NCHRP

REPORT 574

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Ronald D. McCready
Staff Officer
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This guidebook presents approaches to cost estimation and management to overcome the root causes of cost escalation and to support the development of consistent and accurate project estimates through all phases of the development process, from long-range planning, through priority programming, and through project design.

The problem of cost escalation has become a major concern in virtually every field of capital project development. Within the transportation sector, cost escalation has attracted attention at the federal, state, regional, and local government levels for highways, transit, and other modes. State departments of transportation (DOTs), transit agencies, and other government entities responsible for delivering transportation projects historically have experienced increases in project cost estimates from the time that a project is first proposed or programmed until the time that it is completed. Recent studies have shown that this has been a worldwide problem, particularly for large projects. Cost estimate increases that occur after a project is first identified in a plan but before the project is designed create a substantial disruption in priority programs, because other projects have to be delayed or removed in order to accommodate higher cost estimates. The challenges of accurate cost estimation and management of costs are faced by almost every state DOT, transit agency, and metropolitan planning organization (MPO) in the country as projects evolve from concept in the long-range planning process, are prioritized within programs, and are subject to detailed development prior to construction.

Cost estimates increasing over the course of project development may be caused by any number of factors, such as an inadequate project scope at the time of planning or programming, insufficient information on the extent of utility relocation requirements, insufficient knowledge of right-of-way costs and locations, required environmental mitigation costs to avoid certain impacts, traffic control requirements, and work-hour restrictions. As is often the case with very large and complex projects, the project scope and concept may not be fully understood until well after a substantial commitment has been made to its construction. In addition, the project scope often expands as more internal and external stakeholders provide input on what elements should be included. Sometimes, if the cost of an item is not known, it is not included in early project cost estimates. In other instances, items such as right-of-way or construction engineering may be included with only tentative or superficial information to support their estimated costs. Initial cost estimates may be prepared by an agency other than the agency responsible for project delivery; this can result in different understandings of project requirements and vastly different estimates. There is sometimes speculation that, to secure funding for projects, items may be purposefully excluded from initial project scopes and costs with the intention of adding them later. Questions about honesty or competence can threaten the credibility of the planning and programming process and that of the transportation agency and create increased frustration by professional staffs, policy makers, elected officials, and the general public.

Both the Federal Highway Administration and the Federal Transit Administration have initiated major efforts to overcome this problem in federally aided projects. In recent years, states, transit agencies, and local public works agencies have studied the problem and attempted to find causes and solutions to improve the procedures, with varying degrees of success. There is a need for research into all aspects of cost estimation management and cost estimation procedures aimed at addressing consistency and accuracy throughout the entire project development process, from long-range planning, through priority programming, up to preconstruction engineering and design.

The objective of this project was to develop a guidebook on highway cost estimation and management practice aimed at achieving greater consistency and accuracy between long-range transportation planning, priority programming, and preconstruction cost estimates. The guidebook provides strategies, methods, and tools to develop, track, and document more realistic cost estimates during each phase of the process.

Under NCHRP Project 8-49, "Guidance on Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction," a research team led by Texas Transportation Institute carried out a comprehensive investigation into current and effective practices for cost estimation and management during the various planning and project development phases prior to construction. The project resulted in a practical guidebook designed to provide users with the most appropriate practices to develop and manage realistic cost estimates throughout the project development process.

The guidebook should be of significant use to managers, practitioners, and decision makers interested in development and management of realistic and accurate cost estimates for transportation projects from the earliest stages of planning through final project design. The guidance provided is intended to provide methods and tools that will reduce unintended or unanticipated escalation of costs as transportation projects proceed through the development process.

CONTENTS

SUMMARY

Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction

State highway agencies face a major challenge in controlling project budgets over the time span between project initiation and the completion of construction. Project cost increases, as reflected by budget overruns during the course of project development, are caused by factors that have been identified through a large number of studies and research projects. These factors, the root causes behind estimation problems, differ with project development phase and project complexity. This Guidebook presents cost estimation management and cost estimation practice approaches to address the root causes of cost escalation and to support the development of consistent and accurate project estimates. These approaches are aligned with project development phases and project complexity. The Guidebook provides appropriate strategies, methods, and tools to develop, track, and document realistic cost estimates during each phase of project development.

A Strategic Approach

Agencies will have to do more than simply institute changes in estimation practices if they are to achieve consistent and accurate estimates. Project cost estimation management and cost estimation practice should be viewed as interdependent processes that span the entire project development process. An analysis of estimation literature and exhaustive data provided by state highway agencies led to the development of eight global strategies to address state highway agency estimation problems. These strategies focus on the critical causal factors behind project cost escalation and support the objective of consistent and accurate estimation:

- **Management strategy**—Manage the estimation process and costs through all stages of project development;
- **Scope and schedule strategy**—Formulate definitive processes for controlling project scope and schedule changes;
- **Off-prism strategy**—Use proactive methods for engaging external participants and assessing the macroenvironmental 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 strategy**—Apply appropriate delivery methods to better manage cost because 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 consistency and accuracy; and
- **Integrity strategy**—Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates.

In this Guidebook, these eight strategies are linked to over 30 recommended methods for implementing the strategies and to over 90 tools for executing specific methods.

Keys to Success

Disciplined cost estimation management and cost estimation practice should be applied in the context of the eight global strategies. This research has determined that 10 key principles—5 cost estimation management principles and 5 cost estimation practice principles—must be focused on to ensure creation of consistent and accurate estimates. Each individual principle by itself can help improve cost estimation management and cost estimation practice. However, maximum improvement of these two processes will only occur if the 10 key principles are incorporated into the agency's business practices throughout the organization. The key principles, in prioritized order, are as follows.

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 this estimate 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 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 that the estimate is accurate and fully reflects project scope.

Challenges

Implementing new concepts involves facing the challenges that accompany change. State highway agencies must consider several challenges when deploying this 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 processes 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 state highway agency practices is difficult when resources are scarce.
- **Dedicating sufficient human resources** to cost estimation practice and cost estimation management beyond the resources that have previously been allocated to estimation processes.

Meeting these challenges will ultimately require a commitment by the agency's senior management to direct and support change. The benefit of this commitment will be manifested in projects that are consistently within budget and on schedule and that fulfill their purpose as defined by their scope. This benefit will also improve program management by allowing for better allocation of funds to projects to meet the needs of the ultimate customer, the public.

CHAPTER 1

Introduction

Background

Project cost escalation is a major challenge for state highway agencies. 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, but for highly complex and technologically challenging projects the time span can easily exceed a decade. Over that period, numerous changes to the project scope and schedule will occur. Many factors that influence project costs are undefined during the early stages of project development, such as knowledge about right-of-way cost and alignment, environmental mitigation requirements, traffic control requirements, or work-hour restrictions. Moreover, there are process-related factors that can drive project cost increases, such as 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. All of these and other cost escalation factors create distinct challenges related to the development of project estimates and effective cost estimation management. These challenges are

- Difficulty in describing scope solutions for all issues early in project development,
- Difficulty in evaluating the quality and completeness of early cost estimates,
- 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.

Industry Problem

Managing large capital construction projects requires the coordination of a multitude of human, organizational, and technical resources. Quite often, the engineering and construction complexities of such projects are overshadowed by economic, societal, and political challenges. Within the transportation community, project cost escalation has attracted management, political, and stakeholder attention at federal, state, regional, and local levels. News reports of project cost escalation cause the public to lose confidence in the ability of transportation agencies to effectively perform their responsibilities. Additionally, state highway agency management must deal with the disruption that project cost increases cause in priority programs (the disruption occurs when other projects have to be delayed or removed in order to accommodate higher project costs).

As projects move from concept to construction, cost escalation is faced by every state highway agency, transit agency, and metropolitan planning organization (MPO) in the country. Although project cost escalation is usually caused by lack of project scope control and factors external to the state highway agency, it results in cost estimation practice and cost estimation management approaches that do not promote consistency and accuracy of cost estimates across the project development process.

Guidebook Concepts

This Guidebook presents a strategic approach for achieving accurate project cost estimates based on strategies, methods, and tools for project cost estimation practice and cost estimation management that are linked to (1) planning and the project development process and (2) project complexity.

A strategy is a plan of action intended on accomplishing a specific goal. Strategies typically address a specific problem and are formulated to address a problem's root cause. For example, a strategy might be risk. The risk strategy for controlling cost seeks to identify risks, quantify the impact of a risk on cost, and take actions to mitigate that impact. This strategy would likely address a root cause of cost escalation such as scope changes caused by external and internal stakeholders providing input during project development.

The strategy is implemented through a method. A method is a means or manner of procedure, especially a regular and systematic way of accomplishing something. The method must support the strategy. A method for the described risk strategy might be a formal or structured risk analysis. This method is typically applied when preparing early project estimates, as the scope is being defined and detailed. One purpose of this method is to narrow the range of scope uncertainty.

A method is then implemented using a tool. A tool is something used in the performance of an operation. In this case, the operation is the method. A newly used tool for the risk analysis method is estimation ranges. At the core of this tool are risk identification, risk assessment, and the communication of uncertainty. This tool makes use of probabilities and simulation to produce a probabilistic range of project costs rather than a single-point estimate.

Project estimates are made at various points in time during project development for a variety of reasons. An estimation method and tool must fit the information available at the time the estimate is developed. Thus, certain types of estimates apply to specific project development phases. For example, the risk analysis method is used when project-specific estimates are prepared during the early phases of project development.

State highway agencies deal with a variety of project types; thus, the Guidebook considers strategies, methods, and tools in terms of their application to small or straightforward projects, rehabilitation projects, major reconstruction projects, major new construction projects, and special situations such as when a state highway agency uses an innovative contracting method and does not prepare a complete set of plans and specifications. Project complexity is also important because it may determine when, and to what extent, a specific method and tool should be used. As an example, the risk analysis method is typically used to expose areas associated with large, complex projects that have significant uncertainties associated with construction methods.

The hierarchical decomposition of strategies, methods, and tools is illustrated in Figure 1.1. Methods are used to implement strategies. As shown, more than one method may be used to implement a particular strategy. One or more tools can be used to implement a method. The use of specific strategies,

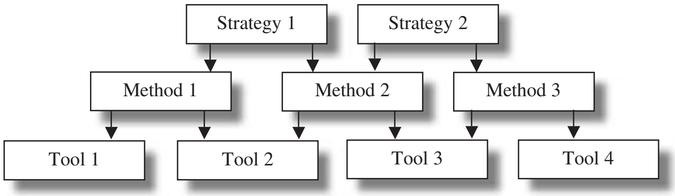


Figure 1.1. Strategy, method, and tool hierarchy.

methods, and tools changes with project development phases and different levels of project complexity.

Guidebook Development

This Guidebook was developed under NCHRP Project 8-49, "Procedures for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction." Approaches for addressing the transportation community problem of accurately estimating and managing project cost are proposed based on this research.

The research was conducted in two phases. The first phase focused on a state-of-practice review of cost estimation practice and cost estimation management processes. The current state of estimation practice was characterized by an extensive review of the literature supported by interviews of transportation agencies. Major factors causing project cost escalation were identified during this first phase of the research. Over 23 state highway agencies provided input on the practices they use during different project development phases. A critical review of these practices formed the basis for identifying viable and successful approaches to cost estimation practice and cost estimation management. Based on this literature and interview work, eight strategies were identified to address the root causes of project cost escalation. These eight strategies were then linked to over 30 implementation methods. From the discussion with state highway agencies, over 90 tool applications were identified to support the 30 methods. These strategies, methods, and tools align with planning, programming, and preconstruction. This strategic approach, including the methods and tools, was reviewed and approved by the NCHRP 8-49 panel.

Based on the state-of-practice data from the state highway agencies, the second phase of the research developed this Guidebook. The Guidebook, with a focus on addressing cost escalation through the use of strategies, methods, and tools, was prepared in draft form. It was then critically reviewed by 10 state highway agencies. These state highway agencies provided a critique of the Guidebook's content, structure, layout, and user friendliness. The NCHRP 8-49 panel reviewed and commented on this final version of this Guidebook.

Guidebook Organization

The Guidebook has nine chapters, including the introduction. The background information and fundamental concepts concerning the content of the Guidebook are developed in Chapters 2, 3, and 4. Chapter 2, "Agency Cost Estimation Practice and Cost Estimation Management Processes," demonstrates how cost estimation practice and cost estimation management are linked to planning and the project development process. The key information exchanged between different development phases is presented in a flow chart format.

This flow chart is critical to understanding that achievement of accurate estimates requires a systematic approach. Further, the purposes of cost estimates prepared during different project phases are also discussed because estimates at specific points in planning and project development are critical to making sound financial decisions. Chapter 3, "Factors and Strategies," identifies and categorizes 18 cost escalation factors that have been found to repeatedly cause cost overruns on state highway agency projects. Eight strategies are then introduced that address these cost escalation factors. If these strategies are systematically implemented as suggested in the Guidebook, state highway agencies will reduce project-specific cost increases and subsequent increases in capital program budgets. Chapter 4, "Guidebook Framework," presents a consistent approach used to describe the strategies, methods, and tools as applied during planning and the project development process.

Chapters 5, 6, and 7—"Guide for Planning Phase," "Guide for Programming and Preliminary Design Phase," and "Guide for Final Design Phase," respectively, focus on the application of the fundamental concepts presented in Chapters 2, 3, and 4. These chapters provide guidance on cost estimation practice and cost estimation management process implementation during each phase. Guidance is provided with a specific focus on the dominant cost escalation factors that most often occur during a specific project phase and the strategies that are effective in addressing these cost escalation factors. Specific methods employed to implement strategies are identified in terms of key information relevant to applying the method. Tools are linked to methods and strategies through an extensive appendix—Appendix A—which provides support for implementation of the methods described in Chapters 5, 6, and 7. Appendix A provides information concerning tools, including examples and illustrations of all tools.

New concepts and innovative ideas require a planned approach to facilitate their implementation into practice. Chapter 8, "Implementation," covers key implementation thrust areas and steps in the implementation process that must be considered when introducing changes to current cost estimation practice and cost estimation management within a transportation agency. Finally, Chapter 9 summarizes the main features of the Guidebook and the challenges users may encounter when striving to improve agency cost estimation practice and cost estimation management. This chapter also provides 10 key principles that will lead to successful application of the strategies, methods, and tools presented in this Guidebook.

Use of Guidebook

The intent of the Guidebook is to provide transportation agencies with guidance on preparing realistic estimates and managing project cost. The material contained in the following chapters does not provide "how to" procedures with specific details on cost estimation practice or cost estimation management. However, the Guidebook does provide the necessary knowledge and information for state highway agencies to create "how to" approaches that fit within their own agency processes and culture.

The Guidebook is designed to provide information to various users in a number of ways. Guidebook information is categorized as having an implementation thrust or topic focus. Several examples are provided. The user is encouraged to use a strategic approach, but there are other ways to use the methods and tools presented in the Guidebook.

Implementation Thrust

Organization Level

If cost escalation is a significant problem for an agency, changes in agency policy that influence how cost estimation practice and cost estimation management is performed may be necessary to improve the processes and provide more consistent and accurate estimates throughout project development. If this is the case, executive managers should review Chapters 2, 3, and 4 of the Guidebook. These chapters provide a basic structure and approach for developing agencywide policies that will lead to improved cost estimation practice and cost estimation management processes. Chapter 8 will provide assistance in implementing changes related to cost estimation practice and cost estimation management from an agencywide perspective.

Program Level

Program-level managers are often charged with implementing policy changes. If policy changes in cost estimation practice and cost estimation management are necessary, then these managers should read Chapter 2; Chapter 3; Chapter 4; the relevant Chapter 5, 6, and/or 7; and Chapter 8 on implementation issues. For example, planning directors can focus on Chapter 5, "Guide for Planning Phase," while managers of engineering and environmental programs can focus on Chapter 6, "Guide for Programming and Preliminary Design Phase."

Project Level

Project-level managers, engineers, and discipline leaders (the chiefs of sections such as design, right-of-way, and/or estimation) who are directly responsible for cost estimation practice and cost estimation management processes should read Chapter 3; Chapter 4; the relevant Chapters 5, 6, and/or 7; and Appendix A according to their area of expertise. Those leaders directly involved in estimation should read the same chapters and Appendix A. If the estimator has a specific area of expertise—such as plans, specifications, and estimates

(PS&E)—then Chapter 7, "Guide for Final Design Phase," should be studied in detail, including the relevant tools in Appendix A.

Topic Focus

Cost Escalation Problem

If the user has a specific cost escalation problem to solve, the user should read Chapter 3. The user should determine which cost escalation factor is most closely aligned with the problem and then select a strategy or strategies that address the problem. Based on the development phase of interest, the user can determine methods to implement specific strategies covered in Chapters 5, 6, and/or 7.

Estimation Tools

If the user is interested in finding a specific type of tool, the user should review the list of tools at the beginning of Appendix A. After finding a tool of interest, the user should study the description of the tool under the method that is relevant to the tool. If the user wants to determine where the tool is used, the user can locate the method and tool in the summary section of Chapters 5, 6, and 7.

Summary

Cost escalation, or estimate increases, over the course of project development constitute the major problem that is addressed by this Guidebook. As projects evolve from concept to detailed development prior to construction, this problem is faced by every state highway agency, transit agency, and MPO in the country. Estimation strategies, methods, and tools provide a structured approach for addressing the project cost escalation problem. This Guidebook was developed as part of NCHRP Project 8-49, "Procedures for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction."

CHAPTER 2

Agency Cost Estimation Practice and Cost Estimation Management Processes

To successfully address transportation needs and deficiencies, state highway agencies must have reliable cost estimation practice and cost estimation management processes that support the spectrum of costing from early conceptual alternatives through to definitive project PS&E. This Guidebook focuses on the cost estimation practice and cost estimation management processes required to achieve this result. This chapter frames these two processes by estimate type and purpose in broadly defined phases common to how state highway agencies develop solutions to transportation needs. The approach is from an agency-level viewpoint. Additional, more specific materials relevant to cost estimation practice and cost estimation management will be covered in Chapters 5, 6, and 7.

Transportation Development Phases

Cost estimates are made at various times during the development of solutions to identified transportation needs and deficiencies. These estimates support funding and program decisions. The estimation approach that is used at these various times must conform to the information available when the estimate is prepared. For example, when only concept information is available, then conceptual estimation practice methods are used to determine planning-level cost projections. Cost estimation management is practiced as projects are identified and developed. Cost estimation management methods will also vary depending on the level of project scope definition and cost details provided in the estimates.

An understanding of the phased progression to developing a solution for a transportation need is critical to the strategies, methods, and tools that can be used for cost estimation practice and cost estimation management. The terms used to describe the development phases can vary slightly, or even significantly, from agency to agency. Therefore, the development phases and their descriptions in this Guidebook, as presented in Table 2.1, were adapted from *NCHRP Synthesis of Highway Practice 331: Statewide Highway Letting Program Management* (Anderson and Blaschke, 2004). The planning, programming and preliminary design, and final design phases are discussed throughout this Guidebook. The Guidebook does not cover the advertise-and-bid and construction phases. The planning, programming and preliminary design, and final design phases are depicted as overlapping in Figure 2.1. This overlapping indicates the cyclical nature of these four phases, as transportation needs are identified and developed into projects that move to construction.

Cost Estimation Practice and Cost Estimation Management Overview

Figure 2.2 provides a summary flowchart representing an agencywide view of cost estimation practice and cost estimation management. As shown in Figure 2.2, there is a relationship between the cost estimation practice and cost estimation management processes. There is also a relationship between cost estimation practice and cost estimation management and the phases followed in addressing transportation needs. These two sets of relationships are portrayed by key information flows. Further, Figure 2.2 shows typical estimate types and key purposes of the cost estimates as related to each development phase.

Cost estimates are prepared to support funding decisions as planning documents, program documents, and specific projects are developed. Cost estimation management is performed to support the work of preparing estimates and to ensure that program funding levels are in line with planned funding levels and project budgets. When cost estimation practice and cost estimation management processes are integrated, the transportation agency should have the capability to effectively manage its overall capital program as well as individual project budgets.

As shown in Figure 2.2, the development phases are generally categorized into "planning" and "project development process." The planning phase has a longer time horizon and includes both plans that do not identify projects and plans that

Table 2.1. Development phases and activities.

Development Phase	Typical Activities
Planning	Determine purpose and need, determine whether it's an improvement or requirement study, consider environmental factors, facilitate public involvement/participation, and consider interagency conditions.
Programming and Preliminary Design	Conduct environmental analysis, conduct schematic development, hold public hearings, determine right-of-way impact, determine project economic feasibility, obtain funding authorization, develop right-of-way, obtain environmental clearance, determine design criteria and parameters, survey utility locations and drainage, make preliminary plans such as alternative selections, assign geometry, and create bridge layouts.
Final Design	Acquire right-of-way; develop plans, specifications, and estimates (PS&E); and finalize pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, and cost estimates.
Advertise and Bid	Prepare contract documents, advertise for bid, hold a pre-bid conference, and receive and analyze bids.
Construction	Determine the lowest responsive bidder; initiate contract; mobilize; conduct inspection and materials testing; administer contract; control traffic; and construct bridge, pavement, and drainage.

identify projects. In this Guidebook, the project development process begins with the programming phase, in which specific projects are developed and prioritized for inclusion in shorter-range capital programs based on target letting dates for construction.

The purpose of planning for both statewide areas and metropolitan areas is to identify the set of the most cost-effective projects and approaches that achieves the stated goals of the planning process. Federal law requires that state highway agencies develop a statewide transportation plan (STP) and that MPOs develop a regional transportation plan (RTP). The horizon year for these long-range plans is usually 25 years into the future. While some states do identify major projects, or even unique minor projects, most STPs do not identify specific projects, but rather establish strategic directions for state investment in its transportation system. The RTP is very different from the STP. The RTP identifies specific projects that are to be implemented over the next 25 years, usually defined in short-, medium-, and long-term implementation stages. Federal law also requires that the statewide and metropolitan plans be consistent and that plan development include the participation of both groups, along with many other stakeholders. A long-range plan is considered to be the output of the planning phase for purposes of this Guidebook.

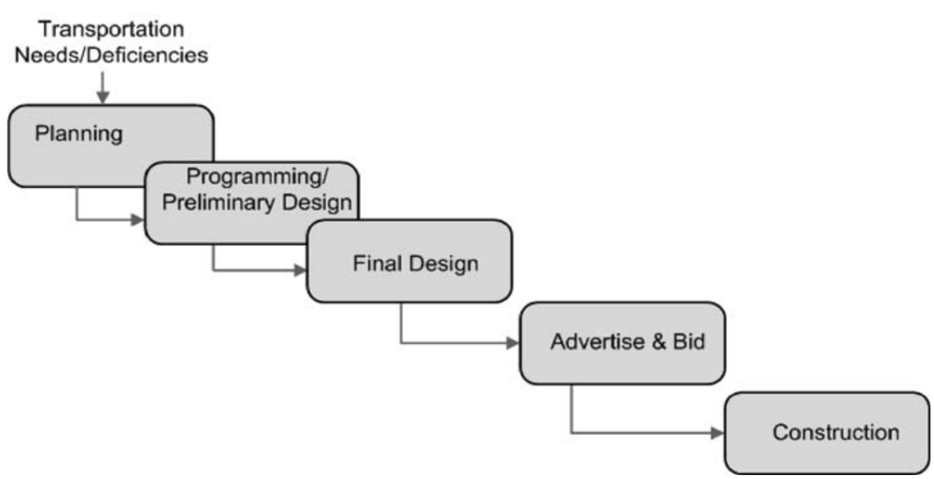
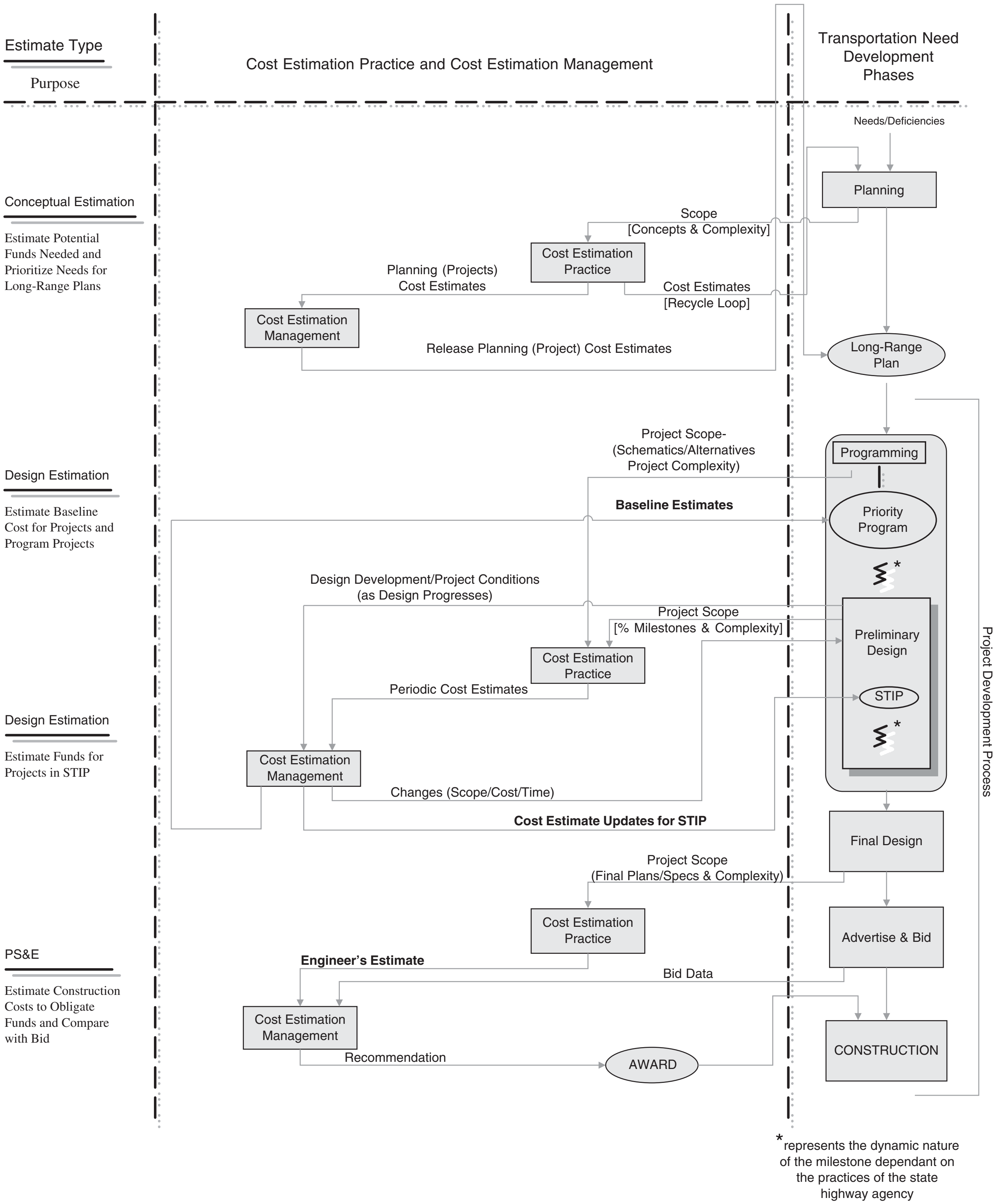


Figure 2.1. Typical transportation need development phases for highway projects.



PS&E = plans, specifications, and estimates
STIP = statewide transportation improvement plan

Figure 2.2. Agency-level flow chart for cost estimation practice and cost estimation management.

As depicted in Figure 2.2, cost estimates that are prepared to support these long-range plans have, as their fundamental purpose, to provide a gross estimate of the funds needed over the 25-year planning horizon. These cost estimates are also often used in benefit-cost analysis for prioritizing dollars in long-range plans. Planning-phase cost estimates are most often developed using the conceptual estimation method with a cost-per-mile tool. During the planning phase, cost estimation management is focused primarily on updating planning dollar amounts and determining how these dollars are communicated to the public.

The programming and preliminary design phase starts the project development process, as shown in Figure 2.2. In programming, federal law requires the transportation improvement program (TIP) for a metropolitan area to become part of the state's transportation improvement program (STIP). It is thus very common for state highway agencies and MPOs to work closely on identifying the likely costs associated with candidate projects. Project cost estimates can have a significant affect on the overall transportation program and, thus, on the ability of states and metropolitan areas to meet their transportation needs. Thus, estimates prepared during programming are critical in terms of setting a baseline cost, schedule, and scope for managing project development.

The baseline cost sets the budget used to develop a 5- to 10-year authorized priority program, as shown in Figure 2.2. Authorization allows for preliminary design to begin, and it typically includes a target date for a construction letting. The first 3 to 5 years of the priority program form the basis for the STIP. When preliminary design falls within this minimum 3-year period and federal funds are used, the preliminary design cost is included in the STIP. Right-of-way and construction costs will be added to the STIP later, as the STIP is updated regularly. In some cases, if the project needs to be let for construction within 3 years, the entire project cost covering preliminary design, right-of-way, and construction will be included in the STIP. Once preliminary design begins, this baseline cost estimate becomes the basis for cost estimation management.

Preliminary design develops the project scope at ever increasing levels of detail, as shown in Figure 2.2 (e.g., the percentage milestones such as 15%, 30%, and 60%). At various times during preliminary design, project cost estimates are prepared to ensure that scope changes have not increased cost above the baseline and for management control of the budget. During preliminary design, design estimation approaches are based on both conceptual estimation and design estimation methods. When the project is within 3 to 4 years of the construction letting, an updated cost estimate is prepared so that current construction costs are reflected in the STIP. This estimation is critical because the STIP is fiscally constrained, and costs for each project in the STIP must be closely monitored.

Cost estimation management is an important activity during preliminary design. Periodic estimation updates should be constantly compared with the project baseline estimate included in the authorized priority program. Further, to effectively manage overall project cost, changes in scope, in design development, and in project site or market conditions must be evaluated in relation to cost and time impact. Cost estimation management is a process for evaluating changes in scope or other issues that affect project cost.

The final design phase typically represents that point in the project development process when plans and specifications are nearing completion. Prior to final approval of the project design, PS&E is initiated, and the engineer's estimate is prepared, as shown in Figure 2.2. The basic purpose of this estimate is to provide cost data for comparing bid prices with estimated costs. The estimate provides management with a reference for determining whether a project should be awarded for construction and whether, if a project is awarded, to obligate funds for construction. The engineer's estimate is a detailed line-item estimate of project costs based on a schedule of work items and their corresponding quantities. The line items that make up this estimate are the same as those in the contract documents that serve as the basis for bidding the project. Cost estimation management at this phase focuses on comparing the engineer's estimate with the current STIP estimate and the contractor's bid.

Cost Estimation Practice and Cost Estimation Management Steps

Cost estimation practice and cost estimation management processes can be described in terms of a number of steps. For purposes of this Guidebook, a small number of steps are identified for each of these two processes. Methods and tools associated with these steps are elaborated in later chapters.

Cost estimation practice is described in terms of four basic steps. The four steps and a brief description of each step are provided in Table 2.2. The descriptions are general and, therefore, applicable to the estimation process across each development phase.

