Chapter 3 had been developed. Therefore, these methods and tools were eventually addressed fully in the Guidebook.

The definitions identified in Chapter 1 guided the description of a particular method and tool. 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]."* 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. The use of the method and tool may change slightly to fit cost estimation practice or cost estimation management requirements for that particular phase. Finally, the tables indicate where a strategy may currently have only a small number of applicable methods and tools. The strategies, methods, and tools that were recommended and included in the Guidebook were fully developed in Phase II.

Planning Phase Strategies, Methods, and Tools

Current methods and tools being used by DOTs in support of planning phase estimation are shown in Table 4.3. Table 4.3 makes it very clear that in certain strategic areas DOTs may be not be prepared to deal with critical issues that influence the quality of their estimates. While some DOTs 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 DOTs having structured processes for looking at project delivery and procurement methods as they might impact cost estimation. There are individual reports of project delivery and procurement courses of action being carefully developed for selected projects (Federal lands Division of FHWA for the Hoover Dam Bypass project, and the Maryland State Highway Administration's repackaging of the bid packages for the Woodrow Wilson Bridge) but from the reports it does not appear that this was considered during the planning phase. Fewer methods and tools identified address the strategic issue of estimate integrity. There are, however, several tools that had been put in place for other reasons but may also serve to monitor estimate integrity.

Programming and Preliminary Design Phase Strategies, Methods, and Tools

Current methods and tools being used by DOTs in support of Programming and Preliminary Design phase estimation are show in Table 4.4. Table 4.4 makes it very clear that in certain strategic areas DOTs may not be prepared to deal with critical issues that influence the quality of their estimates. In the area of estimate integrity, a few more tools are being used by a limited number of DOTs. But there obviously needs to be more tools and methods developed to handle the off-prism issues that impact project cost, for developing project delivery and procurement strategies, and for achieving document quality.

Final Design Phase Strategies, Methods, and Tools

Current methods and tools being used by DOTs in support of Final Design phase estimation are show in Table 4.5. Table 4.5 makes it very clear that even at this late stage in project development DOTs may not focusing on certain critical issues that influence project cost and the quality of their estimates. In the area of estimate integrity no specific tools were identified during the interviews. Again there is a conspicuous lack of tools to address off-prism issues, for developing project delivery and procurement strategies, and for achieving document quality.

Table 4.3. Strategies, Methods, and Tools for the Planning Phase

	Cost Estimating Practices		**Cost Estimating Management**	
	Planning			
Strategy	Method	Tool	Method	Tool
1. Management			Communication	Simple Spreadsheet
				Communication of Importance
				Proactive Conveyance of Information to the Public
			Budget Control	Budget by Corridor
				Constrained Budget
				Variance Reports of Cost and Schedule (original/previous/current)
				Summary of Key Scope (original/previous/current)
			Recognition of Project Complexity	Complexity Definitions
2. Scope / Schedule			Communication	Communication of Uncertainty
				Communication of Importance
			Computer Software	Simple Spreadsheet
				In-house Conceptual Estimating Software
			Buffers	Management Approvals
				Board Approvals
				Constrained Budget
3. Off-Prism Issues	Identifying Off-Prism Issues	Percentage of Total Project Cost		
4. Risk			Identification	Red Flag Items
			R/W Land Values	Consider Full Cost
				Condemnation
				Advance Purchase
5. Delivery / Procurement				
6. Document Quality	Document Estimate Basis and Assumptions	Project Estimate File	Computer Software	Simple Spreadsheet
				In-house Conceptual Estimating Software
7. Estimate Quality	Cost/Mile Factors Using Typical Sections	Cost/Mile Handbook (LRE)	Computer Software	Simple Spreadsheet
		Spreadsheet Templates		In-house Conceptual Estimating Software
	Cost/Mile Factors Using Similar Projects	Scoping Document	R/W Cost	Specify Corridor Width
	Project Scoping	Estimate Checklist		Acres for Interchanges
				Depressed Sections
		Scoping Document		Relocation Costs
				Demolition
	Conceptual Order of Magnitude Estimating	Confidence Ranges		Asbestos Abatement
8. Integrity			Computer Software	Simple Spreadsheet
				In-house Conceptual Estimating Software

Table 4.4a. Strategies, Methods, and Tools for the Programming & Advanced Planning/Preliminary Design Phase

	Cost Estimating Practices		**Cost Estimating Management**	
	Programming & Advanced Planning / Preliminary Design			
Strategy	Method	Tool	Method	Tool
1. Management			Communication	Communication of Uncertainty
				Communication within DOT
				Definitive Management Plan
				Year of Construction Costs
				Proactive Conveyance of Information to the Public
			Computer Software	Commercial Estimating Software
				In-house Software
			Gated Process	Cost Containment Table
			Consistency	Estimate Manual
				Estimator Training
				Estimating Checklist
				State Estimating Department
				Cradle to Grave Estimators
			Budget Control	Budget by Corridor
				Constrained Budget
				Variance Reports of Cost and Schedule (original/previous/current)
				Summary of Key Scope
2. Scope / Schedule			Communication	Communication of Uncertainty
				Communication within DOT
				Definitive Management Plan
				Year of Construction Costs
			Gated Process	Cost Containment Table
			Creation of Project Baseline	Scoping Documents
				Scope Change Form
				Cost Containment Table
				Estimate Scorecard
			Value Engineering	Value Engineering
			Buffers	Management Approvals
				Board Approvals
				Constrained Budget
3. Off-Prism Issues	Project Milestones	Environment Assessment	Communication	Communication of Uncertainty
				Communication within DOT
	Internal Estimate Reviews	Off-Prism Evaluation	ROW, Utilities, Environment	Lists
				Software
				Separate Estimators
				Estimator Training
			Public	Workshops

Table 4.4b. Strategies, Methods, and Tools for the Programming & Advanced Planning/Preliminary Design Phase

	Cost Estimating Practices		Cost Estimating Management	
	Programming & Advanced Planning / Preliminary Design			
Strategy	Method	Tool	Method	Tool
4. Risk	Risk Analysis	Cost Estimate Validation Process - Estimate Ranges	Communication	Communication of Uncertainty
				Communication within DOT
		Contingency - Fixed Percentage	Identification	Red Flag Items
				Risk Charter
		Contingency - Sliding Scale	R/W Land Values	Consider Full Cost
				Condemnation
				Advance Purchase
5. Delivery / Procurement				
6. Document Quality	Internal Estimate Reviews	In-house/Peer	Computer Software	Trns•port
		Formal Committee		Other Commercial Concept/Parametric Software
	External Estimate Reviews	Expert Team		In-house Software
	Document Estimate Basis and Assumptions	Project Estimate File	Constructability	Constructability Reviews
7. Estimate Quality	Major Cost Items Using Standardized Sections	Spreadsheet Template (6-Page Estimate)	Computer Software	Trns•port
				Other Commercial Concept/Parametric Software
		Long Range Estimating		In-house Software
	Volumetric Estimating	LWD Template	Consistency	Estimate Manual
				Estimator Training
	Parametric Estimating	In-house Estimating Software		Estimating Checklist
				State Estimating Department
				Cradle to Grave Estimators
		Scope of Work Estimating Software	Gated Process	Cost Containment Table
				Checklists
		AASHTO's Trns•port Software	Creation of Project Baseline	Scope Change Form
				Cost Containment Table
	Internal Estimate Reviews	In-house/Peer	R/W Cost	Specify Corridor Width
		Formal Committee		Acres for Interchanges
		Scope Checklist		Depressed Sections
	External Estimate Reviews	Expert Team		Relocation Costs
				Demolition
				Asbestos Abatement
8. Integrety	Internal Estimate Reviews	In-house/Peer	Computer Software	Trns•port
		Formal Committee		
	External Estimate Reviews	Expert Team		Other Commercial Concept/Parametric Software
	Validate Costs	Estimating Software		
	Verify Scope Completeness	Estimate Checklist		In-house Software
	Consistent Estimate Processes	FHWA Mega Project Estimating Guidelines	Design to Cost	Design to Cost

Table 4.5a. Strategies, Methods, and Tools for the Final Design Phase

	Cost Estimating Practices		Cost Estimating Management	
	Final Design			
Strategy	Method	Tool	Method	Tool
1. Management			Computer Software	Commercial Estimating Software
			Consistency	Estimate Manual
				Estimator Training
				Estimating Checklist
				State Estimating Department
				Cradle to Grave Estimators
			Gated Process	Cost Containment Table
			Estimate Review	In-house/peer
				Formal Committee
			Budget Control	Budget by Corridor
				Constrained Budget
				Variance Reports of Cost and Schedule (original/previous/current)
				Summary of Key Scope (original/previous/current)
2. Scope / Schedule			Computer Software	Commercial Estimating Software
			Identification	Scope Change Form
				Cost Containment Table
				Project Baseline
				Estimate Scorecard
			Estimate Review	In-house/peer
				Formal Committee
3. Off-Prism Issues	Risk Analysis	Cost Estimate Validation Process - Estimate Ranges	Communication	Communication of Uncertainty
				Communication within DOT
		Contingency - Fixed Percentage	ROW, Utilities, Environment	Lists
				Software
		Contingency - Sliding Scale		Separate Estimators
				Estimator Training

Table 4.5b. Strategies, Methods, and Tools for the Final Design Phase

	Cost Estimating Practices		Cost Estimating Management	
	Final Design			
Strategy	Method	Tool	Method	Tool
4. Risk	Risk Analysis	Cost Estimate Validation Process - Estimate Ranges	Communication	Communication of Uncertainty
		Contingency - Fixed Percentage		Communication within DOT
		Contingency - Sliding Scale	Identification	Risk Charter
5. Delivery / Procurement				
6. Document Quality	Document Estimate Basis and Assumptions	Project Estimate File	Computer Software	Trns•port
				Other Commercial Software
				In-house Software
			Estimate Review	In-house/peer
				Formal Committee
7. Estimate Quality	Detailed Line Item Cost Estimates	In-house Estimating Software	Consistency	Estimate Manual
		Historical Bid Price Databases		Estimator Training
		AASHTO's Trns•port Software		Estimating Checklist
				State Estimating Department
	Internal Estimate Reviews	In-house/Peer		Cradle to Grave Estimators
		Formal Committee	Computer Software	Trns•port
				Other Commercial Software
	External Estimate Reviews	Expert Team		In-house Software
			Estimate Review	In-house/peer
				Formal Committee
8. Integrity	Internal Estimate Reviews	In-house/Peer		
		Formal Committee		
	External Estimate Reviews	Expert Team		

CONCLUSIONS

This chapter identified eight global strategies for address cost escalation. These proposed strategies were linked to seventeen different cost escalation factors. The eight strategies are described. The proposed strategies are then linked to a set of preliminary methods to implement the strategies. Each method is tied to one or more preliminary tools that can be used to execute the method(s). The next chapter discusses a preliminary outline for the Guidebook and the interim report that was developed and presented to the panel. The results of the interim report review, which delineated the directives of the panel for Phase II, are also discussed in the next chapter.

CHAPTER 5
INTERIM REPORT

Chapter 5 covers both Task 4, *Prepare Preliminary Outline of Guidebook* and Task 5, *Prepare Interim Report*. The main goal of Task 4 was the development of an annotated outline for a Guidebook on highway cost estimation practice and project cost estimation management. The main goal of Task 5 was to prepare an Interim Report and deliver this report to the Panel for review and discussion of the work plan to complete the project. The basic focus of these two tasks, including inputs and outputs, is shown in Figure 5.1.

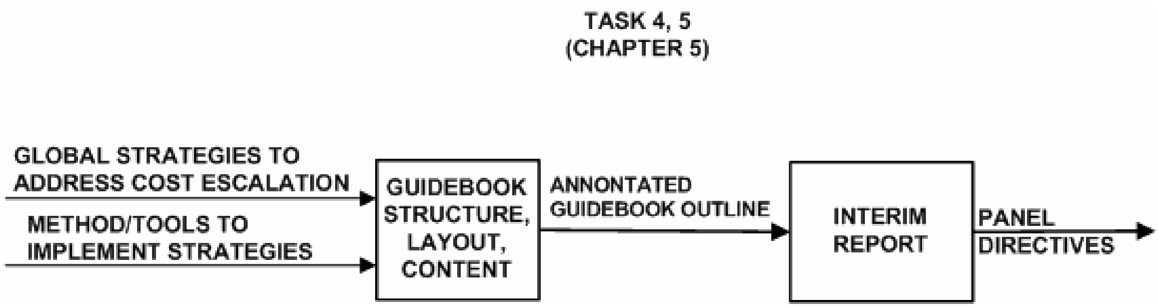

Figure 5.1. Preliminary Report Outline and Interim Report Inputs and Outputs

INTRODUCTION

At this stage in the development of the research, the research team recommended one Guidebook that covers both cost estimation practice and cost estimation management. This recommendation was the result of conducting interviews with the potential users of this research. Both areas must be linked together to adequately address the fundamental objective of the Guidebook, that is, accurate and consistent estimates from the initial planning estimate to the engineer's estimate at final design. Thus, the proposed Guidebook structure, layout, and content were based on eight chapters. An overview of the proposed Guidebook table of contents is shown in Figure 5.2.

The first three chapters would "set the stage" for a detailed description of the recommended strategies, methods, and tools to be used in practice. These first three chapters would provide an overview of the guide and present the strategies, methods, and tools that would be detailed in the later chapters. Chapter's 4 through 6 would describe methods and tools corresponding to Long-range Planning, Programming and Advanced Planning/Preliminary Design, and Final Design. Chapters 4 through 6 would also discuss the impact of project complexity in relation to cost estimation practice and cost estimation management. Chapter 7 would discuss implementation issues and how a DOT might integrate the Guidebook content into current and future DOT practices. The final chapter, Chapter 8, would provide a path forward. Appendices will be used as appropriate to provide additional information to users.

Each chapter of the Guidebook described in the table of contents, Figure 5.2, was annotated to provide additional insights into its proposed structure, format and content. A brief summary of key issues the research team needed to consider when developing the Guidebook materials was also presented.