While the steps and their descriptions in Table 2.2 could be shown in greater detail, the four steps are sufficient to provide guidance on cost estimation. The four steps must be implemented in each of the development phases. However, the manner in which these steps are performed varies depending on the development phase. These variations are reflected in the methods and tools that are implemented during each project phase. The performance of each step is supported by historical databases; input from different project disciplines (e.g., planners, roadway, structures, right-of-way, real estate services, utilities, environment, and construction); and input from third parties, such as MPOs, environmental agencies, local agencies, and the

Table 2.2. Cost estimation process.

Cost Estimation Step	Description
Determine estimate basis	Document project type and scope, including • scope documents; • drawings that are available (defining percent engineering and design completion); • project design parameters; • project complexity; • unique project location characteristics; and • disciplines required to prepare the cost estimate.
Prepare base estimate	Prepare estimate, including • documentation of estimate assumptions, types of cost data, and adjustments to cost data; • application of appropriate estimation techniques, parameters, and cost data consistent with level of scope definition; • coverage of all known project elements; • coverage of all known project conditions; and • checking of key ratios to ensure that estimates are consistent with past experience.
Determine risk and set contingency	Identify and quantify areas of uncertainty related to • project knowns and unknowns, • potential risks associated with these uncertainties, and • appropriate level of contingency congruent with project risks.
Review total estimate	Review estimate basis and assumptions, including • methods used to develop estimate parameters (e.g., quantities) and associated costs; • completeness of estimate relative to the project scope; • application of cost data, including project-specific adjustments; • reconciliation of current estimates with the baseline estimate (explain differences); and • preparation of an estimation file that compiles information and data used to prepare the project estimate.

public. The types of information provided through databases and diverse entities also vary depending on the phase.

Cost estimation management is described by a number of steps. Five steps and a general description of each step are provided in Table 2.3. Again, the descriptions are general and, therefore, applicable to the cost estimation management process across each development phase. Implementation of these steps varies by phase.

Similar to the cost estimation practice steps, the cost estimation management steps and their descriptions could be shown in greater detail, but five steps are sufficient to provide guidance on cost estimation management. The required number of steps performed in each phase varies. The manner in which the steps are performed also varies depending on the development phase. These variations are reflected in the strategies, methods, and tools that are implemented during each phase.

Specific graphic depictions of the cost estimation practice and cost estimation management processes are presented and discussed in the introductory sections of the chapters that specifically discuss each phase: Chapter 5, "Guide for Planning Phase"; Chapter 6, "Guide for Programming and Preliminary Design Phase"; and Chapter 7, "Guide for Final Design Phase."

Summary

Cost estimates are created at various times during project development. There is a relationship and interaction between these phases and the cost estimation practice and cost estimation management processes. During the planning phase, cost projections are developed most often using the conceptual estimation method. Design estimation methods include parametric estimation as well as line-item estimation. Detailed estimates are developed based on the final design. The appropriate estimation approach will vary with the project's scope definition, design development, and complexity. Chapter 3 identifies cost escalation factors and the strategies that a state highway agency can implement in the context of its cost estimation and cost estimation management processes to overcome project cost escalation.

Table 2.3. Cost estimation management process.

Cost Estimation Management Step	Description
Obtain appropriate approvals	Obtain management authorization to proceed by • review of current project scope and estimate basis; • securing of approvals from appropriate management levels; • approval of current estimates, including any changes from previous estimates; and • release of estimate for its intended purpose and use.
Determine estimate communication approach	Communication approach is dependent upon the stakeholder who is receiving the information, but should consider • mechanism for communicating the cost estimate for its intended purpose, • level of uncertainty to be communicated in the estimate given the information upon which it is based, and • mechanism to communicate estimate to external parties.
Monitor project scope and project conditions	Identify any potential deviation from the existing estimate basis, including • changes in project scope; • changes due to design development; • changes due to external conditions; • the nature and description of the potential deviation; and • whether the deviation impacts the project budget and/or schedule (potential increase or decrease).
Evaluate potential impact of change	Assess potential impact of change, including • cost and time impact of the deviation and • recommendation as to whether to modify the project scope, budget, and/or schedule due to change.
Adjust cost estimate	Document changes to the baseline estimate, including • appropriate approval of the deviation; • the new project scope, new budget, and/or new schedule; and • notification of the change to project personnel.

CHAPTER 3

Factors and Strategies

Before the strategies, methods, and tools are developed to address cost escalation problems, the causal factors that influence and create changes in cost estimates must be delineated and explained. This chapter first identifies the causal factors and then presents the strategies to address specific problem areas.

Cost Escalation Factors

The factors that lead to project cost escalation have been identified through a large number of studies and research projects. These factors can be distilled into 18 fundamental cost escalation factors, as depicted in Table 3.1. Each cost escalation factor describes a reason behind changes in cost estimations. These factors can be managed throughout the project development process either through cost estimation practice or cost estimation management methods and tools.

Internal Cost Escalation Factors

Bias is a systematic tendency to be overly optimistic about key project parameters. It is often viewed as the purposeful underestimation of project costs to ensure that a project remains in the construction program. This underestimation of costs can arise from the state highway agency estimators' or consultant's identification with the agency's goals for maintaining a construction program. The project development 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 state highway agencies feel the pressure to estimate with an optimistic attitude about cost. (Akinci and Fischer, 1998; Condon and Harman, 2004; Bruzelius et al., 2002; Flyvbjerg et al., 2002; Hufschmidt and Gerin, 1970; Pickrell, 1990; Pickrell, 1992)

Delivery and procurement approach affects the division of risk between the state highway agency and the constructors. When risk is shifted to a party that is unable to control it, project cost will likely increase. The decision regarding which project delivery approach (e.g., design-bid-build, design-build, or build-operate-transfer) and procurement methodology (e.g., low bid, best value, or qualifications-based selection) affects 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. (Harbuck, 2004; New Jersey DOT, 1999; Parsons Brinckerhoff Quade & Douglas, Inc., 2002; SAIC, 2002; Weiss, 2000)

Project schedule changes, particularly extensions, caused by budget constraints, timing of fund allocations, environmental impacts, or design challenges can result in unanticipated increases in project overhead and/or inflation. Additional project overhead costs can be incurred by both the state highway agency and the consultants, designers, and contractors. Project schedule changes can be viewed in terms of the time value of money. There are two primary components to the issue: (1) the inflation rate and (2) the timing of the expenditures. Many state highway agencies have a fixed annual or bi-annual budget, and project schedules must often be adjusted to ensure that project funding is available as needed for all projects. Estimators frequently do not know what expenditure timing adjustments will be made by management or caused by external circumstances. (Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Hufschmidt and Gerin, 1970; U.S. General Accounting Office, 1999a; Semple et al., 1994; Touran and Bolster, 1994)

Engineering and construction complexities caused by the project's location or purpose can make early design work very challenging and lead to internal coordination errors between project components. Internal coordination errors can include conflicts or problems between the various disciplines involved in the planning and design of a project. Constructability problems that need to be addressed may also be encountered as the project develops. If these issues are not addressed, cost

Table 3.1. Factors causing cost escalation of projects*.

Source	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 Estimation
	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.

increases are likely to occur. (Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Hufschmidt and Gerin, 1970; U.S. General Accounting Office, 1999a; Touran and Bolster, 1994; U.S. General Accounting Office, 2003; U.S. General Accounting Office, 1997; U.S. General Accounting Office, 2002)

Scope changes, which should be controllable by the state highway agency, but which still happen, can lead to project cost escalation. Such changes may include additions to or deletions from the project scope. Examples of this phenomenon are the addition of a lane to the project scope or increasing the project right-of-way. (Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Chang, 2002; Harbuck, 2004; Hufschmidt and Gerin, 1970; Mackie and Preston, 1998; U.S. General Accounting Office, 1999a; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Semple et al., 1994; Touran and Bolster, 1994)

Scope creep is the tendency for the accumulation of many minor scope changes to increase project cost. While individual scope changes have only minimal cost effects, the accumulation of these minor changes, which are often not essential to the intended function of the facility, can result in a significant cost increase over time. 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 environmental compliance in the area being served. (Akinci and Fischer, 1998; Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Chang 2002, Harbuck, 2004; Hufschmidt and Gerin, 1970; Mackie and Preston, 1998; U.S. General Accounting Office, 1999a; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Semple et al., 1994; Touran and Bolster, 1994)

Poor estimation can also lead to underestimation, which subsequently translates into increases in project cost as errors and omissions are exposed. 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 relating to plan details and project 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 et al., 1985; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Carr, 1989; Chang, 2002; Harbuck, 2004; Hufschmidt and Gerin, 1970; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Pickrell, 1990; Pickrell, 1992)

Inconsistent application of contingencies causes confusion as to exactly what is included in the line items of an estimate and what is covered by contingency amounts. Contingency funds are typically meant to cover a variety of *possible* events and problems that are not specifically identified or to account for a lack of project definition during the preparation of 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 is lack of design definition. State highway agencies run into problems when the contingency amounts are applied inappropriately. During project execution, contingency funds are often inappropriately used to cover project overruns, instead of being applied to and available for their intended purpose. (Noor and Tichacek, 2004; Ripley, 2004; AACE International, 1997)

Faulty execution by the state highway agency in managing a project is one factor that can lead to project cost overruns. This factor can include the inability of the state highway agency's representatives to make timely decisions or actions, to provide information relative to the project, and to appreciate design and construction difficulties caused by coordination of connecting work or work responsibilities. (Committee for Review, 2003; Callahan, 1998; Chang, 2002; Merrow et al., 1981; Merrow, 1986; Touran and Bolster, 1994)

Ambiguous contract provisions dilute responsibility and cause misunderstanding between the state highway agency and other contractual parties, including design consultants and/or project constructors. Providing too little information in the project documents can lead to cost overruns during the execution of the contract. When the core assumptions underlying an estimation are confused by ambiguous contract provisions, forecast accuracy cannot be achieved. (Callahan, 1998; Chang, 2002; State of Alaska, 1994; Harbuck, 2004; Mackie and Preston, 1998; MassHighway and ACEC, 1998; Tilley et al., 1997; Touran and Bolster, 1994)

Contract document conflicts lead to errors and confusion when preparing an estimate and cause change orders and rework during project construction. (Callahan, 1998; Chang, 2002; State of Alaska, 1994; Harbuck, 2004; Mackie and Preston, 1998; MassHighway and ACEC, 1998; Tilley et al., 1997; Touran and Bolster, 1994)

External Cost Escalation Factors

Local concerns and requirements typically result in mitigation efforts to minimize project effects and negotiated scope changes or additions. Actions by the state highway agency are often required to alleviate perceived negative impacts of construction on the local societal environment, as well as on the natural environment. Local government concerns and requirements can affect the project costs during any project development phase, especially as legislatures seek to add specific scope to a project. 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, thereby affecting inflation allowances, and can add direct cost. By not anticipating these changes, state highway agencies can be plagued by project cost increases. (Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Chang, 2002; Daniels, 1998; Hall, 1980; Harbuck, 2004; Hudachko, 2004; Utah Department of Transportation, 2004; Mackie and Preston, 1998; U.S. General Accounting Office, 1999a; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Parsons Brinckerhoff, 2002; Pearl, 1994; Sawyer, 1951–52; Schroeder, 2000; Maryland DOT, 2002; Touran and Bolster, 1994; Woodrow Wilson Bridge, 2002)

Effects of inflation add cost to a project. The time value of money can adversely affect projects when (1) the 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. (Akinci and Fischer, 1998; Arditi et al., 1985; Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Hufschmidt and Gerin, 1970; Merrow, 1988; Pickrell, 1990; Pickrell, 1992; Touran and Bolster, 1994)

Scope changes, which are not controllable by the state highway agency, can lead to underestimation of project cost escalation, similar to internal scope changes. (Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Chang, 2002; Harbuck, 2004; Hufschmidt and Gerin, 1970; Mackie and Preston, 1998; U.S. General Accounting Office, 1999a; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Semple et al., 1994; Touran and Bolster, 1994)

Scope creep from external causes is similar to scope creep from internal causes; however, the former category is usually the accumulation of minor scope changes from external participants. (Akinci and Fischer, 1998; Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Chang, 2002; Harbuck, 2004; Hufschmidt and Gerin, 1970; Mackie and Preston, 1998; U.S. General Accounting Office, 1999a; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Semple et al., 1994; Touran and Bolster, 1994)

Market conditions or changes in the macroenvironment can affect the costs of a project, particularly large projects. The size of the project affects competition for a project and the number of bids that a state highway agency receives for the work. Inaccurate assessment of the market conditions can lead to incorrect project cost estimation. Changing market conditions during the development of a project can reduce the number of bidders, affect the available labor force, or result in increased commodity prices, all of which can disrupt the project schedule and budget. (Committee for Review, 2003; Booz Allen & Hamilton, Inc., and DRI/McGraw-Hill, 1995; Callahan, 1998; Chang, 2002; Hall, 1980; Mackie and Preston, 1998; U.S. General Accounting Office, 1999a; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Pearl, 1994; Sawyer, 1951–52; Maryland DOT, 2002; Touran and Bolster, 1994; Woodrow Wilson Bridge, 2002)

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

Unforeseen conditions are notorious for causing project cost overruns. Unknown soil conditions can effect excavation, compaction, and structure foundations. Contaminated soils may be present, thereby resulting in the need for special mitigation work. Utilities are often present that are not described or are described incorrectly on existing drawings. There are a multitude of problems that are simply unknown during the early project phases and that can increase project cost when they become apparent during construction. (Akinci and

Fischer, 1998; Arditi et al., 1985; Callahan, 1998; Harbuck, 2004; Hufschmidt and Gerin, 1970; Merrow et al., 1981; Merrow, 1986; Merrow, 1988; Semple et al., 1994; Touran and Bolster, 1994; U.S. General Accounting Office, 1999)

Strategies

The methodology used to develop the potential list of strategies, methods, and tools focuses on the causes of cost escalation and potential strategies that would address these causes. This linkage between the causes of cost escalation and strategies was found in the estimation literature, in an assessment of current practice, and in a review of deficiencies found in unique practice approaches. From the literature concerning project cost estimation and from interviews with people in the industry, it is clear that there exist eight overarching or global strategies that can affect the accuracy and consistency of project estimates and costs.

As mentioned previously, a strategy is "a plan of action intended on accomplishing a specific goal." This definition is used as the basis for developing short statements about each strategy as follows:

- **Management strategy**—Manage the estimation process and costs through all stages of project development;
- **Scope and schedule strategy**—Formulate definitive processes for controlling project scope and schedule changes;
- **Off-prism strategy**—Use proactive methods for engaging external participants and assessing the macroenvironmental 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 strategy**—Apply appropriate delivery methods to better manage cost because 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 consistency and accuracy; and
- **Integrity strategy**—Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates.

Management Strategy

Manage the estimation process and costs through all stages of project development. State highway agency leadership can advance an estimation management strategy that fosters and supports estimate accuracy and consistency through all phases of project development. The highest levels of state highway agency leadership have the responsibility to publicly explain how the project development processes works and most importantly to ensure that cost estimation practice and cost estimation management processes are transparent. To produce accurate estimates, state highway agency personnel must be properly trained, there must be established estimation processes, and there must be critical reviews of all estimates. Currently, 40 state highway agencies use only on-the-job training to train their estimators. Twenty-six state highway agencies have no published standard estimation procedures. (Schexnayder et al., 2003) Senior management must take an active role in advancing strategies to increase estimator knowledge and estimate consistency.

Scope and Schedule Strategy

Formulate definitive processes for controlling project scope and schedule changes. Scope control ensures that project changes are identified, evaluated, coordinated, controlled, reviewed, approved, and documented. Scope control requires that the proposed scope of a project be continually evaluated against the essential functions necessary to accomplish its intended purpose. 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, cost impacts will result from increases in land costs and inflation effects. The cost effect of a change depends on the point in time when it is introduced. Early in project development, before estimations are prepared, a change in scope does not cause significant problems. Scope changes during the later stages of engineering design and construction have ripple effects and can increase project cost exponentially.

Off-Prism Strategy

Use proactive methods for engaging external participants and assessing the macroenvironmental 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 and often fail to recognize market and macroeconomic changes. These cost drivers are termed "off-prism" items in the literature because they are not within the roadway prism. The lack of focus on such external issues has been changing as some state highway agencies are experimenting with context-sensitive design and construction. (Neuman et al., 2002; Werkmeister and Hancher, 2001) However, technical alternatives are frequently discussed at early stages of project development before community outreach efforts are undertaken, and concerns related to the external effects are not addressed until later in the development cycle. "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., 2002) Additionally, how environmental compliance and the acquisition of right-of-way impacts the public is a consideration when addressing off-prism issues. Finally, few state highway agencies ever evaluate the impact of macroeconomic market forces on project cost.

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 probable range of estimated 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 state highway agency project estimations, 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 must consider probabilities in assessing uncertainties and related risks and translate these risks into costs.

Delivery and Procurement Strategy

Apply appropriate delivery methods to better manage cost because 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; determination of project size; determination of 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 features critical to a successful construction process.

Document Quality Strategy

Promote cost estimate accuracy and consistency through improved project documents. All documents used to prepare estimates, at any point during project development, must be clear and convey the intent of the project's scope. In particular, contract documents must be clear and unambiguous as to what must be constructed and what is standard. The documents must clearly state the responsibilities of all parties—consultants, contractors, the state highway agency, and third parties. It is critical that all parties involved understand third-party involvement in the project construction process.

Estimate Quality Strategy

Use qualified personnel and uniform approaches to achieve improved estimate consistency and accuracy. It appears that the estimation practices of many state highway agencies are based solely on the experience of the personnel in charge of estimation, usually the head of the estimation section or the chief of design. State highway agencies must approach estimation development in the same manner as design and construction—with documented processes to guide cost estimation practice and cost estimation management throughout project development. Specifically, structured approaches to quality control (e.g., internal estimate reviews) and quality assurance (e.g., external estimate reviews) are also essential.

Integrity Strategy

Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates. The potential for conceptual (e.g., parametric) or even design estimation error can result from pressure by project sponsors who seek the approval of their projects. (Cost/Schedule Controls Task Force, 1986) In a conceptual estimate, judgment replaces straightforward material takeoffs and costing; therefore, it is difficult to justify estimates quantitatively. Estimators must be protected from internal and external pressures to produce estimates that are less than some preestablished budget amount.

Summary

The factors that lead to project cost escalation have been documented through a large number of studies and matched to changes in cost estimates. Each factor presents a challenge to the state highway agency seeking to produce accurate project cost estimates. These factors can be mitigated through the strategies that focus on controlling the possible effects of these factors.

Table 3.2 illustrates the link between the strategies and cost escalation factors. This table is further developed for each of the project phases in Chapters 5, 6, and 7. The next chapter, Chapter 4, addresses the framework of this Guidebook and provides guidance for navigating through the Guidebook.

Table 3.2. Link between strategies and cost escalation factors.

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

CHAPTER 4

Guidebook Framework

Background

This chapter describes the Guidebook framework used to present information contained in Chapters 5, 6, and 7. Each chapter covers a different phase of the project development process—planning, programming and preliminary design, and final design, respectively. And each phase has unique requirements for cost estimation practice and cost estimation management. Although there is overlap and redundancy in the information presented, the overlap and redundancy is necessary to meet the needs of state highway agency personnel involved in each of the project development phases. The structure and format of Chapters 5, 6, and 7 is the same; however, the content varies depending on the project phase, the project information and data available, and the purpose of cost estimates prepared during that phase.

Strategy, Method, and Tool Integration

Chapters 5, 6, and 7 use strategies to address the causes of estimation problems. In support of each strategy, methods and tools are described that can be used to deal with specific estimation difficulties.

As is illustrated in Figure 4.1, the strategies and cost escalation factors influence the choice of methods, and the project phase and the project complexity influence the choice of tools. An example of this interaction is shown in Figure 4.2. In this example, poor estimation could be an agencywide problem for many projects. The Guidebook can be used to identify multiple methods and tools to address this problem. If poor estimation is a project-specific problem, then a particular method and tool may help solve this problem, such as the estimation checklist tool.

Although the organization of the Guidebook enables the user to proceed directly from the problem to an appropriate tool, this approach does not serve the primary purpose of the Guidebook, which is to encourage users to explore several methods and tools to address a problem.

Based on data collected through interviews with state highway agencies and the literature search, over 30 methods and over 90 tool applications are included in the Guidebook. Implementation of the methods and tools varies depending on the project phase.

Structure and Layout of Content

Chapters 5, 6, and 7 are structured as described in Table 4.1. Each chapter begins with a flow chart discussing the general steps for cost estimation practice and cost estimation management. The number of steps varies depending on the project phase. Common symbols are used to describe the information in these flow charts (see Table 4.2).

In each of the project phase chapters, a cost escalation factor and strategy relationship matrix is provided. These relationship matrixes are identical in format to the presentation in Table 3.2. The difference between the phase chapter matrixes and the matrix shown in Table 3.2 is that the cost escalation factors presented in the phase chapters are specific to the project phase being considered. Thus, these matrixes are customized to a specific project phase situation.

The methods and tools are summarized in a table for each strategy by relevance to cost estimation management and cost estimation practice. Guidance is provided through a common descriptive structure for each proposed method. For each of the methods presented, the structure provides the following situational knowledge:

- **Why:** Why use the steps in the cost estimation and/or estimation management process (i.e., flow chart)?
- **Project complexity:** How is use of the method impacted by project complexity?
- **Tips for success:** What makes the use of the method successful?
- **Tools:** How is the method applied? This question will be addressed in Appendix A.

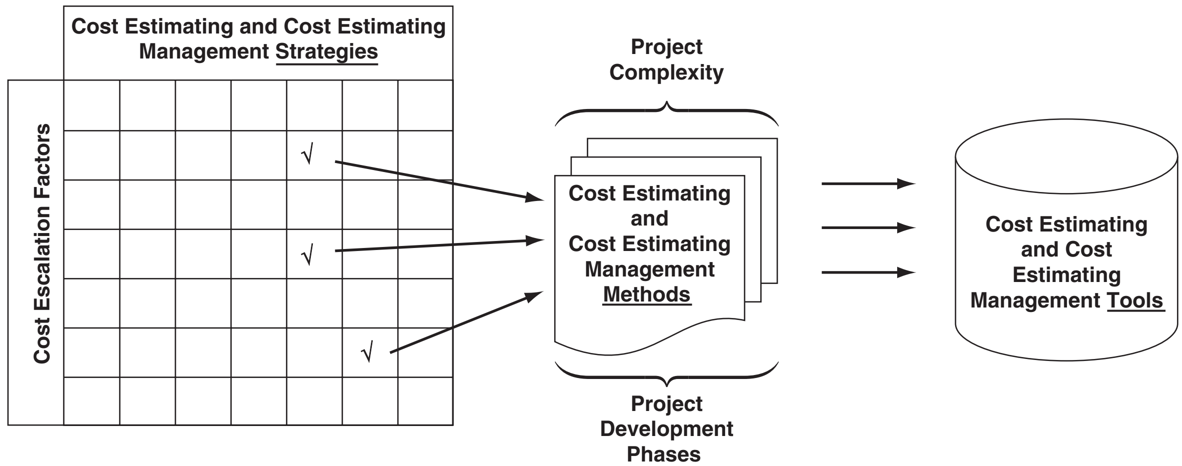


Figure 4.1. Illustration of strategy, method, and tool interaction.

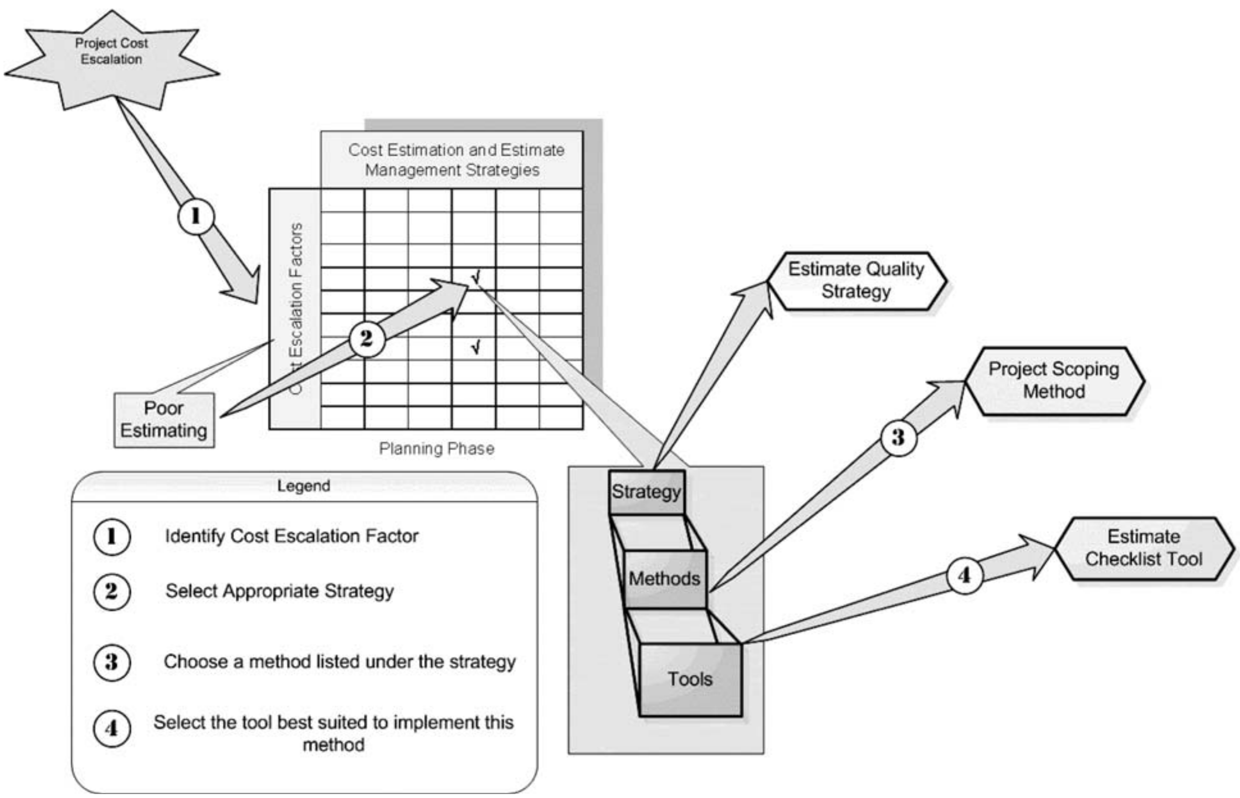


Figure 4.2. Strategy, method, and tool example.

Table 4.1. Chapter structure.

Sections	Content
Guide for Project Phase	• Cost estimation practice and cost estimation management flow chart for project phase • Relationship matrix between cost escalation factors and strategies for project phase
Strategies (1 through 8)	• Methods and tools for implementation to address cost escalation • Application of methods for relevant strategies • Tools to implement methods

Table 4.2. Flow chart symbols and significance.

Symbol	Significance
Input	• Denotes all *inputs* into the estimation process, from both internal and external sources. The input can be information such as plans, designs, milestones, and scope from various disciplines (planners, designers, etc.).
Step	• Denotes all *action/process* steps in the flow charts such as preparation of estimates, review of estimates, and risk analysis.
Document	• Denotes the *documents* resulting from the preceding action step(s). They can be different types of estimates, such as the baseline estimate or the state transportation improvement plan estimate.
Milestone	• Denotes a *milestone* in the system, which can relate to a significant point in development. The milestone may require meeting criteria for further actions or repeating the preceding steps.
Decision	• Denotes a *decision* where a binary verdict automatically directs the process to continue on either of the available options based on requirements. This can be a simple gate with a go or no-go decision.
Database	• Denotes the input from an established database.
Phase	• Represents the different phases of project development. This symbol is placed on the right side of each flow chart.

Each chapter discusses the eight strategies as applicable to that phase together with identified methods that are applicable to each strategy. Subsequently, the tools for each method are listed with the method. Tools often support multiple methods. The methods are sorted alphabetically and numbered with an alphanumeric numbering system for methods within the same alphabet heading. As a consequence, tools are referenced by an alphanumeric code—for example, Tool B1.1 is Tool 1 under Method B1. All tools are found in Appendix A (i.e., the Tool Appendix).

Tool Appendix

The Tool Appendix describes all the tools referenced for each method in Chapters 5, 6, and 7. The common informational structure for describing each tool is the following:

- 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?

A table of contents is provided at the beginning of Appendix A to guide the user to the location of the tool description in the appendix. The table of contents is arranged by the method name sorted alphabetically with an alphabet-serial number coding pattern. The tools are then listed alphabetically under each method with a serial number suffix to the method code (e.g., B1.1 is Tool 1 under Method B1, and C2.3 is Tool 3 under Method C2).

Summary

A common framework is used in Chapters 5, 6, and 7 to describe cost estimation practice and cost estimation management methods. This framework is structured around factors that can lead to cost escalation and the strategies that address these factors.

CHAPTER 5

Guide for Planning Phase

Introduction

For both states and metropolitan areas, the purpose of transportation planning is to identify a set of the most cost-effective projects and approaches that achieve the stated system goals. Federal law requires that state highway agencies develop a statewide transportation plan and that MPOs develop a regional transportation plan (RTP). The horizon year for these long-range plans is usually 25 years into the future.

Approaches, or at least terminology, for statewide transportation planning vary across the country. While some states identify major projects, or even unique minor projects, most statewide transportation plans (STPs) do not identify specific projects, but rather establish strategic directions for state investment in the transportation system and present future challenges that could constrain the ability of the state highway agencies to improve the performance of their systems. Statewide plans also often identify areas of the state where more detailed planning is required. One of the more common approaches to providing such focused planning is through corridor or subarea studies. These targeted study efforts usually identify specific projects and their associated costs that are considered during the programming process, when projects are prioritized.