COST ESTIMATION PRACTICES AND COST ESTIMATION MANAGEMENT: A GUIDEBOOK FOR TRANSPORTATION PROJECTS

Summary

Chapter 1 – Introduction
- Background
- Guidebook Layout
- How to Use Guidebook

Chapter 2 – Issues and Strategies
- Issues
- Strategies

Chapter 3 – Guideline Framework
- Introduction
- Recommended Strategies, Methods, and Tools

Chapter 4 – Long-Range Planning
- Introduction
- Methods and Tools
- Cost Estimation Practice
- Cost Estimation Management

Chapter 5 – Programming and Advanced Planning/Preliminary Design
- Introduction
- Methods and Tools
- Cost Estimation Practice
- Cost Estimation Management

Chapter 6 – Final Design
- Introduction
- Methods and Tools
- Cost Estimation Practice
- Cost Estimation Management

Chapter 7 – Implementation
- Introduction
- Barriers
- Staffing
- Culture
- Use

Chapter 8 – Path Forward
- Summary
- Challenges

Appendices
- Glossary of Terms

Figure 5.2. Guidebook Table of Contents (Preliminary)

INTERIM REPORT RESULTS

The Interim Report covered the first five tasks of the research and included Chapters 1 through 4 of this final report. The Interim Report also included the proposed Guidebook table of contents, as shown in Figure 5.2, plus a Phase II work plan to accomplish Tasks 6 through 10. This information was presented for review to the NCHRP. The key action items from this review were as follows:

- The literature review on the planning area would be enhanced to the extent possible.
- The Guidebook tone would provide examples and suggest practices rather than direct actions.
- The Guidebook would speak to upper management who creates policy on cost estimation practice and cost estimation management within the department. The research team would not develop detailed “how to” procedures manual for cost estimation and cost management, as this type of effort was considered beyond the scope of a Guidebook. The Guidebook would enable a State Highway Agency to develop detailed procedures manuals.
- A chapter providing an agency overview of cost estimation practice and cost estimation management would be added to the table of contents. This created a new Chapter 2 which moved the original contents by one chapter further down. The inclusion of the new chapter and the modified table of contents is discussed in the next chapter of this report.
- Items to include in the Guidebook based on specific Panel comments are the Caltrans three point strategy under the methods and tools, an agencywide perspective in the Guidebook as a separate chapter (between proposed Chapter’s 2 and 3 as shown in the Interim Report, Figure 5.2) and the scope development process.
- Revise Phase II plan to develop a preliminary draft report under Task 8 that would be the basis of the industry review under Task 7. This revised plan has altered the focus of Task’s 6, 7, and 8 and timing of these tasks. The team believed ranking of the strategies, methods, and tools as proposed in Task 7 is not as critical as originally thought. The team now believes that industry input on the format and level of detail in the presentation of Guidebook material is more important than input for the ranking of items for filtering purposes. To that end, the team proposed to produce a draft Guidebook earlier than originally planned in order to present it to industry for review and comment. This step will ensure that the Guidebook can be immediately applied by state highway agencies (SHAs) and suggested changes can be made within the environment of current practices.

CONCLUSIONS

The Interim Report including the Phase II revised work plan was approved by the NCHRP. The directives from the NCHRP set the path forward for Phase II. The next chapter provides a detailed discussion of the development of the Guidebook including the industry critiquing process followed to confirm the Guidebook structure, layout, and content.

CHAPTER 6
GUIDEBOOK DEVELOPMENT

INTRODUCTION

The Guidebook was developed in the second phase of the research under the combined effort applied to *Task 6 – Develop and Evaluate Strategies, Methods and Tool*s, *Task 7 – Present Strategies, Methods and Tools to Industry*, and *Task 8 – Develop Recommended Strategies, Methods, and Tools*. The primary objective of Task 6 was to develop and evaluate in greater detail the proposed preliminary set of strategies, methods and tools projected from the Phase I research. The goal of Task 7 was to obtain input and feedback from professional practitioners on the preliminary strategies, methods, and tools from Task 6. The primary objective of Task 8 was to refine the recommended strategies, methods, and tools based on Industry input

The original Guidebook development framework proposed for Phase II required preview input from industry and sought recommendations based on which the research team could further refine the strategies, methods and tools (Task 7). However, this approach was revised in the second phase of the research to perform a simultaneous development and recommendation process. This revision was deemed necessary and beneficial by the research team to accomplish a better end product. Thus, Task 6 and 8 were performed simultaneously until a draft Guidebook was sufficiently available for critiquing under Task 7. The critique process was conducted with substantial SHA input. Once this process was completed, effort on Task 6 and 8 focused on the completion of a final draft Guidebook. The Panel agreed that this revised approach was acceptable and would likely yield better results. The revised research plan for Phase II was approved by the Panel. This chapter details processes and steps adopted by the research team in achieving the goals of these Tasks 6, 7, and 8. Figure 6.1 summarizes the inputs and outputs of these tasks and reflects the revised research plan for Phase II.

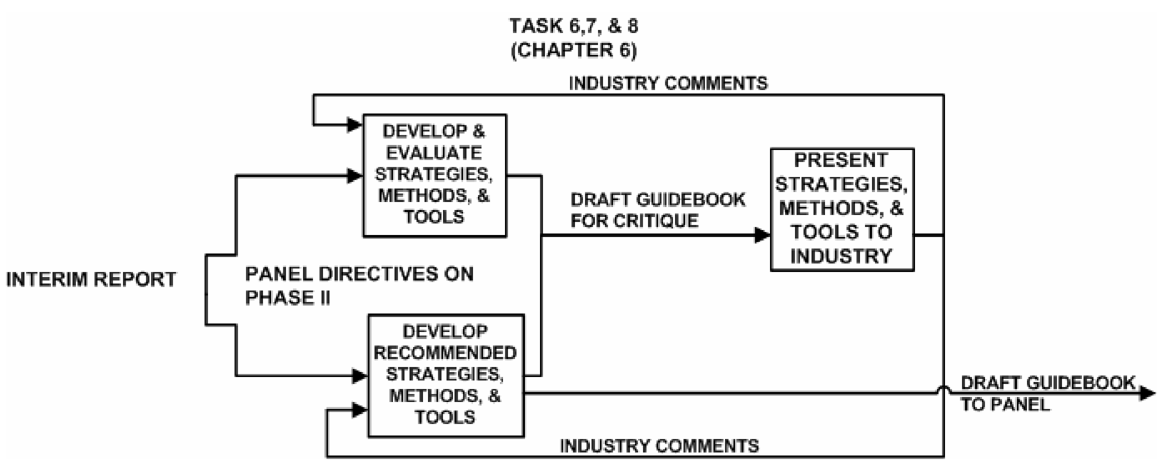

Figure 6.1. Guidebook Development Inputs and Outputs

AGENCYWIDE APPROACH

At the beginning of the second phase and as a result of the Interim Report Panel directive, the research team realized a need to incorporate an agencywide perspective for performing cost estimation practice and cost estimation management within a State Highway Agency (SHA). A graphical representation was proposed to best illustrate these processes. The primary idea behind this effort was to identify inputs and outputs for cost estimation practice and cost estimation management during the different phases of project development. The different types of estimates and their purposes were also demarcated alongside the project development timeline. Several iterations were required before the flow chart could be presented to the Panel and industry. Figure 6.2 shows the flowchart that was finalized for the Guidebook.

At the beginning of the Guidebook a separate chapter was also developed to present an agencywide approach to cost estimation practice and cost estimation management by discussing several important aspects relevant to this approach. A brief discussion was provided covering the project development process including key project phases, typical activities involved in these phases, and the cyclical nature of these phases. Further, the cost estimation practice and cost estimation management processes were described in terms of typical steps performed under each of these processes. The intent of this chapter is to set a general context in which SHAs perform cost estimation practice and cost estimation management in relation to a generic project development process.

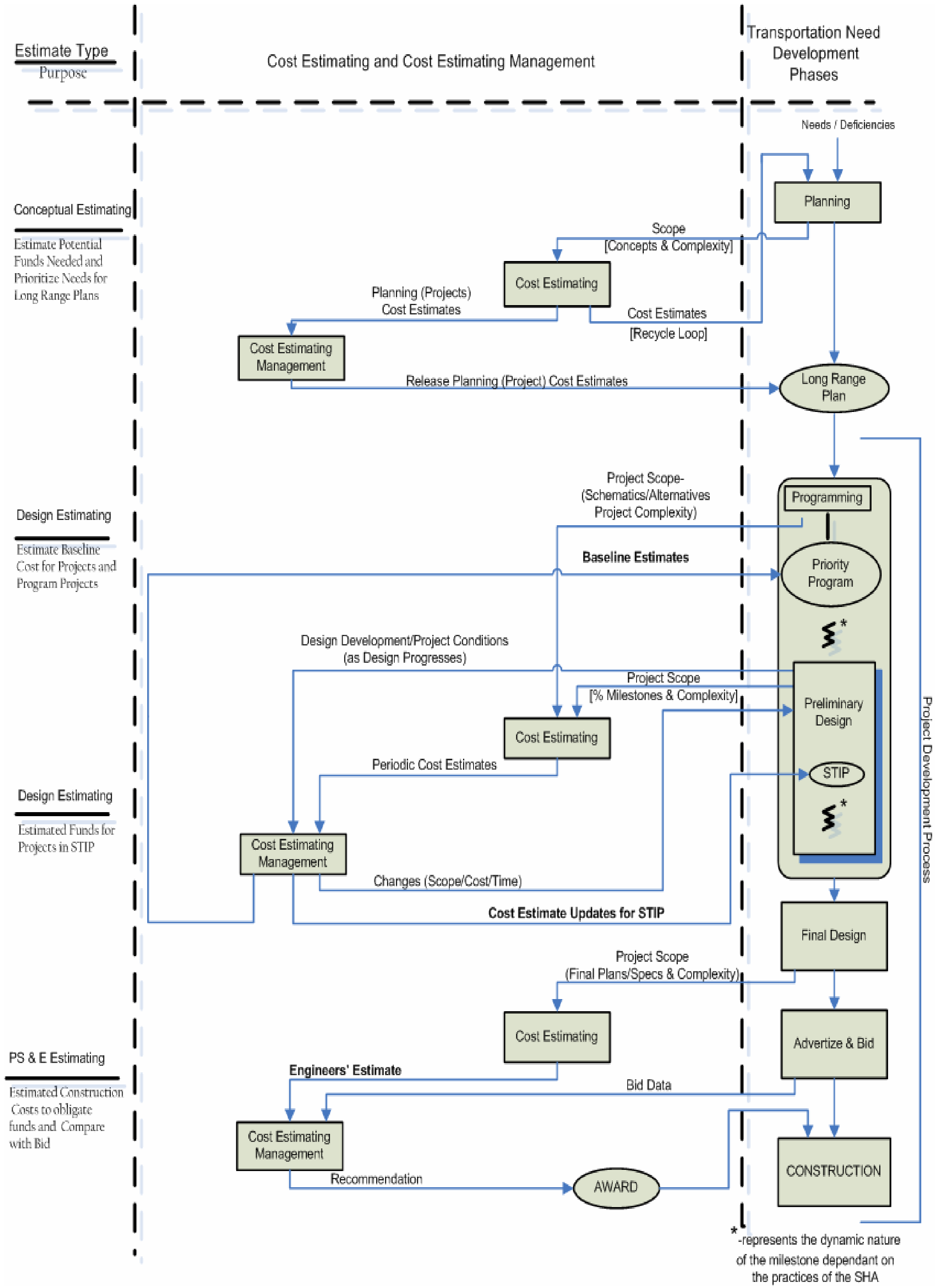

Figure 6.2.: Agency Level Flowchart for Cost Estimation Practice and Cost Estimation Management

While the agencywide approach set a general context for cost estimation practice and cost estimation management, there was a consensus among research team members that a more detailed graphical illustration by means of a flowchart supporting each project development phase was needed. These flowcharts further described the steps required to effectively perform cost estimation practice and cost estimation management. The flowcharts also portrayed the inputs and supporting documents created through these two processes. Thus, while the agencywide approach was a condensed form covering all phases, the individual phases are then described in more detail in these flowcharts. With this objective in mind, the research team drafted several flowcharts, one for each project development phase. The flowcharts served as a basis for describing the project development phase in more detail and then introducing cost estimation practice and cost estimation management as these two processes are applied in the phase.

As the research team members developed Guidebook content and critiqued the Guidebook, these flowcharts incorporated several changes to include greater detail of inputs, end products, and milestones. A graphical legend helped in identifying inputs, steps, documents produced, milestones, and phases. Figures 6.3 (a), (b), and (c) show the flowcharts for the planning, programming and preliminary design, and final design phases respectively. As the strategy, method, and tool content was developed the text referenced the step or steps in the cost estimation practice and cost estimation management processes where the strategies, methods, and tools would be most effectively applied.

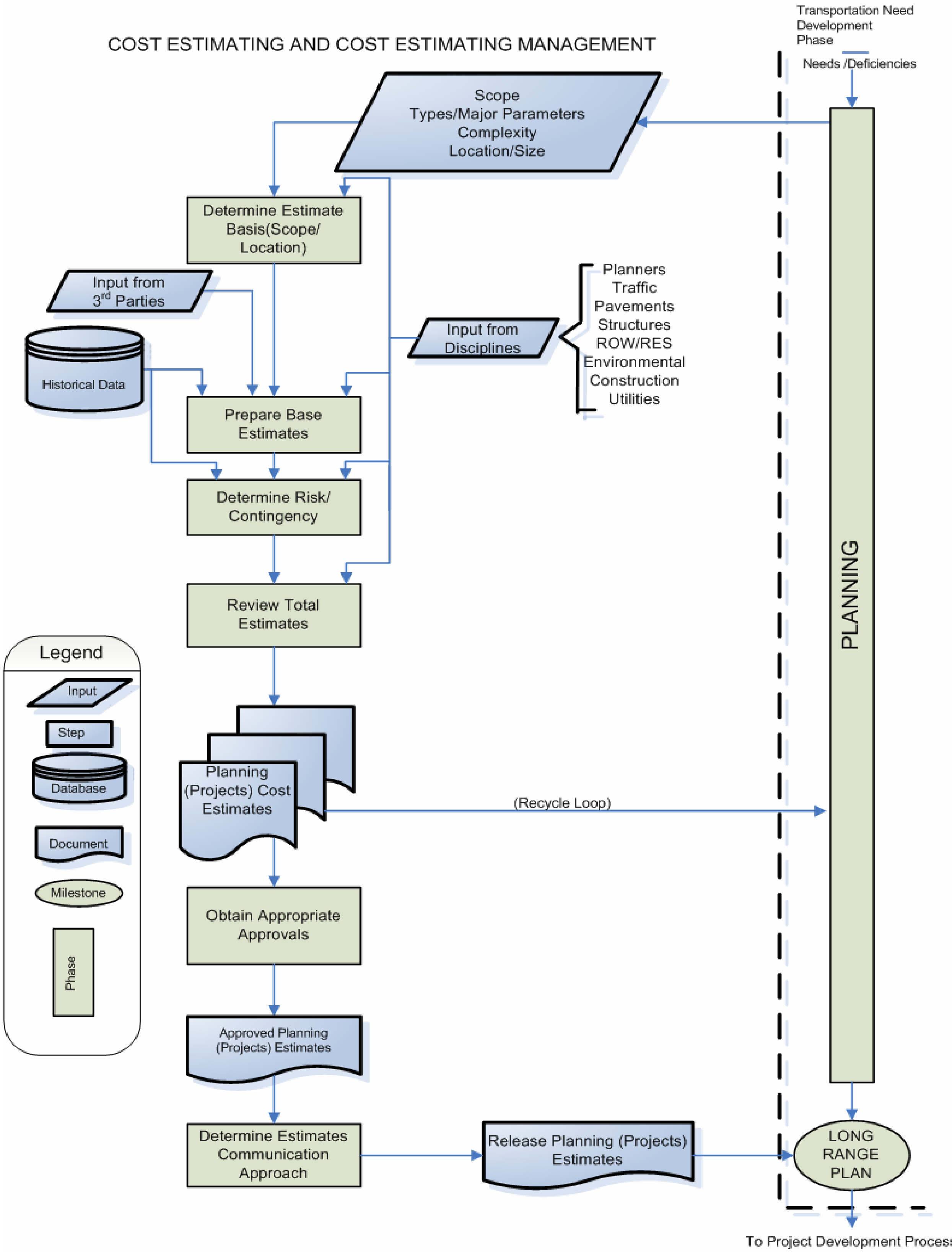

Figure 6.3(a): Cost Estimation Practice and Cost Estimation Management during Planning

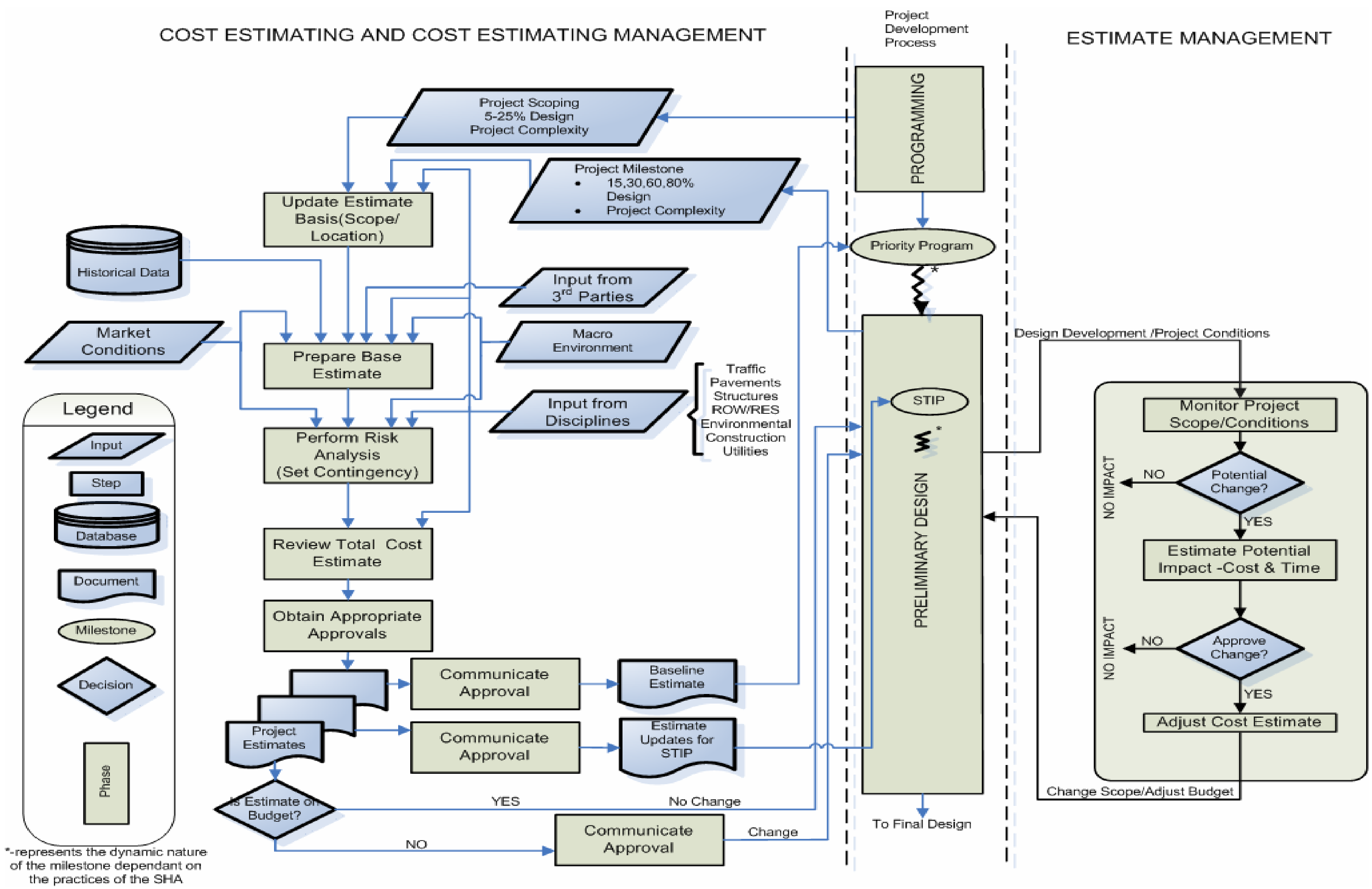

Fig 6.3(b) Cost Estimation Practice and Cost Estimation Management during Programming and Preliminary Design

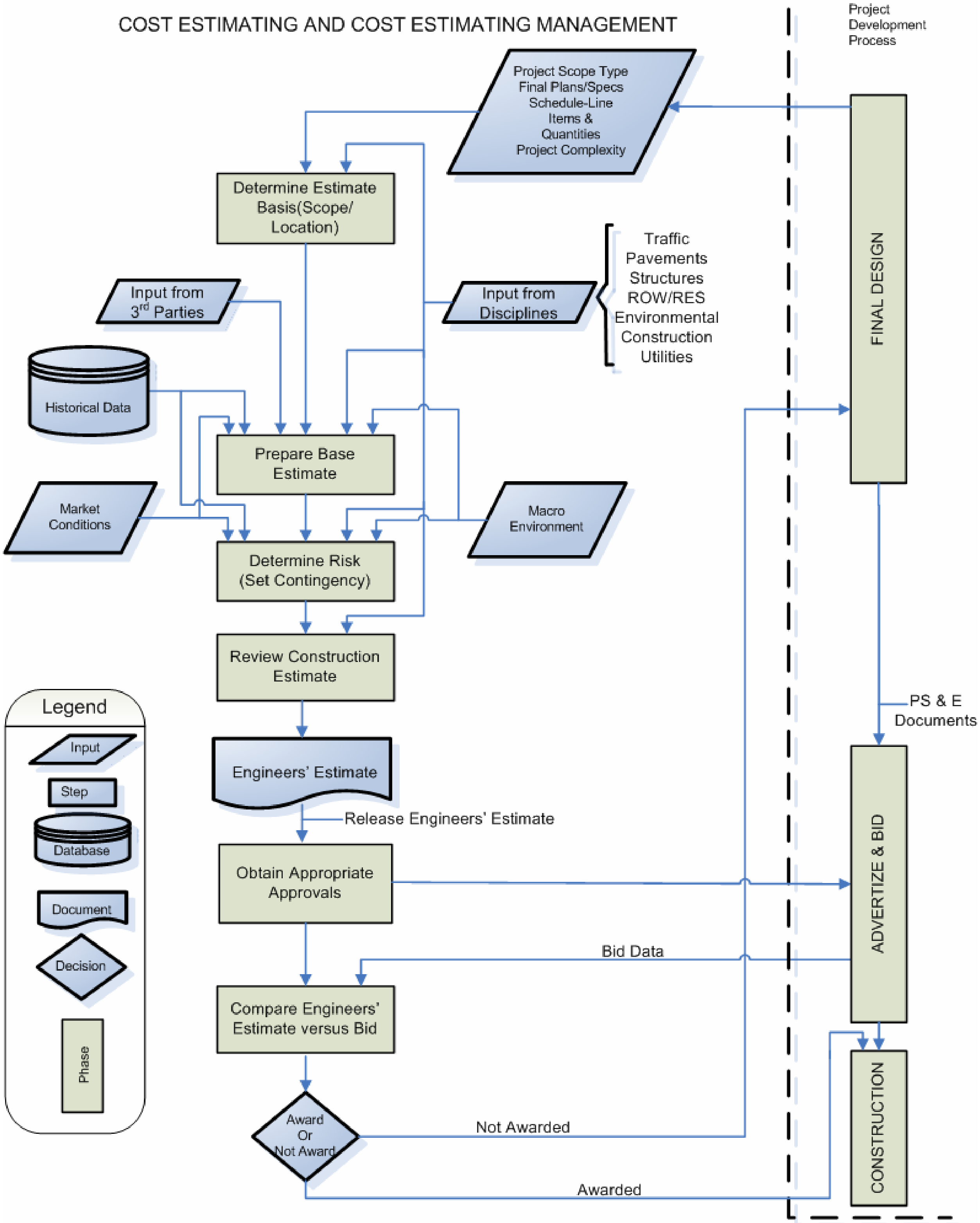

Fig 6.3(c): Flow Diagram for Cost Estimation Practice & Cost Estimation Management During Final Design.

GUIDEBOOK CONTENT AND STRUCTURE

The content development, testing, and Guidebook structure is the primary focus of this section. Content development describes how the research members began with the strategy, method, and tool approach described in Chapter 4 and then details how cost escalation factors and strategies were developed based on interviews relevant to current issues plaguing the industry. A link between these identified cost escalation factors and a strategic approach is also explained. The processes and steps the research team followed to compile the Guidebook are then discussed. The preliminary testing approach to critique the Guidebook structure and its contents along with the results of this effort are also covered in this section.

Strategy, Method, and Tool Approach

Phase I of the research helped identify cost escalation factors from the various interviews and intensive literature review (Chapter 2). The research team also identified unique practices and approaches and general deficiencies in current practices (Chapter 3). Further, based on the strategy, method and tool approach suggested by the NCHRP Panel through the Research Project Statement, the research team identified a preliminary set of strategies addressing cost escalation factors based on the interviews, literature survey and brainstorming sessions. Eight Strategies were finally identified to contain all cost escalation factors. While each strategy was evaluated under the two different processes of cost estimation practice and cost estimation management, several methods and tools were listed to address each practice under these two processes. This resulted in a significant overlap of methods and tools, which was resolved by a hierarchical decomposition.

The hierarchical decomposition of strategies, methods, and tools is illustrated in Figure 6.4. Methods are used to implement the eight strategies. As shown, more than one method may be used to implement a particular strategy. One or more tools can be used to support the performance of a method. The use of specific strategies, methods, and tools changes with project development phases and different levels of project complexity.

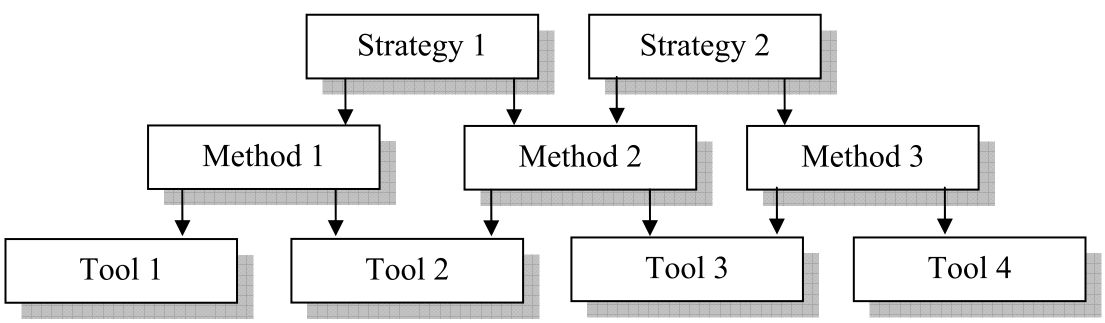

Figure 6.4: Schematic Illustration of Strategy, Method, and Tool Hierarchy

Cost Escalation Factors and Strategies

Before developing strategies, methods, and tools to address cost escalation problems the causal factors that influence and create changes in cost estimates were delineated and explained. Once the causal factors were identified, strategies were presented which address specific problem areas.

The factors that lead to project cost escalation were identified through a large number of studies and research projects. They were then classified as either internal or external. Also, a greater level of detail on defining the cost escalation factors that are common to the industry was performed.

These factors were then distilled into eighteen fundamental Cost Escalation Factors, as depicted in Table 6.1. Each Cost Escalation Factor describes a reason behind changes in cost estimates. These factors can be managed throughout the project development process through cost estimation practice and cost estimation management methods and tools. The basis for selecting each method and supporting tools was essentially drawn from a strategic viewpoint. The interlinked nature of the strategy, method, and tool approach became the common theme that to addressing highway agency cost escalation problems.

Table 6.1: Factors Causing Cost Escalation of Projects*

	Cost Escalation Factor
Internal	1. Bias
	2. Delivery/Procurement Approach
	3. Project Schedule Changes
	4. Engineering and Construction Complexities
	5. Scope Changes
	6. Scope Creep
	7. Poor Estimating
	8. Inconsistent Application of Contingencies
	9. Faulty Execution
	10. Ambiguous Contract Provisions
	11. Contract Document Conflicts
External	1. Local Concerns and Requirements
	2. Effects of Inflation
	3. Scope Changes
	4. Scope Creep
	5. Market Conditions
	6. Unforeseen Events
	7. Unforeseen Conditions

* Note: these factors are numbered for reference only. The numbering does not indicate a level of influence.

The methodology used to develop the potential list of strategies, methods, and tools focused on the causes of cost escalation and potential strategies that would address these causes. The definition of a strategy is, "*a plan of action intended on accomplishing a specific goal.*" From the literature concerning project cost estimation and from interviews with industry, it is clear that the eight overarching or global strategies can affect the accuracy and consistency of project estimates and costs. The eight strategies, first identified in Chapter 4, remained unchanged as the Guidebook was critique by industry. Further, the 18 cost escalation factors also held up under the Guidebook critiquing process with some changes to the description of selected factors based on industry input.

Link between Strategies and Cost Escalation Factors

The Guidebook development process involved the compilation of a considerable amount of information and hence necessitated a structured layout to direct the user to the appropriate information. The first step in achieving this goal was to link the strategies to the cost escalation factors. The research team first defined both cost escalation factors and strategies separately to help the user understand terminology and concur with viewpoints as addressed by the research team. The next step was to link strategies that address the identified cost escalation factor. Several iterations ensued to finalize a matrix of cost escalation factors and the eight strategies based on brainstorming sessions among research team members, reference to existing literature, and the vast experience background of the research leaders.

Considering the voluminous nature of the Guidebook, there was a concern that users may not recall the original meaning of the eighteen cost escalation factors as defined by the research team while they explore the vast compilation of methods and tools. This necessitated the formation of an exclusive chapter with definitions of cost escalation factors which could be readily referenced. Similar to the cost escalation factors, the eight global strategies are also discussed in this chapter with the cost escalation factors. A brief description of each strategy is provided beyond the one sentence definition that accompanies each strategy. Users can periodically refresh their understanding of the strategies by reviewing the strategy descriptions.

The eight global strategies, which are supported by various methods and tools, that address cost escalation factors are considered in terms of how they are uniquely applied during the different project phases. The research team devised a matrix concept to demonstrate this variation of strategic approaches at different project phases and also would facilitate a consistent framework for users to aid in the implementation of the strategies.

The overall final matrix is illustrated in Table 6.2. As it can be seen one or more strategies can be applicable to each cost escalation factor. The user is encouraged to explore all suggested strategies to identify the most suitable one as applicable. This table further became the basis for the three phases and the strategies suggested as applicable to address a specific cost escalation factor in each phase. Tables 6.3, 6.4 and 6.5 depict the cost escalation and strategy linkage for the planning, programming and preliminary engineering and design phases, respectively.