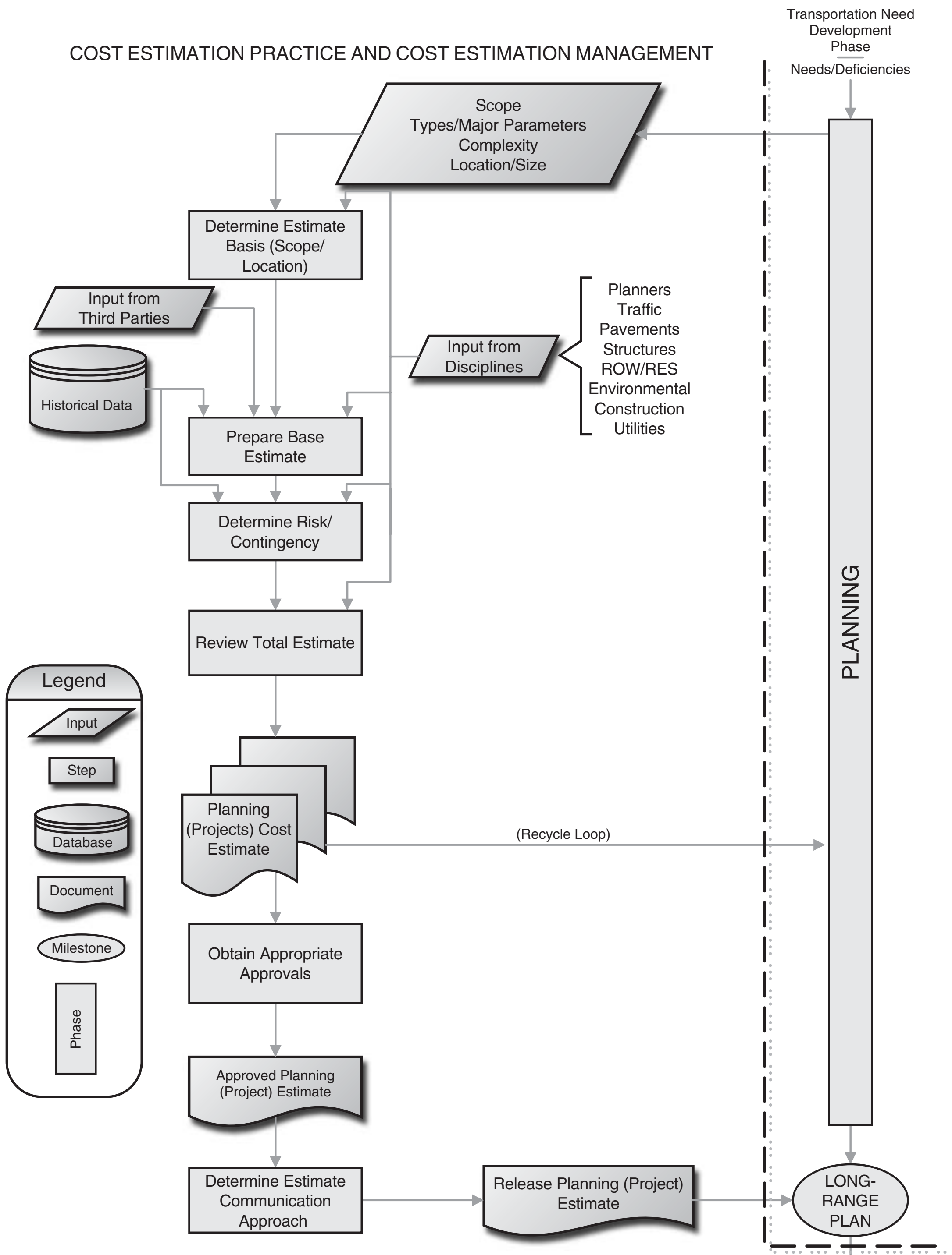
The RTP is very different from the STP. The RTP identifies specific projects that are to be implemented over the next 25 years, usually defined in short-, medium-, and long-term implementation stages. Thus, for example, in a typical RTP, one would find projects that the agency expects to implement in the next 5 years, in the next 5 to 15 years, and in the next 15 to 25 years. Federal law requires the RTP to be "fiscally constrained"; that is, the sum of the total project costs in the plan cannot exceed the amount of funding that is expected over the next 25 years. This limit places great importance on having valid and realistic cost estimates for the projects in the MTO's plan.

Federal law also requires that the statewide and metropolitan plans be consistent and that plan development include the participation of the state; the MPO; and many other stakeholders, such as local government agencies. Planning-level cost estimates can have a significant effect on the overall transportation program and, thus, on the ability of the state highway agency and MTO to meet their area transportation needs. The term "conceptual estimation" is often used to describe the general method of estimating project costs during the planning phase.

As indicated above, the role of cost estimation varies by whether one is developing a statewide plan or a metropolitan plan. However, it is important that, from the beginning of the planning process and through all planning and project development phases, the overall approach and management philosophy toward cost estimation (e.g., year-of-construction dollars, treatment of project risks, and quality control procedures) be consistent.

Figure 5.1 provides an overview of the cost estimation practice and cost estimation management processes that can provide input into transportation planning and project-level planning. The level of cost estimate detail will likely vary between estimates prepared for transportation planning and those prepared for project-level planning and could easily vary from one jurisdiction to another. Cost estimates that are prepared during planning have, as their fundamental purpose, to provide an order-of-magnitude estimate of the anticipated funds needed to support long-range plans. These cost estimates are also often used in benefit-cost analysis for ranking projects and including them in the 25-year planning horizon.

Key inputs into the cost estimation practice and cost estimation management processes are, where applicable, project scope and type, major project parameters, project complexity based on location, and anticipated size. Three sources of information and data on these inputs usually characterize the cost estimation process. The first of these is third-party stakeholders. For the development of estimates during the planning process, this source of information is usually the most common. The second major source of cost estimation information comes from the planning or engineering staff. For example, when soil conditions require costly design solutions, geotechnical engineers should be consulted because they can



ROW = right-of-way
RES = real estate services

Figure 5.1. Cost estimation practice and cost estimation management during planning.

provide input based on experience even if they cannot conduct extensive soil tests at this stage of need development. Historic cost data from similar works is the final source of cost estimation input. Because little if any engineering has occurred prior to the planning process, most estimates at this stage rely heavily on cost data from past works. The historical data form the basis for the conceptual cost estimates prepared during planning.

The cost estimation process is frequently iterative in that initial cost estimates are prepared and used in the planning process to form investment decisions. These same cost estimates become the point of departure for cost estimates prepared during programming, which are necessary when projects are placed in a state transportation improvement program (STIP), and are then further refined as projects make their way through preliminary design and final design. Because cost estimates used for the planning process include considerable uncertainty, it is incumbent upon engineers and planners to understand the likely range of uncertainty associated with these cost estimates and to communicate this level of uncertainty to decisions makers (i.e., managers).

Methodology

This chapter is organized around the cost escalation factors and strategies presented in Chapter 3. A familiarity with the definitions of identified cost escalation factors and strategies is helpful in understanding the methods described in this chapter. Table 5.1 provides a link and quick reference between cost escalation factors and strategies to address estimation issues during planning. The table can be used to select appropriate strategies when systematic cost escalation problems are found in an agency. The remainder of this chapter describes methods for the application of the strategies, and Appendix A provides information on the tools used with each method.

The strategies address cost escalation issues that arise early in planning. All of the strategies can address at least a portion of the cost escalation factors in the earliest development phases. As seen in Table 5.1, the management, scope and schedule, off-prism issues, and risk strategies address a large number of cost escalation factors. These strategies can and should be applied in the early stages of planning and continued throughout the project development process. The integrity strategy is also important in dealing with bias that can occur when projects are being developed without a definitive scope. The delivery and procurement strategy is only applied on those projects in which early decisions about procurement methods will be made. Generally, this strategy is not applicable during planning. The document quality and estimation quality strategies have less impact during planning than in the later phases of the project development process. However, these strategies can begin to be applied, particularly when consultants are being used, as is often the case, to develop concepts and related cost estimates. The faulty execution cost escalation factor is not considered an issue during planning. This factor is of greater concern during the project development process.

Table 5.1. Link between strategies and cost escalation factors in the planning phase.

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

Methods and tools presented in Chapter 6 but not presented in this chapter could be used during planning if the state highway agency deems them appropriate to their culture and environment. Further, if the state highway agency must estimate a single project rather than a group of projects during the planning phase, the state highway agency is encouraged to examine the methods and tools in Chapter 6 in addition to those in this chapter.

5.1 Strategy: Management

Table 5.2 lists five different management methods along with their associated tools for use during project planning and, in the case of metropolitan areas, during the transportation plan development process.

5.1.1 Budget Control

Why?

The use of the budget control method can assist in providing a disciplined approach to project cost estimation. The method must begin early, even though project scopes are not fully detailed during the planning phase. Lack of budget control causes increases in project costs, which translates into a reduction in the number of projects that can be completed at any given time.

The budget control method is an essential element in the "recycle loop" shown in Figure 5.1. A variance report of cost and schedule tool is necessary to control the budget in this loop. Estimates are based upon little more than a summary of key project scope characteristics at this point, but these characteristics and changes to them need to be tracked during the evolving scope definition process.

Project Complexity

There is a greater need to control the budget of complex projects due to the detrimental impact this type of project can have on an agency's total program. Rising cost estimates for larger projects could ultimately affect many other projects, causing them to be down-scoped or be cancelled altogether. The budget by corridor tool provides agencies with an approach to control their budgets on complex projects by making cost-benefit tradeoffs to the entire system rather than focusing on particular projects.

Tips for Success

To control a budget successfully, a disciplined cost estimation and monitoring system must be established early in planning and be used continually until a project is constructed. Budget Control must be an active endeavor rather than a passive attempt.

Table 5.2. Planning phase management strategy: Methods and tools.

MANAGEMENT STRATEGY Manage the estimation process and costs through all stages of project development		
Cost Estimation Management		Cost Estimation Practice
Budget Control		
B1.1	Budget by Corridor	
B1.2	Constrained Budget	
B1.3	Standardized Estimation and Cost Management Procedures	
B1.4	Summary of Key Scope Items (Original/ Previous/Current)	
B1.5	Variance Reports on Cost and Schedule	
Communication		
C1.1	Communication of Importance	
C1.5	Proactive Conveyance of Information to the Public	
C1.6	Simple Spreadsheet	
C1.7	Year-of-Construction Costs	
Consistency		
C4.5	Major Project Estimation Guidance	
C4.6	Standardized Estimation and Cost Management Procedures	
Recognition of Project Complexity		
R1.1	Complexity Definitions	
Risk Analysis		
R3.2	Contingency—Idenfitied	

Tools

B1.1 Budget by Corridor
B1.2 Constrained Budget
B1.3 Standardized Estimation and Cost Management Procedures
B1.4 Summary of Key Scope Items (Original/Previous/Current)
B1.5 Variance of Reports on Cost and Schedule

5.1.2 Communication

Why?

Because cost estimates used during the planning process can have such significant implications to the rest of the proposed investment program, it is important that the different organizations involved with planning, as well as units within these organizations, effectively communicate with each other during the cost estimation process. Because it is the policy boards and commissions of the transportation agencies that most often approve investment programs, it is important that the underlying uncertainties associated with the cost estimates be conveyed to these officials as well.

This communication must center on the importance of the estimate and the confidence that the agency has with the estimate. What will this estimate be used for? If the estimate is being used in a feasibility study, its accuracy will be less important than if the estimate is used for establishing a project budget as part of the programming process. Communication can occur continuously as necessary in the recycle loop shown in Figure 5.1, but the estimators must be cautious about sharing incomplete estimates with stakeholders and even with their counterparts within the agency. If the estimate is to be shared with external stakeholders or will be used for executive management decision making, it should go through a rigorous and appropriate review process.

Communication relating to project estimates could include such factors as project engineering and construction complexities, local government concerns and requirements, the significance of the project, and the required accuracy of an estimate at the particular point in the process. The availability of information through project files, including documentation and agency forms that are available to agency staff and to the public, will help to address questions that might be asked later during project development. The communication method is also discussed in Section 5.2.2.

Project Complexity

The more complex projects become, the greater the need for communication both within the agency and with external participants. The need to communicate the uncertainty surrounding the cost estimation also increases. As one might expect, larger and more complex projects typically include greater design uncertainty.

Tips for Success

Communication among all of the involved parties regarding expected project costs substantially increases the level of information associated with all of the projects being considered. Hopefully, this communication will lead to fewer surprises later in project development. Communication should include both verbal and nonverbal methods. Early stakeholder involvement with the project promotes ownership of the project that could possibly lead to increased acceptance. When possible, estimates, especially during planning, should be communicated as ranges of costs, because it is nearly impossible to predict accurately final costs with the limited information that is available in this phase. If point estimates are required, estimators must be cautious about including an appropriate contingency. Finally, always communicate estimates in inflated year-of-construction costs to all internal and external stakeholders to avoid any confusion or discrepancies in the later estimates.

Tools

C1.1 Communication of Importance
C1.5 Proactive Conveyance of Information to the Public
C1.6 Simple Spreadsheet
C1.7 Year-of-Construction Costs

5.1.3 Consistency

Why?

An estimate is a permanent document that serves as a basis for business decisions. It must be in a format that can be understood, checked, verified, and corrected—there must be consistency.

Consistency ensures that estimates are prepared following a single standard. Estimate consistency is important, even as early as planning, because estimates are easier to review and revise when they are prepared in a similar manner. Consistency is achieved by instituting standards that serve as a guide for cost estimation practices and cost estimation management. Agency management should ensure that the agency's planners, or others involved in preparing planning estimates, follow standard practices and use procedures that are documented. In Figure 5.1, the consistency method influences each step in the process and the types of information used to prepare planning-level estimates.

Project Complexity

At the planning level, estimates may be required for major projects or corridors. Specialized guidance is required for these larger and more complex facilities. Sound cost management practices are also needed because these major facilities are evaluated throughout the planning phase.

Tips for Success

Adequate knowledge of agency procedures and practices is important for this method to be successfully implemented. When different organizations or agencies are involved in planning, common procedures must be implemented for consistency to be achieved. When this method is implemented during planning and carried forward into the project development process, improved estimation accuracy can be achieved over time.

Tools

C4.5 Major Project Estimation Guidance
C4.6 Standardized Estimation and Cost Management Procedures

5.1.4 Recognition of Project Complexity

Why?

Understanding project complexity will allow for the determination of appropriate risk and contingency factors, as depicted in Figure 5.1. Agencies should estimate base (or known) amounts separately from risk and contingency (or unknown) costs. Also see the steps described in Table 2.2. Recognition of project complexity is a critical step in determining the uncertainty of a project estimate.

Project Complexity

By defining and recognizing project complexity, a proper contingency estimate can be developed. Also, over time, lessons can be learned for different levels of project complexity that will be useful for future project cost estimation. This "institutional memory" should eliminate some of the relearning that often takes place during the development of many projects.

Tips for Success

Early recognition of a project's complexity can aid in ensuring that all criteria for a project are met in the decision process. Criteria can include the size of staff required for the project; the necessary level of review; the level of definition at certain project milestones; the authorization level for the project; and the changes in scope, schedule, and quality. Complexity can also relate to factors associated with the project setting, either rural or urban. The definition levels and criteria should be established for use throughout the agency, and each project should be classified as belonging to a complexity level early in project development. Changes to the complexity should be noted and communicated as they become apparent.

Tool

R1.1 Complexity Definitions

5.1.5 Risk Analysis

Why?

Agencies should estimate base (or known) amounts separately from risk and contingency (or unknown) costs. Also see the steps described in Table 2.2. Understanding the risks associated with the project and having a clear definition of contingency coverage is very important. The definition of contingency helps in understanding what is or is not covered in the contingency amounts included in the planning-level cost estimates and can aid in managing costs.

Project Complexity

By defining and recognizing project contingency, a proper level of contingency can be incorporated into the cost estimate to account for the risks associated with the project.

Tips for Success

Each project is unique and reflects a specific situation; therefore, each project should be looked at individually. Lessons learned regarding risk and contingency from similar projects or previous projects should be considered; however, they should not be applied without careful analysis of the project-specific context.

Tool

R3.2 Contingency—Identified

5.2 Strategy: Scope and Schedule

Under the scope and schedule strategy, at least three different methods can be used during the planning phase. The methods and their associated tools are listed in Table 5.3.

5.2.1 Buffers

Why?

Buffers are designed to protect the estimators and project team against external and even internal agency influences that can cause the misrepresentation of project scope, estimate, and schedule. Buffers are used as a means to ensure integrity in the processes of developing and tracking the project scope, estimate, and schedule.

Buffers are important in the re-estimation of costs as projects proceed through development and also in obtaining appropriate approvals. For estimators to act objectively and create

Table 5.3. Planning phase scope and schedule strategy: Methods and tools.

SCOPE AND SCHEDULE STRATEGY Formulate definitive processes for controlling project scope and schedule changes			
Cost Estimation Management			Cost Estimation Practice
Buffers			
	B2.1	Board Approvals	
	B2.2	Constrained Budget	
	B2.3	Management Approvals	
Communication			
	C1.1	Communication of Importance	
	C1.2	Communication of Uncertainty	
Computer Software			
	C2.1	Agency Estimation Software	
	C2.3	In-House Conceptual/Parametric Estimation Software	
	C2.4	Simple Spreadsheet	

accurate estimates, they must be shielded from pressures to make unrealistic cost estimates.

Project Complexity

High-profile projects may be more susceptible to manipulative pressures. Such pressures are typically present with the larger, more complex projects that affect a larger number of people or projects that have a greater impact on the environment. However, the use of buffers at some minimum standard should also be considered for smaller, less complex projects.

Tips for Success

The successful use of buffers requires a minimum standard on all projects. However, more extensive protection features should be developed for projects judged by the agency to be of greater vulnerability. Projects should be continuously monitored for indications of increased demands to maintain a fixed estimate amount. Such demands are a sure indicator that there is a need for added buffer protection.

Tools

B2.1 Board Approvals
B2.2 Constrained Budget
B2.3 Management Approvals

5.2.2 Communication

Why?

As discussed in Section 5.1.2, communication is very important during planning. Communication regarding scope, estimate, and schedule uncertainty will help project participants understand the project and the confidence that can be placed in project cost estimates. Communication about the importance of the project and the accuracy of the estimate reduces confusion as the project moves into the project development process and as it establishes the need to develop the project scope, schedule, and estimate to appropriate standards.

To manage the project scope and schedule, estimators must clearly communicate the level of uncertainty associated with project cost estimates, especially those in the very early stages of planning. All too often, a cost estimate for a project or design component is quickly produced as a feasibility estimate, but then is later kept as part of the budget decisions as if it were an accurate prediction of cost. Planners must clearly communicate the importance and uncertainty of estimates.

Project Complexity

As projects become more complex, the need to maintain communication among all project participants increases. While larger projects require more extensive communication efforts, a minimum effort and standard should be set for smaller and less complex projects.

Tips for Success

The successful application of communication methods requires the involvement of all project participants, including MPOs, local government agencies, and the public. Success in project cost estimation is dependent on the lines of communication remaining open, honest, and forthright.

Tools

C1.1 Communication of Importance
C1.2 Communication of Uncertainty

5.2.3 Computer Software

Why?

Computer software can be used in a variety of ways to deal with a number of cost escalation factors. Computer software can be used to develop and track a project's scope, schedule, and cost estimate and to highlight deviations or changes in project attributes. This capability permits immediate recognition of changes and their possible impacts. This will aid in the identification of changes that may remain hidden for prolonged periods during project development. The use of computer software most commonly occurs in the preparation of base estimates and in the releasing of corridor- or project-level estimation tasks, as depicted in Figure 5.1. Placing a project in a database as early as possible increases the ability to effectively develop and track the project. The use of computer software for different strategies is also discussed in Sections 5.6.1, 5.7.1, and 5.8.1.

Project Complexity

All levels of project complexity can benefit from the use of appropriate computer software. More complex projects, with a greater number of attributes that are difficult to monitor closely, lend themselves to the use of computer software. Less complex projects can often be accurately estimated in the early stages of planning using parametric estimation software.

Tips for Success

The most successful application of computer estimation software occurs when the agency has dedicated staff assigned to maintaining both the software and the databases that support the software. Both commercially produced software and agency software can be successfully used if they are properly maintained and updated. Use of a database management system for keeping track of project information and costs needs to occur from the earliest planning phase and throughout the project development process.

Tools

C2.1 Agency Estimation Software
C2.3 In-House Conceptual/Parametric Estimation Software
C2.4 Simple Spreadsheet

5.3 Strategy: Off-Prism Issues

State highway agencies should be aware of two off-prism issues strategy methods that are described in this Guidebook for use during planning. The methods and associated tools are listed in Table 5.4.

5.3.1 Communication

Why?

Communication is a critical key to project development success. The communication of off-prism issues both within the agency and with outside parties can eliminate some of the problems that may be faced later in project development. Early communication can help manage the issues themselves, provide information to parties that will participate later in the project development process, and provide a general awareness to all involved.

Project Complexity

Projects of all levels of complexity should benefit from identification, management, and communication of relevant off-prism issues.

Tips for Success

Early introduction of communication regarding off-prism issues will increase the likelihood of project success. Inclusion of all parties that may be remotely involved in any off-prism issues encountered during project development should occur early in planning. This will help eliminate resentful actions that could occur as a result of parties believing that they were excluded intentionally.

Table 5.4. Planning phase off-prism issues strategy: Methods and tools.

OFF-PRISM STRATEGY Use proactive methods for engaging external participants and assessing the macroenvironmental conditions that can influence project costs					
Cost Estimation Management			Cost Estimation Practice		
Communication			**Identifying Off-Prism Issues**		
	C1.4	Definitive Management Plan		I3.2	Percentage of Total Project Cost
	C1.5	Proactive Conveyance of Information to the Public			

Tools

C1.4 Definitive Management Plan
C1.5 Proactive Conveyance of Information to the Public

5.3.2 Identifying Off-Prism Issues

Why?

The identification of off-prism issues during the planning phase enables the agency to address fully these issues during the scoping process and subsequently during design with a full understanding of impacts. Research has shown that decisions made early in project development usually have the greatest impact on final cost. Early identification and active participation of outside groups, which could negatively or positively impact the project, should result in more cost-effective ways for addressing the concerns of these outside groups. This identification should occur in the form of input from third parties and input from professional disciplines, as shown in Figure 5.1.

Project Complexity

Projects of greater complexity may experience the greatest benefits from proactive efforts to identify and mitigate off-prism issues; however, smaller projects can also experience benefits by involving participants with off-prism issues early in planning. More complex projects will require proactive management of off-prism issues, while straightforward projects will benefit from the use of checklists and peer reviews to identify such issues.

Tips for Success

To enhance project success, agencies must begin identifying off-prism issues and mitigating possible negative impacts early in project development. State highway agencies must be more aware of the macroeconomic environment of construction and consider the impact of such economic forces when developing planning-level estimates. Continuing this endeavor into the project development process will increase the effectiveness and accuracy of cost estimates.

Tool

I3.2 Percentage of Total Project Cost

5.4 Strategy: Risk

Risk is inherent in any project. Three methods under the risk strategy provide tools for managing risk during early planning efforts and the planning phase of transportation need development. The risk management methods and associated tools are listed in Table 5.5.

5.4.1 Identification of Risk

Why?

As depicted in Figure 5.1, this Guidebook strongly promotes identifying project risks as early as possible and carrying contingency amounts that correspond to identified risk. Also see the steps described in Table 2.2. Risks can be identified through comprehensive qualitative studies, qualitative team assessment, or risk checklists. A comprehensive quantitative risk analysis that assesses the likelihood and impacts of risks may not be the most cost-effective or meaningful measure for planning; however, it should be considered for very large or highly complex projects. In general, the qualitative identification of possible risks will aid in developing a better understanding of the project and what constitutes an appropriate contingency amount. Understanding the project will enable the agency to make better decisions throughout project development.

Project Complexity

A structured risk identification effort should be instituted by the agency for all types of projects. Comprehensive quantitative risk assessments should be made on complex projects,

Table 5.5. Planning phase risk strategy: Methods and tools.

RISK STRATEGY Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed			
Cost Estimation Management		Cost Estimation Practice	
Identification of Risk		**Risk Analysis**	
I2.1	Red Flag Items	R3.1	Analysis of Risk and Uncertainty
		R3.2	Contingency—Identified
		R3.4	Estimate Ranges
		R3.5	Programmatic Cost Risk Analysis
Right-of-Way			
R2.2	Advanced Purchase (Right-of-Way Preservation)		

and team studies or historical checklists should be used on less complex projects.

Tips for Success

An agency might consider developing a standard form, based on project complexity or type, that identifies common risks that should always be considered as a project is being developed. These lists would prompt the involved parties to identify and consider specific project risks. Decisions on what to do about the risks should be considered later in the project development process.

Tool

I2.1 Red Flag Items

5.4.2 Right-of-Way

Why?

Right-of-way issues are often a major cause of escalating project costs. By identifying and addressing the risks associated with right-of-way issues and values early in project development, it is possible to correctly estimate these costs. As shown in Figure 5.1, right-of-way estimates should involve input from the agency's right-of-way and real estate services section and must be continuously revisited as the scope is "recycled" through planning and later through the project development process.

Project Complexity

Project complexity is not always a good indicator of potential right-of-way issues. In the case of project overlays or projects using a similar type of right-of-way, requirements are often minimal; however, projects that involve new alignments or require a greater amount of additional right-of-way acquisition are likely to have higher risks. This problem is not necessarily limited to urban areas; rural areas also experience increases in land values and opposition to property takings.

Tips for Success

A key to success is to involve the right-of-way and real estate service sections of the agency actively and early in planning and keep them involved as project scope iterations occur. The specialized knowledge found in the right-of-way and real estate service units can provide a strong basis for cost estimates and for identifying potential problems.

Another key to success is to educate right-of-way and real estate service staff on the importance of project planning estimates and provide them with resources to perform risk-based estimation. All too often, the duties of these staff involve only right-of-way acquisitions, and, as a result, these staff do not have resources to support project planning or to develop tools for developing long-range right-of-way estimates. Poor right-of-way cost estimates can have significant impacts on estimation accuracy.

Tool

R2.2 Advanced Purchase (Right-of-Way Preservation)

5.4.3 Risk Analysis

Why?

Every design and construction project contains uncertainty. Project uncertainty is even more prevalent when plans do not identify specific projects, but rather establish strategic directions for state investment in the transportation system. Risk is uncertainty that negatively impacts a plan or a project. Uncertainty and risk can often be quantified and probabilistically modeled. These models can generate range estimates that more transparently convey risk and uncertainty than do single-point estimates. As specific projects are identified and more is known about a group of projects or an individual project, the level of risk and uncertainty decreases. Risk analysis is useful, and in many cases necessary, to identify and evaluate the impact of risks. Based on risk analysis, total cost ranges can be generated, the appropriate level of contingency can be added to the cost estimate and schedule, and sensitivity analyses can be used to focus planning and engineering efforts.

Project Complexity

Complexity is often correlated with additional project risks. Identification, assessment, and evaluation of risks on a macro level, or sometimes a project level, can assist in generating more realistic planning estimates. Complexity of planning estimates can stem from many issues, including project size; length of time until programming, design, and construction; and environmental or third-party uncertainty.

Tips for Success

Proper care and appropriate tools must be used to identify, assess, and evaluate risk at the planning level. However, the proper communication of uncertainty in planning estimates may be the most important tip for success. A misinterpretation of a range estimate can stop a project before it actually starts. There must be a clear description of what is driving the risk or uncertainty and a realization that these elements can be controlled and mitigated through proper planning and engineering. Additionally, risk analysis cannot end with planning. As described in Chapters 6 and 7 of this Guidebook, risk analysis must be continued throughout the entire project development process.

Tools

R3.1 Analysis of Risk and Uncertainty
R3.2 Contingency—Identified
R3.4 Estimate Ranges
R3.5 Programmatic Cost Risk Analysis

5.5 Strategy: Delivery and Procurement

In most cases, the delivery and procurement strategy is not selected during planning. The vast majority of U.S. highway construction projects employ traditional design-bid-build project delivery with a low-bid procurement. However, agencies may wish to consider alternative project delivery methods when projects have unusual time constraints, market conditions, or financing needs. In these cases, project cost estimation practice and cost estimation management processes must account for project delivery and procurement strategies. Table 5.6 shows the delivery and procurement methods and associated tools.

5.5.1 Delivery and Procurement Method

Why?

Although design-bid-build project delivery is by far the most prevalent project delivery method in the U.S. transportation sector, planners and engineering have many alternative delivery and procurement methods available to them. Design-build delivery, time-plus-cost bidding, and warranties have moved from alternative methods into the mainstream and are acceptable methods for federal-aid projects. With the advent of FHWA Special Experimental Project 15 (SEP 15), the private sector can participate in projects before environmental clearance and is also being encouraged to participate in financing projects. The impacts of these methods on project cost and time can be beneficial or detrimental, as explained below, but in any case, these impacts must be considered when preparing estimates and managing costs. The selected project delivery and procurement method impacts the risks that the state highway agency will assign to the contractor and that the contractor will have to price and manage.

For example, large projects can be designated as design-build as early as planning. Eventually, when the project is programmed, the design-build contractor will commit to a lump sum price for a project before design is complete and therefore take on nontraditional risks. These risks must be accounted for in the cost estimate. The state highway agency will, in turn, benefit from cost certainty earlier in the project development process because the design-build contractor will be committed to this price very early.

Planners can begin considering the project packaging in terms of single or multiple contracts during planning. If multiple contracts are used, the dollar value of a single contract may decrease, so the contractor may have less risk to price. Smaller contracts tend to encourage a greater number of bidders and can reduce costs if the market conditions are right. If these decisions are made in planning, the state highway agency must remain consistent with them during the subsequent phases of the project development process or they could risk substantial cost escalation, as documented in Chapter 3 of this Guidebook.

Project Complexity

Project size and duration are perhaps the best indicators of complexity for project delivery and procurement decisions. Larger projects may require a greater effort to adequately identify the potential risks and how these risks will impact project costs in relation to proposed project delivery and procurement methods. If project delivery and procurement methods are selected to accelerate construction on any size project, then the use of the risk strategy must account for the potential impact of acceleration.

Tips for Success

Risk analysis should be closely tied to any alternative project delivery and procurement strategies. The risk strategy should include an evaluation of the impact that project delivery and procurement methods have on cost. Additionally, any project delivery or procurement decisions made during planning must remain consistent throughout the latter phases of project development, or their impact must be accounted for in the state highway agency's cost estimation management systems.

Table 5.6. Planning phase delivery and procurement strategy: Methods and tools.

<table>
<tr><th colspan="4">DELIVERY AND PROCUREMENT STRATEGY
Apply appropriate delivery methods to better manage cost because project delivery influences both project risk and cost</th></tr>
<tr><td>Cost Estimation Management</td><td colspan="3">Cost Estimation Practice</td></tr>
<tr><td rowspan="3"></td><td colspan="3">Delivery and Procurement Method</td></tr>
<tr><td></td><td>D1.1</td><td>Contract Packaging</td></tr>
<tr><td></td><td>D1.2</td><td>Delivery Decision Support</td></tr>
</table>

Tools

D1.1 Contract Packaging
D1.2 Delivery Decision Support

5.6 Strategy: Document Quality

As shown in Table 5.7, three different methods can be used during planning to address the document quality strategy issue.

5.6.1 Computer Software

Why?

To increase the quality of project documents, a standardized set of document templates should be used as part of the project database. This template should include all of the information that should be known about the project at certain phases of need development. Using these templates to prompt project participants for project information will increase the quality of the project documentation. Computer software can be used to prepare the base estimate, as shown in Figure 5.1. The template establishes a minimum standard of quality. The use of computer systems is also discussed in reference to other strategies under sections 5.2.3, 5.7.1, and 5.8.1.

Project Complexity

The standard set of documents that must be available and incorporated into the computer software should have templates for each level of project complexity. Less complex projects, such as overlay work, will often include more known information earlier in planning than large or very complex projects.

Tips for Success

Successful implementation of computer software to encourage quality documents requires the agency to identify accurately the minimum quality standard and to use a software system that portrays the information in a meaningful manner. Projects are not the same, so a method for handling exceptions needs to be built into the system. The software should allow for the incorporation of additional information, even if the information is not required until a later stage of project development.

Tools

C2.1 Agency Estimation Software
C2.4 Simple Spreadsheet

5.6.2 Document Estimate Basis and Assumptions

Why?