Table 6.2: Link Between Strategies and Cost Escalation Factors

Cost Escalation Factors		Global Strategies: Management	Scope/Schedule	Off-Prism Issues	Risk	Delivery/Procurement Methods	Document Quality	Estimate Quality	Integrity
Internal	Bias	√							√
Internal	Delivery/Procurement Approach	√	√		√	√			
Internal	Project Schedule Changes	√	√		√			√	
Internal	Engineering & Construction Complexities	√	√		√		√	√	
Internal	Scope Changes	√	√		√		√		
Internal	Scope Creep	√	√				√		
Internal	Poor Estimating	√	√		√		√	√	
Internal	Inconsistent Application of Contingencies				√			√	
Internal	Faulty Execution	√	√				√		
Internal	Ambiguous Contract Provisions						√		
Internal	Contract Document Conflicts						√		
External	Local Concerns & Requirements	√	√	√	√				√
External	Effects of Inflation		√	√				√	√
External	Scope Changes	√	√		√				
External	Scope Creep		√	√					
External	Market Conditions	√		√	√	√		√	
External	Unforeseen Events				√				
External	Unforeseen Conditions				√				

Table6.3: Link between Strategies & Cost Escalation Factors in the Planning Phase

Cost Escalation Factors		Strategies: Management	Scope/Schedule	Off-Prism Issues	Risk	Delivery/Procurement Methods	Document Quality	Estimate Quality	Integrity
	Section	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8
Internal	Bias	√							√
Internal	Delivery/Procurement Approach	√	√		√	√			
Internal	Project Schedule Changes	√	√		√			√	
Internal	Engineering & Construction Complexities	√	√		√		√	√	
Internal	Scope Changes	√			√		√		
Internal	Scope Creep	√			√		√		
Internal	Poor Estimating	√					√	√	
Internal	Inconsistent Application of Contingecies				√		√	√	
Internal	Faulty Execution								
Internal	Ambiguous Contract Provisions								
Internal	Contract Document Conflicts								
External	Local Concerns & Requirements	√	√	√	√				√
External	Effects of Inflation		√	√				√	√
External	Scope Changes	√	√	√	√		√		
External	Scope Creep						√		
External	Market Conditions	√		√	√	√		√	
External	Unforeseen Events								
External	Unforeseen Conditions								

Table 6.4: Link between Strategies and Cost Escalation Factors during a Project Programming and Preliminary Design Phase

	Cost Escalation Factors	Strategies							
		Management	Scope/Schedule	Off-Prism Issues	Risk	Delivery/Procurement Methods	Document Quality	Estimate Quality	Integrity
	Section	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8
Internal	Bias	√							√
Internal	Delivery/Procurement Approach	√	√		√	√			
Internal	Project Schedule Changes	√	√		√			√	
Internal	Engineering & Construction Complexities	√	√		√		√	√	
Internal	Scope Changes	√	√		√		√		
Internal	Scope Creep	√	√				√		
Internal	Poor Estimating	√	√		√		√	√	
Internal	Inconsistent Application of Contingecies				√			√	
Internal	Faulty Execution	√	√				√		
Internal	Ambiguous Contract Provisions						√		
Internal	Contract Document Conflicts								
External	Local Concerns & Requirements	√	√	√	√				√
External	Effects of Inflation		√	√				√	√
External	Scope Changes	√	√		√				
External	Scope Creep		√	√			√		
External	Market Conditions	√		√	√	√		√	
External	Unforeseen Events				√				
External	Unforeseen Conditions				√				

Table 6.5: Link between Strategies and Cost Escalation Factors in the Final Design Phase

	Cost Escalation Factors	Strategies							
		Management	Scope/Schedule	Off-Prism Issues	Risk	Delivery/Procurement Methods	Document Quality	Estimate Quality	Integrity
	Section	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8
Internal	Bias	√							√
Internal	Delivery/Procurement Approach	√			√	√			
Internal	Project Schedule Changes	√	√						
Internal	Engineering & Construction Complexities	√			√		√	√	
Internal	Scope Changes	√	√		√				
Internal	Scope Creep	√	√						
Internal	Poor Estimating	√	√				√	√	
Internal	Inconsistent Application of Contingencies				√			√	
Internal	Faulty Execution		√				√		
Internal	Ambiguous Contract Provisions						√		
Internal	Contract Document Conflicts						√		
External	Local Concerns & Requirements	√	√	√	√				√
External	Effects of Inflation		√					√	
External	Scope Changes	√	√		√				
External	Scope Creep		√	√					
External	Market Conditions	√		√	√	√		√	
External	Unforeseen Events				√				
External	Unforeseen Conditions				√				

Simultaneous Development and Recommendation of the Strategies, Methods, and Tools

The research plan originally was proposed to present the strategies, methods, and tools to the industry immediately upon development and evaluation to rank order these strategies, methods and tools. A subsequent development of the higher ranked strategies, methods, and tools based on the feedback was intended as a part of the original plan. The team believed that industry input on the quality and content in the presentation of the Guidebook was more critical than the ranking input and, therefore, decided to realign the tasks. The research team realized that change in the sequence of tasks could result in a better quality end product and revised the original plan in the second phase. The research team then planned to produce a draft Guidebook which could be presented to the industry and seek current practitioners opinion on various aspects such as format, content, ease of navigation, concurrence on the tools proposed, and identification of any missing information. The research team also presented a preliminary outline of the Guidebook listing key content to the panel which reviewed and commented on the development approach of the Guidebook development before approving it.

The research team then began the process of enlisting and delegating several tasks to complete the compilation of the Guidebook among the different research participants. The bulk of the Guidebook was placed in Chapters 5, 6, and 7 which comprised of addressing the cost escalation factors in the planning, programming and preliminary design, and final design project phases. Each phase was developed by a separate researcher. Several tools were found to be cross referenced and were being developed simultaneously.

Guidebook Framework

It was clear from the beginning that there would be a diverse audience for the Guidebook and it was necessary to structure the Guidebook in a manner to specifically cater to different groups. This was supported by the interviews from Phase I of the research, which revealed that personnel involved at the three project phases were often distinctly different groups of individuals working that based on the stage of project development had different amounts of definitive information . Thus, the research team agreed on framing the first four chapters, which were comprised of common information such as definitions and steps to use the Guidebook. These four chapters were deemed mandatory reading for all groups. Phase specific information was then placed in separate chapters. While the front end presented a roadmap to the Guidebook, the strategies, methods and tools for cost increase alleviation were compiled in Chapters 5, 6 and 7 addressing the planning, programming and preliminary design, and final design phases of project development, respectively. The research team recognized a large variation in the timeline of estimate development and the often mutually exclusive participants involved with different project phases. This translated into a highly diverse audience for the Guidebook, and the need to cater explicitly to the different agency groups. Therefore, the framework of addressing cost escalation by phases was justified.

The initial approach was to present each strategy with the recommended methods to implement the strategy and also present the tools to execute each method within a given strategy. The research team realized the overlap and redundancy in this approach as many methods and tools were cross referenced and applied across different strategies. The immediate solution was to extract all tools and place them into an appendix. This step helped in listing and discussing methods alone within each strategy. While the user had the option of exercising one or more methods to address the cause of cost escalation, it was advised to consider all suggested options. To justify each method as an effective method, a common template was necessary to evaluate methods using similar parameters.

Another challenge faced by the research team was the ease of navigation through the Guidebook. The foremost thought to resolve this was by color coding pages. The use of tabs also was considered. However, due to potential publication constraints these two alternative formats were discarded. One research member proposed a tabular format discussing the three phases for each method. As previously mentioned, the audience for the three phases was to be addressed individually and this approach attempted to combine them. Hence, this approach was eliminated as well. Finally, after several iterations concerning the placement of information, the research team decided to continue with the development of the methods within each strategy, including a list of appropriate tools for each method and then describing the details of all tools in an appendix. This approach was deemed the most feasible option and the best layout for the Guidebook.

Sources for Content Development

This first phase of this research enabled the collection of a significant amount of information. The research team maintained a website where it indexed and stored the collected information for future retrieval. In addition to these documents, the interviews conducted served as a starting point in the development of this Guidebook.

Online resources and search engines such as Google and Engineering Village were constantly used to locate further information on the methods and tools discussed in the Guidebook. The University Library also provided a large selection of publications and text books which were of considerable use to the research team members. SHA websites were also a significant source of information for developing the tool component of the Guidebook. The research leaders past experiences on some aspects were good leads in development of several sections of the Guidebook

Method Development

A method was defined as "*a means or manner of procedure, especially a regular and systematic way of accomplishing something.*" Methods are listed and discussed under each of the eight strategies for the three project phases. Methods are further classified in terms of a cost estimation management context or a cost estimation practice context. While similar methods may be listed under the same strategies an attempt to connect them progressively over the phases wherever possible was made. With these goals in mind, the research team formulated a template to provide common descriptions of each method. This template addressed the following set of questions:

- In which step(s) in the cost estimation practice and/or cost estimation management process (flow chart) is the method used?
- Why use the method?
- How is the use of the method impacted by project complexity?
- What makes the use of the method successful?
- How is the method applied?

Two important points to discuss in terms of method content development were the use of the consistent set of questions to guide the discussion of each method and the use of an appendix to provide detailed descriptions of the respective tools and how to use these tools. Tools that are proposed with a method are simply listed under each method. The user must refer to the Tool Appendix to find descriptive information about the tool.

Excerpts from interviews, literature survey, online resources such as Google, Engineering Village, Agency Homepages, were the basis to develop the content of the answers to these method questions. Also, prior experiences of research leaders played an important role in organizing thoughts and presenting the material in a succinct form. Throughout the development of content of the Guidebook the primary concept of strategy, method and tool philosophy was peremptory. Thoughts were developed on the basis of how a particular strategy was the impetus for a method. The descriptive material for methods that were covered under multiple strategies was modified to fit the strategy of interest. Finally, the last question was answered in a listing of the appropriate tools, which were described in the Tool Appendix.

Tool Appendix

Tools were defined as "*something used in the performance of an operation[method].*" The research team intended them as a means to help the user identify the right method. Most of the tools were extracted from current practices which would portray a sense of familiarity among the users. The Tool Appendix soon grew into a large compilation in itself and required a roadmap to help users to locate a specific tool. A coding system was used to provide a systematic format for describing the methods and tools. The tools for each method were listed with the method. Tools often support multiple methods. The methods were sorted alphabetically and numbered with an alphanumeric numbering system for methods within the same alphabet heading. As a consequence, tools were referenced by an alphanumeric code, that is, B1.1, where B1 is the first method and .1 is the first tool related to that method.

Tool Development

After structuring an appendix for the tools, the research team shared the tools to be developed based on their knowledge about the individual tools and as applicable to their chapters (phases). Here again, like the methods, there was a need to have a consistent set of questions to describe the tools with sufficient depth. The set of questions were:

- What is the tool?
- What is the tool used for and why is the tool used?
- What does the tool do or create?
- When should the tool be used?
- What are examples or applications of the tool?
- What tips will lead to successful use of the tool?
- Where can the user find more information to support development of a specific tool?

Each of these questions was answered within the context of which method or methods the tool was supporting. There was a significant overlap in allocating tools to different methods. However, the usage of these tools varied for each method. Hence, the appropriateness of a tool under different circumstances and how the tool contributed to help implement a certain method was considered on a case by case basis while developing the content for tools which had an overlap.

Tool development followed different paths for different tools. Some tools are currently being used in some agencies that had provided adequate information in forms of training manuals, presentations, and other literature. The research team reviewed this information and extracted the key features to educate the audience of the tools impact on cost alleviation. While this Guidebook was not intended to be a "how to" manual, it certainly showcased the benefits of these tools to the user. Leads to further information were provided for users to better understand the tool, if they wished to use it. There were instances where new and upcoming techniques were identified by the research team and included in the tool appendix.

Building Draft Guidebook for Industry Review

The draft Guidebook used for industry review contained seven chapters and the tool appendix. The first three chapters "set the stage" for the detailed description of the recommended strategies, methods, and tools used during planning, programming and preliminary engineering, and final design project phase. These chapters provide the context and intent of the Guidebook. Chapter 4 outlined the Guidebook layout and provides a roadmap for how to use the materials presented in subsequent chapters. Chapter's 5 through 7 describe methods and tools corresponding to Long-range Planning, Programming and Preliminary Design, and Final Design respectively. Chapters 5 through 7 also discuss the impact of project complexity in relation to cost estimation practice and cost estimation management.

The draft Guidebook was still a work in progress with several incomplete sections when the critique process commenced. However, since the three core chapters were being developed by different research team members, the decision to test which chapter was prioritized based on the level of progress. Efforts were made to identify key components of each chapter and complete them before presenting them to the industry.

The division of several chapters of the Guidebook among research team members enabled an efficient environment to accomplish several tasks simultaneously. The delegation of the chapters was based on the experience of the research leaders in the chapter subject area and a subsequent internal rotation of the developed material for review. This process ensured that the knowledge base was widened and the quality of the content was maximized. This process was followed for development of the tools as well.

Tools that were relevant to the chapters being tested were prioritized for completion then developed to enable a complete pass of the entire strategy, method and tool process. The research team also found a few sections lacked adequate information and made good use of the opportunity to request any possible input from the testing participants on these aspects. The draft Guidebook was assembled each time with a separate core chapter until there was adequate progress to compile a comprehensive Guidebook.

The reviews soon confirmed that the front end four chapters were adequate and well suited for the Guidebook. Reviews also indicated that a listing of all methods and tools at the end of the chapter would be beneficial for a user. This suggestion was incorporated into the Guidebook and the final versions of the methods and tools are listed in Tables 6.6, 6.7 and 6.8 for the planning, programming and preliminary design and final phase respectively.

Table 6.6 List of Planning Phase Methods and Tools

		Method/ Tool
Budget Control		
	B1.1	Budget by Corridor
	B1.2	Constrained Budget
	B1.4	Summary of Key Scope Items
	B1.5	Variance Reports on Cost and Schedule
Buffers		
	B2.1	Board Approvals
	B2.2	Constrained Budget
	B2.3	Management Approvals
Communication		
	C1.1	Communication of Importance
	C1.2	Communication of Uncertainty
	C1.4	Definitive Management Plan
	C1.5	Proactive Conveyance of Information to Public
	C1.6	Simple Spreadsheet
	C1.7	Year-of-Construction Costs
Computer Software		
	C2.1	Agency Estimation Software
	C2.3	In-House Conceptual/Parametric Estimation Software
	C2.4	Simple Spreadsheet
Conceptual Estimation		
	C3.3	Cost Parameter Using Similar Projects
	C3.4	Cost Parameter Using Typical Sections
	C3.5	TRNS*port
Document Estimate Basis & Assumptions		
	D4.1	Project Estimate File
Delivery and Procurement Method		
	D1.1	Contract Packaging
	D1.2	Delivery Decision Support
Estimate Review - External		
	E2.1	Independent or Expert Team
Estimate Review - Internal		
	E3.3	In-house/Peer
Identification of Risk		
	I2.1	Red Flag Items
Identifying Off-Prism Issues		
	I2.1	Environmental Assessment
	I2.2	Percentage of Total Project Cost
Project Scoping		
	P3.1	Estimation Checklist
	P3.2	Scoping Document
Recognition of Project Complexity		
	R1.1	Complexity Definitions
Right-of-way		
	R2.1	Acres for Interchange
	R2.2	Advanced Purchase (Right-of-Way Preservation)
	R2.4	Relocation Cost
	R2.5	ROW Estimator Training
Risk Analysis		
	R3.1	Analysis of Risk and Uncertainty
	R3.2	Contingency
	R3.4	Estimate Ranges
	R3.5	Programmatic Cost Risk Analysis

Table 6.7 List of Programming and Preliminary Design Methods and Tools

Method/ Tool		
Budget Control		
	B1.2	Constrained Budget
	B1.3	Standardized Estimation and Cost Management Procedures
	B1.4	Summary of Key Scope Items
	B1.5	Variance Reports of Cost and Schedule
Buffers		
	B2.1	Board Approvals
	B2.2	Constrained Budget
	B2.3	Management Approvals
Communication		
	C1.1	Communication of Importance
	C1.2	Communication of Uncertainty
	C1.3	Communication with DOT
	C1.4	Definitive Management Plan
	C1.5	Proactive Conveyance of Information to Public
	C1.7	Year of Construction Costs
Computer Software		
	C2.1	Agency Estimation Software
	C2.2	Commercial Estimation Software
	C2.3	In-house Conceptual/Parametric estimation software
	C2.4	Simple Spreadsheet
Consistency		
	C4.1	Cradle to Grave Estimators
	C4.2	Estimation Checklist
	C4.3	Estimation Manual (Guidelines)
	C4.4	Estimator Training
	C4.5	Major Project Estimation Guidance
	C4.6	Standardized Estimation and Cost Management Procedures
	C4.7	State Estimation Section
Constructability		
	C5.1	Constructability Reviews
Creation of Project Baseline		
	C6.1	Cost containment Table
	C6.2	Estimation Scorecard
	C6.3	Scope Change Form
	C6.4	Scoping Documents

Table 6.7 List of Programming and Preliminary Design Methods and Tools (contd.)

Delivery and Procurement Method		
	D1.1	Bundling
	D1.2	Delivery Decision Support
Design Estimation		
	D2.1	Analogous or Similar Project
	D2.2	Agency Estimation Software
	D2.3	Cost based bottoms up
	D2.4	Historical Bid Based
	D2.5	Historical Percentages
	D2.6	Major Cost Items using Standardized Sections
	D2.7	Parametric Estimation
	D2.8	Spreadsheet Template
	D2.9	Trns•port®
Design to Mandated Budget		
	D3.1	Design to Cost
Document Estimate Basis & Assumptions		
	D4.1	Project Estimation File
Estimate/Document Review		
	E1.1	Estimate/Document Review – External
	E1.2	Estimate/Document Review– Internal
Estimate Review- External		
	E2.1	Expert Team
Estimate Review- Internal		
	E3.1	Formal Committee
	E3.2	Off Prism Evaluation
	E3.3	In house/Peer
	E3.4	Round Table
	E3.5	Year-of-Construction Costs
Gated Process		
	G1.1	Checklists
	G1.2	Cost Containment Table
Identification of Changes		
	I1.1	Cost Containment Table
	I1.2	Estimation Scorecard
	I1.3	Project Baseline
	I1.4	Scope Change Form
Identification of Risk		
	I2.1	Red Flag Items
	I2.2	Risk Charter
Identifying Off-Prism Issues		
	I3.1	Environmental Assessment
	I3.2	Percentage of Total Project Cost
Public		
	P3.1	Meetings
Project Scoping		
	P2.1	Estimation Checklist
	P2.2	Scoping Document
	P2.3	Work Breakdown Structure
Recognition of Project Complexity		
	R1.1	Complexity Definition

Table 6.7 List of Programming and Preliminary Design Methods and Tools (contd.)

Right-of-way		
	R2.1	Acres for Interchange
	R2.2	Advance Purchase
	R2.3	Condemnation
	R2.4	Relocation Cost
	R2.5	ROW Estimator Training
	R2.6	Separate ROW Estimators
Risk Analysis		
	R3.1	Analysis of Risk and Uncertainty
	R3.2	Contingency – Identified
	R3.3	Contingency – Percentage
	R3.4	Estimate Ranges
	R3.5	Programmatic Cost Risk Analysis
Validate Costs		
	V1.1	Estimation Software
Value Engineering		
	V2.1	Value Engineering
Verify Scope Completeness		
	V3.1	Estimation Checklist

Table 6.8 List of Final Design Phase Methods and Tools

		Method/ Tool
Budget Control		
	B1.2	Constrained Budget
	B1.4	Summary of Key Scope Items
	B1.5	Variance Reports of Cost & Schedule
Buffers		
	B2.1	
	B2.2	
	B2.3	
Communication		
	C1.1	Communication of Importance
	C1.2	Communication of Uncertainty
	C1.3	Communication with SHA
	C1.4	Definitive Management Plan
	C1.5	Proactive Conveyance of Information to the Public
	C1.7	Year-of-Construction Costs
Computer Software		
	C2.1	Agency Estimation Software
	C2.2	Commercial Estimation Software
Consistency		
	C4.1	Cradle to Grave Estimators
	C4.2	Estimation Checklist
	C4.3	Estimation Manual (Guidelines)
	C4.4	Estimator Training
	C4.5	Major Project Estimation Guidance
	C4.6	Standardized Estimation and Cost Management Procedures
	C4.7	State Estimation Section

Table 6.8 List of Final Design Phase Methods and Tools (continued)

Method/ Tool		
Constructability		
	C5.1	Constructability Reviews
Document Estimate Basis & Assumptions		
	D4.1	Project Estimation File
Estimate/Document Review		
	E1.1	Estimate/Document Review – External
	E1.2	Estimate/Document Review – Internal
Estimate Review- External		
	E2.1	Independent or Expert Team
Estimate Review- Internal		
	E3.1	Formal Committee
	E3.2	Off-Prism Evaluation
	E3.3	In house/Peer
	E3.4	Round Table
Gated Process		
	G1.1	Checklists
	G1.2	Cost Containment Table
Identification of Changes		
	I1.1	Cost Containment Table
	I1.2	Estimation Scorecard
	I1.3	Project Baseline
	I1.4	Scope Change Form
Identification of Risk		
	I2.1	Red Flag Items
	I2.2	Risk Charter
Identifying Off Prism Issues		
	I3.3	Market Conditions
PS&E Estimates		
	P1.1	Agency Estimation Software
	P1.2	Commercial Estimation Software
	P1.3	Cost Based
	P1.4	Historical Bid Based
	P1.5	Trns•port®
Right-of-way		
	R2.5	ROW Estimator Training
	R2.6	Separate ROW Estimators
Risk Analysis		
	R3.2	Contingency–Identified
	R3.3	Contingency–Percentage
	R3.4	Estimate Ranges
Value Engineering		
	V2.1	Value Engineering

DRAFT GUIDEBOOK REVIEW PROCESS

Protocol

An industry review was considered a key to success in developing the Guidebook content and structure, as this review would validate content and provide feedback from potential industry users. Task 7 revolved around the presentation of strategies, methods, and tools to the industry. The research team began developing a protocol to conduct reviews.

While the research team realigned the tasks to accomplish preliminary testing at a draft Guidebook phase, the researchers began to identify potential testing agencies willing to participate in the review process. The goal of Task 7 was to obtain feedback from professional practitioners on the preliminary strategies, methods, and tools as described in each of the chapters.

The research team developed a draft protocol concept for testing the Guidebook. The protocol contained two parts: 1) a structured methodology for critiquing the results of the Guidebook test; and 2) a typical agenda for a one-day test. The draft protocol concept is shown in Appendix D. The protocol was proposed to be used in a number of ways. One approach was to follow the full day testing process, as represented in the typical agenda. This approach would require a SHA to provide different personnel for the review and critique of the Guidebook. An alternate approach was to test parts of the Guidebook such as those chapters related to specific phases of the project development process. In this case, the agenda would be modified but would always include an overview of Chapter's 1, 2, 3 and 4. For example, if planning is the primary focus of the review then Chapter 5 would be the focus of the critique with the appropriate personnel.

The team contacted several SHAs to enlist their help in testing the Guidebook. Material was sent to each SHA in advance to allow for sufficient preview from participating SHA before the review date. The research team expected to obtain a critique of the Guidebook content, the structure and layout of the Guidebook, its user friendliness, and suggestions on areas of the Guidebook that need improvement. A survey instrument was developed with questions that address all of these issues. This instrument was used to guide the discussion during each review.

Input received from each review site was aggregated as the reviews were conducted. A comprehensive analysis of the information received from the site interviews and interpretation of the results of this analysis was reported. The research team expected that the testing process would ultimately lead to improvements in the Guidebook that might include changes, enhancements, additions, and/or deletions.

Critique Approach

The protocol for critiquing the draft Guidebook was continuously developed based on past models used by the research team members. A preliminary list of review questions were brainstormed by research members. This list comprised of questions concentrating on areas that the research members perceived as challenges. Modifications and additions were continuously made as the review process progressed.

A brief summary of the proposed protocol is described as follows:

> The most efficient critique approach is to conduct on-site and structured interviews. The focus of the interviews would include three main components: 1) overview of the key concepts behind the Guidebook (Chapters 1 through 4); 2) discussions and reviews of the main project development phases (i.e., planning, programming and preliminary design, and final design – Chapter's 5, 6, and 7 respectively); and 3) general critique of the Guidebook. The research team anticipates that the interview process would take a full day. A number of different personnel would be requested to participate. However, these personnel would not necessarily be required the entire day.

The proposed protocol discussed above was modified somewhat for two reasons. First, critiquing of the first seven chapters in one day was not deemed feasible in terms of the time commitment required of the SHA and the extent of the material covered. Second, the development of the Guidebook proceeded slower than anticipated, so those chapters related to project phases were not sufficiently complete to critique them all at one time.

All discussions focused on Guidebook content, the structure and layout of the Guidebook, its user friendliness, and suggestions on areas of the Guidebook that need improvement. Notes were taken during all discussions to capture specific comments. Also, in some cases, copies of comments written in the draft Guidebook were provided. After the interviews the draft Guidebook was revised to reflect comments from the SHAs. A revised version of the draft Guidebook was used in subsequent critiques. Each iteration of revising the Guidebook further refined the content of the Guidebook. In some cases, not every comment was included. However, sections of the Guidebook were growing in detail filling in any missing information. The research team was also tracking key comments to see if a comment was stated more than one time. Final inclusion of comments was made when the critique process was complete.

Agenda

As agencies began confirming participation, the research team organized the review process based on different approaches. Most tests followed a one-day approach with any one of the phases being targeted based on the background and experience of the participants. This approach of targeting reviews by project phases was feasible in terms of time constraints and the review duration.

The participants were walked through the first four chapters of the Guidebook by a research team member to give them an overview of the structure and concepts of the Guidebook. Discussion and comments on these initial chapters were provided by the participants. Subsequently, participants were encouraged to explore the Guidebook for any specific cost escalation issue they deemed as a current problem in their SHA. Research team members would assist in navigation and seek feedback as the participant used the Guidebook. A complete agenda is listed in Appendix E.

State Highway Agency Reviews

When sufficient progress was made to commence the critiquing process with industry practitioners, the research team began presenting the draft Guidebook to the industry. The first interview was with the Georgia Department of Transportation (DOT). Since the first interview, a total of ten SHAs were involved, either directly or through a peer exchange held at Minnesota, in critiquing the draft Guidebook. The other SHAs involved were from California, Florida, Kentucky, Louisiana, Massachusetts, Minnesota, North Carolina, Virginia, and Washington . The draft Guidebook was continuously revised as comments were received throughout the critique process.

Georgia Department of Transportation

The first one day workshop was held at Georgia Department of Transportation (GDOT) offices in Atlanta. Attendees included five representatives of GDOT, one member of the NCHRP 8-49 Review and Implementation team, and four members of the NCHRP 8-49 research team. The GADOT members represented planning, scheduling, design, and construction functional groups.

The scope of the workshop included a critique of Chapters 1 through 4, Chapter 5, and the Tool Appendix portions of the draft Guidebook. Attendees were sent the material ahead of time and asked to critique it and ask questions ahead of time. No questions were received by the project team prior to the meeting. The meeting began with a statement that the material has not been reviewed or approved yet by the NCHRP oversight panel. Attendees were requested to keep the material confidential and not to distribute the material outside of the workshop evaluation team.

The workshop in Atlanta, Georgia was with representatives from the GADOT who are part of a committee who is charged with reviewing the estimation practice and estimation management process from the earliest concept phase through bid. The committee has been meeting for approximately one year and has mapped out the GADOT process and has modified the process to fill in some holes or gaps. The meeting was very positive and commented that they wished this research project had been completed about a year earlier, as this would have made their work in reviewing and modifying the GADOT estimation and estimation management processes much easier and much more efficient. This committee is currently developing a report which identifies policy changes very similar to the strategies proposed in the NCHRP 8-49 Guidebook. The attendees were very receptive of the strategy, method, tool concept.

Virginia Department of Transportation

A one day workshop was held with the Virginia Department of Transportation (VDOT) at Richmond, Virginia to review and to obtain a critique of the working draft of the Guidebook. Attendees included four representatives of GDOT, and three members of the NCHRP 8-49 research team. The VDOT was represented by an Estimation Process Engineer, a Principal Transportation Engineer; a Senior Transportation Engineer; and a District Planning Engineer.

The participants from VDOT had professional experience ranging from 12 to 44 years performing various aspects of estimation over the time with VDOT. They were well versed with policies and procedures.

The Guidebook was presented in parts covering Chapters 1 through 4 and a more detailed review of Chapter 5, the planning phase. The participants were in agreement with the general intent and content of the Guidebook.

Florida Department of Transportation

The NCHRP Project 8-49 Research Team conducted a workshop with the Florida Department of Transportation, to critique the following portions of the draft Guidebook.

- Chapters 1 to 4 – Introductory materials that describe Guidebook concepts and framework
- Chapter 7 – Guide for Final Design Phase
- Tool Appendix

Greg Davis a member of the NCHRP Panel organized this workshop. Attendees were sent the material ahead of time and asked to critique it. Attendees included six representatives of Florida Department of Transportation, and two members of the NCHRP 8-49 research team. The FDOT was represented by a District Utility Estimator, a District Final Plan Engineer, a Turnpike Estimate Coordinator, a Roadway Design Engineer, a State Estimates Engineer, and a State Structures Design Engineer.

The meeting began with a statement that the material has not been reviewed or approved yet by the NCHRP oversight panel. Attendees were requested to keep the material confidential and not to distribute the material outside of the workshop evaluation team. The presented materials were well received with the primary comment being that they would like there to be several approaches for selecting tools.

Louisiana Department of Transportation

The meeting was planned as a one-day workshop in Baton Rouge, Louisiana, but due to hurricane Katrina, the meeting was held via an internet conference. The length of the meeting was also shortened due to the internet conference format. The Louisiana Department of Transportation and Development (LA DOTD) members all attended from one meeting room in Baton Rouge, Louisiana and the NCHRP research team joined from Boulder, Colorado and Phoenix, Arizona.

Attendees included eleven representatives of LA DOTD, and three members of the NCHRP 8-49 research team. The LA DOTD team was led by the Director of Project Development and accompanied by ten other LA DOTD members from planning, design and construction functional groups.

Two members from outside of the LA DOTD were also present both representing the Dye Management. Dye Management is a consultant to DOTD that is assisting them with project management improvement. The workshop critiqued Chapters 1 to 4, 7 and the Tool Appendix of the Guidebook. The LA DOTD attendees were sent the material ahead of time and asked to critique it.

The meeting began with a statement that the material has not been reviewed or approved yet by the NCHRP oversight panel. Attendees were requested to keep the material confidential and not to distribute the material outside of the workshop evaluation team. The internet format made the exchange of ideas somewhat difficult given the large size of attendance, but the meeting was still beneficial to both the NCHRP research team and the LA DOTD.

The LA DOTD assisted the research team by explaining their current state of estimation and estimation management and their desires for what should be included in the book. The LA DOTD is currently working on an effort to improve their cost estimation and project management practices. They are working to identify high risk projects that would be assigned to a specific project manager for different risk management. The LA DOTD was very interested in what the researchers have found to be "bottom line" areas that need to be addressed. The LA DOTD would like to see guidelines for risk and contingency. They understand that the Guidebook will need to provide a general framework for creating agency specific guidance, and that they need to develop their own for their specific practices. They also wanted to know what the level of effort was that they need to expend (i.e. money, labor, development and organizational change).