A well-documented estimate basis and comprehensive documentation of the assumptions used in the development of a project estimate can eliminate the overlap of future estimate assumptions and provide a document trail regarding what is known about the project. This allows the project "knowns" as well as the "unknowns" to be clearly identified. This documentation enables the agency to easily track changes to project scope, cost, and schedule. Documentation should occur during both the "prepare base estimate" and "determine project contingency" steps described in Figure 5.1. The importance of a comprehensive documentation of the basis and assumptions for an estimate cannot be overemphasized because transportation projects often take years to develop and estimates must be completed multiple times during the needs development cycle.

Project Complexity

The documentation of the estimate basis and assumptions is important for all projects, but is particularly important on large projects. Multiple estimators may be engaged on a complex project. There needs to be a record of what one estimator has prepared and the basis and assumptions used to prevent overlap by the other estimators. There are also many factors involved in complex projects, and estimators may not be able to store and recall all of that information from memory;

Table 5.7. Planning phase document quality strategy: Methods and tools.

DOCUMENT QUALITY STRATEGY Promote cost estimate accuracy and consistency through improved project documents			
Cost Estimation Management		Cost Estimation Practice	
Computer Software		**Document Estimate Basis and Assumptions**	
C2.1	Agency Estimation Software	D4.1	Project Estimation File
C2.4	Simple Spreadsheet		
		Identifying Off-Prism Issues	
		I3.1	Environment Assessment
		I3.2	Percentage of Total Project Cost

therefore, documentation is vital in reducing the need to repeat estimation efforts.

Tips for Success

To be successful, the documentation of the estimate basis and assumptions needs to be consistent throughout the agency. Consistency can be achieved by developing a set of forms or a manual that outlines the documentation requirements. Additionally, both the base estimate and the incorporated contingency amount must be documented to properly communicate the accuracy of the estimate.

Tool

D4.1 Project Estimation File

5.6.3 Identifying Off-Prism Issues

Why?

Planning involves statewide planners, metropolitan planners, and a wide host of other stakeholders. Projects are influenced by the views of external participants and other conditions that impact project scope and cost. Cost estimation practice and cost estimation management issues are communicated in documents given to these external participants. The importance of valid cost estimates in environmental documentation, and any other documents concerning off-prism issues, must not be overlooked. The identification of off-prism issues, particularly in the environmental area, can greatly increase the accuracy of cost estimates and assist in cost estimation management. Assumptions about off-prism conditions made during planning can be validated, and their impact on cost should be reevaluated.

Project Complexity

Projects of greater complexity may gain the most benefits from proactive efforts to identify off-prism issues and assess their cost impact.

Tips for Success

Off-prism issues are, by nature, uncertain. Their identification should be incorporated into the risk strategy. To enhance the success of identifying off-prism issues and mitigating possible negative impacts, agencies must start this effort during planning. Early involvement of environmental experts is critical. Continuing this endeavor throughout the project development process will ensure that the scope and cost reflect the impact of off-prism issues. Communicating off-prism issues to upper management should be accomplished quickly because most of these types of issues have or will have political implications.

Tools

I3.1 Environmental Assessment
I3.2 Percentage of Total Project Cost

5.7 Strategy: Estimate Quality

The estimation quality strategy will change with the different phases of need development. This Guidebook describes six different methods for use during planning. These methods and associated tools are listed in Table 5.8.

5.7.1 Computer Software

Why?

The development of a consistent estimate format that is used throughout the agency supports the ability to easily review, update, and modify estimates throughout all phases of need development. The use of computer software for developing estimates, even during planning, establishes a common standard of care. Computer software can be used to track estimate development and highlight any changes that are made to cost values. Computer software can also be used to identify items, quantities, or costs that appear abnormal or have changed as estimates are revised. The use of computer software is also discussed under other strategies in Sections 5.2.3, 5.6.1, and 5.8.1.

Project Complexity

Computer software will provide greater benefits when preparing estimates for highly complex projects. Less complex projects will also benefit, although it might be better to use less sophisticated software or even standard spreadsheets for very simple projects.

Tips for Success

The successful use of computer software to support estimate quality requires the agency to identify a minimum acceptable estimation standard and to provide accurate and adequate information for use in estimation development. Success is also dependent upon agency investment in maintaining and updating the software.

Tools

C2.1 Agency Estimation Software
C2.3 In-House Conceptual/Parametric Estimation Software
C2.4 Simple Spreadsheet

Table 5.8. Planning phase estimate quality strategy: Methods and tools.

ESTIMATE QUALITY STRATEGY Use qualified personnel and uniform approaches to achieve improved estimate consistency and accuracy					
Cost Estimation Management			Cost Estimation Practice		
Computer Software			**Conceptual Estimation**		
	C2.1	Agency Estimation Software		C3.3	Cost/Parameter Using Similar Projects
	C2.3	In-House Conceptual/Parametric Estimation Software		C3.4	Cost/Parameter Using Typical Sections
	C2.4	Simple Spreadsheet		C3.5	Trns•port
			Estimate Review—External		
				E2.1	Expert Team
			Estimate Review—Internal		
				E3.3	In-House/Peer
			Project Scoping		
				P2.1	Estimation Checklist
				P2.2	Scoping Document
			Right-of-Way		
				R2.1	Acres for Interchange
				R2.2	Advanced Purchase (Right-of-Way Preservation)
				R2.4	Relocation Costs
				R2.5	Right-of-Way Estimator Training

5.7.2 Conceptual Estimation

Why?

Conceptual estimation uses tools to account for the fact that very little information is known about the project in the early planning stages. Conceptual estimation should be performed only by experienced estimators because these estimates are based primarily upon the assumptions that are being made by the estimator from past experience. Conceptual estimation techniques are used for both the base estimate and contingency estimate depicted in Figure 5.1. Various estimation tools are available for developing early project estimates. Agencies, project teams, and estimators should consider implementation of the appropriate tool for each project. It should be noted that the appropriateness of a tool may change throughout the project development process. Tools that may be appropriate at later phases may not be justifiable during the planning phase. Alternatively, some tools used later, especially in the programming phase, might work in the planning phase (see Section 6.7.7).

Project Complexity

Routine or straightforward projects and projects that are less complex do not require the same estimation tools as those necessary for more complex projects. Tools may also be tailored to the various stages of project development as different levels of information detail and quality become known.

Tips for Success

Each estimator needs to be knowledgeable of the range of estimation tools available and be able to make an informed decision regarding the most appropriate tool to use in estimating a specific project. The estimator needs to have adequate information available for developing each project estimate or needs to have some basis for making reasonable assumptions. Assumptions need to be documented for later review, justification, and revision.

Tools

C3.3 Cost/Parameter Using Similar Projects
C3.4 Cost/Parameter Using Typical Sections
C3.5 Trns•port

5.7.3 Estimate Review—External

Why?

Planning estimates have a substantial range in terms of accuracy. These estimates should be reviewed for the validity of their basis; however, the formality and depth of the review will vary depending on the type of project and its size and complexity. In Figure 5.1, an estimate review is positioned after the project risk has been quantified and an appropriate contingency amount is included in the estimate. While this review is depicted as a single activity, it would normally be repetitive, taking place to some extent whenever a planning-level estimate is revised.

Project Complexity

At the planning phase, only cost estimates for large projects or corridors in urban areas that are extremely complex will be subjected to an external review by qualified professionals. There may be certain critical elements of these estimates that require a unique expertise to verify estimated costs. This external review should include the results of a risk analysis that identifies the risks associated with these critical elements, the high and low cost limits for each critical element, and the assigned probability that the risk will occur.

Tips for Success

Knowledgeable and experienced individuals who are independent of the project team must conduct this review. The review must closely examine the assumptions that form the basis of the estimate and the scope that is used to prepare the estimate of all critical elements.

Tool

E2.1 Expert Team

5.7.4 Estimate Review—Internal

Why?

It is always necessary to independently verify that an estimate is complete and that it matches the project scope and is consistent with known site conditions, even when this information is very limited, as is the case in planning. In Figure 5.1, an estimate review is positioned after the project risk has been quantified and an appropriate contingency amount is included in the estimate. While this review is depicted as a single activity, it is normally a repetitive step, taking place to some extent whenever a planning-level estimate is revised.

Consulting peers and subject matter experts adds value to the cost estimation process. These individuals can identify possible errors, omissions, and clarifications in estimate basis and assumptions. Estimates are based on many assumptions, which need to be justified as the estimation is reviewed. Reviews provide feedback to planners about the completeness and accuracy of their work.

Project Complexity

The extent of the estimate review at this stage will vary depending on the type of project and project complexity. As project complexity increases, the reviewer or review team must devote more attention to probing the assumptions that form the basis of the estimate and ensuring that the scope is covered to the extent possible.

Tips for Success

To be successful, the review must closely examine the assumptions that form the basis of the estimation, and knowledgeable and experienced individuals from within the state highway agency must conduct the review. Conducting reviews at an appropriate time during the development of planning estimates provides some assurance that the estimates are reasonably accurate for the scope and site conditions known at the time.

Tool

E3.3 In-House/Peer

5.7.5 Project Scoping

Why?

Thorough and accurate scoping during planning enhances the quality of cost estimates. Definitive scoping efforts at the very beginning have been shown to be more cost-effective than scope control efforts in the later stages of the project development process. Scoping provides the input for the estimate basis, as shown in Figure 5.1.

Project Complexity

Projects of all levels of complexity will benefit from project scoping efforts, even in the earliest stages of project development. Larger, more complex projects will, however, greatly benefit from the project scoping effort. Good documentation of the project scope eliminates errors and omissions in the estimate.

Tips for Success

The agency should consider developing standard management practices and a standard set of forms to document project scope. Because project scope is often revisited during the planning phase, standard practices provide an audit trail of how the project's scope was developed and changed. Scope forms need to be completed early and regularly updated as changes are made. This will allow agency management to track project scope, and estimators will always know what should be included in the estimate. The forms are a graphic view of what has changed since the previous estimate was completed.

Tools

P2.1 Estimation Checklist
P2.2 Scoping Document

5.7.6 Right-of-Way

Why?

Early efforts in identifying right-of-way costs can greatly improve the quality of an estimate. Right-of-way costs are often a significant unknown for planning-level estimates. History has shown that the potential cost of land acquisition can be much higher than predicted, especially when cases go to court for judgment. The ancillary costs of land acquisition, including appraisals, negotiations, consultants, court fees, potential judgment, and others, can be substantial and often have a great amount of uncertainty. In extreme cases, judgments can occur years after the project has been built and can require large program adjustments to compensate.

Early identification and inclusion of accurate right-of-way costs in initial estimates will avoid difficulties later in project development process phases. As stated in Section 5.4.2, the involvement of right-of-way and real estate services staff with adequate resources is imperative to producing an accurate estimation. Right-of-way costs should also be considered carefully in the Risk Strategy.

Project Complexity

Projects that require little or no additional right-of-way will not need to consider higher levels of effort in estimating right-of-way cost. However, projects that require the purchase of more than the minimal amounts of right-of-way should benefit from increased efforts aimed at quantifying right-of-way cost. Right-of-way issues are not necessarily reliant on complexity, nor are they only a concern reserved for urban projects.

Tips for Success

The success of implementing additional right-of-way cost efforts is dependent in part on the inclusion of experts from the right-of-way and real estate service sections of the agency. This is particularly important during planning, as there are often issues relating to land value market condition projections that are beyond the expertise of project developers and that should be part of the scope alternatives discussion. Right-of-way estimators must be conscious of escalating costs to the point at which right-of-way will be purchased in the project development process. They must realize that (1) right-of-way can be purchased early in some circumstances and (2) right-of-way is typically purchased before construction begins and should not be escalated to the midpoint of construction like the rest of the estimate. Additionally, these specialists need to be provided with training and resources to develop long-range right-of-way estimates.

Tools

R2.1 Acres for Interchange
R2.2 Advanced Purchase (Right-of-Way Preservation)
R2.4 Relocation Costs
R2.5 Right-of-Way Estimator Training

5.8 Strategy: Integrity

The integrity strategy is difficult to capture in terms of methods and tools. Keys to this strategy involve communication, transparency, and good management. One method for the integrity strategy, shown in Table 5.9, is described in this Guidebook for use during planning.

5.8.1 Computer Software

Why?

The use of computer estimation software starting with the earliest phases of project delivery can increase estimation integrity. Computer software can be programmed to highlight abnormalities within an estimate. The integrity strategy can be

Table 5.9. Planning phase integrity strategy: Methods and tools.

INTEGRITY STRATEGY Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates			
Cost Estimation Management			Cost Estimation Practice
Computer Software			
	C2.1	Agency Estimation Software	
	C2.4	Simple Spreadsheet	

applied in the base estimate, contingency estimate, or approval tasks shown in Figure 5.1. Such identification helps in recognizing errors and the existence of bias. One way to maintain estimation integrity is to control the bias that can be introduced into the estimation process. Computers are immune to pressures to introduce bias into the estimate and will use the appropriate values such as average unit cost without feeling the need to change the value to appease others. The use of computer software is also discussed in Sections 5.2.3, 5.6.1, and 5.7.1.

Project Complexity

The use of computer software as a method to increase project estimation integrity even at early stages is important. However, the need increases as project size and complexity increases. Higher-profile projects are often subject to increased integrity problems as pressure increases both within the agency and from external sources to meet a desired project budget.

Tips for Success

The availability of estimation software to consultants, MPOs, and the planning department of the state highway agency will help to increase the likelihood that appropriate values are used throughout project planning and later during the development process. Training personnel and consultants on the appropriate use of software will improve the integrity of the estimates.

Tools

C2.1 Agency Estimation Software
C2.4 Simple Spreadsheet

5.9 Summary

Table 5.10 lists all of the methods and tools presented in this chapter for possible use in planning. This list can be used as a quick reference to navigate directly to Appendix A for detailed descriptions of the tools. Tools are listed in Appendix A alphabetically by method as shown in Table 5.10.

Table 5.10 can be used as a checklist for an agency estimation department or for project planners responsible for producing planning cost estimates. The checklist forms a self-assessment tool for agencies to benchmark against. The methods and tools were found in highway agencies throughout the country. While no one agency was found to use all of the methods and tools, all methods and tools are used and have the potential to be applied by any one agency.

Table 5.10. Planning phase methods and tools.

Budget Control		
	B1.1	Budget by Corridor
	B1.2	Constrained Budget
	B1.3	Standardized Estimation and Cost Management Procedures
	B1.4	Summary of Key Scope Items (Original/Previous/Current)
	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 the 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
Consistency		
	C4.5	Major Project Estimation Guidance
	C4.6	Standardized Estimation and Cost Management Procedures
Delivery and Procurement Method		
	D1.1	Contract Packaging
	D1.2	Delivery Decision Support
Document Estimate Basis and Assumptions		
	D4.1	Project Estimation File
Estimate Review—External		
	E2.1	Expert Team
Estimate Review—Internal		
	E3.3	In-House/Peer
Identification of Risk		
	I2.1	Red Flag Items
Identifying Off-Prism Issues		
	I3.1	Environmental Assessment
	I3.2	Percentage of Total Project Cost
Project Scoping		
	P2.1	Estimation Checklist
	P2.2	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 Costs
	R2.5	Right-of-Way Estimator Training
Risk Analysis		
	R3.1	Analysis of Risk and Uncertainty
	R3.2	Contingency—Identified
	R3.4	Estimate Ranges
	R3.5	Programmatic Cost Risk Analysis

CHAPTER 6

Guide for Programming and Preliminary Design Phase

Introduction

The programming and preliminary design phase focuses on converting the highest-priority needs included in the state highway agency's long-range plan into specific projects. This decision point marks the beginning of the project development process as individual projects are identified for definition, design, and construction letting. The period from project definition in programming to letting the project for construction is typically between 5 and 10 years. This period between programming and construction letting is a function of project complexity and criticality.

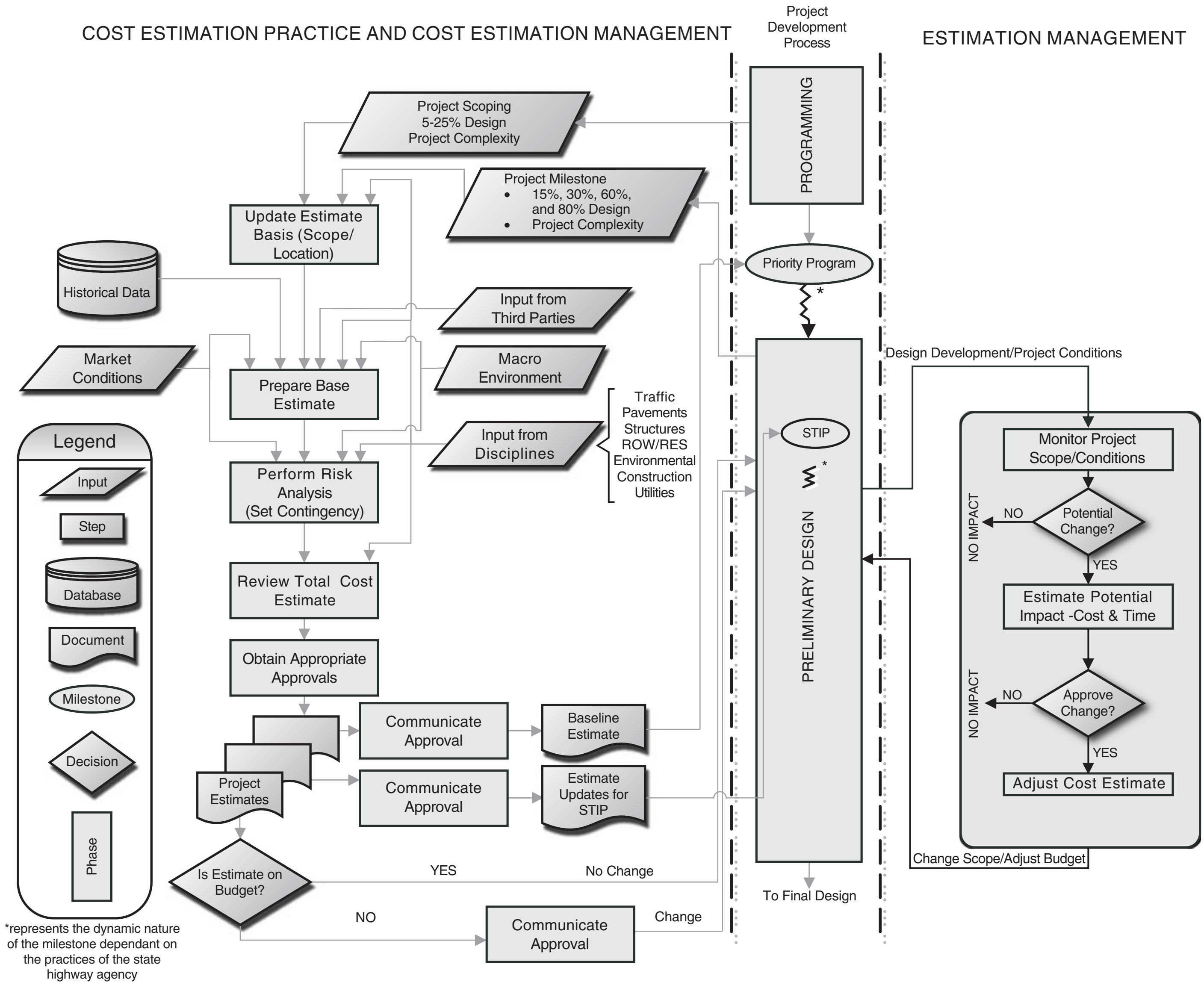
Programming often marks the beginning of a project-specific effort. Federal law requires that the transportation improvement program (TIP) for a metropolitan area become part of the state transportation improvement program (STIP). It is thus very common for state highway agencies and MPOs to work closely in identifying the likely costs associated with candidate projects.

Programming is often referred to as project definition or scoping. The primary goal of programming is to create a baseline scope, cost, and schedule for the project. Once this baseline is approved, the project is included in an authorized priority program. This priority program determines when preliminary design will begin. The target date to commence preliminary design could be several years in the future. When preliminary design falls within the first 3 years of the priority program and federal funds are used, the preliminary design cost is included in the STIP. Right-of-way and construction costs will be added to the STIP later, as the STIP is updated regularly. In some cases, if the project needs to be let for construction within 3 years, the entire project cost covering preliminary design, right-of-way, and construction can be included in the STIP. A project must be included in the STIP if federal funds are used. At the date specified in the priority program, preliminary design of the project development process will commence. During this time, the facility design is prepared, environmental clearance is obtained, right-of-way requirements are determined, and utility relocations are finalized. As the project nears its construction letting date, construction and right-of-way costs are updated for the STIP.

A variety of cost estimation methods are used during programming and preliminary design, from parametric estimation, to standard line items and historical bid-based estimation, to cost-based estimation. These methods should be congruent with the level of scope definition and the complexity of the project. During this period, as successive estimates are prepared, cost estimation management becomes a critical component for managing cost, scope, and time. This is especially true if project requirements change.

Figure 6.1 provides an overview of the cost estimation practice and cost estimation management processes used to prepare baseline project estimates for priority programming and the STIP. The basic steps of the cost estimation process are the same during programming and preliminary design. However, the programming estimate is critical because this estimate establishes the baseline cost (i.e., becomes the project budget) for managing project development. As shown in Figure 6.1, project scoping for this estimate is based on less than 25% design development. The percent design completion that supports the baseline varies depending on project type, size, and complexity. The level of design completion is often influenced by pressure to move projects into the priority program. Some projects may be included in the priority program with as little as 5% design completion. These projects are less complex, such as paving overlays.

The project is defined in terms of the need category and/or project type (e.g., preservation, such as a paving overlay, or a mobility improvement through capacity enhancements, such as adding lanes or new structures). This project definition effort sets the basic design parameters and criteria for the project. Project complexity is often related to the project's location and specific location characteristics (e.g., urban setting in high-traffic volumes or rural setting with



STIP = statewide transportation improvement plan

Figure 6.1. Cost estimation practice and cost estimation management during programming and preliminary design.

significant changes in terrain) and the relative magnitude of projected cost. Sufficient scoping should be completed to determine the potential cost impact of right-of-way requirements; utility relocations; environmental mitigation; and public, local government agency, and legislative involvement. Programming estimates are typically developed using parametric or historical bid-based tools in combination with historical percentages for certain elements. In some cases, data from past projects that are similar to the one being estimated can serve as a basis for line-item estimates or cost-based estimates. The complexity of the project often drives which estimation method or combination of methods might be best used.

Preliminary design for a project begins at the point in time specified in the priority program. During preliminary design, the project scope is developed in greater specificity. Project cost estimates are often prepared at various times during this time. These estimates often correspond to design milestones—such as 15%, 30%, 60%, and 80% design completion—as delineated in Figure 6.1. These cost estimates can be developed using historical unit cost line-item estimation tools. As design advances, the use of line-item, bid-based estimation is usually more common, but the use of cost-based estimation with a bottom-up approach is often required for major projects. Using historical unit cost data from past or current projects similar to the one being estimated is another cost estimation tool that can be used during preliminary design. The estimator must be careful that the specific tool or tools used fit the scope and complexity of the project and time available for preparing the estimate.

When the project is within 3 or 4 years of the construction letting date, the cost estimate is refined so that right-of-way and construction can be included in the STIP or so that the STIP budget for these major categories can be updated. This estimate is critical because the STIP is fiscally constrained and the cost for each project in the STIP must be closely monitored.

During preliminary design, cost estimation management is a critical component in achieving accurate estimates. As the design is developed, successive updated cost estimates should be compared to the baseline cost and any changes communicated to the design disciplines. These changes must also be communicated to agency management.

As a project moves through programming and into preliminary design, there must be a reevaluation of scope and design based on any additional knowledge related to the project site, market conditions, or the macroenvironment. The flow chart segment on the right side of Figure 6.1 shows three steps and two decision points that are important to managing the budget and identifying potential changes to the baseline budget. Changes could result in potential increases in the budget due to, for example, needed scope additions or design developments. Alternatively, changes could result in a potential decrease in the budget due to, for example, a lower estimated quantity. If the project is under the baseline cost, this should also be identified. Timely reaction to potential project changes and to information on the cost and time impact of changes allows management to better manage project funds and keep external constituencies informed about project status. This timely reaction to changes is especially critical when increased funding is required.

The preliminary design effort concludes when the plans and specifications are sufficiently complete to commence preparation of construction documents for advertising the project. This final design phase initiates the preparation of the engineer's estimate during PS&E development (see Chapter 7).

Methodology

This chapter addresses cost estimation practice and cost estimation management practices as applicable to the programming and preliminary design phase of project development. The definition of cost escalation factors and strategies described in Chapter 3 are applicable to this chapter. These definitions aid state highway agencies in recognizing those cost escalation factors that are particularly problematic during the programming and preliminary design phase. Table 6.1 can be used to determine which strategies provide solutions to address the cost escalation problems of concern. Chapter 6 suggests methods and tools that are available for implementing the specific strategies of interest. Detailed information about specific tools can be found in Appendix A.

During the programming and preliminary design phase, the availability of additional project information and an enhanced level of scope definition support more detailed and accurate project estimates. The strategies and methods applied in this chapter emphasize improving estimation accuracy by properly identifying major cost items and then using appropriate quantitative analysis techniques to provide consistent estimates throughout design. Strategies and methods to manage costs as design develops are integral to successfully achieving project cost targets.

Table 6.1 identifies the strategies that may be implemented to address specific cost escalation factors. Further, once a strategy is selected, the user has a choice of methods, classified as either cost estimation management or cost estimation practices, which are briefly described in each section of this chapter. Next, the user is guided to a set of tools for each method. The tools are further discussed in detail in Appendix A.

The methods and tools discussed in the context of the eight strategies under the programming and preliminary design phase are considered appropriate for this phase. Methods and tools presented in this chapter and not covered in Chapters 5 or 7 could be used during the other phases if the state highway agency deems them an appropriate fit within their culture and environment.

6.1 Strategy: Management

The management strategy is critical to successful project development, especially during the programming and preliminary design. Programming is when the project baseline scope, cost, and time are set. The project team must then manage to this scope, cost, and time as the design is further developed. There are six different methods described under the management strategy area for use during the programming and preliminary design phase of project development. These methods are shown in Table 6.2.

6.1.1 Budget Control

Why?

Budget control is critical to managing project costs as the design develops and more is known about project conditions. This method supports the concept of updating estimates and decisions to change or not change the current budget estimate. The identification of changes and making necessary modifications to the budget is reflected through the feedback loop shown on the right side of Figure 6.1. During programming, an approved baseline cost is set for the project. During preliminary design, as scope definition is refined, there is a clearer identification of possible cost escalation factors.

Table 6.1. Link between strategies and cost escalation factors during a project programming and preliminary design phase.

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

Hence, appropriate evaluation of the impact of such factors must be incorporated into the cost estimation management process. Scope changes are primary contributors to cost escalation, and these changes have to be monitored closely as design detail evolves. The budget control method is employed based on different levels of approvals required for a project to proceed. This method also seeks to periodically identify potential deviations and to assess if a project is on track when compared with the baseline budget. As potential deviations are identified, an assessment of their impact on project costs and time are evaluated to determine whether these changes should be approved by management. Timely identification of the impact of potential changes allows project and agency management to make decisions on how best to use the funds allocated to the project and to the overall program of projects.

Project Complexity

It is essential to monitor and control budgets during preliminary design, regardless of the project complexity. Cost overruns on a number of small projects can translate into program-level overruns. Budget overruns on larger and more costly projects are often more visible to stakeholders and may result in unwanted scope reduction or undesirable requests for additional funds.

Tips for Success

Timely tracking and identification of cost items that may lead to project overruns are necessary to manage the baseline project scope, cost, and schedule. Using a formal procedure and reporting process that requires quantifying the potential impact of changes to the project is essential for successful implementation of this method. Integrating this change management process into the agency's project management approach is also critical. If the budget control method is not followed, then there may be a reduced level of funds for other projects in the program.

Tools

B1.2 Constrained Budget
B1.3 Standardized Estimation and Cost Management Procedures

Table 6.2. Programming and preliminary design phase management strategy: Methods and tools.

MANAGEMENT STRATEGY Manage the estimation process and costs through all stages of project development		
Cost Estimation Management		Cost Estimation Practice
Budget Control		
B1.2	Constrained Budget	
B1.3	Standardized Estimation and Cost Management Procedures	
B1.4	Summary of Key Scope Items (Original/Previous/Current)	
B1.5	Variance Reports on Cost and Schedule	
Communication		
C1.1	Communication of Importance	
C1.2	Communication of Uncertainty	
C1.3	Communication within State Highway Agency	
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	
Gated Process		
G1.2	Cost Containment Table	
Recognition of Project Complexity		
R1.1	Complexity Definitions	

B1.4 Summary of Key Scope Items (Original/Previous/Current)
B1.5 Variance Reports on Cost and Schedule

6.1.2 Communication

Why?

The fundamental communication goal is the timely transfer of information between project team participants, agency management, and external stakeholders. Project communication management tools and techniques ensure the timely and appropriate collection and dissemination of project information. Through active communication efforts within the agency and with external entities, project team participants can compile and appropriately address the project's engineering and construction complexities as well as local government concerns and requirements. In Figure 6.1, the communication method is influenced by inputs from disciplines, third parties, and market conditions. Steps that either directly or indirectly facilitate communication include obtaining appropriate approval and communicating approval.

The communication effort begins in programming, when the baseline estimate is prepared and the project is included in the priority program. At this point in project development, the project budget is often released to various constituencies. Unambiguous communication of the scope, cost, and time required to design and let the project for construction is critical. Communication of uncertainty associated with the cost estimate is essential.

Preliminary design involves a significant level of scope definition; hence, proper communication of all additions and/or modifications to the scope is essential to achieving an accurate estimation. Detailed scope definition also translates into reduced design ambiguity. Proper communication channels established between project participants must promote a better understanding of the impact that design has on project cost. The communication method is also discussed in the scope and schedule, off-prism issues, risk, and integrity strategies of this chapter.

Project Complexity

In complex projects, which involve a large number of stakeholders, there is an increased need for skillful communication. These projects are often highly visible within government agencies and to the public. Failure to communicate changes to the appropriate entities and project participants involved with complex projects may result in a lack of confidence in the state highway agency's cost estimates, and the credibility of the agency could be compromised.

Tips for Success

The identification and formulation of an effective communication plan is the key to efficient and effective communication. The requirements and deliverables promised to stakeholders must be identified and matched with corresponding deliverables that a project team produces. Project cost should be communicated in year-of-expenditure dollars.

Tools

C1.1 Communication of Importance
C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency
C1.4 Definitive Management Plan
C1.5 Proactive Conveyance of Information to the Public
C1.7 Year-of-Construction Costs

6.1.3 Computer Software

Why?

The estimation process at the programming and preliminary design phase uses a variety of estimation approaches. Most commercial and agency-developed estimation software bases estimates on line items using bid histories or uses a cost-based approach. Line-item-based approaches do not always suit early programming estimates. These estimates usually have to be created using parametric techniques. As the design is prepared, the use of historical bid-based estimates becomes a more common approach. The use of computer software helps in extracting and summarizing historical cost data. This supports standardization of information presentation across the agency. Computers may also help reduce calculation errors and provide summary reports in numerous ways. When estimating line-item costs, computer software can also assist in analyzing multiple alternatives rapidly. In Figure 6.1, computer software can be used extensively in the maintenance and retrieval of historical data. Computer software also is used to prepare base estimate and perform risk analysis.