Minnesota Department of Transportation Peer Exchange

The Minnesota DOT sponsored the Peer Exchange and paid travel for the invited DOTs from California (Caltrans), Kentucky, North Carolina, and Washington. The Peer Exchange was held over two days at St. Paul, Minneapolis. About 55 MnDOT employees attended representing all levels within the DOT. As the agenda in Appendix F shows, the first half a day was used by all the DOTs, including Minnesota, to present materials related to how the DOT is addressing cost estimation practice and cost estimation management. These presentations were based on questions sent to each participating DOT. The questions focused on issues related to the subject and required some thought on the part of the DOTs (see Appendix F). These data were captured electronically both in terms of PowerPoint Presentations and MS Word files with specific answers to each question. The presentations were excellent and the DOTs were all dealing with common problems with respect to cost estimation. The presentations did support the Guidebook cost escalation factors as issues the DOTs are trying to improve upon in their current practice.

The second day initially revolved around the draft Guidebook. The approach to this discussion was similar to the critique process. The introduction time focused on an overview of the research and the research concept as presented in Chapter's 1 through 4. The presentation of this material created some excellent discussion. Next, breakout groups were formed around Chapter 5, 6, and 7, that is, Planning, Programming and Preliminary Design, and Final Design. The Minnesota DOT participants could chose which project phase that was of interest to them. These chapter discussions were conducted in much the same manner as the Guidebook critiques. Thorough discussions of the process flowchart and cost escalation-strategy table were held. The groups then work through examples identifying cost escalation problems and working through the strategies, methods, and tools to address those problems. Prior to completing these breakout sessions, a critique of each chapter was conducted and notes taken.

The remaining part of the day focused on how MnDOT might use the Guidebook to help focus changes in their cost estimation practice and cost estimation management. This discussion started with a strengths, weaknesses, opportunities, and threats (SWOT) analysis of their current practices. Next, gaps between current practice and what the Guidebook is proposing were discussed. The SWOT and gap analyses were conducted within the three breakout groups. This information was documented. Each group reported their results of this effort to the entire group. The day was concluded with summary comments by the NCHRP research team and the other DOT personnel that participated.

Overall, the Peer Exchange was successful both for MnDOT and the research. A general assessment is that the Guidebook adequately covers the topic areas and can be used by different levels of practitioners as a basis for improving DOT cost estimation practice and cost estimation management processes. The Guidebook still needed work and some areas needed more work than others such as the treatment of right-of-way, environmental issues, and utilities in terms how these areas are estimated.

Massachusetts Department of Transportation

A one day workshop was held at the Massachusetts Highway Department (MHD) offices in Boston, Massachusetts. Attendees included 22 representatives of MHD and Cliff Schexnayder of the NCHRP 8-49 research team. The members of MHD represented planning, project development, highway design, bridge development, information technology, liaisons, pavement and rehabilitation.

The scope of the workshop included a critique of Chapters 1 through 7 and the Tool Appendix portions of the draft Guidebook. This was therefore a review of all three of the project phase chapters. Attendees were sent the material ahead of time and asked to critique it and present questions during the workshop. The project team received no questions prior to the meeting. The meeting began with a statement that the material has not yet been reviewed or approved by the NCHRP oversight panel. Attendees were requested to keep the material confidential and not to distribute the material outside of the workshop evaluation team.

The participants at the MHD workshop in Boston were represented by a cross section of Department. MHD was currently working on an effort to improve their cost estimation and project management practices and the workshop included individuals who are part of a committee charged with that effort.

The meeting was very positive and MHD wanted a copy of the Guidebook as soon as possible. Their review committee was currently exploring within MHD the causes of estimation problems; this was very similar to the early NCHRP 8-49 work. The attendees were very receptive of the strategy, method, tools concept.

Guidebook Review Findings

The Research Team recorded key comments from each testing interview at various DOT’s.

Georgia Department of Transportation

Through the workshop a range of suggestions were made to the NCHRP 8-49 research team. Some of these were seen as viable changes that would be made immediately while the research team decided to wait and consider other changes based on input from other workshops. Some suggestions that were included in later revisions of the Guidebook include:

- Modifying the tone of the Guidebook from “problem” to “challenge”
- Revising Figure 2.1 to show the overlap and iteration between the planning, programming/preliminary design, and final design phases of project development

- Removal of the term "government" from the cost escalation factor which originally read "Local Government Concerns and Requirements" to address not only government concerns and requirements but those of non-governmental agencies as well to finally read "Local Concerns and Requirements"
- Revision of the Off-Prism strategy one sentence description to be more in line with the lengthier discussion

Suggestions that the research team decided needed further input from other workshops include:

- Dividing the "Bias" cost escalation factor into two factors
- Including "Market Conditions" as an internal cost escalation factor

One item that was suggested by GDOT which was placed on the list for further input from other workshops which has since been implemented regarded a checklist at the end of each of the project development phase chapters that lists the methods and tools mentioned in the chapter. This sentiment was echoed at other workshops and has been implemented in Chapter 5 through 7. At the Minnesota Peer Exchange Workshop this received high reviews.

Virginia Department of Transportation

The following comments were observed:

- The participants suggested that Influence/Perception by Legislature as an additional challenge to cost estimation be included somewhere in the Guidebook (*note this will be considered*).
- A difference of opinion was expressed regarding the flowchart for the Planning Phase. VDOT moves projects into the STIP irrespective of the development stage as soon as it enters the three year time frame from conception.
- There was a suggestion to differentiate between funding approval and actual cost of projects.
- The participants also expressed concern about the personnel allocating funds not being aware of actual project costs and, hence, resulting in cost escalation.
- Limited resources in terms of both time and funds are forcing the agency to move projects into the "authorize" phase for billing purposes.
- VDOT practices a system wherein designers are primarily involved in estimation and use standards as a basis. Hence, incorporating a strategy was perceived as a challenge.
- Table 3.2, the link between cost escalation factors and strategies was not clear by itself and maybe more narrative would help better understand the intent. Also, maybe moving this table to end of chapter and indicating that more information is available in Chapter 4 regarding its used was also suggested (*note – this change has been made*).
- Due to the exhaustive literature nature of the Guidebook, one participant suggested highlighting key points and repeating them would help the user register the information (*note – recent drafts have attempted to do this*).
- Fig 2.2, agency overall flowchart (*note – still considering this change*):
  - Additional details were suggested in relation to "Estimate Type-Purpose" column like characteristics of the estimate, information available, ideal requirements (suggested for standardizing procedures), and accuracy levels.
  - VDOT has a practice of physically constraining projects at the planning phase.

- Input from MPOs and external sources should be incorporated on the flow charts.
- Maybe use another term for “Authorize”.

The participants urged that environmental requirements be included as a separate cost escalation factor. There was concern over some methods, such as gated processes, not being followed by their agency.

Another finding of the workshop was an approach being adopted by VDOT to mitigate cost escalation. Their approach was to evaluate and send districts a list of projects the agency deems feasible instead of districts turning in wish lists.

Florida Department of Transportation

A primary comment was that the FDOT personnel would like to see several approaches for selecting tools. As currently structured the Guidebook directs users through a strategy, method, tool process. They suggested that a direct problem – tool process be presented. The researchers explored this issue and one technique was added for the MNDOT Peer Exchange. After testing alternate presentations of methods for selecting Tools at the MNDOT Peer Exchange additional modifications was made to the Phase Chapters (5, 6, and 7).

One participant at the Workshop had given Chapter 7 a very hard read and provided a marked up copy to the researchers. Almost all of those suggestions have been incorporated in Chapter 7, as they gave the presentation a much more positive statement of how to successfully implement the Methods and Tools. A revised Chapter 7 was used at the MnDOT Peer Review.

All of the comments received about the approach being recommended were positive. It was obvious that the FLDOT has been studying these issues for a long time and have come to basically the same conclusions that are set forth in the Guidebook, so no major structural changes were recommended.

Louisiana Department of Transportation

The LA DOTD was very pleased with the layout and usability of the Guidebook. They thought that the discussion would be very beneficial as they moved forward implementing their changes to address cost escalation. As the Guidebook was discussed, the LA DOTD provided specific comments. In Chapter 1, Industry problem, they noted that their biggest issues are on complex projects. They defined complexity in terms of cost, technical complexity and management of traffic issues. In Chapter 2, Project Development Stages, they noted that the LA DOTD, uses different names but they understand and can relate to ideas and definitions that the team uses. They did not request any changes. They found the flow chart and tables in Chapter 2 to be very beneficial for discussing issues. It provided a clear idea about what the estimate is going to be used for and how it is produced and managed. They had no substantive comments for Chapters 3, 4 and 7, but again, found the workshop to be very helpful in promoting discussions.

North Carolina Department of Transportation

A detailed review by one of the Minnesota Peer Exchange participants from the North Carolina DOT was received and provided some useful comments related to different portions of the draft

Guidebook, although the Guidebook was incomplete at the time. Generally, this person believes the Guidebook will be a great resource for states to use. However, one of the challenges will be keeping the material current and up-to-date. This DOT reviewer hoped that a structure would be put in place to accomplish this.

This reviewer's major comment related to the extent that peer reviews are frequently referenced as a method. In the NCDOT the experts are the ones preparing the estimates for the most part, so there are not many "peers" available. On the private side, if contractors act as external reviewers this might be perceived as given them the advantage. Bringing contractors from out of state would be one answer on larger projects but the cost would have to be evaluated.

This reviewer thought that even at the planning stage some thought should be given to project delivery methods. This would set a flag as the project goes through the development process.

Massachusetts Department of Transportation

Through the workshop a range of suggestions were made to the NCHRP 8-49 research team. Some of these were seen as viable changes that would be made immediately while the research team decided to wait and consider others upon further input from other reviews. Some suggestions that were included in later revisions of the Guidebook include:

- Revising Figure 4.1 as it did not clearly present the idea
- On the Phase flow charts add input from Traffic Management and Construction disciplines.
- Table 5.0, in the external section first line (Local Concerns & Requirements) add Reviewing Agencies
- The idea that SHAs should be sharing bidding and cost information was not receive well during our previous workshops, however, in the Northeast where the same contractors work in the bordering states MHD thought this was a good ideas and would like more data from other SHAs.
- MHD utilizes consultants to a great extent in design and the consultant is responsible for developing the estimate. Therefore, MHD thought the Guidebook should include information about achieving estimate consistence from consultants.
- Need to discuss in the Guidebook quality control of consultant estimates.
- MHD has investigated using Trns•port but there are both cost and technical issues that have caused them to not purchase the software. The technical issue has to do with file names being linked to the set bid opening date and if that date slips there are problems with the files.

Two years ago MHD introduced two new Transportation Evaluation Criteria forms related to the project development planning process. They are still evolving, both in content (still working on definitions for quantifying some of the criteria) and in process (i.e., how and when they are included in the process). A copy of one form is shown here. The other form is a spreadsheet for calculating the scores.

Summary of Review Process

Based on the critiques obtained, the general concept of the Guidebook was acceptable and appeared to be useful to DOTs as a mechanism to promote change in DOT cost estimation practice and cost estimation management. The format and layout of the Guidebook evolved and was improved based on comments from the DOTs. The content of Chapter’s 1 through 4 had become clear and concise through changes based on the critiques. The content of Chapter 5 and 7 was good and improving. Chapter 6 needed work as this chapter had had fewer reviews. All process flowcharts in Chapter’s 5, 6, and 7 provided a good representation of the key steps in cost estimation practice and cost estimation management. The tool appendix was perceived reasonable but extensive. Some tool descriptions required further information to be helpful and it was suggested that, perhaps, a little more “how to” type discussions would be helpful.

Panel Review

The iterative testing process culminated in the final draft of the Guidebook being presented to the NCHRP Panel for review and approval. Members of the panel carefully reviewed and commented on the final draft of the Guidebook. While there was a general agreement that the Guidebook served its purpose, there were several specific comments. The researchers responded to the panel members comments clarifying the context and improving the book. Some panel members suggested inclusion of additional information, such as references to certain legal statutes, which would improve the quality of the content. These suggestions were also incorporated to further validate any references made in the Guidebook.

GUIDEBOOK LAYOUT

The Guidebook contains nine chapters. The first three chapters “set the stage” for a detailed description of the recommended strategies, methods, and tools to be used in practice. These first three chapters provide an overview of the guide and present the strategies, methods, and tools that will be detailed in the later chapters. Chapter 4 outlines the Guidebook layout and directs the proper usage as intended by the authors. Chapter’s 5 through 7 describe strategies and their methods and tools corresponding to Long-range Planning, Programming and Preliminary Design, and Final Design respectively. Chapters 5 through 7 also discuss the impact of project complexity in relation to cost estimation practice and cost estimation management. Chapter 8 discusses implementation issues and how a DOT might integrate the Guidebook content into current and future DOT practices. A four step process suggesting changes at the organizational, programmatic, project, and strategic levels is incorporate into this chapter. The final chapter, Chapter 9, provides a path forward. Appendices have been used as appropriate to provide additional information to users. The first Appendix, which is the bulk of the document, discusses all tools compiled and has been indexed by methods for ease of navigation within the document. An overview of the Guidebook table of contents is shown in Figure 6.5.

The content of each chapter is a combination of running text, bullet items, graphic schematics to illustrate key concepts and/or points, and specific documents to better illustrate a tool. In an effort to make the Guidebook user friendly, the level of running text is kept to a minimum. The research team has found that the best Guidebooks are ones that have minimal running text and more concise content in bullet form supported by figures and tables. While this approach is ideal, some running text is always necessary to explain content that is more complex.

The key chapters of the Guidebook are 5, 6, and 7. A strategic layout to encompass all elements of each phase was required. Considering the varying audience of the Guidebook a consistent layout was believed to eliminate any discrepancies in the presentation of information. Hence, each of these chapters was develop on the following framework: an overview of each phase with a graphical representation of generic processes involved in a particular phase was discussed at the front end of the chapter. The aim of the overview was to help readers identify with the different processes in accordance to their own SHA practices. Also, references to possible locations along the flow of these processes are made while addressing each method. The next sub section within each of these chapters suggests strategies that are applicable to the different cost escalation factors in agreement with the concerned phase. This serves as a precursor to determining which methods could be utilized to alleviate cost escalation. Methods are hence classified by eight strategies and discussed accordingly in the next subsection of the chapter. With the discussion of methods a lead to different tools to implement the method is indicated. This layout was found most suitable to educate the audience on a strategy, method, and tool concept for addressing cost escalation factors as originally suggested by the NCHRP panel.

The Tool Appendix supports all core chapters of the Guidebook. The compilation of the Tool Appendix, which was a major effort for the research team, included the classification and listing of a vast collection of information. The research team recognized the critical nature of the tools for the success of the Guidebook and hence listed them in an appendix to enable easy navigation for users.

PROCEDURES FOR ESTIMATION PRACTICE AND MANAGEMENT FOR HIGHWAY PROJECT DURING PLANNING, PROGRAMMING, AND PRECONSTRUCTION

Executive Summary

Chapter 1 – Introduction
- Background
- Guidebook Development
- Guidebook Layout
- Use of Guidebook

Chapter 2 – Agency Cost Estimation Practice & Cost Estimation Management
- Project Development Phases
- Cost Estimation Practice and Cost Estimation Management Overview
- Cost Estimation Practice and Cost Estimation Management Steps

Chapter 3 – Factors and Strategies
- Cost Escalation Factors
- Internal Cost Escalation Factors
- External Cost Escalation Factors
- Strategies

Chapter 4 – Guidebook Framework
- Background
- Strategy, Method, and Tool Integration
- Structure and Layout of Content
- Tool Appendix

Chapter 5 – Guide for Planning
- Introduction
- Methodology
- Strategies
  - Methods

Chapter 6 – Guide for Programming and Preliminary Design
- Introduction
- Methodology
- Strategies
  - Methods

Chapter 7 – Guide for Programming and Preliminary Design
- Introduction
- Methodology
- Strategies
  - Methods

Chapter 8 – Implementation
- Introduction
- Steps

Chapter 9 – Path Forward
- Industry Problem
- Guidebook Development
- Path Forward
- Keys to Success
- Challenges

Figure 6.5 Guidebook Table of Contents

CONCLUSIONS

This chapter has described the different steps that were involved in the development of the Guidebook. The research team performed several iterations before an efficient version of the Guidebook was crafted. The process of simultaneous development and recommendation of strategies, methods, and tools was found to be a successful process. The continual evaluation process of the Guidebook proved beneficial to mould the final product for the audience and to validate the contents. There was a general consensus on the intent and content of the Guidebook during the testing period with continuous improvements as each test was conducted. This chapter also includes a summary of the test procedures at different sites and the key findings of each test location. An analysis of these findings finally helped in improving the final product. Chapter 6 will provide an overview of an implementation plan for this Guidebook and the challenges involved with implementation.

CHAPTER 7
IMPLEMENTATION

The main goal of Task 9, *Develop Implementation Plan,* was to develop a practical implementation plan to help accelerate the use of the Guidebook in industry. The implementation plan proposed has two main focuses. The first focus is to aid the immediate user of the Guidebook with implementation within a state highway agency (SHA). This implementation approach is described in the Guidebook under Chapter 8 and briefly summarized in this chapter. The second focus is a broader plan that will lead to implementation across the highway industry. This plan is briefly described in this chapter but described in more detail in a white paper, titled "Proposed Implementation Plan for the NCHRP Guidebook on Cost Estimating and Cost Estimating Management of Highway Projects." The white paper also briefly discusses the implementation plan for an individual state highway agency as proposed in the Guidebook. Figure 7.1 summarizes the inputs and outputs of this task.

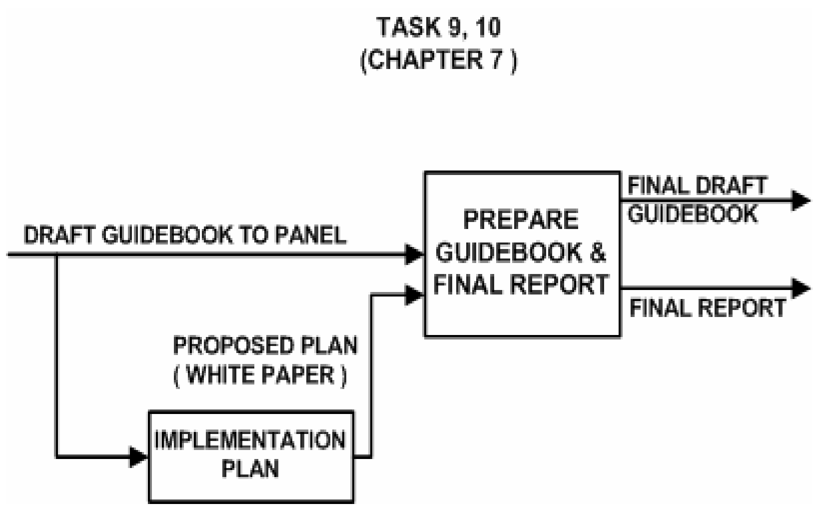

Figure 7.1 Development of Implementation Plan

INTRODUCTION

The implementation plans were developed with input from an advisory team member who is actively involved in accelerating innovation in the highway industry. The SHA plan was proposed initially by the research team based on the concept of strategies, methods and tools. Each of these components is purposely linked to a level of operation within an agency, specifically at the organizational, programmatic, and project levels, respectively. A draft chapter on implementation was written and then critically reviewed by the advisory team member. Based on comments received the final draft was developed for use in the Guidebook.

The same advisory team member provided a basic outline of ideas on how to promote implementation on an industrywide basis. This outline formed the context for drafting a white paper on a proposed approach to facilitate implementation of the Guidebook throughout the highway industry. This plan is structured around three steps namely show or inform, evaluate, and apply. Other suggestions are provided for industrywide implementation.

STATE HIGHWAY AGENCY IMPLEMENTATION PLAN

The Guidebook is intended to assist in creating a strategic change in agency estimation and cost management approaches. It aligns strategies with identified problem areas and can be used to create organizational structures for achieving consistent and accurate project estimates. Additionally, it presents detailed methods and tools to support the strategic approaches.

While implementation of individual strategies, methods, and tools is essential, they should not be used in an “al la Carte” fashion. Implementation must occur within the context of a greater vision for integrating cost estimation practice and cost estimation management processes across all agency programs and with agency consultants.

Although the estimation approach transformation can begin at any organizational level, *ultimately all levels must participate* to create a cultural change in addressing the challenges of cost estimation practice and cost estimation management throughout project development. Table 7.1 summarizes the implementation goals at the organizational, programmatic, and project levels. Achieving some of the goals may require organizational change and all will require a commitment of resources.

Table 7.1 Implementation Goals

Implementation Thrusts	Implementation Focus	Implementation Goals
Organizational Level	Strategies	Implement Strategies Across the Agency • Assess current status of strategy implementation • Plan for long term implementation • Assign responsibility for implementation • Measure results of implementation
Program Level	Methods	Implement Methods Across Programs • Assess current status of method implementation • Develop policies and procedural manuals • Develop training and education
Project Level	Tools	Implement Tools Across Projects • Assess current status of tool implementation • Determine subject matter experts • Conduct pilot studies for new implementation • Develop/revise agency specific tools

.

A four step process is proposed as follows:

- Step 1. Implementation of Strategies – Organizational Change
- Step 2. Implementation of Methods – Programmatic Change
- Step 3. Implementation of Tools – Project Change
- Step 4. Integrating the System – A Strategic Plan

Implementation of Strategies – Organizational Change

Successful control of project cost escalation may require a strategic change in the organizational approach that many SHAs have towards cost estimation practice and cost estimation management. Project cost estimation practice and project cost management should be viewed as an interdependent system that spans the entire project development process. Eight strategies are proposed to improve cost estimation practice and cost estimation management. These strategies were developed by observing and synthesizing practices from highway agencies around the country. The implementation of the eight strategies will require a long-term commitment to change. Implementation should be approached as a continuous process of 1) assessment, 2) planning, 3) assigning responsibility, and 4) measuring performance. Tools that might be useful in ensuring successful implementation at the organizational level include forming a cross cutting steering committee similar to the Georgia Department of Transportation approach and conducting an agencywide workshop such as the Minnesota Department of Transportation "Peer Exchange."

Implementation of Methods – Programmatic Change

The second implementation step involves change at the program level with the institution of methods. Over thirty methods that support the strategies for producing consistent and accurate estimates were described in the Guidebook. In this step, an agency should first examine its current practices, then develop policies and manuals, and finally develop training and education modules to promote improved cost estimation and cost management.

Implementation of Tools – Project Change

The third level of implementation involves the application of tools at the project level. Tools should be developed and evaluated on a trial basis before they become agency practice or are incorporated into agency policy. Over 90 different tool applications are described in the Tool Appendix of the Guidebook. These tools support the execution of the methods.

Integrating the System – A Strategic Plan

The previous sections described the implementation of strategies, methods, and tools at the organizational, program, and project levels. While each of these elements is individually important, success will only be completely realized when the agency integrates these elements as a long-term strategic initiative. An integrated approach is proposed based on these elements:

- Cost Management or Cost Estimation Strategy

- Performance Improvement Opportunity/Action
- Implementation Steps
- Responsible Party and Performance Measurement

Using a structure based on the four elements provides a framework for implementing the strategies, methods, and tools described in this Guidebook. But agencies can develop alternate approaches or frameworks as dictated by their needs and resources. A more complete description of the agency implementation plan can be found in Chapter 8 of the Guidebook.

INDUSTRYWIDE IMPLEMENTATION PLAN

Much of this plan is based on the experiences of TRB Task Force AFH35T, *Accelerating Innovation in the Highway Industry*. For example, workshops similar to the Cost Estimation workshop that was sponsored by the AFH35T Task Force in February 2004 can be used to expose DOT management to the Guidebook. Collaboration with other groups has proven to be successful in exposing new products. Such groups might be the ASSHTO Technical Committee on Cost Estimation and the AASHTO Technology Implementation Group (TIG).

Implementation takes on several modes. It can be broken down into three step:

1. Show or Inform;
2. Evaluate; and
3. Apply.

Show Product

The first step is to **SHOW or INFORM** the industry the results of the NCHRP 8-49 work. The goal of this category is to expose the Guidebook as a comprehensive work and let industry professionals know that the Guidebook exists. The case has to be made convincingly how very important it is for them to learn what is contained in the Guidebook. Several tools are needed to encourage and facilitate this learning process. Some potential tools discussed include:

A news release that tells people the Guidebook is available. This news release is for everyone in the industry.

A short brochure (flyer) that succinctly describes the product–the Guidebook–and tells potential users why they should pick it up, read it, and learn about the potential benefits. This flyer should tell them why these Guidebook will improve estimate CONSISTENCY and ACCURACY, as stated in the definition. This flyer is specifically for DOT professionals responsible for cost estimation practice and cost estimation management.

A PowerPoint presentation that can inform the broader community.

AASHTO gives this official recognition as an **interim Guideline**, using either the Technology Implementation Group or the Technical Committee on Cost Estimating.

A performance measure that might be appropriate for assessing the success of this category is that every pertinent DOT official is informed of the work and understands the potential benefits if the Guidebook is applied in their organization.

Evaluate Product

The second step is to **EVALUATE** the product. This is the most difficult but obviously the most important step. Identify those agency professionals from Step 1, **SHOW or INFORM**, that are highly interested in the Guidebook. Several education products would be available to them, in addition to the Guidebook. These extra products could be:

A comprehensive *HOW TO IMPLEMENT* step-by-step guide. A template should be developed that would then be adapted by a specific SHA to its unique organizational culture and work processes.

Regional workshops with several SHAs participating. This could also be segmented by SHAs with similar types of Cost Estimation and Cost Management Systems.

Formation of a technical working group of six to eight SHAs that are actually evaluating the product inside their SHA. This could also be a networking mechanism and a working group.

Conduct periodic reviews and try to capture the benefits from each SHA project.

Develop case studies and share with others in the working group and the broader industry community.

Attempt to determine improvements in consistency and accuracy. There is a need to develop metrics to measure consistent and accuracy improvements in cost estimates and the management of estimates over time.

Update the Guidebook as lessons are learned.

Towards the end of this effort, FHWA and AASHTO could consider the Guidebook as an **approved Guideline**.

A performance measure that would be appropriate for this step is to have the six to eight SHAs seriously evaluate the Guidebook and report on its benefits and/or shortcomings. This evaluation would lead to an **approved Guideline**, perhaps with recommended changes incorporated.

Apply Product

The final step is to **APPLY** the product permanently. This is the final step in the process. Achieving this step would mean that the SHA has fully incorporated the Guidebook into its cost estimation practice and cost estimation management work processes, has established internal policies and protocols, and no longer considers the Guidebook experimental or in the evaluation stage.

A performance measure that would be appropriate for this step is to have identified three SHAs that have successfully applied the Guidebook and that are actually accruing long-term benefits from its application.

Other Implementation Suggestions

The following other suggestions regarding implementation can complement the three step process:

An executive session might work under Step 2, Evaluation, if the SHA cost estimation managers considers it to be beneficial. They may want help in convincing the local SHA executives that this is important to them.

An NHI course later down the road is important. But it comes after Step 2 has shown the Guidelines are actually a winner.

If SHAs cannot agree to an evaluation and trial implementation approach as suggested under Step 2, downplay this to a cost estimation peer review process using the Guidebook as a resource.

Develop from the Guidebook the 10 Commandments of Cost Estimation Practice and Cost Estimation Management that pulls people to the major principles that must be inherent in a successful cost estimation practice and cost estimation management system. Ten key principles to successful implementation have already been incorporated into the Guidebook. These ten principles could be aligned with a 10 Commandments list.

Try to keep the Guidebook a system product, not a series of individual practices or tools.

One caution is that a SHA could treat this as an "al la Carte" Guidebook. If so, professionals will usually implement the easiest or the quickest methods and tools first, not necessarily the methods and tools that, perhaps, have the bigger payback in terms of benefits. A more comprehensive discussion of the industrywide implementation plan is covered under a white paper prepared under Task 9 titled, "Proposed Implementation Plan for the NCHRP Guidebook on Cost Estimating and Cost Estimating Management of Highway Projects."

CHAPTER 8
CONCLUSIONS AND RECOMMENDATIONS

Cost escalation that occur over the course of project development constitute the major research problem that this project has addressed. This problem is manifested in cost estimation practice and cost estimation management approaches that do not promote consistency and accuracy of cost estimates over the project development process. This issue has been addressed through meeting the following research objective:

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

The contents of the Guidebook that was developed is based on an extensive review of literature, current industry practice, and inputs from experts in the area of cost estimation practice and cost estimation management. The Guidebook contents are structured around a strategic approach to addressing cost escalation. Eighteen cost escalation factors were identified. Eight strategies are proposed to address these cost escalation factors. Over 30 methods were identified and described to implement the strategies. Finally, over 90 tool applications are presented to support the execution of the methods. The Guidebook strategies, methods, and tools are aligned with three main project development phases: planning; programming and preliminary design; and final design. The Guidebook was critiqued by ten state highway agencies and reviewed in detail by the NCHRP Project 8-49 Panel. Finally, an implementation plan is proposed for state highway agencies and the industrywide application of the Guidebook.

This chapter provides conclusions based on the totality of the research effort. Specific recommendations are provided. The chapter is concluded with “Ten Key Principles” that must be focused on to ensure consistent and accurate estimates.

CONCLUSIONS

General Industry Related Conclusions

- Cost increases continue to be a problem facing SHAs especially in view of recent trends in increasing prices of steel, concrete, asphalt, and other materials.

- Many of the current approaches to solving this problem appear to be unstructured and do not provide a comprehensive approach.

- Most efforts have focused on creating tools to improve cost estimates with less emphasis on tools for cost estimation management.

- There is a lack of comprehensive strategies for creating a systematic approach to the problem across the project development life cycle.

- Within some SHAs a variety of approaches to estimation often exist, thereby, creating a lack of consistency in preparing estimates, particularly as the responsibility passes between groups during development stages.

- Planning and design personnel have primary responsibility for performing project development work. These professionals also are responsible for project estimation and cost management. This may influence the ability of these SHA personnel to produce accurate estimates with an appropriate level of research on unit costs and other factors impacting estimated costs. It can also promote an optimistic bias towards cost estimates as it is difficult to make objective cost assessments on one's own design.

- There appears to be a disconnect between cost estimates developed for planning and the cost estimate developed to program a project as different functional groups are responsible for these estimates. In some cases, planning estimates do serve as a basis for programming estimates that will set a baseline budget. Different states approach planning differently in terms of policy based versus project based planning.

- There appears to be a significant lack of any structured analysis directed at uncertainty and associated risks with respect to cost estimates. This appears in the form of unsatisfactory risk assessments and corresponding risk management.

- Many agencies do not set a baseline cost for individual projects, or if they do, they are often not set at consistent times in the project development process. The establishment of a baseline estimate is critical to proper cost management.