Project Complexity

Larger, more complex projects involve a significant number of cost items. Further, many project participants are often involved in preparing estimates for complex projects. In this environment, computer software can aid in performing numerous calculations quickly, reducing errors, and improving efficiency. Computer software can also aid in making changes rapidly, especially when the project team is evaluating a number of alternatives based on estimated costs.

Tips for Success

Computer software is useful for making calculations and, in particular, summarizing information in a manner that aids in checking estimate results. However, the output of estimation software is only as good as the input. Estimation software that provides some mechanism for checking the output (i.e., through comparisons of cost elements using percentages, ratios, and/or appropriate ranges against historical averages) will enhance the usefulness of the software.

Tools

C2.1 Agency Estimation Software
C2.2 Commercial Estimation Software

6.1.4 Consistency

Why?

An estimate is a permanent document that serves as a basis for business decisions. It must be in a form that can be understood, checked, verified, and corrected. There must be consistency.

Consistency ensures that estimates are prepared following a single standard. Estimation consistency is important, especially across state highway agency districts and regions, because estimates are easier to review when they are prepared in a similar format. Consistency is achieved by instituting project management procedures that serve as guides for the cost estimation management process. Agency management should ensure that the agency's estimators, or other project team members involved in preparing estimates, have developed standard practices and use procedures that are documented in a manual of practice and that all project participants involved in cost estimation are trained and knowledgeable in the established procedures. In Figure 6.1, the consistency method influences each step in the process and the types of information used to prepare the baseline estimate and the estimate updates. Consistency influences cost management steps, as well.

Project Complexity

Complex projects require the involvement of many different project participants, often representing different organizations or agencies. Complex projects also span a considerable period of time. Consistency in cost estimation management is essential to bridge the gap between these different project participants and to integrate the flow of information during project development. Although consistency is likely more important for complex projects, it is certainly still important for smaller and less complex projects because the number of these types of projects is generally high within state highway agencies. Consistent cost estimation management across these smaller projects will provide program-level consistency in cost estimation.

Tips for Success

Adequate training and knowledge of agency procedures and practices are important for this method to be successfully implemented. Using the same estimators throughout project development further contributes to achieving estimate consistency. When different organizations or agencies are involved in a project, consistency can be achieved if common procedures are implemented on a project-specific basis.

Tools

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

6.1.5 Gated Process

Why?

The project estimated early in project development is often not the project actually built. Scope changes to the original concept usually result from a better understanding of the needs that drive a project, and with most scope changes there is a resulting increase in project cost. 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.

Using a gated process can focus decision making during project development. A gated process involves identification of critical project development milestone points. At these predetermined milestones, a cost estimate is prepared to support a management review of scope, cost, and schedule before the project can proceed to the next milestone. This gated process prevents a project from moving forward without proper reviews and approvals. This method can reduce potential cost escalation. Setting an approved baseline cost at the end of the programming is an example of a gate in the project development process. In Figure 6.1, gates can be placed at critical points, such as at review and approval steps, to support baseline cost estimates for priority programming and to meet key project requirements such as when a project is included to the STIP.

Project Complexity

Complex projects involve many components that may easily be overlooked as the estimate is developed. A thorough review prior to releasing the project for further development facilitates scope, cost, and time control. This type of review "at a gate" in project development may ensure a more reliable estimate and potentially reduce cost growth.

Tips for Success

The placement of these gates at appropriate points on the project development time line and in conjunction with cost estimate development is critical if this method is to be successful. Standardizing these gates for all projects will further aid in developing consistent and accurate estimates. It is important that the review process at each gate be effective and expeditious to ensure that the project is not delayed.

Tool

G1.2 Cost Containment Table

6.1.6 Recognition of Project Complexity

Why?

Understanding the impact on project complexity can influence the choice of design estimation methods. The impact of complexity on method selection would influence the preparation of the base estimate and, perhaps, the estimate reviews.

Further, communication of project complexity and the associated estimate uncertainty is critical during programming and early in preliminary design. An understanding of project complexity will allow for the determination of appropriate risk and contingency, as depicted in Figure 6.1. As presented in Table 2.2, agencies should estimate base (or known) costs separately from risk and contingency (or unknown) costs. Recognition of project complexity is a critical step in determining the uncertainty of a project estimate.

Project Complexity

Through the act of definition and recognition of project complexity, a proper contingency can be developed. Also, a set of lessons learned for each level in the complexity scale can be developed. This will allow personnel throughout the agency to benefit from previous project knowledge. This knowledge should eliminate some of the relearning that takes place during the development of many projects.

Tips for Success

Recognition of the project's complexity early in its development can aid in ensuring that all criteria for a project of a given complexity are introduced into the cost estimation practice and cost estimation management processes. Criteria can include the size of staff required for the project, the necessary level of review, the level of definition at certain project milestones, and the necessary authorization level for the project, in addition to changes in scope, schedule, and quality. Complexity can also address the project setting (rural or urban). The definition levels and criteria should be established for use throughout the agency, and each project should be cataloged as a certain complexity early in project development. Changes related to complexity should be noted and communicated as they become apparent.

Tool

R1.1 Complexity Definitions

6.2 Strategy: Scope and Schedule

Controlling project scope and schedule changes requires sound cost estimation practice and cost estimation management methods. These methods must identify and quantify changes in scope and schedule in a timely manner so that decisions can be made to mitigate or accept the impact associated with the change. Controlling scope and schedule can only be achieved if there are a valid project baseline, effective tools to convey information, and proactive ways to evaluate scope and schedule when preparing cost estimates. There are four different types of cost estimation management methods and two different cost estimation practice methods applicable to the scope and schedule strategy. These methods are listed in Table 6.3.

6.2.1 Buffers

Why?

Buffers are used as a means to ensure integrity in the processes of developing and tracking scope, cost, and schedule elements during project development. They are designed to safeguard projects against external and internal influences that might misrepresent the level of definition of the project scope and the accuracy of the project schedule and budget estimate. In Figure 6.1, buffers can be included as part of the "prepare base estimate," "perform risk analysis," and "review total cost estimate" steps to enable estimators to independently develop estimates based on the best information available.

Project Complexity

Manipulative pressures, especially from external third parties, may influence estimates that are developed for high-profile projects. Although such pressures are typically present with more complex projects that often affect a larger number of stakeholders or with projects that have a greater impact on the environment, the establishment of buffers at some minimum standard should also be considered for smaller, less complex projects.

Tips for Success

Establishing a minimum standard to protect the project scope and cost from external and internal manipulative influences is important to creation of accurate estimates. Careful evaluation of such influences and how these influences should be mitigated during programming and early in design is important.

Tools

B2.1 Board Approvals
B2.2 Constrained Budget
B2.3 Management Approvals

6.2.2 Communication

Why?

Project communication management ensures the timely and appropriate generation, collection, dissemination, storage,

Table 6.3. Programming and preliminary design phase scope and schedule strategy: Methods and tools.

SCOPE AND SCHEDULE STRATEGY Formulate definitive processes for controlling project scope and schedule changes					
Cost Estimation Management			Cost Estimation Practice		
Buffers			**Constructability**		
	B2.1	Board Approvals		C5.1	Constructability Reviews
	B2.2	Constrained Budget			
	B2.3	Management Approvals			
Communication			**Value Engineering**		
	C1.2	Communication of Uncertainty		V2.1	Value Engineering
	C1.3	Communication within State Highway Agency			
	C1.4	Definitive Management Plan			
	C1.7	Year-of-Construction Costs			
Creation of Project Baseline					
	C6.1	Cost Containment Table			
	C6.2	Estimation Scorecard			
	C6.3	Scope Change Form			
	C6.4	Scoping Documents			
Delivery and Procurement Method					
	D1.2	Delivery Decision Support			
Identification of Changes					
	I1.1	Cost Containment Table			
	I1.2	Estimation Scorecard			
	I1.3	Project Baseline			
	I1.4	Scope Change Form			

and ultimate disposition of project information. Scope and schedules changes are prevalent in the programming and preliminary design phase of project development. Proper communication of these changes is crucial to cost estimation management. Communication is important in interfacing with external participants, especially when changes originate from third parties. Communication influences the inputs received from agency disciplines and third parties. The communication method directly guides how the "communicate approval" step is performed (see Figure 6.1).

Project Complexity

In complex projects, which involve a large number of stakeholders, there is an increased need for skillful communication. These projects are often highly visible to government agencies and the public. Failure to communicate scope and schedule changes to the appropriate entities and to involved project participants in a timely manner may result in a lack of confidence in the state highway agency's cost estimate and schedule. As a consequence, the credibility of the agency could be compromised.

Tips for Success

A project communication plan is critical to ensure that this strategy is successfully implemented. This plan should outline who is responsible for what aspects of project communication. This plan must especially focus on how project changes are communicated as the project is developed during programming and preliminary design.

Tools

C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency
C1.4 Definitive Management Plan
C1.7 Year-of-Construction Costs

6.2.3 Creation of Project Baseline

Why?

To properly track cost and the impact of changes due to better definition of project conditions, all projects must be monitored against a performance benchmark as the design is developed. Hence, a project cost baseline consistent with a defined scope and schedule must be established. The establishment of this baseline over the timeline of project development can be variable. One practice is to set this baseline when the scope of all major cost items can be adequately defined (i.e., 80% of cost lies in 20% of the project elements). This typically occurs during programming when an appropriate level of design completion is achieved (10% to 25%), although when the project baseline cost is set varies depending on agency policy. Setting a cost baseline ensures that scope changes and their impact can be documented and evaluated against the project budget. Deviations can be mapped over time for reconciliation with periodic estimation updates. This mapping process cannot successfully occur without a baseline. The baseline estimate document is the output of following all the steps shown on the left side of Figure 6.1 during programming.

Project Complexity

Complex projects involve many work items, and the probability of change is higher because it is difficult to define these work items early in design development. Hence, recording potential scope changes and periodically evaluating them for inclusion in the baseline scope ensures that the project will remain on schedule and on budget. Early detection of deviations from the baseline schedule and cost helps the project participants make necessary budget adjustments, recognize if additional funds are needed, and avoid substantial cost overruns.

Tips for Success

Project baselines are best established only when critical cost elements have been sufficiently defined. This means that the design basis and project definition is completed to a level of detail such that critical scope items can be properly estimated. Documenting the scope basis and assumptions that support the baseline cost estimate is also critical. This documentation will be the benchmark from which changes can be identified and assessed as potential deviations from the baseline scope and schedule.

Tools

C6.1 Cost Containment Table
C6.2 Estimation Scorecard
C6.3 Scope Change Form
C6.4 Scoping Documents

6.2.4 Delivery and Procurement Method

Why?

The use of alternate project delivery and procurement methods for transportation projects is increasing. The impact of these methods on project cost and time must be considered when preparing estimates and managing estimated costs. The design-build delivery method is considered to be a vehicle for controlling scope. This is particularly the case when a request for proposal is based on a well-described design basis and design criteria. The detailed design is then left to the design-build contractor. The design-build contractor can better control the schedule and reduce overall project time by overlapping design and construction. The delivery and procurement method would influence the preparation of the base estimate and the performance of the risk analysis.

Project Complexity

The effort required to prepare a conceptual design for a design-build project increases as project complexity increases. Thus, the state highway agency must be prepared to dedicate an adequate level of resources and time to completely develop the request for proposal (RFP), including the cost estimate and proposed schedule to support the design-build approach.

Tips for Success

A decision support tool to help select the appropriate delivery and procurement approach should be used during programming when setting the baseline cost. An early decision to use design-build can help the project team plan for the activities needed to support the preparation of the RFP, including development of an engineer's estimate and schedule that is compatible with the design-build approach.

Tool

D1.2 Delivery Decision Support

6.2.5 Identification of Changes

Why?

Every project should have an established baseline for both scope and cost. The project baseline scope and cost estimate is used to measure performance throughout project development and construction. Different agencies that already practice baselining of their projects report doing so usually when an identified need becomes a real project and is budgeted.

The identification method is normally positioned to intercept inputs impacting scope and cost. In Figure 6.1, identification of changes would filter the input from disciplines and the input from third parties. It would also identify any downstream changes to the "determine estimate basis (scope/location)" step and be used frequently as a basis for performing the steps on the right side of Figure 6.1. The method is also tied closely to the "creation of a project baseline" method (see Section 6.2.3).

Project Complexity

Establishing reliable baseline definitions of scope and cost in the early stages of project development for large projects is difficult, primarily because of the many unknowns at that point in time. Further, large projects tend to have more elements to properly scope and estimate. As such, identifying potential changes requires a more systematic approach. Thus, it is with the complex projects that the use of this method will yield the greatest benefits.

Tips for Success

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. Constructability problems that need to be addressed may also be encountered as the project develops. Early identification of such issues and a structured system for controlling their impacts is essential to achieving estimate quality.

Tools

I1.1 Cost Containment Table
I1.2 Estimation Scorecard
I1.3 Project Baseline
I1.4 Scope Change Form

6.2.6 Constructability

Why?

Construction knowledge and experience must support development of construction schedules. This focus is particularly useful when evaluating alternate construction staging plans to integrate with traffic management strategies. Traffic control and construction staging is often one of the most complex aspects of designing a project. Often designers do not fully understand the impact that a particular traffic control scheme has on ease and efficiency of construction. This impact will translate into a schedule that will likely change when the project is bid. If the traffic management design is developed with construction input, the result should be a more cost-effective and timely project. The constructability method would influence the type of input received from the disciplines. Constructability would impact the "update estimate basis" step in Figure 6.1 and influence the accuracy of the cost estimate and schedule.

Project Complexity

The more complex a project, especially if the project is set in a highly congested urban environment, the more attention should be given to the integration of traffic control and construction sequencing. This effort will provide a better baseline schedule for the project and, hence, increased accuracy of the estimated project duration. The cost estimate should reflect an efficient construction approach.

Tips for Success

Constructability analysis is most successful when the process is formalized and is an integral part of the programming and preliminary design project phase. Identifying constructability experts is also critical in achieving successful constructability programs. A constructability expert must be able to work effectively with project designers and provide meaningful input as designs are developed.

Tool

C5.1 Constructability Reviews

6.2.7 Value Engineering

Why?

Value engineering is a process that can be used to facilitate scope control and to contain or reduce project cost. Value engineering has its largest impact during programming and early in preliminary design, up to about 30% design completion. A significant project impact can be achieved during this period because the design has not been fixed. Thus, the primary objective of value engineering is value improvement. Value improvements might focus on exactness in scope definition, the functionality of designs, constructability of designs, and/or the project schedule. Value engineering also provides a vehicle for project teams to interact in a creative atmosphere. Value engineering contributions are made via input from disciplines and impact the "update estimate basis" step with respect to the scope of the project (see Figure 6.1).

Project Complexity

The FHWA mandates the use of value engineering on federally funded National Highway System projects with an estimated cost greater than $25 million, but small-dollar projects have successfully employed value engineering. Value engineering is effective on projects with alternative solutions that vary with scope and cost, on capacity improvement projects that widen an existing highway (especially in high-volume traffic environments), on projects requiring major traffic control, and on interchanges on multilane facilities.

Tips for Success

Value engineering is most successful when it is performed early in project development so that the proposed improvements can be easily incorporated into the design. Value engineering is a structured process. It is important to use a knowledgeable and experienced facilitator and have a value engineering team with diverse backgrounds. The value engineering process should be conducted away from the office environment to ensure focus and creativity. The period for conducting a value engineering process is typically 3 to 5 days.

Tool

V2.1 Value Engineering

6.3 Strategy: Off-Prism Issues

During programming and preliminary design, the off-prism strategy plays an important role in cost estimation management and cost estimation practices. As the project's scope is defined and then developed through design activity, the design often incorporates the influence of community interest and concerns. In some cases, this could include a requirement for a context-sensitive design. This type of design may add cost to a project, and this possibility should not be overlooked when preparing estimates during programming and preliminary design. During this phase, environmental analysis and clearance activities are completed. The results of these activities may introduce compliance and mitigation requirements that must be also addressed in estimates for design and construction work. Further, macroeconomic events can significantly influence cost. These events may drastically influence cost, but historical data may not reflect significant increases due to lack of material and subsequent material price increases.

There are five different off-prism methods described in Table 6.4 for use during the programming and preliminary design phase of project development.

6.3.1 Communication

Why?

Failure to account for off-prism issues in the cost estimation process can result in cost overruns. The uncertainties related to off-prism issues have to be identified during programming and throughout preliminary design to mitigate risks associated with these issues. Communication of these uncertainties, the risks, and the associated potential cost impact is a critical method in cost estimation management. Effective communication of off-prism issues must occur within the state highway agency and between all external project stakeholders to achieve project success. The communication method influences the "communicate approval" step in Figure 6.1.

Table 6.4. Programming and preliminary design phase off-prism strategy: Methods and tools.

OFF-PRISM STRATEGY Use proactive methods for engaging external participants and assessing the macroenvironmental conditions that can influence project costs			
Cost Estimation Management		Cost Estimation Practice	
Communication		**Estimate Review—Internal**	
C1.1	Communication of Importance	E3.2	Off-Prism Evaluation
C1.2	Communication of Uncertainty		
C1.3	Communication within State Highway Agency		
Right-of-Way		**Identifying Off-Prism Issues**	
R2.5	Right-of-Way Estimator Training	I3.1	Environmental Assessment
R2.6	Separate Right-of-Way Estimators	I3.2	Percentage of Total Project Cost
Public Involvement			
P3.1	Meetings		

Project Complexity

The importance of off-prism issues to complex and large-dollar projects is paramount. Complex project are affected by a multitude of external and internal elements that require careful and timely evaluation, especially since larger projects are often high-profile projects from a community perspective.

Tips for Success

The establishment of a functional communication protocol is essential for the state highway agency to effectively provide information addressing community interests and concerns while maintaining internal awareness of off-prism issues. A focus on cost estimate attributes tied to scope and schedule and explained in a simple format will keep the public informed.

Tools

C1.1 Communication of Importance
C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency

6.3.2 Right-of-Way

Why?

Failure to account for all relevant scope elements when preparing a cost estimate adversely affects the accuracy of an estimate. Some of these elements include right-of-way, utilities, and environmental elements. The impact of these elements will vary for every project, and input from appropriate project team participants must be evaluated to prepare accurate estimates. Scope definition is continuously refined over preliminary design and improves the clarity of project requirements. Hence, an early determination of the parameters related to right-of-way, utilities, and environmental issues, and inclusion of these issues in cost estimates, will improve the accuracy of the estimate. In Figure 6.1, this method guides the type of input received from disciplines when performing the "prepare base estimate" step.

Project Complexity

Right-of-way becomes an issue more often when adding system capacity. If a project is located in a highly urbanized area, right-of-way may be costly and acquisition of property can demand considerable time. Utilities can be a problem for projects in any area, but are more likely for projects in urban areas. Environmental compliance may require that land be purchased for creating a new wetland to replace existing wetlands displaced by the project. While this issue is not dependent on complexity, it may be more difficult to solve in an urban setting.

Tips for Success

The location of the project is critical when implementing this method in the off-prism strategy context. The identification of all factors that may impact project scope, cost, and time must be clearly identified so they can be properly addressed in the cost estimate. Estimators should not work in a vacuum because they may fail to consider off-prism issues and other information provided by other state highway agency disciplines. Interaction with others is critical to preparing accurate estimates.

Tools

R2.5 Right-of-Way Estimator Training
R2.6 Separate Right-of-Way Estimators

6.3.3 Public Involvement

Why?

Public opinion and concerns about various aspects of a project must be accounted for early in scope development. Early involvement of the public may help prevent future modifications to project scope. This would decrease the impact that scope creep or scope changes have on project costs. The fact that projects are developed in and around communities that will be affected augments the need to consult and incorporate the public in the scope definition process. Input from third parties, as shown in Figure 6.1, provides information from the public that can be used to prepare the base estimate and perform the risk analysis.

Project Complexity

Projects proposed in densely populated areas or growing urban or suburban regions are highly sensitive to public opinion. Failure to consult and consider public opinion can cause project scope to change over time. Hence, assessment of the public concerns is very important when developing the project scope.

Tips for Success

Setting up amiable mechanisms to educate and explain the benefits of a project to the local community and seeking their cooperation during construction are the aims of this method. This cooperation and input is particularly important during programming when decisions are made regarding the project scope and when preparing baseline cost estimates.

Tool

P3.1 Meetings

6.3.4 Estimate Review—Internal

Why?

Cost estimates are merely predictions and can therefore be wrong. Thus, all estimates must be reviewed to ensure that they do not contain discrepancies, errors, or omissions. Consulting peers and subject matter experts always improves an estimate. This is particularly helpful in assessing the impact of off-prism issues on project costs and risks. This method supports the "review total cost estimate" step (see Figure 6.1). In this case, the peers and experts are likely from the disciplines most closely impacted by off-prism issues, such as environmental, right-of-way, real estate services, and utilities.

Project Complexity

Complex projects may have several cost elements that estimators may be unfamiliar with and that require an expert opinion in estimating their cost. Estimate reviews provide the opportunity to minimize ambiguities related to cost by obtaining input from the appropriate experts and peers within the state highway agency.

Tips for Success

Conducting reviews at appropriate times during estimation development and consulting the right expert peers will help mitigate cost escalation. The integrity of such reviews is essential for this method to be successful.

Tool

E3.2 Off-Prism Evaluation

6.3.5 Identifying Off-Prism Issues

Why?

Projects are often influenced by the views of external participants and other conditions, such as those related to environmental compliance, that impact project scope and cost. The identification of off-prism issues is most beneficial when conducted during programming. During preliminary design, scope development progresses significantly, which in turn provides more information on project elements. Assumptions about off-prism conditions made during programming can be validated, and their impact on cost should be reevaluated. In Figure 6.1, input from third parties and information on current market conditions are inputs that can help implement this method when performing the "update estimate basis" and "prepare base estimate" steps.

Project Complexity

Projects of greater complexity may gain the most benefits from proactive efforts to identify off-prism issues, such as environmental concerns, and assess their cost impact. Environmental issues are more related to the location of the project. Environmental regulations and design considerations to accommodate mitigation requirements must be considered when developing cost estimates (e.g., noise reduction near a residential community may require installing noise walls or upgrading existing wetlands). Larger projects can be more substantially impacted by the macroeconomic environment than less complex projects.

Tips for Success

To enhance the success of identifying off-prism issues and mitigating possible negative impacts, agencies must start this effort early in project development. Continuing this endeavor throughout project development will ensure that the scope and cost reflect the impact of off-prism issues. Communicating off-prism issues to upper management should be accomplished quickly because most of these types of issues have or will have political implications. The ability to evaluate and attribute the most appropriate percentage to cover the cost of different issues will improve early estimate accuracy.

Tools

I3.1 Environmental Assessment
I3.2 Percentage of Total Project Cost

6.4 Strategy: Risk

When effectively applied during programming and preliminary design, risk may be the single most important strategy that will help control project cost escalation. Many different approaches to account for risk are used by state highway agencies. These approaches have led to inconsistent application of contingencies. The methods suggested to implement the risk strategy provide a consistent and valid approach to assigning cost and time contingencies in a cost estimate. Table 6.5 lists five different methods applicable to the risk strategy used during the programming and preliminary design phase of project development.

Table 6.5. Programming and preliminary design phase risk strategy: Methods and tools.

RISK STRATEGY Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed					
Cost Estimation Management			Cost Estimation Practice		
Communication			**Risk Analysis**		
	C1.2	Communication of Uncertainty		R3.1	Analysis of Risk and Uncertainty
	C1.3	Communication within State Highway Agency		R3.2	Contingency—Identified
				R3.4	Estimate Ranges
				R3.5	Programmatic Cost Risk Analysis
Identification of Risk			**Delivery and Procurement Method**		
	I2.1	Red Flag Items		D1.1	Contract Packaging
	I2.2	Risk Charter		D1.2	Delivery Decision Support
Right-of-Way					
	R2.1	Acres for Interchange			
	R2.2	Advance Purchase (Right-of-Way Preservation)			
	R2.3	Condemnation			
	R2.4	Relocation Costs			

6.4.1 Communication

Why?

Communication has been discussed in earlier strategies of this Guidebook. Communicating project uncertainty is critical to understanding what risks the project might encounter and what the potential cost and time impact of these risks would likely be if they are not mitigated. As applicable to the risk strategy, communication predominantly means keeping all project team members and external parties informed about project uncertainties and constraints. Conveying risk-related information in an easy-to-understand manner is extremely important. The communication of risk analysis results is critical during the "communicate approval" step (see Figure 6.1).

Project Complexity

Inherently, project complexity typically increases the risk of project cost and schedule increases. Therefore, the importance of communication, particularly communication of estimate uncertainty and the risks associated with that uncertainty and the potential cost consequences is essential to improving stakeholder confidence in the accuracy of the cost estimate.

Tips for Success

The ability to anticipate possible risk-related constraints on both a macro and micro level and the timely communication of their potential impact on project cost is a key to method success.

Tools

C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency

6.4.2 Identification of Risk

Why?

At the programming and preliminary design phase, there is a continuous process of scope clarification. An increased level of scope information facilitates better identification of possible risks. Necessary risk mitigation actions can be identified and adequate contingencies can be included in cost estimates to reduce the potential for cost overruns. Input from disciplines and third parties will contribute to identifying risks during the "risk analysis" step, as shown in Figure 6.1.

Project Complexity

Complex projects are accompanied by larger ambiguities; hence, there is a greater need for risk identification and mitigation. Formalized and structured risk-related procedures are critical to properly identifying risks for complex projects.

Tips for Success

The use of appropriate risk identification techniques must be instituted during programming, when the baseline project cost is set. Risks must be continuously reassessed during preliminary engineering to validate the assumptions used to identify risks in the baseline cost estimate. This approach will reduce ambiguities in project scope as the design is completed.

Tools

I2.1 Red Flag Items
I2.2 Risk Charter

6.4.3 Right-of-Way

Why?

Land acquisition and related issues have always constituted a significant cost estimate risk. During programming, there remains considerable uncertainty related to right-of-way requirements, so the risks remain high and must be accounted for in baseline cost estimates. However, as preliminary design proceeds, there is clarity on project alignment that in turn enables designers and right-of-way estimators to identify the financial and legal aspects of the required land acquisition. Input from disciplines is critical to performing the "risk analysis" step, as shown in Figure 6.1.

Project Complexity

Complexity in this case revolves around several circumstances, such as real estate values, public or business opposition, and compensatory conditions. The more right-of-way needed for the project, the more risks that will have to be considered, including assessment of the potential cost impacts due to adverse settlements when parcels are taken. Furthermore, on larger projects, the time impact of acquiring parcels may be the most critical risk because estimated project durations could be extended significantly if delays are encountered in acquiring parcels.

Tips for Success

Early land acquisition may be a key to success for this method. Design efforts to define right-of-way needs in conjunction with specialized advice from real estate personnel can reduce the impact of right-of-way on project cost and time.

Tools

R2.1 Acres for Interchange
R2.2 Advance Purchase (Right-of-Way Preservation)
R2.3 Condemnation
R2.4 Relocation Costs

6.4.4 Risk Analysis

Why?

Every project scope, cost estimate, and schedule has uncertainty. Uncertainty can be translated into project risks. These risks require a contingency amount to protect the project against cost increase and time increase. The level of uncertainty is highest when developing the cost baseline during programming, when project scoping reflects a low level of design completion (5% to 25%). As the extent of project definition increases during preliminary design, the level of uncertainty decreases. Some form of risk analysis is necessary to identify and evaluate the impact of risks. Based on this risk analysis, an appropriate level of contingency can be added to the cost estimate and schedule. Risk analysis also supports risk mitigation of identified risks. This risk analysis must start during programming and continue throughout project development. This method, along with input from reliable sources both within the project team and external to the project team, supports the "perform risk analysis" step.

Project Complexity

Complexity is often correlated with additional project risks. Identification, assessment, and evaluation of risks on a micro level in complex projects can help alleviate cost escalation due to inconsistent application of contingency. Alternatively, macro-level issues such as market conditions can create significant risks for very large projects. The macro-level risks require careful analysis because these risks can impact both cost and time. The risk analysis effort will vary with project size, type, and complexity. With project complexity comes added risk; therefore, the attempt to account for risk using a single-percentage contingency amount based on the construction value of the expected contract often fails.

Tips for Success

There must be a clear description of what the contingency amount included in a cost estimate and project schedule covers in terms of project risks. The contingency must be determined through a careful analysis and identification of specific risks. Simply using a percentage for contingency likely will make managing risks difficult because risks are not specifically identified. Tools are available to implement a risk analysis. These tools should be used consistently and tailored to fit the project type, dollar size, and complexity.

Tools

R3.1 Analysis of Risk and Uncertainty
R3.2 Contingency—Identified

R3.4 Estimate Ranges
R3.5 Programmatic Cost Risk Analysis

6.4.5 Delivery and Procurement Method

Why?

The use of alternative project delivery and procurement methods for transportation projects is increasing. The impact of these methods on project cost and time must be considered when preparing estimates and managing estimated costs. The influence of project delivery and procurement is critical to the "prepare base estimate" and "risk analysis" steps (see Figure 6.1). The project delivery and procurement method impacts the risks that the state highway agency will assign to the contractor and that the contractor will have to price and manage.

With design-build project delivery, the design-build contractor takes on increased risk and will price this risk based on the level of scope definition, understanding of proposed contract terms and conditions, and project complexity. The impact of risks the design-build contractor is expected to carry must be covered in the state highway agency's cost estimate. The decision to use design-build project delivery should be made during programming, when baseline budgets are established.

Other procurement methods may ultimately accelerate construction, such as when cost plus time (A+B) contracting and incentive/disincentive approaches are used in design-bid-build project delivery. These types of procurement methods shift risk to the contractor. Again, the uncertainty associated with this risk shifting and the impact on cost and time must be included in the risk analysis and the cost estimate.

The packaging of a project in terms of a single contract or multiple contracts must be considered early in design. If multiple contracts are used, the dollar value of a single contract may decrease, so the contractor may have less risk to price. Smaller contracts tend to encourage a greater number of bidders. The state highway agency would then take on the normal risk associated with a typical design-bid-build project. However, there may be increased risk to the state highway agency, because it has to manage the interface between contractors when multiple contracts are used. The uncertainty associated with this risk shifting and the impact on cost and time should be included in the risk analysis.

Project Complexity

Larger projects that are more complex may require a greater effort to adequately identify the potential risks and how these risks will impact project costs in relation to proposed project delivery and procurement approaches. This need is most apparent when design-build project delivery is employed. If project delivery and procurement approaches are selected to accelerate construction on any size of project, then the use of the risk strategy must account for the potential uncertainty related to the impact of acceleration.

Tips for Success

How a project is delivered must be considered when performing the risk analysis. Thus, evaluating the impact that project delivery and procurement approaches have on cost and time is necessary when implementing a project-level risk strategy.

Tools

D1.1 Contract Packaging
D1.2 Delivery Decision Support

6.5 Strategy: Delivery and Procurement

Once a project is considered for programming, the state highway agency management should begin to examine whether an alternative project delivery method would better fit the project than the traditional design-bid-build approach. Perhaps the most important decision is the use of design-build verses design-bid-build. During programming and preliminary design, if design-build is selected, then management must determine the level of design needed to support an RFP. If design-build is selected, then the engineer's estimate will be prepared based on less definitive information and must account for all engineering costs and costs related to other project factors. One key factor is the risk that the design-build contractor will evaluate when proposing on a design-build project based on limited design information.

When the traditional design-bid-build approach is selected and other alternative procurement methods are used to accelerate construction, then cost estimates must reflect the impact that acceleration has on construction costs. This impact may be reflected in higher unit costs.

The method shown in Table 6.6 provides insights into the issue of project delivery and procurement considerations during programming and preliminary design. This method is considered a cost estimation management method.

6.5.1 Delivery and Procurement Method

Why?

The impact of alternative project delivery methods on project cost and time must be considered when preparing estimates and managing estimated costs. Some project delivery methods, such as design-build, will require an engineer's estimate at an early point in preliminary design. In design-build project delivery, the design-build contractor takes on increased risk and will

Table 6.6. Programming and preliminary design phase delivery and procurement: Methods and tools.

DELIVERY AND PROCUREMENT STRATEGY Apply appropriate delivery methods to better manage cost because project delivery influences both project risk and cost			
Cost Estimation Management			Cost Estimation Practice
Delivery and Procurement Method			
	D1.1	Contract Packaging	
	D1.2	Delivery Decision Support	

price this risk based on the level of scope definition, proposed project responsibilities identified in the RFP, and project complexity. Early estimates must reflect the impact of using the design-build delivery approach. The influence of project delivery and procurement is important to the "prepare base estimate" and "risk analysis" steps (see Figure 6.1).

Other procurement methods may accelerate construction, such as when cost plus time (A+B) contracting approaches are used with design-bid-build project delivery. Costs for potential incentives must be included when cost estimates are prepared. The impact of construction acceleration might require increases in labor, material, and equipment costs. These types of impacts must be considered when preparing early cost estimates, especially when historical unit costs are used.

The packaging of a project in terms of a single contract or multiple contracts or establishing project limits must be considered early in design. Decisions that impact the number of contracts will influence the design processes and the costs of construction. The earlier decisions are made on project delivery and procurement approaches, the better the opportunity to incorporate appropriate costs into the estimates congruent with the delivery and procurement approach selected.

Project Complexity

The larger and more complex the project, the earlier decisions should be made with respect to delivery approach. Even with smaller and less complex projects, where procurement approaches such as cost plus time or incentives and disincentives are used, an early decision will enable cost estimates to properly reflect the impact that alternative delivery and contract approaches have on project cost and schedule.

Tips for Success

Prior to setting a baseline, the use of a decision support tool to identify the appropriate delivery and procurement approach may be beneficial to preparing an estimate consistent with the project delivery approach. The point here is to include costs in the estimate that reflect the impact of delivery and procurement approaches such as an engineer's estimate for a design-build project.

Tools

D1.1 Contract Packaging
D1.2 Delivery Decision Support

6.6 Strategy: Document Quality

The document quality strategy is perhaps most critical during the programming and preliminary design phase of a project, when plans and specifications are being developed. Document quality includes both design documents and the documents that the contractor will eventually use to price and construct the project. The methods suggested address both areas.

The three different methods applicable to the document quality strategy are described in Table 6.7.

6.6.1 Computer Software

Why?

The use of computer software facilitates consistent practices, which in turn support the document quality strategy. The ability of computer software to provide a structured format for preparing estimates promotes accurate data inclusion by multiple participants. Using templates to prompt project participants for general and specific project information will increase the quality of the project documents. The use of computer software is also discussed in the management, estimate quality, and integrity strategies of this chapter. Computer software is extensively used in the extraction of historical data, computations for risk analysis, and preparation of estimates (see Figure 6.1).

Project Complexity

With increased project complexity, there is an increased need to document adjustments and alternative evaluations as

Table 6.7. Programming and preliminary design phase document quality strategy: Methods and tools.

DOCUMENT QUALITY STRATEGY Promote cost estimate accuracy and consistency through improved project documents			
Cost Estimation Management		Cost Estimation Practice	
Computer Software		**Constructability**	
C2.1	Agency Estimation Software	C5.1	Constructability Reviews
C2.2	Commercial Estimation Software		
C2.4	Simple Spreadsheet	**Estimate/Document Review**	
		E1.1	Estimate/Document Review—External
		E1.2	Estimate/Document Review—Internal

cost estimates are prepared. Considering the potential for many adjustments due to additions, omissions, and alternative design solutions, it is essential to track adjustments accurately. Computer software enables the estimator to easily incorporate adjustments when more detail is available. A comparative analysis can be performed, especially for alternatives, to produce quality documents supporting project estimates.

Tips for Success

Successful implementation of computer software to encourage quality documents requires the agency to accurately identify minimum quality standards and to use computer software that portrays the information in a meaningful manner. Since all projects are not the same, the flexibility and ease with which changes can be incorporated and tracked with computer software makes the use of computers and supporting software imperative to the document quality strategy.

Tools

C2.1 Agency Estimation Software
C2.2 Commercial Estimation Software
C2.4 Simple Spreadsheet

6.6.2 Constructability

Why?

The quality of the documents used to prepare estimates impacts the quality of the estimate in terms of accuracy. Thus, design documents that provide the basis for cost estimates must accurately portray the design intent. Implementing constructability analysis will enhance project documents by reducing the potential for errors and omissions and will produce designs that are constructible. Constructability reviews can provide guidance as to the project construction phasing and staging approaches required to cost-effectively build the project. In this way, constructability will influence both "update design basis" and "prepare base estimate" steps (see Figure 6.1).

Project Complexity

As project complexity increases, the need for construction knowledge and experience in reviewing designs becomes critical. Construction input can aid the designer in developing designs that can be constructed more efficiently. This need is especially important for very large and complex projects, such as those in urban areas under high-traffic volumes. These types of projects require continuous input from construction experts beginning with project definition during programming and throughout preliminary design.

Tips for Success

Constructability is most successful when the process is formalized and is an integral part of the programming and preliminary design phase of project development. Identifying and using appropriate constructability experts is also critical in achieving successful constructability reviews. A constructability expert must be able to work effectively with project designers and provide meaningful input on design documents.

Tool

C5.1 Constructability Reviews

6.6.3 Estimate/Document Review

Why?

During the estimate review activity identified in Figure 6.1, there should also be a check on the quality of any documents used to prepare the estimate, even if the documents are considered preliminary. This is perhaps more important as preliminary design progresses and the plans and specifications are approved. As discussed in other sections, a very effective management approach for establishing the reliability of a cost estimate is to subject the estimate to review and verification.

Project Complexity

The formality of a project estimate review and the depth of the review will vary depending on the type of project and project complexity. In the case of routine, straightforward projects, a formal review may not be necessary. However, as project complexity and scope increase, it is necessary to conduct formal reviews. When very complex projects are being estimated, management should require an external review of the estimate by qualified professionals.

Tips for Success

Knowledgeable and experienced individuals who bring a broad perspective to the project and estimate formulation should be assigned to conduct these reviews. To be of value, the review must closely examine the assumptions that form the basis of the estimate.

Tools

E1.1 Estimate/Document Review—External
E1.2 Estimate/Document Review—Internal

6.7 Strategy: Estimate Quality

Both cost estimation management and cost estimation practices are critical to achieving accurate and consistent cost estimates during the programming and preliminary design phase. Agencies should seek to implement the methods identified in Table 6.8. It must not be forgotten that success in estimation practice is linked to the environment created by agency management.

Eleven methods are applicable to estimate quality for use during the programming and preliminary design phase of project development. Management support for internal estimate reviews is usually not an issue, but, in the case of complex projects, management should have procedures in place for organizing and conducting external reviews.

6.7.1 Computer Software

Why?

Estimate development at the programming and preliminary design phase involves a series of repetitive operations, use of historical data, and complex predictive analysis. Also, as the design progresses (from 5% to 80%), it will be necessary to periodically update the cost estimate. Computer software provides a platform to easily review, update, and modify estimates. The need for greater accuracy is met by cost-modeling techniques using computer software. Predictive analysis of various parameters (like market conditions) can identify cost influences. The ability to track changes efficiently is another useful feature of computer software. The use of computer software is also discussed in the management, document quality, and integrity strategies of this chapter. Computer software is extensively used in the maintenance and retrieval of historical data. Computer software can efficiently perform a large number of computations in support of the "estimate preparation" and "risk analysis" steps (see Figure 6.1).

Project Complexity

Large and complex projects may benefit more from computer software because these projects involve increased levels of detail and more calculations. This is particularly the case when multiple alternatives are being considered during the programming and/or early in preliminary design. As alternatives are analyzed, scope adjustments reflecting different scenarios are frequent and must be estimated quickly. Computer software aids in timely cost analysis. For more complex projects, tracking changes is also facilitated by computer software.

Tips for Success

The level of user skills and the flexibility of the software will determine the success of computer software. In addition, templates and output formats will enhance multiple-user environments and maintain consistency. Finally, computer software should facilitate automatically changing cost items that are estimated on a percentage basis.

Tools

C2.1 Agency Estimation Software
C2.2 Commercial Estimation Software
C2.3 In-House Conceptual/Parametric Estimation Software

6.7.2 Consistency

Why?

Estimations must be structured and completed in a consistent manner. Consistency is achieved by instituting operating procedures that serve as guides for all who prepare estimates. Consistency influences how information is used, such as input from disciplines, input from third parties, market conditions, and historical data (see Figure 6.1). Consistency is also required when preparing the base cost estimate and performing a risk analysis. Estimate consistency enables analysis, evaluation, validation, and monitoring of item costing.

Table 6.8. Programming and preliminary design phase estimate quality strategy: Methods and tools.

ESTIMATE QUALITY STRATEGY Use qualified personnel and uniform approaches to achieve improved estimate consistency and accuracy				
Cost Estimation Management			**Cost Estimation Practice**	
Computer Software			**Communication**	
C2.1	Agency Estimation Software		C1.7	Year-of-Construction Costs
C2.2	Commercial Estimation Software			
C2.3	In-House Conceptual/Parametric Estimation Software			
Consistency			**Design Estimation**	
C4.1	Cradle-to-Grave Estimators		D2.1	Analogous or Similar Project
C4.2	Estimation Checklist		D2.2	Agency Estimation Software
C4.3	Estimation Manual (Guidelines)		D2.3	Cost Based, Bottom Up
C4.4	Estimator Training		D2.4	Historical Bid Based
C4.6	Standardized Estimation and Cost Management Procedures		D2.5	Historical Percentages
C4.7	State Estimation Section		D2.6	Major Cost Items using Standardized Sections
			D2.7	Parametric Estimation
			D2.8	Spreadsheet Template
			D2.9	Trns•port
Creation of Project Baseline			**Document Estimate Basis and Assumptions**	
C6.1	Cost Containment Table		D4.1	Project Estimation File
C6.3	Scope Change Form			
Gated Process			**Estimate Review—External**	
G1.1	Checklists		E2.1	Expert Team
G1.2	Cost Containment Table			
Right-of-Way			**Estimate Review—Internal**	
R2.1	Acres for Interchange		E3.1	Formal Committee
R2.2	Advance Purchase (Right-of-Way Preservation)		E3.3	In-House/Peer
R2.3	Condemnation		E3.4	Round Table
R2.4	Relocation Costs		E3.5	Year-of-Construction Costs
			Project Scoping	
			P2.1	Estimation Checklist
			P2.2	Scoping Document
			P2.3	Work Breakdown Structure

Project Complexity

Consistent practices and procedures facilitate a multiple-user interface, minimize errors and omissions, and strengthen reporting and data-sharing activities. This becomes essential in the case of large and complex projects because they involve multiple disciplines and often require specialized input that must be acquired and integrated by estimators.

Tips for Success

Consistency in how information is used and how cost estimates are prepared is essential to producing accurate estimates. However, each project has different issues and conditions that influence the type of information used and the approaches to preparing the estimate.

Tools

C4.1 Cradle-to-Grave Estimators
C4.2 Estimation Checklist
C4.3 Estimation Manual (Guidelines)
C4.4 Estimator Training
C4.6 Standardized Estimation and Cost Management Procedures
C4.7 State Estimation Section

6.7.3 Creation of Project Baseline

Why?

For costs and the impact of changes to be tracked, all projects have to be monitored against a performance benchmark. Hence, a project cost baseline consistent with a defined scope and schedule must be established. A practice is to set this baseline when the scope of all major cost items can be adequately defined (i.e., 80% of cost lies in 20% of the project elements). This typically occurs during programming, although when the cost baseline is set may vary depending on agency policy. Further, setting a baseline provides a benchmark against which deviations and their impact can be documented and evaluated to ensure successful project delivery within budget. Deviations can be mapped over time for reconciliation with future estimates. Completing all the cost estimation steps, which are initiated during programming, leads to an approved baseline estimate, as shown in Figure 6.1.

Project Complexity

A cost baseline is required for every project, regardless of the project's size or complexity. The level of effort for creating the baseline cost may change and is substantial for large and complex projects. These large projects will likely require a greater percent of design completion prior to setting a baseline cost. A baseline cost can be set on less complex projects with a lower design completion (5% to 10% for a paving preservation project).

Tips for Success

It is necessary to create cost baselines when the major cost elements of a project have been defined and scope has been established. The baseline cost, schedule, and scope must be developed in sufficient detail to ensure that tracking of deviations can be accomplished. The timing of creating a cost baseline is best set during programming. The ability to identify deviations from the baseline and evaluate their impact in a timely manner is ultimately what makes this method successful.

Tools

C6.1 Cost Containment Table
C6.3 Scope Change Form

6.7.4 Gated Process

Why?

Critical milestones are often identified in the project development process, where decisions are made before a project can proceed to the next stage. At these decision milestones, cost estimates are prepared to aid in decision making. This mechanism of not permitting a project to move past a milestone point without proper approvals will allow for checks to ensure that cost estimates reflect the known scope and project conditions. Setting an approved cost baseline at the end of programming is an example of a gate in the project development process. A second gate may be when environmental clearance is obtained. A third gate may be when the construction estimation for the STIP is prepared and construction is approved for inclusion in the STIP. The cost estimation practice and cost estimation management processes depicted in Figure 6.1 must coincide with gates in the project development process.

Project Complexity

Complex projects involve many components that may easily be overlooked as the estimate is developed. A thorough review prior to releasing the project for further development provides a reasonable mechanism for ensuring that the project is ready to move forward to the next stage of design. This type of review at a gate in project development can ensure a more reliable estimate and control cost growth.

Tips for Success

The placement of gates over the project development time line is critical for this method to be successful. Another important aspect is that the review process at each gate must be effective and be performed in a timely manner to ensure that project development is not delayed.

Tools

G1.1 Checklists
G1.2 Cost Containment Table

6.7.5 Right-of-Way

Why?

Right-of-way costs are a significant component for many projects. Land acquisition requirements must be consistent with the scope of the project. To obtain realistic projections of right-of-way cost, appropriate experts must evaluate geographic, demographic, and market information. Other costs for acquiring land must be factored into estimates so that the estimates include all costs associated with right-of-way. Possibilities of litigations and other public concerns must also be accounted for in the estimate. Scope inputs from design disciplines and third parties are critical to preparing base estimates with appropriate contingencies covering right-of-way risks (see Figure 6.1).

Project Complexity

Typically, more complex projects that intersect with urban neighborhoods, historical sites, or environmentally sensitive areas require greater effort in estimating right-of-way costs.

Tips for Success

Identification and evaluation of several alternatives may lead to an economical solution when scoping right-of-way requirements during programming and early in preliminary design. Early identification of parcels that will be taken is critical to estimating right-of-way costs.

Tools

R2.1 Acres for Interchange
R2.2 Advance Purchase (Right-of-Way Preservation)
R2.3 Condemnation
R2.4 Relocation Costs

6.7.6 Communication

Why?

The project development process duration can be 2 years to over 10 years. The identification of project duration, and especially when construction will occur, is critical to accounting for inflation effects. Capturing future inflation will produce more realistic estimates. Estimate credibility will be increased when the estimate includes future inflation. In Figure 6.1, assessing market conditions when preparing base estimates and performing a risk analysis is influenced by this method.

Project Complexity

Complex projects typically have longer project duration from programming through construction than simple projects. The dollars added to account for inflation can be substantial in complex projects. These dollars must be included in cost estimates to properly reflect the estimated costs when construction is scheduled to be completed.

Tips for Success

Clearly communicating the estimated cost in year-of-expenditure dollars is critical. This approach ensures that project stakeholders are informed of all costs related to the project and that these costs are visible.

Tool

C1.7 Year-of-Construction Costs

6.7.7 Design Estimation

Why?

Project scope definition is continuously refined during the programming and preliminary design phase. The focus of programming is related to developing a baseline cost estimate. As the project moves into preliminary design, periodic estimate updates will be required. At some point during the preliminary design, the latest cost estimate becomes the basis for updating the STIP or for including construction cost into the STIP. Design estimation must produce consistent and accurate estimates at all points during the preliminary design. Estimators must incorporate more detailed data into their estimate by consulting with the design team. Design estimation must follow the steps shown in Figure 6.1, starting with the "update estimate basis" step and continuing through the "review total cost estimate" step. The critical step is "prepare base estimate."

Project Complexity

Complex projects will impact the tools used rather than the method itself. Some large projects may not fit standardized procedures typically used to estimate projects, so a cost-based, bottom-up approach may be the only way to estimate these projects. If the agency has adequate historical data on similar complex projects, these data are often used to develop early cost estimates. A combination of different tools may be required. Also, many different disciplines may be involved in developing cost estimates for large projects. Design estimation must be sufficiently flexible to accommodate these subsequent inputs and to ensure that project estimates are consistent. Smaller and less complex projects still can rely on spreadsheets and historical bid-based approaches.

Tips for Success

The level of scope definition and adaptation of standardized sections from previous projects will help in developing accurate early estimates. This is a scope-driven approach. During programming, the focus should be on the 20% of the items that contribute to 80% of the cost. Proper use of appropriate software is essential to successfully implement the design estimation method. Software, to be effective, must be supported by well-trained estimators. The tools that support design estimation must fit the application in terms of scope, available data, and time to prepare the estimate.

Tools

D2.1 Analogous or Similar Projects
D2.2 Agency Estimation Software
D2.3 Cost Based, Bottom 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

6.7.8 Document Estimate Basis and Assumptions

Why?

A critical component of preparing an estimate is documentation of the basis and assumptions used to derive costs. Such documentation will provide a vehicle for confirming to management that the estimate is accurate and follows sound practice. Further, with appropriate documentation, there is a means of tracking changes from the baseline cost relative to estimate basis and assumptions. This will aid in explaining cost impacts due to these changes. Because many disciplines are involved in estimate preparation, providing good documentation on the estimate basis and assumptions will help others who may update the estimate in the future. A substep of the "prepare base estimate" step in Figure 6.1 is to document the estimate basis and assumptions (see Table 2.2). This method would influence how the documentation is prepared.

Project Complexity

Large and complex projects require greater estimate efforts. Many times, multiple estimators are engaged to perform project estimation. Thus, all estimators must follow a set standard for documenting estimate basis and assumptions. On larger projects, a center point of contact for ensuring that proper documentation occurs is often required. The documentation of this information is crucial in maintaining consistent cost estimation practices.

Tips for Success

Creating standard procedures and educating estimation personnel about the procedures is the key to success for this method. Good state highway agency estimation manuals support good estimation practice.

Tool

D4.1 Project Estimation File

6.7.9 Estimate Review—External

Why?

Cost estimates are merely predictions and can therefore be wrong. All project estimates should be reviewed for the validity of their basis; however, the formality and depth of the review will vary depending on the type of project and its complexity. External estimate reviews are conducted for complex projects and projects employing new technology. A lack of in-house competency in specialized areas will lead to the need for consulting external experts. Some project elements may require, for example, unique construction methods where expert review would be helpful in confirming estimated costs. At times, external estimate reviews are important to confirm that good estimation practices are being followed. These reviews typically focus on the estimate basis, assumptions, and methodology. This method supports the "review total cost estimate" step (see Figure 6.1).

Project Complexity

The formality of a project estimate review and the depth of the review at this stage in project development will vary depending on the type of project and project complexity. When very complex projects or projects involving new construction methods are being estimated, management should require that there be an external review of the estimate by qualified professionals. This external review should include a risk analysis that identifies the critical elements of the estimate, identifies the high and low cost limits for each critical element, and assigns a probability to the actual cost.

On very large projects or projects with unique design features, using external experts to provide an unbiased review of project estimates is sound practice. This type of review can help ensure estimate consistency and accuracy. Further, an expert review team can ensure estimate credibility for large projects that are most often highly visible to the public.

Tips for Success

Selecting an external expert team with the right qualifications is critical to obtaining a credible estimate review. A team approach may also provide a more unbiased review. An independent review by an individual is often appropriate for specialized construction methods.

Tool

E2.1 Expert Team

6.7.10 Estimate Review—Internal

Why?

All estimates must be reviewed to ensure that they do not contain any discrepancies, errors, or omissions. Consulting peers and subject matter experts adds value to an estimate and can identify possible weaknesses. Estimates are based on many assumptions, and these assumptions need to be justified as the estimate is reviewed. Reviews provide feedback to estimators about the completeness and accuracy of their work. This method supports the "review total cost estimate" step shown in Figure 6.1.

Project Complexity

Complex projects may have cost elements that estimators are unfamiliar with and require an expert review. Estimate reviews provide the opportunity to minimize ambiguities by imparting appropriate expertise from within the agency.

Tips for Success

Conducting reviews at an appropriate time during the estimation development process and consulting suitable experts will minimize project cost estimate changes. The integrity of such reviews is essential for this method to be successful.

Tools

E3.1 Formal Committee
E3.3 In-House/Peer
E3.4 Round Table
E3.5 Year-of-Construction Costs

6.7.11 Project Scoping

Why?

Thorough and accurate scoping during programming enhances the quality of the baseline cost estimate. Definitive scoping efforts at the very beginning have been shown to be more cost-effective than scope control efforts in the latter stages of the project development process. Scoping provides the input for the estimate basis shown in Figure 6.1. It also can help structure the scope in a framework that provides a systematic breakdown of the scope into project deliverables.

Project Complexity

Projects of all levels of complexity will benefit from project scoping efforts, even in the earliest stages of the project development process. Larger, more complex projects will especially benefit from the project scoping effort. Good documentation of the project scope eliminates errors and omissions in the estimate. Estimate reviews can be further facilitated if the scope is properly structured and documented systematically.

Tips for Success

The agency should consider developing standard management practices and a standard set of forms to document the project scope. Because project scope is often revisited during preliminary design, standard practices provide an audit trail of how the project's scope was developed, structured, and changed. Management needs to complete scope forms early and update them regularly as changes are made. Doing so will allow management to track project scope, and estimators will always know what should be included in the estimate. Scope forms provide a graphic view of what has changed since the previous estimate was completed.

Tools

P2.1 Estimation Checklist
P2.2 Scoping Document
P2.3 Work Breakdown Structure

6.8 Strategy: Integrity

The establishment of management structures that shield estimators from external and internal pressures to produce a low project estimate will support accurate project estimation. Estimate reviews to ensure integrity are repetitive, taking place to some extent whenever the estimate is modified. Agencies should institute cost estimation management and cost estimation practices as identified in Table 6.9 to ensure estimate integrity.

Eight methods are applicable to the integrity strategy described in Table 6.9 for use during the programming and preliminary design phase of project development.

6.8.1 Communication

Why?

Communication has been discussed in earlier strategies of this Guidebook. As applicable to the integrity strategy, it is predominantly focused on keeping all project team members and external parties informed and updated with respect to the current estimated project cost. Efficient communication channels must be established, and the exchange of information must be clear and succinct. Efforts must be made to ensure that the significance of cost information, which is communicated, is interpreted appropriately. Communication of uncertainty and any discrepancies observed must be

Table 6.9. Programming and preliminary design phase integrity strategy: Methods and tools.

INTEGRITY STRATEGY Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates					
Cost Estimation Management			Cost Estimation Practice		
Communication			**Consistency**		
	C1.2	Communication of Uncertainty		C4.3	Estimation Manual (Guidelines)
	C1.7	Year-of-Construction Costs		C4.5	Major Project Estimation Guidance
				C4.6	Standardized Estimation and Cost Management Procedures
Computer Software			**Estimate Review—External**		
	C2.1	Agency Estimation Software		E2.1	Expert Team
	C2.2	Commercial Estimation Software			
	C2.3	In-House Conceptual/Parametric Estimation Software			
Design to Mandated Budget			**Estimate Review—Internal**		
	D3.1	Design to Cost		E3.1	Formal Committee
				E3.3	In-House/Peer
				E3.4	Round Table
				E3.5	Year-of-Construction Costs
			Validate Costs		
				V1.1	Estimation Software
			Verify Scope Completeness		
				V3.1	Estimation Checklist

brought to the notice of peers immediately for remedial procedures. In Figure 6.1, several steps that are concerned with the transmission of information and approvals are supported by this method. Inputs from disciplines, third parties, and project requirements have to be communicated without ambiguity.

Project Complexity

Complex projects are highly visible to project stakeholders. Proper communication of estimate information is critical to maintaining stakeholder support. Further, proper communication of changes in project costs and the reasons for these changes is needed to ensure the credibility of the agency with respect to cost estimation management for large and complex projects.

Tips for Success

Training personnel on tools that are useful to communicate project cost information is helpful. Developing mechanisms to describe project cost information in a simple and understandable manner is important for successful communication.

Tools

C1.2 Communication of Uncertainty
C1.7 Year-of-Construction Costs

6.8.2 Computer Software

Why?

The use of computer estimation software in all phases of project development can increase estimate integrity. One way to maintain estimate integrity is to control the bias that can be introduced into the estimation process. Bias can be intentionally or unintentionally introduced into an estimate due to pressures, real or perceived. One way to reduce bias is to use standardized computer software. Computer software can be programmed to highlight abnormalities within the estimate by checking cost ratios between related elements or whether historical data used in the estimate are outside of predetermined ranges. Such identification helps in recognizing errors and the existence of bias. The use of computer software is also discussed in the management, document quality, and estimate quality strategies of this chapter. In Figure 6.1, the "maintenance of historical databases" step and the "use of complex calculations" step are supported by computer software. Computer software also provides a secure and reliable environment for estimate review and communication.

Project Complexity

Highly complex projects may have a greater vulnerability to integrity issues in cost estimation management. The need to meet a desired price may influence the use of data in estimation. Computer software can help identify such problems when checks are generated to determine if data are outside a normal range.

Tips for Success

Secure and reliable features built into computer software can help ensure the success of the software in resolving cost escalation factors associated with integrity. Restricted and endorsed access by all users will assist in identification of responsible defaulters.

Tools

C2.1 Agency Estimation Software
C2.2 Commercial Estimation Software
C2.3 In-House Conceptual/Parametric Estimation Software

6.8.3 Design to Mandated Budget

Why?

In some cases, funding for a project is fixed by an external source, such as the state legislature. The scope of work may or may not be congruent with the allocated project funds. The design to mandated budget method is often used when a project team encounters a predetermined fixed budget. The design that matches the cost estimate and the budget cost of the project are compared. If the estimated cost during design exceeds the budget cost of the project, then one or both need to be reevaluated before continuing with project development. The scope will be reduced if the current cost estimate is higher than the fixed budget. The scope may be added if the current estimate is substantially less than the fixed budget. This method impacts the entire process shown in Figure 6.1.

Project Complexity

This method is more likely used on small to medium-sized projects, where the scope is easier to define and control. This method would not be recommended for major projects that are technically complex, although it has been used on some large transportation projects in the nonhighway area. If projects are approved by the state legislature based on a line-item budget, then the size of the project makes little difference when applying this method.

Tips for Success

Proper identification and evaluation of appropriate designs will increase the likelihood of the project being completed within budget. Cost estimates must be periodically updated to ensure that the current cost is under the fixed budget. Documenting areas of scope reduction is important so that project stakeholders understand what is being delivered.

Tool

D3.1 Design to Cost

6.8.4 Consistency

Why?

Estimation processes often involve the participation of multiple estimators with diverse backgrounds and approaches to estimation. Practices and regulations can vary from district/region to district/region within a state. There is a need to establish acceptable and common procedures before any project can be estimated. Procedures and guidelines will lead to consistent approaches to estimating cost and will help to ensure integrity in the estimation process. Procedures should be developed to encompass all steps and inputs shown in Figure 6.1.

Project Complexity

It may be helpful to develop specific guidelines for estimating major projects, such as those with a cost greater than some fixed figure or having certain attributes. Projects less than this cost should follow standard procedures related to cost estimation management and cost estimation practices.

Tips for Success

Training and education about the procedures and/or guidelines being adopted for every project is mandatory for all project team participants. Choosing the right estimation approach is essential for this method to succeed.

Tools

C4.3 Estimation Manual (Guidelines)
C4.5 Major Project Estimation Guidance
C4.6 Standardized Estimation and Cost Management Procedures

6.8.5 Estimate Review—External

Why?

Projects are often accompanied by significant ambiguity. This fact, in addition to lack of specialized personnel within a state highway agency, may necessitate consulting with external subject matter experts regarding project estimates or cost management practices. External expert reviews can be used to validate internal reviews. In Figure 6.1, this method supports the "review total cost estimate" step for specialized items of work. Also, the change loop shown on the right side of Figure 6.1 may require expert opinion to assess the impact of potential changes.

Project Complexity

Agencies generally have staff capable of handling normal issues and a limited extent of complex issues. On very large projects or projects with unique designs, using external experts to provide an unbiased review of project estimates is sound practice. This type of review can help ensure estimate consistency and accuracy.

Tips for Success

Identifying elements that may adversely affect project cost and seeking the right expertise to review these elements on a timely basis are essential for this method to succeed. Also, a thorough review of estimate assumptions and basis is required if an external expert team is used to review an estimate.

Tool

E2.1 Expert Team

6.8.6 Estimate Review—Internal

Why?

It is always necessary to independently verify that an estimate is complete and that it matches the project scope. In Figure 6.1, there is an "estimate review" step that is positioned after the "risk determination" step has quantified the project risk and an appropriate contingency amount has been included in the estimate. While this is depicted as a single step, it is normally a repetitive step, taking place to some extent whenever the estimate is modified.

Estimate reviews have been discussed in earlier sections of this chapter in several contexts. With respect to integrity, this method revolves around unbiased reviewers and using personnel independent from the project development team. Candid opinions and timely modifications to estimates at different levels of reviews will improve estimate accuracy.

Project Complexity

In the case of an uncomplicated overlay project, the review may be limited to verification that all elements are accounted for by the use of a simple checklist. However, as project complexity and scope increase, it is necessary to conduct more formal reviews. Complex projects may have several cost elements that estimators are unfamiliar with and require an expert opinion. Estimate reviews provide the opportunity to minimize ambiguities by imparting appropriate expertise from within the agency.

Tips for Success

Reviewers must have adequate expertise and credibility from the state highway agency viewpoint based on previous project experience. There should be no tolerance for any compromise on the results of internal review evaluations. Reviewers should ensure that all costs include future inflation to the midpoint of construction.

Tools

E3.1 Formal Committee
E3.3 In-House/Peer
E3.4 Round Table
E3.5 Year-of-Construction Costs

6.8.7 Validate Costs

Why?