- There is a general lack of consistency in how estimates are communicated both internally and externally. Key components include the communication of uncertainty and contingency in an estimate. Communication in year-of-construction dollars was also found to be inconsistent.

- There is a lack of an integrated approach to cost estimation practice and cost estimation management.

- Few SHAs have comprehensive documented process supported by flowcharts that describe cost estimation practice and cost estimation management covering these processes over the project development timeline.

- Understanding the influence of market conditions on cost estimates and the tracking of changes in market conditions and the impact these changes have on budgets is lacking in many agencies.

- Both external and internal estimate reviews appear to be underutilized.

Specific Issue Areas

- Contingency is typically applied to SHA cost estimates but its application is still considered problematic. Very often the specific aspects of contingency dollars are not define—what do the dollars cover, they cannot be use later to add items to the project.

- Risk-based estimation and management is used by only a small number of transportation agencies. Range estimates and risk charters are common practice in the other industries, but the highway sector is just beginning to apply these techniques.

- Many SHAs inflate their estimates to the prospective date of construction by applying a factor that reflects the current economic situation. However, SHAs often do not usually consider the impact of inflation that results from a schedule change.

- The issue of scope control is paramount to managing project costs. SHAs are attempting to use a variety of methods and tools to control scope changes and scope growth, but their use is not widespread and scope control practices are far from standard practice.

- A system of cost validation points must be established if a project is to remain on budget. Few SHAs have a process, which is gated based upon continually updated estimated cost.

- 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 a single individual's judgment to impartially review the estimate. The reliance on estimators who lack sufficient experience is another deficiency that SHAs must surmount.

- Proper estimation documentation is a common deficiency, which causes accountability issues.

- The SHAs also lack coordination and communication between the disciplines participating in the development of the project's scope and estimate.

- Many SHAs do not adequately consider project complexity and the impact complexity has on a project when the SHA creates a cost estimate.

RECOMMENDATIONS

Implementation

- The Guidebook presents an industry-wide set of strategies, methods, and tools to combat the problem of cost escalation, but each agency will need to create its own unique "how to" procedural manual to change its own unique practices.

- Find an agency that will champion the industrywide implementation plan.

- SHAs should consider the following challenges to implementing the Guidebook:

Challenging the status quo and creating a cultural change requires leadership and mentoring to ensure that all steps in the cost estimation management and cost estimation practice are performed.

Developing a systems perspective requires organizational perspective and vision to integrate cost estimation management and cost estimation practice throughout the project development process.

Dedicating sufficient time to changing agency attitudes toward estimation and incorporating the strategies, methods, and tools from this Guidebook into current SHA practices is difficult when resources are scarce.

Dedicating sufficient human resources to cost estimation practice and cost estimation management beyond those that have previously been allocated to estimation processes.

Future Research

- Assist in some aspects of implementation – longitudinal study on Guidebook Implementation with selected SHAs.
- Develop more specific "how to" guidance in the form of procedures is some critical areas such as ROW, Utilities, Environmental, and Risk.
- Study methodologies to assess future inflation and changes in market conditions.

KEYS TO SUCCESS

This research has determined that "Ten Key Principles" must be focused on to ensure creation of consistent and accurate estimates. Each individual principle in itself can help improve cost estimation management and cost estimation practice. However, maximum improvement of these two processes will only occur if the ten keys are considered as guiding principles that must be incorporated into the agency's business practices throughout the organization. Within each group the keys are stated here in prioritized order.

Cost Estimation Management

6. ***Make estimation a priority*** by allocating time and staff resources.
7. ***Set a project baseline cost estimate*** during programming or early in preliminary design and manage to it throughout project development.
8. ***Create cost containment mechanisms*** for timely decision making that indicate when projects deviate from the baseline.
9. ***Create estimate transparency*** with disciplined communication of the uncertainty and importance of an estimate.

10. ***Protect estimators*** from internal and external pressures to provide low cost estimates.

Cost Estimation Practice

6. ***Complete every step in the estimation process*** during all phases of project development.

7. ***Document estimate basis***, assumptions, and back-up calculations thoroughly.

8. ***Identify project risks and uncertainties*** early and use these explicitly identified risks to establish appropriate contingencies.

9. ***Anticipate external cost influences*** and incorporate them into the estimate.

10. ***Perform estimate reviews*** to confirm the estimate is accurate and fully reflects project scope.

Implementing the "Ten Key Principles" ultimately will require a commitment by the agency's senior management to direct and support change. The benefit of doing so will be manifested in projects that are consistently within budget and on schedule, and that fulfill their purpose as defined by the scope. This benefit will also improve program management in terms of better allocation of funds to projects to meet the needs of the ultimate customer, the public.

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APPENDIX A
INTERVIEW INSTRUMENT

Texas Transportation Institute

MEMORANDUM
January 18, 2007

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 (*insert day/month*) and time (*insert 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.*

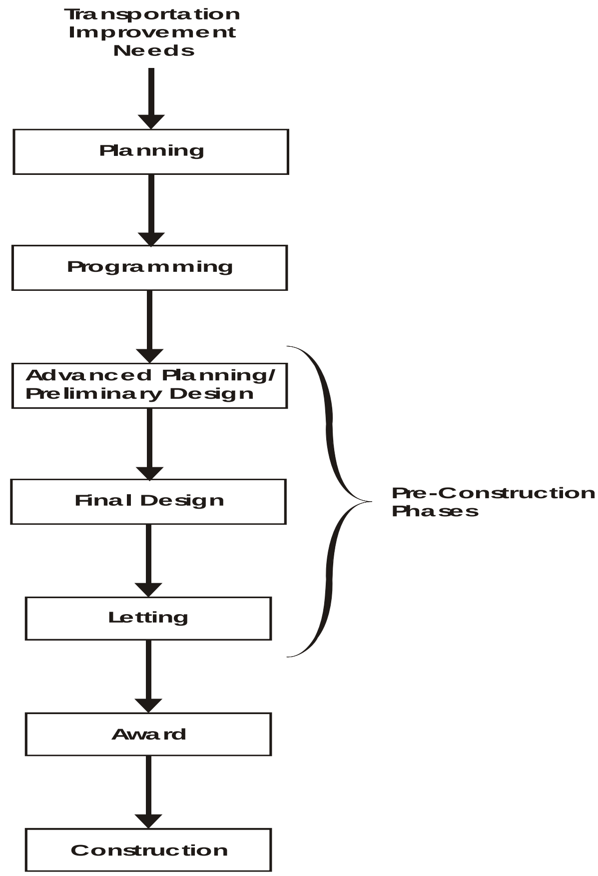
Because the study scope requires the research team to consider estimating procedures and management methods during various phases of project development, we have developed an interview instrument that addresses the following general issue areas:

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.



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

- For further information regarding this project please visit our website at

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

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?

Conceptual Estimate (Programming):

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?

6. 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?

Estimate Reviews

7. 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?

Preliminary Design Estimates (Advanced Planning/Prelim Design):

Cost Estimating Management

9. 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.

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

11. 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?

12. 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 and construction) 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

TYPICAL LETTER FOR CONTACT NAMES

April 7, 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:

1. How conceptual estimates are prepared for long range-planning and priority programming;
2. How advanced planning/preliminary design estimates are prepared;
3. The procedures for preparing engineer's estimates; and
4. 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.

Sincerely,

Stuart D. Anderson, PhD, PE

Manager, Construction Program

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

EXAMPLE 1

Kentucky Transportation Cabinet
June 14-17, 2004

Attending

Kentucky Transportation Cabinet (KTC)

Texas Transportation Institute

Documentation Provided

- Link to the department's external website http://www.kytc.state.ky.us/

Interview Summary

Strengths of DOT

- The Kentucky Transportation Cabinet considers similar projects and terrain when developing their conceptual estimates.
- KTC has project identification forms that are used to document information about the project including changes.
- The Cabinet has started a Project Manager's Academy to train the preconstruction engineers and project managers in cost estimating.
- For preliminary design estimates, KTC established trigger values for projects that exceed their budget.

Weaknesses of DOT

- Accountability is an issue the Kentucky Transportation Cabinet has during the conceptual estimating.
- A major problem for Kentucky is the change of project scope and failing to make the proper adjustment in cost.
- Problems with the estimates arise because the estimates are not always routinely updated or updated with the right attention to inflation and other issues; as a result, the project usually ends up being underestimated.
- The Kentucky Transportation Cabinet does not have formal estimating procedures or reviews for most of their estimates. Their long-range planning estimates rely on the estimator's experience.
- The Cabinet applies a range of contingency (0-50%) for the different estimates depending on their confidence with the estimate and not on a formal analysis.

Overview of Project Development Phases

Kentucky has 12 districts and 9 MPOs. Most of the conceptual estimates are part of the unscheduled needs list, which is updated on a two-year cycle. The Kentucky Transportation Cabinet has a six-year program that is updated every two years, and the first two years are funded. Kentucky has four levels of estimating, levels A, B, C, and D. At the initial concept of the project, the estimate is a level D. When a project reaches about 40% design completion, an estimate for each of the alternatives being considered is prepared, which is a B or C level estimate depending on the amount of information. When 60-80% of the design is complete, another B or C level estimate is produced. When the plans are 90% complete and the final plans are reviewed, a level A estimate is created.

EXAMPLE 2

New York State Department of Transportation
July 15, 2004

Attending

New York State Department of Transportation

University of Colorado

Documents Provided

flowchart.pdf This is a chart showing the process of project development in the New York State Department of Transportation.

NYSDOTHDM21-5.pdf This is the section of the New York State Department of Transportation Highway Design Manual pertaining to estimating procedures in all project development phases.

TRNS PORT at NYSDOT (http://dot.state.ny.us/trns-port/index.html) This link provides information regarding the use of the AASHTO software Trans Port by the New York State Department of Transportation.

Also provided by NYSDOT are written responses to the State-of-Practice Survey. These responses are provided within this document and are in all uppercase letters.

Interview Summary

Strengths of Estimating System

Region Estimating System

- Projects are estimated at the local level which allows for the people doing the estimating to be in tune with the local project and political climate.

Same Estimator Throughout Project Life

- The person that prepares the first estimate also prepares the estimates throughout the project life. This allows the person to become knowledgeable about all projects detail.

Problems Identified by NYSDOT

Preliminary Estimating

- Estimating at this level is difficult and not always accurate. NYSDOT is starting to phase in Trans Port to help make estimating at the early phases easier.
- General guidelines are provided for early estimates in the design manual, however, methodologies vary throughout the state. There is a need to standardize some aspects.
- There needs to be better early exploration of combining projects as sometimes projects that have gone through the system separately end up being combined into one project at the time of letting.

Tracking System

- Projects are tracked by the current system, but this is only on paper. The tracking system needs to be updated and refined.

- There is a need to ensure that projects are tracked throughout project development, from early estimates through letting. The current system is fine as long as there are funds available, but when funds become tight, projects are cut, highlighting problems in the system.

Overview of Project Development Process

The process is similar to the process described by the NCHRP 8-49 Figure 1. The first conceptual estimate is at the Initial Project Proposal, when the job is put on the program. There is a preliminary estimate when the project is first put on the program and it is developed from there. Following this, there are estimates done at the Advanced Planning/Preliminary Design stage, Design approval, Final Design and then at the PS&E phase. The first estimate that is recorded is when the project is put on the 5 year program. See schematic of process-flowchrt.pdf.

The highway design manual provides guidance for estimates in all phases. Many of the answers are similar for the questions.

APPENDIX D
TYPICAL ONE DAY AGENDA

Time	Description	Who (typical personnel)
8:30 – 10:00	Overview Guidebook Contents (Chapters 1-4) Agency Overview Cost Escalation Factors/Strategies Strategies, Methods, and Tools Discussion Critique	Management Planning Directors, Planners, Design Directors/Chief Lead Designers Estimators
10:15 – 12:15	Planning (Chapter 5) Guidebook Details Discussion Critique	Planners, Planning Directors Local Agency Representatives Estimators
12:15 – 1:00	Lunch	
1.00 – 3:00	Programming and Preliminary Engineering (Chapter 6) Guidebook Details Discussion Critique	Programmers/Design Chief Design Leads Estimators Regional/Dist Personnel
3.00 – 4:00	Final Design (Chapter 7) Guidebook Details Discussion Critique	Design Chief Lead Designers Estimators Regional/Dist Personnel
4:00 – 5:00	Wrap Up General Critique Implementation Issues	Management Planning Directors, Planners, Design Directors/Chiefs Lead Designers Estimators

APPENDIX E
TYPICAL DRAFT AGENDA FOR AGENCY CRITIQUE

Typical Agenda (Based on the Florida DOT Site Visit)

Time	Description
8:30-9:00	Introduction and Background ❑ NCHRP and FDOT ❑ 8-49 Project Statement
9:00-10:30	Overview Guidebook Contents (Chapters 1-4) ❑ Introduction ❑ Agency Overview ❑ Cost Escalation Factors/Strategies ❑ Framework ❑ Discussion-as we go ❑ Critique-as we go
10:45-12:00	Guidebook Application (Chapter 7 and Tool Appendix) ❑ Introduction ❑ Methodology ❑ Discussion-as we go ❑ Critique-as we go ❑ Example SMT-Discussion/Critique
12:00-1:00	Lunch
1:00-3:00	Guidebook Application (Chapter 7 and Tool Appendix) ❑ FDOT Problem ❑ SMT Evaluation ❑ Discussion ❑ Critique

APPENDIX F
MINNESOTA DOT PEER EXCHANGE AGENDA

Minnesota Cost Estimating Peer Exchange
Best Western Maplewood Inn, Maplewood, Minnesota
September 26 and 27, 2005

AGENDA – Day 1

Noon	Lunch provided, Best Western Dining Room
1:00 – 1:15	**Introduction** *Mn/DOT & TTI*
1:15 – 3:00	**Presentations and Perspectives** Cost Estimation and Cost Estimation Management *Bob Winter, Division Director, District Operations Division* *Tom Sorel, FHWA* *Victor Barbour, P.E- Construction Unit* *North Carolina DOT* *Daryl Greer, P.E Transportation Engineering Branch Manager* *Kentucky DOT*
3:00 – 3:15	**Break**
3:15 – 4:15	**Presentations and Perspectives** Cost Estimation and Cost Estimation Management *Jack Young Structure Office Engineer/Division of Engineering Services* *CALTRANS* *Sio Ng, P.E, Cost Risk Estimating Engineer* *Washing State DOT*
4:15 – 5:00	**Wrap-Up/Prep for Day 2** *Mn/DOT & TTI*

AGENDA – DAY 2

8:00 – 9:50 **National Cooperative Highway Research Program 8-49**
Introduction and Agency Overview
Stuart Anderson, TTI

Strategies, Methods, and Tools
Keith Molenaar, TTI

9:50 – 10:00 **Break**

10:00 – 11:30 Concurrent sessions:
Planning - Keith Molenaar, University of Colorado, Section A
Final Design--Cliff Schexnayder, Arizona State University Section

B

Programming and Preliminary Design, Stuart Anderson, TTI,

Section C

11:30 – 12:15 **Lunch**

12:15 – 1:30 **Concurrent sessions continued - return to sessions**

1:30 – 1:45 **Break**

1:45 – 2:45 **MnDOT response to presentations/small groups**

2:45 – 3:00 **Break (need to open room back up again)**

3:00 - 3:30 **General Session – small groups report back**

3:30 – 4:15 **NCHRP Researchers and DOT Panelists respond**

4:15 – 4:30 **Wrap Up**
Evaluation
Mn/DOT & TTI