Early estimation procedures involve a large number of assumptions and require validation as the scope is developed and assumptions are reflected in estimated costs. Estimate assumptions and basis must be compared with standard practices. Reasonable adjustments can be made to assumptions and basis for specific project conditions. Review of these assumptions and basis can ensure that costs are valid and represent the best engineering judgment of project estimators. The performance of the "review total cost estimate" step and subsequent "estimate approval" step would be guided by this method (see Figure 6.1).

Project Complexity

Estimate assumptions and a statement of the basis are required for every project. Larger and more complex projects may require more time and effort to fully document and explain assumptions.

Tips for Success

Assumptions and the basis used to estimate costs must be clearly documented to validate costs and for future evaluation as estimates are updated and used for cost management. Estimation software should allow for documenting assumptions as the estimator prepares the estimate.

Tool

V1.1 Estimation Software

6.8.8 Verify Scope Completeness

Why?

Projects typically are broken down into many work packages and distributed among different project participants. It is very easy for personnel to overlook certain items of work while preparing estimates under time pressures. Hence, a method to check for completeness of work packages is required. This can be accomplished by generating simple scope checklists and reviewing the estimate for completeness (see Figure 6.1).

Project Complexity

Complex projects involve a significantly large number of work packages that may be independent or dependent on preceding activities. Ensuring that all elements included in work packages are covered in cost estimates is more time consuming and more difficult to achieve on large projects, especially during the programming and preliminary design phase, when project scope is evolving.

Tips for Success

A key to successful use of this method is the careful consideration of all critical elements that are shown on the checklist during the cost estimation process and ensuring that the impact of these elements is accurately captured in the estimate.

Tool

V3.1 Estimation Checklist

6.9 Summary

Table 6.10 lists all the methods and tools presented in this chapter for use in the programming and preliminary design phase of project development. This list can be used as a quick reference to help navigate Appendix A for descriptions of the tools. Table 6.10 can also be used as a checklist for selecting tools that should be employed on any one project. The checklist forms a self-assessment tool for agencies to benchmark against. These methods and tools were found in highway agencies throughout the country. While no agency was found to possess all of the methods and tools, all methods and tools exist and have the potential to be applied by any single agency.

Table 6.10. 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 (Original/Previous/ Current)
	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
	C1.3	Communication within State Highway Agency
	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
	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
Delivery and Procurement Method		
	D1.1	Contract Packaging
	D1.2	Delivery Decision Support
Design Estimation		
	D2.1	Analogous or Similar Project
	D2.2	Agency Estimation Software
	D2.3	Cost Based, Bottom 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

Method/Tool		
Design to Mandated Budget		
	D3.1	Design to Cost
Document Estimate Basis and 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
Project Scoping		
	P2.1	Estimation Checklist
	P2.2	Scoping Document
	P2.3	Work Breakdown Structure
Public Involvement		
	P3.1	Meetings
Recognition of Project Complexity		
	R1.1	Complexity Definitions
Right-of-Way		
	R2.1	Acres for Interchange
	R2.2	Advance Purchase (Right-of-Way Preservation)
	R2.3	Condemnation
	R2.4	Relocation Costs
	R2.5	Right-of-Way Estimator Training
	R2.6	Separate Right-of-Way Estimators
Risk Analysis		
	R3.1	Analysis of Risk and Uncertainty
	R3.2	Contingency—Identified
	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

CHAPTER 7

Guide for Final Design Phase

Introduction

Once a project reaches the final design phase of its development, cost estimation focuses on the engineer's estimate and the project's scope is now reflected in the contract plans and specifications, including specific line items with quantities.

Figure 7.1 is a flow diagram of how the cost estimation practice and cost estimation management processes proceed during final design. As shown in Figure 7.1, consideration of market conditions, the requirements imposed by third parties, and the macroeconomic environment are critical inputs to cost estimation in this phase. In addition, the estimate should reflect a level of contingency congruent with project risks. Estimation management would cover the steps of obtaining appropriate approval of the engineer's estimate and comparing the engineer's estimate with bid prices received from contractors. Additionally, it is necessary to consider the funds available in the STIP once the engineer's estimate is complete. Finally, another purpose of the engineer's estimate is to obligate funds for construction.

In the final design phase of a project, many of the methods and tools of a strategy help address the pressure to meet previous commitments concerning cost and schedule and to expand project scope. Additionally, many of the methods and tools discussed in this chapter help identify and mitigate project risk by drawing attention to market conditions, including the possibility of unforeseen events and unforeseen conditions. Table 7.1 shows the link between strategies and cost escalation factors in the final design phase.

Methodology

This chapter is based on and uses the cost escalation factor definitions and strategies described in Chapter 3. Agencies should seek to identify the cost escalation factors that, during the final design phase of a project, have historically caused estimation problems for their organization and then apply the appropriate strategies to achieve better performance.

Use Table 7.1 to determine which strategies may provide resources to address escalation factors that are causing problems. Specific strategies of interest for the final design phase, along with the methods and tools that are available, are found within Chapter 7. Detailed information on the tools can be found in Appendix A.

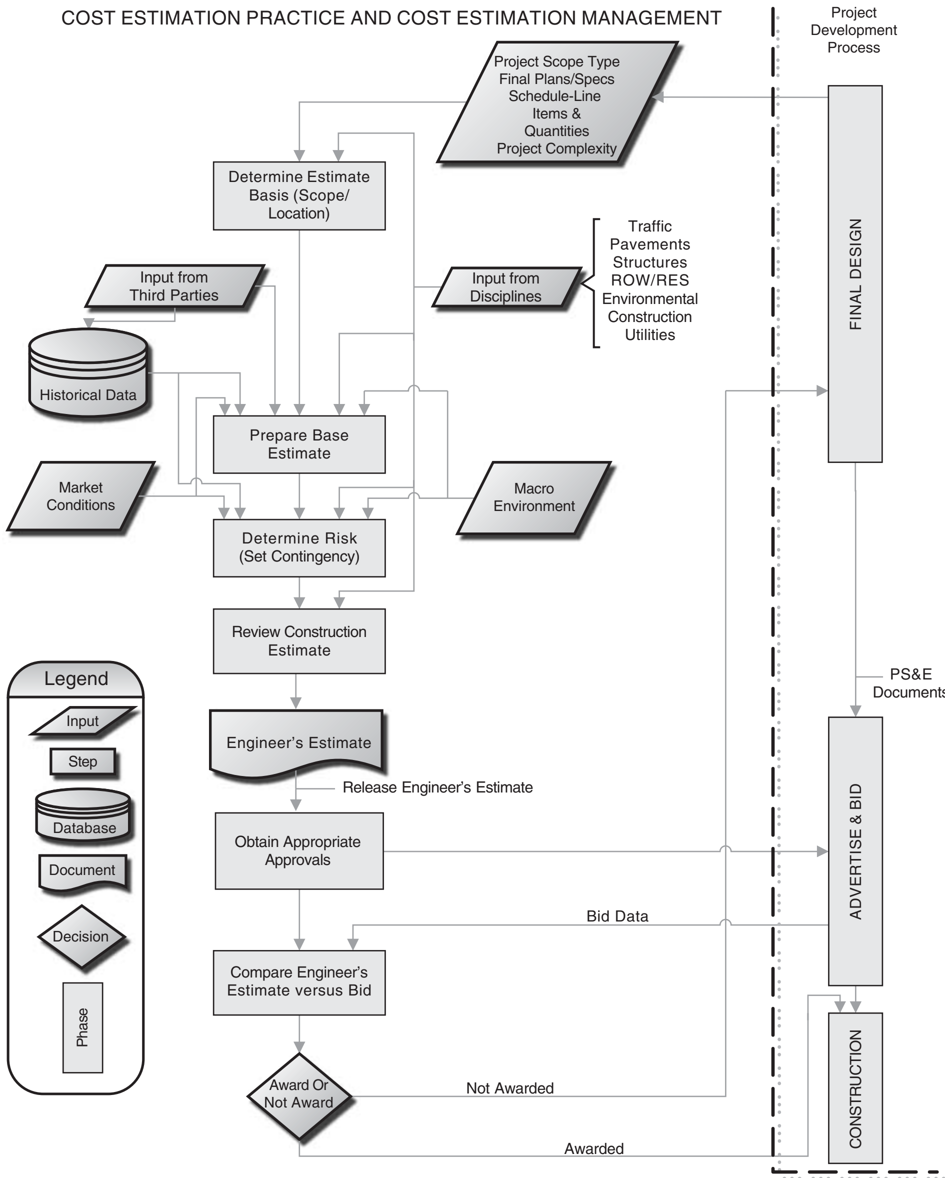
Once a strategy is selected to address a cost escalation factor, the user must decide if it is better to use a cost estimation management solution, a cost estimation practice solution, or both. The question of which approach should be used is influenced by internal agency constraints.

7.1 Strategy: Management

The execution side of cost estimation—cost estimation practice—depends highly on how the agency manages project development and the management support provided to those charged with executing project development, including estimate and schedule preparation.

This section specifically identifies management methods and tools that support achieving estimate quality. The estimation practice methods that track with the management strategy methods are also identified in Table 7.2 and will be discussed in the estimate quality section of this chapter.

Senior state highway agency managers should view themselves as investors, developers, and strategists. Management has the responsibility to invest and develop project staff and to provide the staff with the resources to effectively perform their jobs. Senior management can create an environment for success, ensure that appropriate oversight processes are established and functioning, and position the right people for the tasks. Success in estimation practice is linked to the environment created by agency management.



ROW = right-of-way
RES = real estate service
PS&E = plans, specifications, and estimates

Figure 7.1. Flow diagram for cost estimation practice and cost estimation management during final design.

There are seven different management methods described here for use during the final design stage of project development, as shown in Table 7.2.

7.1.1 Budget Control

Why?

Even during final design, there can be scope changes; therefore, management must approve the scope that is the basis for the final estimate. This confirmation would normally take place before the final estimate is prepared. As depicted in Figure 7.1, the "determine estimate basis" step would encompass this assumption of management control.

One way to control scope and cost is to demand that the project design conform to the project budget; this forces designers to be constantly aware of the cost implications of their designs.

Even at this late stage in project development, management must maintain strict control of the budget and be regularly updated as to scope and cost changes or to external pressures that could impact cost.

Table 7.1. Link between strategies and cost escalation factors in the final design phase.

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

Project Complexity

The importance of strict budget control increases with more complex projects and with projects that have longer development durations. Because external groups view project dollars as a source of funds for their pet schemes, longer development times provide more opportunities for such groups to prevail.

Tips for Success

Budget control is tied to scope control and rests in the hands of state highway agency management. The estimator provides a forecast of cost based on a defined project scope. To control cost—that is, to protect the estimate—management can use budget control methods to limit scope creep.

Tools

B1.2 Constrained Budget
B1.4 Summary of Key Scope Items (Original/Previous/Current)
B1.5 Variance Reports on Cost and Schedule

7.1.2 Consistency

Why?

An estimate is a permanent document that serves as a basis for business decisions. It must be in a form that can be understood, checked, verified, and corrected. There must be consistency.

Necessary consistency is achieved by instituting operating procedures that serve as guides for all parties engaged in the estimation processes. Therefore, in Figure 7.1, consistency comes to play in all the activities: input from disciplines, input from third parties, assessing market conditions, extracting historical data, prepare base estimate, determine risk, and review estimate.

Management should ensure that the agency's estimation group has developed a standard estimation manual of practice and that training is provided to all those involved in estimate preparation. Other good practices are the establishment of a section or staff dedicated to estimate preparation and the use of cradle-to-grave estimators.

Table 7.2. Final design phase management strategy: Methods and tools.

MANAGEMENT STRATEGY Manage the estimation process and costs through all stages of project development			
Cost Estimation Management		Cost Estimation Practice	
Budget Control		**Budget Control**	
B1.2	Constrained Budget	B1.2	Constrained Budget
B1.4	Summary of Key Scope Items (Original/Previous/Current)	B1.4	Summary of Key Scope Items (Original/Previous/Current)
B1.5	Variance Reports on Cost and Schedule		
Consistency		**Consistency**	
C4.1	Cradle-to-Grave Estimators	C4.1	Cradle-to-Grave Estimators
C4.2	Estimation Checklist	C4.2	Estimation Checklist
C4.3	Estimation Manual (Guidelines)	C4.3	Estimation Manual (Guidelines)
C4.4	Estimator Training	C4.4	Estimator Training
C4.5	Major Project Estimation Guidance	C4.5	Major Project Estimation Guidance
C4.6	Standardized Estimation and Cost Management Procedures	C4.6	Standardized Estimation and Cost Management Procedures
C4.7	State Estimation Section	C4.7	State Estimation Section
Estimate Review—External		**Estimate Review—External**	
E2.1	Expert Team	E2.1	Expert Team
Estimate Review—Internal		**Estimate Review—Internal**	
E3.1	Formal Committee	E3.1	Formal Committee
E3.2	Off-Prism Evaluation	E3.2	Off-Prism Evaluation
E3.3	In-House/Peer	E3.3	In-House/Peer
E3.4	Round Table	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		
Plans, Specifications, and Estimates (PS&E)		**Plans, Specifications, and Estimates (PS&E)**	
P1.1	Agency Estimation Software	P1.1	Agency Estimation Software
P1.2	Commercial Estimation Software	P1.2	Commercial Estimation Software
P1.5	Trns•port	P1.5	Trns•port

Project Complexity

Consistency is an important feature of all estimates, but its impact on performance increases with project complexity.

Tips for Success

Poor administration—including overly complex organizational structures, convoluted contracting practices, and inexperienced personnel—will cause project cost problems stretching from the original estimate to completion of construction.

Tools

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

7.1.3 Estimate Review—External

Why?

Cost estimates are merely predictions and can therefore be wrong. All project estimates should be reviewed for the validity of their basis; however, the formality and depth of the review will vary depending on the type of project and its complexity. In Figure 7.1, there is an "estimate review" step that is positioned after the "determine risk" step has quantified the project risk and an appropriated dollar amount has been included in the estimate. While this is depicted as a single activity, it would normally be repetitive, taking place to some extent whenever the estimate is modified.

Project Complexity

The formality of a project estimate review and the depth of the review at this stage in project development will vary depending on the type of project and project complexity. When very complex projects or projects involving new construction methods are being estimated, management should require that there be an external review of the estimate by qualified professionals. This external review should include a risk analysis that identifies the critical elements of the estimate, identifies the high and low cost limits for each critical element, and assigns a probability to the actual cost.

Tips for Success

To be of value, the review must closely examine the assumptions that form the basis of the estimate, and knowledgeable and experienced individuals who are independent of the project team must conduct the review.

Tool

E2.1 Expert Team

7.1.4 Estimate Review—Internal

Why?

Often, estimators focus mainly on the accuracy of unit costs and the project quantities and fail to consider the effects of soft issues. Therefore, to address such lack of perspective, an "estimate review" step is positioned after the "determine risk" step in Figure 7.1. While this is depicted as a single activity, it would normally be repetitive, taking place whenever the estimate is modified.

Project Complexity

In the case of a simple overlay project, the review may consist of a simple verification against a standard checklist. However, as project complexity and scope increase, it is necessary to conduct formal reviews. When very complex projects or projects involving new construction methods are being estimated, management should require that, in addition to the internal review, there be an external review of the estimate by qualified professionals.

Tips for Success

To be of value, the review must closely examine the assumptions that form the basis of the estimate. Knowledgeable and experienced individuals who are independent of the project team must conduct the review.

Tools

E3.1 Formal Committee
E3.2 Off-Prism Evaluation
E3.3 In-House/Peer
E3.4 Round Table

7.1.5 Gated Process

Why?

The project estimated early in project development is often not the project actually built. Scope changes to the original concept usually result from a better understanding of the needs that drive a project. With most scope changes, there is a resulting increase in project cost. 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. Management can then create a gated project development process that controls the project development steps and the advance of project development from one milestone to the next. Projects cannot advance to the next step without approval. Gates can be placed at management's discretion, but the critical points during final design are after the "determine risk" and "review estimate" steps.

One nontransportation source reported using an extremely formalized gated process. Before a project can continue in the development process, the project team in this organization must hold a meeting in which the Construction Industry Institute's (CII's) Project Definition Rating Index (PDRI) is completed. The PDRI scores a project's level of scope definition as compared with historic data on scope definition. The project must achieve a minimum score before the project can continue. If the project does not obtain the minimum score, then the project is returned to the previous phase for more definition.

Project Complexity

As project complexity increases, the benefits to be derived from a gated process increase because the gated process forces the project development team to carefully review the issues impacting project cost increases before proceeding.

Tips for Success

A gated process is a means for achieving project and estimate success because it provides the basis for a structured assessment of scope definition, cost, and schedule before a project can move to the next step in its development. State highway agencies could make a gated process part of their work program update cycles.

Tools

G1.1 Checklist
G1.2 Cost Containment Table

7.1.6 Identification of Changes

Why?

The scope and cost baseline of every project should be the reference against which all changes are compared. Throughout project development and construction, the baselines are used to evaluate performance. Most agencies that practice baselining of their projects report doing so usually when an identified need becomes a real project and is budgeted.

The identification of changes method is normally positioned to intercept inputs impacting scope and cost. In Figure 7.1, identification of changes would filter the inputs from disciplines and the inputs from third parties. It would also identify any downstream changes to the "determine estimate basis" step.

Project Complexity

As project complexity increases, more rigorous management attention to conformance with the scope and cost baseline is critical. The establishment of a project scope and cost baseline is fairly straightforward for routine projects but becomes much more difficult as project complexity increases. This is primarily because complex projects have many more scope and design unknowns during the early phases of project development.

Tips for Success

Management must be informed of project changes and external impacts that affect the baselines and should have procedures in place that restrict changes unless approved by senior management.

Tools

I1.1 Cost Containment Table
I1.2 Estimation Scorecard
I1.3 Project Baseline
I1.4 Scope Change Form

7.1.7 Plans, Specifications, and Estimates (PS&E)

Why?

Computer software supports consistence, allows the manipulation of large amounts of data, and speeds the transfer of information. In Figure 7.1, the impact is primarily with the handling of the historical data and in the estimate creation activities, but software is also used in the "determine risk" step when simulations are conducted to assess the impact of specific risks.

Computers and estimation software enhance the ability of engineers to manage large data sets that are used in developing estimates for all types of projects. Additionally, estimation software provides a record of changes to the estimate and permits easy screening of decisions.

In the case of state highway agencies, the most widely used estimating software is Estimator™ by InfoTech. Due to the flexibility that software provides, the estimator can adjust unit costs or percentages according to the project's complexity. One state highway agency currently uses a commercial estimation program that is used by many contractors and that was originally developed to facilitate detailed estimation by a large contracting organization. Such programs allow the development of estimates based on selected materials, equipment, methods, and crew productivity instead of historical bid data.

Project Complexity

In the case of a complex project for which there is no historical bid data, the development of a bottom up estimate using commercial software maybe the only way to arrive at a realistic estimate of project cost.

Tips for Success

Estimation programs with preloaded templates help project teams define the project scope, cost, and schedule. The software provides a means to track estimate changes during project development, and it can assist in project review. A training program is vital—this can be a formal set of classes for all estimators, mentoring among the estimators in the section, or support for estimators to attend off-site conferences, seminars, or classes pertinent to their work.

Tools

P1.1 Agency Estimation Software
P1.2 Commercial Estimation Software
P1.5 Trns•port

7.2 Strategy: Scope and Schedule

Even at this late stage in project development, cost estimation management is the key to controlling project scope and schedule. Agencies should seek to implement management solutions, as identified in Table 7.3. However, it must not be forgotten that success in estimating practice is linked to the environment created by agency management.

There are six different scope and schedule methods described here for use during the final design phase of project development.

7.2.1 Buffers

Why?

Underestimation—driven by optimism—is the demonstrated systematic tendency to be overoptimistic about key project parameters. Internally, underestimation of cost can arise from the state highway agency estimator's or consultant's identification with the agency goals for maintaining a construction program. External pressures can also cause problems.

Actions by the state highway agency 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. All such changes in scope must be approved by management with a full understanding of their cost impacts.

Buffers are positioned between or within processes impacting scope and cost. In Figure 7.1, buffers would typically be found separating any scope and schedule decision from actual estimation processes, such as the "prepare base estimate" step.

Table 7.3. Final design phase scope and schedule strategy: Methods and tools.

SCOPE AND SCHEDULE STRATEGY Formulate definitive processes for controlling project scope and schedule changes			
Cost Estimation Management			Cost Estimation Practice
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 within State Highway Agency	
	C1.4	Definitive Management Plan	
	C1.7	Year-of-Construction Costs	
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	
Identification of Changes			
	I1.1	Cost Containment Table	
	I1.2	Estimation Scorecard	
	I1.3	Project Baseline	
	I1.4	Scope Change Form	
Value Engineering			
	V2.1	Value Engineering	

Project Complexity

Internal and external pressures can become problems, even on very small (dollarwise) and seemly simple projects. Urban projects that impact the community and projects through environmentally sensitive areas will usually generate significant external pressure. So the issue is more dependent on project content than on complexity.

Tips for Success

If state highway agencies truly want accurate project estimates, there must be organization structures in place that shield estimators from external and internal pressures to produce a low project estimate. Additionally, to control scope and, consequently, project cost, management must require that an estimate of the cost associated with any scope change accompany the change request.

Tools

B2.1 Board Approvals
B2.2 Constrained Budget
B2.3 Management Approvals

7.2.2 Communication

Why?

A thorough understanding of community expectations, together with the identification and communication of the uncertainty, project scope, and cost unknowns, helps in managing project cost in all phases of project development.

Communication is a very important aspect of state highway agency relations with third parties, and it is important in conveying the precision of the estimate. In Figure 7.1, this involves the input from third parties, the "determine risk" step, and the statements about estimated cost (including the values from the "prepare base estimate," "review estimate," and "engineer's estimate" activities).

Project Complexity

Inherently, complexity adds risk to a project; therefore, the importance of communication, particularly communication of uncertainty, becomes more important with project complexity and project visibility.

Tips for Success

Institutional communication demands attention not just to content, but also to attitude—openness, accessibility, and sincerity are necessary. As the project moves through preliminary design to final design, the amount of uncertainty in the estimate should diminish, but there will still be uncertainty, and the level of uncertainty must be effectively communicated. Communication between internal departments of an agency is imperative throughout project development given the intricacy and number of people involved in developing even the simplest project.

Tools

C1.1 Communication of Importance
C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency
C1.4 Definitive Management Plan
C1.7 Year-of-Construction Costs

7.2.3 Estimate Review—External

Why?

Estimation experience of state highway agency personnel charged with developing estimates ranged from less than 1 year to more than 40 years across the 50 state highway agencies. Several state highway agencies have reported having estimators with minimal experience and additionally stated that they had in recent years lost their most experienced personnel to retirement and had not retained mid-level personnel to ensure that the overall experience level in estimation would remain high.

Previously, in Section 7.1.4, an external estimate review was offered as a validation of the estimated project cost, but an external review also serves to ensure that the estimate matches the scope and schedule of a project. In Figure 7.1, the "estimate review" step is positioned after the "risk determination step." However, for major projects this could be a repetitive activity.

Project Complexity

The formality of a project estimate review and the depth of the review will vary depending on the type of project and the project's complexity. In the case of very complex projects or projects involving new construction methods, estimation management should require that there be an external review of the estimate by qualified professionals.

Tips for Success

The external review should carefully study the scope and schedule of the project as described in the contract documents. To be of value, the review must closely examine the match between the stated scope and the project design as presented in the contract documents that are available at this point in project development.

Tool

E2.1 Expert Team

7.2.4 Estimate Review—Internal

Why?

As discussed in Sections 7.1.4 and 7.1.5, a very effective management approach for establishing the reliability of a cost estimate is to subject the estimate to review and verification. In Figure 7.1, reviews occur to some extent following each "prepare estimate" activity, but the primary examination is the depicted "review estimate" step.

Project Complexity

Whether the review is conducted by agency personnel or by individuals who are independent of the agency depends on the type of project and project complexity. In the case of a straightforward overlay project, a formal review may not be necessary. However, as project complexity and scope increase, it is necessary to conduct formal reviews. Very complex and high-profile projects should have an external review of the estimate by qualified professionals.

Tips for Success

To be of value, the review must closely examine the assumptions that form the basis of the estimate and the review must be conducted by knowledgeable and experienced individuals who are independent of the project team.

Tools

E3.1 Formal Committee
E3.2 Off-Prism Evaluation
E3.3 In-House/Peer
E3.4 Round Table
E3.5 Year-of-Construction Costs

7.2.5 Identification of Changes

Why?

Every project should have an established baseline for both scope and cost. The project baseline scope and cost estimate is used to measure performance throughout project development and construction. Different agencies that already practice baselining of their projects report doing so usually when an identified need becomes a real project and is budgeted.

The identification of changes method is normally positioned to intercept inputs impacting scope and cost. In Figure 7.1, identification of changes would filter the input from disciplines and input from third parties. It would also identify any downstream changes to the "determine estimate basis (scope/location)" step.

Project Complexity

Establishing reliable baseline definitions of scope and cost in the early stages of project development is difficult, primarily because of the many project unknowns at that time. However, studies have found that projects that receive the most robust front-end planning have the fewest problems during execution. The establishment of a project scope and cost baseline is fairly straightforward for routine projects and becomes more difficult as project complexity increases. Yet it is with the complex project that the use of this method will yield the greatest benefits.

Tips for Success

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. Constructability problems that need to be addressed may also be encountered as the project develops. Early identification of such issues and a structured system for controlling their impacts is essential to achieving estimate quality.

Tools

I1.1 Cost Containment Table
I1.2 Estimation Scorecard
I1.3 Project Baseline
I1.4 Scope Change Form

7.2.6 Value Engineering

Why?

Value engineering is used throughout the construction industry. Within state highway agencies, value engineering is used to increase the project deliverables within the limitations of the funds available for a project. By breaking the project into components, reviewing the function, and formulating solutions and developing recommendations for improvements, one state highway agency has shown an increase in constructability, a minimization of right-of-way and/or environmental impacts, and a compression of construction schedules.

Value engineering actions should take place before the final plans and specifications pass into the "determine estimate basis" step in Figure 7.1. Value engineering actions should also be applied to the input from disciplines contributions.

Additionally, the FHWA value engineering regulation (23 CFR Part 627—Value Engineering; the regulation can be found at www.fhwa.dot.gov/ve/vereg.htm and the policy at www.fhwa.dot.gov/ve/veplcyg.htm) requires state highway agencies to ensure that a value engineering analysis has been performed on all federal-aid highway projects on the National Highway System with an estimated cost of $25 million or more and that all resulting, approved recommendations are incorporated into the plans, specifications, and estimate.

Project Complexity

With straightforward or routine projects, there may be limited opportunity to realize savings by means of a value engineering process. However, as project complexity and scope increase, so do the opportunities to apply value engineering and realize significant savings while retaining quality.

Tips for Success

During feasibility studies, preliminary design, and even detail design, the relative expenditures for value engineering studies are small compared with the cumulative cost of the project. Typically, engineering fees amount to less than 10% of total construction costs. However, the decisions and commitments made during design have great influence on the cost of construction, a far greater influence than what the constructor can effect by making changes during the actual construction process.

Tool

V2.1 Value Engineering

7.3 Strategy: Off-Prism Issues

At this stage in project development, cost estimation management is the key to controlling project scope and schedule. However, market conditions and macroeconomic events, which state highway agencies and estimators do not commonly consider, can significantly affect project cost. These events are related to regional or even global economic conditions. Agencies should seek to implement management approaches identified in Table 7.4, which will help in identifying such impacts.

There are three different off-prism issues methods described here for use during the final design phase of project development.

7.3.1 Communication

Why?

Communication was stressed for a scope and schedule strategy in Section 7.2, and communication is also extremely important in an off-prism issues strategy. Agencies are very good at articulating the engineering aspects of a project, but often are "blind sided" by macroeconomic events and challenges. Figure 7.1 has a market conditions input activity to call attention to this need to be aware of the economic conditions under which the project will be pursued. This is an area of analysis where the engineering community has very little experience or training.

When dealing with stakeholders, communication of the uncertainty and of project scope and cost unknowns is critically important. As the project moves through design, the amount of uncertainty in the estimate should diminish, but there will still be uncertainty, and the level of uncertainty must be communicated.

Communication between internal state highway agency departments is imperative throughout project development given the number of parties involved in even the simplest of projects. There should be a definite point during project development when the scope is fixed. This decision point should be clearly identified.

Table 7.4. Final design phase off-prism issues strategy: Methods and tools.

OFF-PRISM ISSUES STRATEGY Use proactive methods for engaging external participants and assessing the macroenvironmental conditions that can influence project costs			
Cost Estimation Management		Cost Estimation Practice	
Communication		**Risk Analysis**	
C1.2	Communication of Uncertainty	R3.2	Contingency—Identified
C1.3	Communication within State Highway Agency	R3.4	Estimate Ranges
C1.5	Proactive Conveyance of Information to the Public		
Right-of-Way			
R2.5	Right-of-Way Estimator Training		
R2.6	Separate Right-of-Way Estimators		

Project Complexity

Inherently, complexity adds risk to a project; therefore, the importance of communication, particularly communication of uncertainty, becomes more important with increasing project complexity and project visibility.

Tips for Success

Communication is about both listening to stakeholders and providing accurate information to include knowledge about uncertainty. Estimators must realize that the project cost can be severely impacted by market and macroeconomic factors, and they must communicate this to state highway agency management.

Tools

C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency
C1.5 Proactive Conveyance of Information to the Public

7.3.2 Right-of-Way

Why?

Estimators who work in a vacuum and fail to consider the information provided by other state highway agency disciplines cannot produce accurate estimates. Figure 7.1 shows the estimation process—prepare base estimate—being supported by an "input from disciplines" step.

The costs of various project items that are included in the estimate must be managed in different ways, and they are usually the responsibility of different sections of a state highway agency, so estimators must involve those supporting sections in order to produce accurate project cost estimates.

Project Complexity

As projects become more complex, there is a greater need for coordination and communication between the disciplines participating in the development of the project's scope and estimate. Many more factors—right-of-way cost, multiple utility companies, railroads, agencies that grant environmental permits—impact the cost of projects in urban environments and projects that cross environmentally sensitive areas. The typical highway or bridge project team must be expanded to include expertise in dealing with these other matters.

Tips for Success

An accurate cost estimate and schedule is dependent on information from the many supporting sections of an agency that feed data to those preparing the estimate. These sections must be active participants in a project's development.

Tools

R2.5 Right-of-Way Estimator Training
R2.6 Separate Right-of-Way Estimators

7.3.3 Risk Analysis

Why?

Estimates include a contingency amount to cover the costs of possible identified and unidentified future events. A risk analysis should be preformed to establish the magnitude of the contingency amount. In Figure 7.1, a "determine risk" step is depicted as a required action encompassing the establishment of the contingency amount.

Risk analysis is concerned with how future events will turn out and how to deal with the uncertainties of these future events by identifying and examining a range of possible outcomes. The objective is to understand, control, and mitigate risks. Understanding the risks inherent in each potential project alternative is important to controlling cost and developing estimates that reflect the cost of accepted risks.

Project Complexity

Added risk comes with project complexity. The need to purchase large quantities of bulk commodities adds uncertainty and often results in restraints being imposed on construction operations. The degree to which the proposed technology for the project has been demonstrated can be very limited. Large, complex projects stretch contractor and agency resources. Some complex projects require specific experience, resources, and knowledge for successful completion.

Tips for Success

The project team, not just the estimator, must conduct a comprehensive risk analysis for all major projects. The purpose of such analyses is first to identify risks by likelihood of occurrence and by consequences and secondly to devise methodologies and strategies for avoiding or managing the risks.

Tools

R3.2 Contingency—Identified
R3.4 Estimate Ranges

7.4 Strategy: Risk

At this stage in project development, cost estimation management is the key to controlling project scope and schedule.

Agencies should be seeking to implement the management solutions identified in Table 7.5. However, it must not be forgotten that success in estimation practice is linked to the working environment created by agency management.

There are three different risk methods described here for use during the final design stage of project development.

7.4.1 Communication

Why?

When dealing with external stakeholders, communication of uncertainty and of project scope and cost unknowns is critically important. Any uncertainty about project scope, schedule, and cost must be clearly communicated both within the agency and to external parties.

Communication was stressed in terms of its requirement to support a scope and schedule strategy in Section 7.2 and in terms of listening to third parties in Section 7.3. In terms of a risk strategy, communication has to do with how the precision of an estimate is communicated to agency management and to parties outside of the agency. Figure 7.1 includes two notations depicting these communication actions: the "release engineer's estimate" sidebar and the "obtain appropriate approvals" step.

Project Complexity

Inherently, complexity and long project development durations add risk to a project; therefore, the importance of communication, particularly communication of uncertainty, becomes greater with greater project complexity and visibility.

Tips for Success

Communication is about providing accurate information, including knowledge about uncertainty. To maintain creditability with stakeholders, it is important to tell the public the truth about project cost and to identify the precision of estimate values.

Tools

C1.2 Communication of Uncertainty
C1.3 Communication within State Highway Agency
C1.4 Definitive Management Plan
C1.7 Year-of-Construction Costs

7.4.2 Identification of Risk

Why?

The identification of risk method is used to capture inputs impacting scope and cost, as discussed in Section 7.2. Additionally, as part of the "determine risk" activity in Figure 7.1, there is a need to be very proactive in identifying possible risks that can impact a project's cost and duration.

Identification of risk was previously discussed in Section 7.2.3. Risk-based estimation and management is used by only a small number of transportation agencies. Range estimates and risk charters are common practice in other industries, but the highway sector is just beginning to apply these management processes. The state highway agencies that use a risk-based estimation approach have found it to be successful in communicating the nature of project costs.

Project Complexity

As project complexity increases, it is necessary to employ formal risk management processes that identify, quantify, and set forth mitigation strategies.

Tips for Success

A risk charter is a list of identified risks that may be encountered during the life of the project. Such a charter is

Table 7.5. Final design phase risk strategy: Methods and tools.

RISK STRATEGY Identify risks, quantify their impact on cost, and take actions to mitigate the impact of risks as the project scope is developed			
Cost Estimation Management		Cost Estimation Practice	
Communication		**Risk Analysis**	
C1.2	Communication of Uncertainty	R3.2	Contingency—Identified
C1.3	Communication within State Highway Agency	R3.3	Contingency—Percentage
C1.4	Definitive Management Plan		
C1.7	Year-of-Construction Costs		
Identification of Risk			
I2.1	Red Flag Items		
I2.2	Risk Charter		

typically based on a scientific assessment of risk rather than on simple engineering judgment. The charter may address the likelihood of the risk, the cost and schedule implications of the risk, and mitigation suggestions, as well as identify which risks can have the largest impacts on the project.

Tools

I2.1 Red Flag Items
I2.2 Risk Charter

7.4.3 Risk Analysis

Why?

Project risk was previously discussed in Section 7.3.3. Contingency is typically applied to state highway agency cost estimates to cover risk, but its application is not usually based on identification of specific risks. In most state highway agencies, the application of a contingency to an estimate is so loosely defined that there is no consistent application of contingency. Before a contingency amount can be incorporated into an estimate, there must be a risk analysis, which is the "determine risk" step in Figure 7.1.

Project Complexity

Added risk comes with added project complexity. Therefore, the use of a single percentage contingency amount based on the construction value of the expected contract to cover risk often has no relation to reality. By definition, contingency is meant to cover (1) an event that may occur but is not likely or intended or (2) a possibility that must be prepared for, the condition being dependent on chance.

Tips for Success

There must be a clear definition of what the contingency amount in an estimate is intended to protect against, and that amount must be determined by a careful analysis of project conditions, market conditions, and the macroeconomic environment.

Tools

R3.2 Contingency—Identified
R3.3 Contingency—Percentage

7.5 Strategy: Delivery and Procurement

At this stage in project development, the project delivery and procurement method would normally have already been selected and the project documents would be prepared accordingly. However, market conditions can change rapidly, and the issue of contract size and market capability should be reviewed again. Market conditions and contractor capability have a substantial impact on the cost of a project. How market forces impact a particular project depends on (1) the specific dates on which a project is advertised and bid (are there a significant number of projects being advertised by other agencies during the same time frame?) and (2) the manner in which the work is packaged into individual contracts (what is the size of a single contract, and how are adjoining contracts coordinated?).

The selected contracting method is the foundation for the project estimate because it explicitly establishes how project risk is distributed between the agency and the contractor. The distribution of risk directly impacts the cost of the project work items.

In Figure 7.1, the assessment of an appropriate delivery and procurement strategy should be addressed during the "review estimate" step, and the assessment should be addressed again during the "obtain appropriate approvals" step.

As shown in Table 7.6, there are two different methods described here for handling delivery and procurement issues during the final design phase of project development.

7.5.1 Off-Prism Issues

Why?

Cost estimation management is the key to controlling project scope and schedule. However, market conditions and macroeconomic events, which state highway agencies and estimators do not commonly consider, can significantly affect project cost. These events are related to regional or even

Table 7.6. Final design phase delivery and procurement strategy: Methods and tools.

DELIVERY AND PROCUREMENT STRATEGY Apply appropriate delivery methods to better manage cost because project delivery influences both project risk and cost					
Cost Estimation Management			Cost Estimation Practice		
			Constructability		
				C5.1	Constructability Reviews
Identifying Off-Prism Issues			**Identifying Off-Prism Issues**		
	I3.3	Market Conditions		I3.3	Market Conditions

global economic conditions—that is, *off-prism* issues. The macroenvironment can affect project cost in two ways: (1) by being unknown or unrecognized by project managers and estimators and (2) by changes in the environment that are completely external to the project.

This method, "Off-Prism Issues," is also another strategy unto itself. See Section 7.3 for more information about this strategy. However, note that the off-prism issue tool that most directly relates to delivery and procurement is I3.3, Market Conditions.

Project Complexity

As project complexity increases, the number of off-prism issues to be considered increases.

Tips for Success

Unlike other aspects of project planning and estimation, understanding the macroenvironment has never been standardized as part of project estimation. It is therefore important to develop planning processes that focus on community concerns, externally imposed requirements, and external market conditions.

Tool

I3.3 Market Conditions

7.5.2 Constructability

Why?

The quality of the documents used to prepare estimates impacts the quality of the estimate in terms of accuracy. Thus, design documents that provide the basis for cost estimates must accurately portray the design intent. Implementing constructability analysis will enhance project documents by reducing the potential for errors and omissions and will produce designs that are constructible. Constructability reviews can provide guidance as to the project construction phasing and staging approaches required to cost-effectively build the project. In this way, constructability will influence both "update design basis" and "prepare base estimate" steps (see Figure 6.1).

Project Complexity

As project complexity increases, the need for construction knowledge and experience in reviewing designs becomes critical. Construction input can aid the designer in developing designs that can be constructed more efficiently. This need is especially important for very large and complex projects, such as those in urban areas under high-traffic volumes. These types of projects require continuous input from construction experts beginning with project definition during programming and throughout preliminary design.

Tips for Success

Constructability is most successful when the process is formalized and is an integral part of the programming and preliminary design phase of project development. Identifying and using appropriate constructability experts is also critical in achieving successful constructability reviews. A constructability expert must be able to work effectively with project designers and provide meaningful input on design documents.

Tool

C5.1 Constructability Reviews

7.6 Strategy: Document Quality

At this stage in project development, cost estimation management is the key to controlling document quality. Agencies should seek to implement the management solutions identified in Table 7.7.

There are three different document quality methods described here for use during the final design phase of project development.

Table 7.7. Final design phase document quality strategy: Methods and tools.

DOCUMENT QUALITY STRATEGY Promote cost estimate accuracy and consistency through improved project documents			
Cost Estimation Management		Cost Estimation Practice	
Computer Software		**Document Estimate Basis and Assumptions**	
C2.1	Agency Estimation Software	D4.1	Project Estimation File
C2.2	Commercial Estimation Software		
Estimate/Document Review			
E1.1	Estimate/Document Review—External		
E1.2	Estimate/Document Review—Internal		

7.6.1 Computer Software

Why?

The use of computer software forces consistent practices, and these practices in turn support the document quality strategy; therefore, the use of computer software in the estimation processes—“prepare base estimate” and “engineer’s estimate” in Figure 7.1—is encouraged.

Often, state highway agencies 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 state highway agencies use a combination of their in-house software and the AASHTO programs. Estimation software provides a structured format for preparing estimates and promotes estimate consistency.

Project Complexity

With increased project complexity, there is an increased need to identify construction conflicts when reviewing the plans and specifications. Computer software enables the estimator to easily analyze large amounts of data and perform searches or information queries.

Tips for Success

AASHTO’s Estimator module allows the user to use several different estimation methods, such as creating estimates based on historical bid data, historical cost data, reference tables, or a collection of price derivations. All data used to generate an estimate—such as crew wages, equipment and material costs, production rates, and historical cost data—are stored in Estimator. This enhances the estimator’s and management’s ability to check the estimate.

Tighter engineering control of document preparation will support better estimates.

Tools

C2.1 Agency Estimation Software
C2.2 Commercial Estimation Software

7.6.2 Estimate/Document Review

Why?

During the review estimate activity that is identified in Figure 7.1, there should also be a check on the quality of the plans and specifications.

As discussed in Sections 7.1.4, 7.1.5, 7.2.3, and 7.2.4, a very effective management approach for establishing the reliability of a cost estimate is to subject the estimate to review and verification.

Project Complexity

The formality of a project estimate review and the depth of the review will vary depending on the type of project and project complexity. In the case of routine straightforward projects, a formal review may not be necessary. However, as project complexity and scope increase, it is necessary to conduct formal reviews. When very complex projects are being estimated, management should require that there be an external review of the estimate by qualified professionals.

Tips for Success

To be of value, the review must closely examine the assumptions that form the basis of the estimate. Knowledgeable and experienced individuals who bring a broad perspective to the project and estimate formulation should be assigned to conduct the review.

Tools

E1.1 Estimate/Document Review—External
E1.2 Estimate/Document Review—Internal

7.6.3 Document Estimate Basis and Assumptions

Why?

During the “prepare base estimate” and “engineer’s estimate” activities shown in Figure 7.1, the estimator must clearly state the basis of the cost calculations and all assumptions.

Estimate documentation must be in a form that can be understood, checked, verified, and corrected. The foundation of a good estimate is the formats, procedures, and processes used to arrive at the cost. Assumptions about what the contract documents require should be available as estimator notes.

Project Complexity

Increased project complexity means that more issues must be considered in preparing the estimate. The decisions and assumptions that the estimator makes as to construction requirements must be clearly stated and communicated to those reviewing the estimate. The decisions and assumptions must be tied to specific statements in the contract documents or in the plans.

Tips for Success

Many state highway agencies do not currently have a published document that establishes estimation procedures. State highway agencies would greatly benefit by producing their own guidelines of standard processes, procedures, and formats to be used by both state highway agency estimators and design consultants retained for estimation purposes. This guidance document should be specifically written for those having responsibility for preparing the final engineer's estimate and should discuss how assumptions are to be documented. It should both address how unit costs are to be derived from the agency's databases and supply the documentation necessary to support decisions to use other cost values.

Tool

D4.1 Project Estimation File

7.7 Strategy: Estimate Quality

Use qualified personnel and uniform approaches to achieve estimate accuracy. At this stage in project development, cost estimation practices are the key to achieving a good project estimate. Agencies should seek to implement the practices identified in Table 7.8. However, it must not be forgotten that success in estimation practice is linked to the work environment created by agency management.

There are four different cost estimation practice methods and two cost estimation management methods for this strategy for use during the final design stage of project development. Management support for internal estimate reviews is usually not an issue, but in the case of complex projects, management should have procedures in place for organizing and conducting external reviews.

7.7.1 Estimate Review—External

Why?

Estimation experience of state highway agency personnel charged with developing estimates ranged from less than 1 year to more than 40 years across the 50 state highway agencies. Several state highway agencies have reported having estimators with minimal experience and additionally stated that they had in recent years lost their most experienced personnel to retirement and had not retained mid-level personnel to ensure that the overall experience level in estimation would remain high.

Previously, in Section 7.1.4, an external estimate review was offered as a validation of the estimated project cost, but an external review also serves to ensure that the estimate matches the scope and schedule of a project. In Figure 7.1, the "estimate review" step is positioned after the "risk determi-

Table 7.8. Final design phase estimate quality strategy: Methods and tools.

ESTIMATE QUALITY STRATEGY Use qualified personnel and uniform approaches to achieve improved estimate consistency and accuracy					
Cost Estimation Management			Cost Estimation Practice		
			Consistency		
				C4.2	Estimation Checklist
				C4.3	Estimation Manual (Guidelines)
				C4.4	Estimator Training
				C4.5	Major Project Estimation Guidelines
				C4.6	Standardized Estimation and Cost Management Procedures
				C4.7	State Estimation Section
Estimate Review—External			**Estimate Review—External**		
	E2.1	Expert Team		E2.1	Expert Team
Estimate Review—Internal			**Estimate Review—Internal**		
	E3.1	Formal Committee		E3.1	Formal Committee
	E3.2	Off-Prism Evaluation		E3.2	Off-Prism Evaluation
	E3.3	In-House/Peer		E3.3	In-House/Peer
	E3.4	Round Table		E3.4	Round Table
			Plans, Specifications, and Estimates (PS&E)		
				P1.1	Agency Estimation Software
				P1.2	Commercial Estimation Software
				P1.3	Cost Based
				P1.4	Historical Bid Based
				P1.5	Trns•port

nation step." However, for major projects this could be a repetitive activity.

Project Complexity

The formality of a project estimate review and the depth of the review will vary depending on the type of project and the project's complexity. In the case of very complex projects or projects involving new construction methods, estimation management should require that there be an external review of the estimate by qualified professionals.

Tips for Success

The external review should carefully study the scope and schedule of the project as described in the contract documents. To be of value, the review must closely examine the match between the stated scope and the project design as presented in the contract documents that are available at this point in project development.

Tool

E2.1 Expert Team

7.7.2 Estimate Review—Internal

Why?

As discussed in Sections 7.1.4 and 7.1.5, a very effective management approach for establishing the reliability of a cost estimate is to subject the estimate to review and verification. In Figure 7.1, reviews occur to some extent following each "prepare estimate" activity, but the primary examination is the depicted "review estimate" step.

Project Complexity

Whether the review is conducted by agency personnel or by individuals who are independent of the agency depends on the type of project and project complexity. In the case of a straightforward overlay project, a formal review may not be necessary. However, as project complexity and scope increase, it is necessary to conduct formal reviews. Very complex and high-profile projects should have an external review of the estimate by qualified professionals.

Tips for Success

To be of value, the review must closely examine the assumptions that form the basis of the estimate and the review must be conducted by knowledgeable and experienced individuals who are independent of the project team.

Tools

E3.1 Formal Committee
E3.2 Off-Prism Evaluation
E3.3 In-House/Peer
E3.4 Round Table

7.7.3 Consistency

Why?

Consistency is achieved by instituting operating procedures that serve as guides for performing estimation processes. Therefore, in Figure 7.1, consistency comes to play in all the processes: the input from disciplines, input from third parties, market conditions, historical data, prepare base estimate, determine risk, and review estimate.

Estimates must be structured and completed in a consistent manner. Uniform estimate presentation supports analysis, evaluation, validation, and monitoring of item costing. The purpose of a uniform estimate structure is to avoid duplications as well as to ensure that there are no omissions.

Project Complexity

Attainment of estimation efficiencies across the agency demands that there be consistent estimation processes to provide ease in reporting, enable data sharing, and make recognition of errors much easier. This becomes critically important as project complexity increases.

Consistency enables multiple estimators to complete various items of the estimate and then combine and coordinate their work. These methods permit a second estimator to continue the work from any point where the first estimator stops or to easily check the work of another estimator.

Tips for Success

The foundation of a good estimate is the formats, procedures, and processes used to arrive at the cost. Success in terms of estimate quality is attained by investing the time and effort in developing consistent estimation processes that match how the agency develops its projects.

Tools

C4.2 Estimation Checklist
C4.3 Estimation Manual (Guidelines)
C4.4 Estimator Training
C4.5 Major Project Estimation Guidelines
C4.6 Standardized Estimation and Cost Management Procedures
C4.7 State Estimation Section

7.7.4 Plans, Specifications, and Estimates (PS&E)

Why?

With many agencies, the PS&E—the "engineer's estimate" activity in Figure 7.1—is a detailed line-item estimate. Detailed PS&E are necessary to verify that the project can be constructed for the budgeted funds and for checking the validity of bids. Approval of the PS&E will obligate funds for construction.

Project Complexity

Estimates for standard items of work can often be constructed based on historical bid averages, but as project complexity increases or new methods or construction techniques are required to accomplish the work, detailed line-item estimation will usually be employed because historical data are normally nonexistent.

Tips for Success

Detailed bottom-up estimation enables the estimator to incorporate knowledge about markets into the estimate directly, specifically into the affected work items, instead of having to rely on percent contingencies to cover such effects.

Tools

P1.1 Agency Estimation Software
P1.2 Commercial Estimation Software
P1.3 Cost Based
P1.4 Historical Bid Based
P1.5 Trns•port

7.8 Strategy: Integrity

The establishment of management structures that shield estimators from external and internal pressures to produce a low project estimate will support accurate project estimation. Estimate reviews to ensure integrity are repetitive, taking place to some extent whenever the estimate is modified, as shown with the "estimate review" activity in Figure 7.1. Agencies should, therefore, institute the estimating practices identified in Table 7.9.

There are two different integrity methods described here for use during the final design phase of project development.

7.8.1 Estimate Review—External

Why?

It is always necessary to independently verify that an estimate is complete and that it matches the project scope.

When very complex projects or projects involving new construction methods are being estimated, management should require that there be an external review of the estimate by qualified professionals. This external review should include a risk analysis that identifies the critical elements of the estimate, identifies the low and high cost limits for each critical element, and assigns a probability of occurrence to the actual cost.

Project Complexity

The degree to which a review probes the estimate at this stage will vary depending on project type and project complexity. More complex projects must receive an exhaustive in-depth estimate review.

Tips for Success

To be successful, the review must closely examine the assumptions that form the basis of the estimate and must be conducted by knowledgeable and experienced individuals.

Tool

E2.1 Expert Team

Table 7.9. Final design phase integrity strategy: Methods and tools.

INTEGRITY STRATEGY Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates			
Cost Estimation Management	Cost Estimation Practice		
	Estimate Review—External		
		E2.1	Expert Team
	Estimate Review—Internal		
		E3.1	Formal Committee
		E3.3	In-House/Peer
		E3.4	Round Table

7.8.2 Estimate Review—Internal

Why?

It is always necessary to independently verify that an estimate is complete and that it matches the project scope.

In Figure 7.1, there is an “estimate review” activity that is positioned after the “risk determination” activity has quantified the project risk and an appropriated dollar amount has been included in the estimate. While this is depicted as a single activity, it is normally a repetitive activity, taking place to some extent whenever the estimate is modified.

In the case of an uncomplicated overlay project, the review may be limited to the use of a simple checklist to verify that all elements are accounted for. However, as project complexity and scope increase, it is necessary to conduct more formal reviews.

Project Complexity

The extent of the estimate review at this stage will vary depending on the type of project and project complexity. As project complexity increases, the reviewer or review team must devote more attention to probing the assumptions that form the basis of the estimate.

Tips for Success

To be successful, the review must closely examine the assumptions that form the basis of the estimate, and knowledgeable and experienced individuals must conduct it.

Tools

E3.1 Formal Committee
E3.3 In-House/Peer
E3.4 Round Table

7.9 Summary

Table 7.10 lists all of the methods and tools presented in this chapter for use in the final design phase of project development. This list can be used as a quick reference to navigate directly to the Tool Appendix for the descriptions of the tools. Tools are listed in Appendix A alphabetically by method, as shown in Table 7.10.

Table 7.10 can also be used as a checklist for selecting tools that should be employed on any one project. The checklist forms a self-assessment tool for agencies to benchmark against. These methods and tools were found in highway agencies throughout the country. While no agency was found to possess all of the methods and tools, all methods and tools exist and have the potential to be applied by any single agency.

Table 7.10. Final design phase methods and tools.

Method/Tool		
Budget Control		
	B1.2	Constrained Budget
	B1.4	Summary of Key Scope Items (Original/Previous/Current)
	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
	C1.3	Communication within State Highway Agency
	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
Constructability		
	C5.1	Constructability Reviews
Document Estimate Basis and 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		
	I3.3	Market Conditions
Plans, Specifications, and Estimates (PS&E)		
	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	Right-of-Way Estimator Training
	R2.6	Separate Right-of-Way Estimators
Risk Analysis		
	R3.2	Contingency–Identified
	R3.3	Contingency–Percentage
	R3.4	Estimate Ranges
Value Engineering		
	V2.1	Value Engineering

CHAPTER 8

Implementation

Introduction

This 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 individual strategies, methods, and tools should be implemented, 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 planning and the project development process. Table 8.1 summarizes the implementation goals at the organization, program, and project levels. Some of the goals may require organizational change, and all of the goals will require a commitment of resources.

This chapter describes each of the implementation thrusts in Table 8.1 and concludes with an integrated approach to their implementation.

Step 1: Implementation of Strategies—Organizational Change

Successful control of project cost escalation may require a strategic change in the organizational approach that many state highway agencies have toward cost estimation practice and cost estimation management. Project cost estimation practice and project cost estimation management should be viewed as interdependent processes that span the entire planning and development process.

Chapter 3 of this Guidebook presented eight strategies that were developed by observing and synthesizing practices from highway agencies around the country:

- **Management strategy**—Manage the estimation process and costs through all stages of project development;
- **Scope and schedule strategy**—Formulate definitive processes for controlling project scope and schedule changes;
- **Off-prism strategy**—Use proactive methods for engaging external participants and assessing the macroenvironmental 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 strategy**—Apply appropriate delivery methods to better manage cost because 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 consistency and accuracy; and
- **Integrity strategy**—Ensure that checks and balances are in place to maintain estimate accuracy and to minimize the impact of outside pressures that can cause optimistic biases in estimates.

The implementation of these strategies will require a long-term commitment to change. Implementation should be approached as a continuous process of assessing, planning, assigning responsibility, and measuring performance. Honest assessment of the strategies is imperative at the beginning of this process. Planning requires a thoughtful approach to staffing and resource commitment in those areas that need the most improvement. The outcome of assessment and planning is the assignment of responsibility—executive managers must champion the implementation of specific strategies. Finally,

Table 8.1. Implementation goals.

Implementation Thrusts	Implementation Focus	Implementation Goals
Organization 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 procedure 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 or revise agency-specific tools

the party that is assigned the responsibility for implementation should measure the performance of the implementation effort and periodically report on the status of progress. The process will create a loop of continuous improvement, as depicted in Figure 8.1.

Establish Steering Committee

An effective initial effort in the implementation process is to form a cross-cutting steering committee with members from all affected disciplines. This steering committee should be familiar with the Guidebook and with current operating practices within the state highway agency. The committee's charge is to examine current practice in detail and guide the implementation of new strategies. This includes three of the activities discussed previously: assessing, planning, and assigning of responsibilities. The last section in this chapter provides an integrated approach for the committee to use in its charge.

A list of possible steering committee members was developed from steering committee experiences in Connecticut, Florida, Georgia, and Virginia:

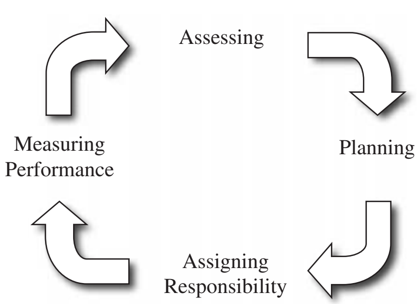


Figure 8.1. Strategy implementation process.

- Program Manager,
- State Construction Engineer,
- Director of Project Development,
- Director of Information Technology,
- Transportation Planning Administrator,
- Value Engineering Coordinator,
- Director of Preconstruction,
- District/Region Preconstruction Engineer,
- State Estimates Engineer, and
- Senior Project Manager.

In Connecticut, design consultants often prepare project estimates and have a place on the committee. Other committee members included representatives from other areas in the state highway agency, such as maintenance, utilities, traffic engineering, right-of-way, real estate services, and environmental. External partners included the FHWA, local governments, MPOs, counties, cities, and local governments.

Conduct Agencywide Workshop

To launch this effort, an agencywide workshop on the subject of cost estimation practice and cost estimation management can be very useful in identifying problems and understanding the roles of the many disciplines within the state highway agency structure that support efforts to accurately estimate project cost.

The Minnesota Department of Transportation (MnDOT) organized such a workshop on the subject and found it to be extremely beneficial for guiding a proposed agencywide implementation effort that includes issues addressing cultural change within MnDOT. The MnDOT workshop, which was called a peer exchange, involved both internal agency employees and invited peers from other state highway agencies. The format of the workshop loosely followed the organization of this Guidebook and is outlined as follows:

- Introduction
  - Strategic goals of cost estimation practice and cost estimation management
  - Presentations and perspectives from state highway agency peers and program managers
- Discussion of current and available strategies, methods, and tools
  - Planning
  - Programming and preliminary design
  - Final design
- Discussion of strengths, weaknesses, opportunities, and threats
- Discussion of strategies for a path forward

The steering committee and workshop examples are provided to demonstrate two initiatives that will assist in the implementation of estimation strategies at the organizational level. The key is to address the problem in a systematic manner.

Step 2: Implementation of Methods—Programmatic Change

The second implementation step involves change at the program level with the institution of methods. Chapters 5, 6, and 7 of this Guidebook describe the methods that support the strategies for producing consistent and accurate estimates. This step involves an assessment of current practices, development of policies and procedures, and development of education and training.

Assess Current Practices

The first task for implementation of the methods is an assessment of the current state of practice within the state highway agency. Table 8.2 can be used to assess an agency's current use of the methods described, for example, in Chapter 5 of this Guidebook. The table should be used in a group setting to assess the current application of methods.

Develop Policies and Procedures

The assessment of current methods will provide a framework for the development of policies and procedures concerning cost estimation practice and cost estimation management. As a reminder, this research discovered that many agencies did not have policies or estimation manuals that specifically address issues that impact estimate accuracy. Some agencies did have policies that were very compartmentalized within specific program areas, such as long-range planning or final engineering estimates (PS&E), but these policies did not include a systems approach to integrating these program areas. It is imperative that policies and procedures specifically address the issue of cost estimation and cost management *across the entire planning and project development process.*

The following list of items should be considered in the development of cost estimation and estimation management policies and procedures. The list is a compilation of documents and procedures provided by state highway agencies during this

Table 8.2. Assessment of planning methods.

Method	Currently in Use	Comments on Future Implementation
Budget Control		
Buffers		
Communication		
Computer Software		
Conceptual Estimation		
Document Estimate Basis and Assumptions		
Delivery and Procurement Method		
Estimate Review—External		
Estimate Review—Internal		
Identification of Risk		
Identifying Off-Prism Issues		
Project Scoping		
Recognition of Project Complexity		
Right-of-Way		
Risk Analysis		

research. While the list is not intended to be comprehensive, it can be used as a starting point for the development of policies and procedures:

- Project scope definition and estimate basis,
- Project baseline definition,
- Estimate timing/milestones,
- Scope change process,
- Project cost containment,
- Communication of estimates,
- Cost risk assessment process,
- Application of contingency,
- Estimate quality control and quality assurance,
- Effects of inflation and year-of-construction costs,
- Appropriate estimation methods,
- Available estimation tools, and
- Historic data maintenance and use.

Develop Education and Training

Cost estimation education and training are a critical component in achieving consistent and accurate estimates. Engineers at all phases of project development should be educated about the pitfalls of project cost escalation and the strategies, methods, and tools available to address the issue. Education and training should be developed from an organizational perspective, but it will likely need to be delivered at the program level because of the varying skill sets of engineers within the different agency programs. For example, as new conceptual estimation software is developed, education and training will be needed for the planning and programming staff. Similarly, if new software is developed for unit price estimation, education and training will be needed for the planning and estimation staff. However, if a new risk-based methodology for determining the contingency included in estimates is deployed throughout project development, implementation of this methodology will require education and training components across a broader cross section of disciplines.

Because, in many states, consultants prepare project estimates, there is also a need to train consultant engineers concerning the state highway agency's cost estimation standards and procedures.

Step 3: 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. The majority of tools described in Appendix A were developed by state highway agencies and have been tested on projects.

Assess Current Practices

Similar to the implementation of strategies and methods, the first activity in the implementation of tools involves an assessment of the agency's current practices. Table 8.3 provides an example for how to assess tool use and identify the subject matter experts with respect to the tool within an agency. The table is based on a partial list of methods and tools for the planning phase described in Chapter 5 of this Guidebook.

The group that completes Table 8.3 should represent perspectives from all project staff disciplines. For the full potential benefit of this approach, the table should be used in

Table 8.3. Assessment of planning phase tools.

Method/Tool			Examples of Use	Subject Matter Experts	Comments on Future Implementation
Budget Control					
	B1.1	Budget by Corridor			
	B1.2	Constrained Budget			
	B1.4	Summary of Key Scope Items (Original/Previous/Current)			
	B1.5	Variance Reports on Cost and Schedule			
Buffers					
	B2.1	Board Approvals			
	B2.2	Constrained Budget			
	B2.3	Management Approvals			
Additional Methods					
		Additional Tools			

conjunction with a detailed review of the tools in Appendix A and the methods described in Chapters 5 through 7. Rather than simply noting a yes or no answer for the assessment of tools, the table suggests noting examples of use. This is necessary because the detailed application of the tools can vary from agency to agency and even within an agency. For example, the tool B2.3, "management approvals," can take many different forms throughout an agency. The key in this example would be to note where the management approvals exist and discuss whether there is a need for this tool in other places in the planning and project development process.

Where tools are already in use by an agency, it is helpful to identify a subject matter expert. Subject matter experts can also be assigned to investigate and develop tools that are not currently in use. Comments for future use should describe whether the tool has potential for implementation and how the agency should begin to implement the tool.

Test New Tools

The adoption of new estimation tools, or the revision of existing estimation tools, should involve testing and verification of the tools' effectiveness. The consequences of implementing inappropriate tools or tools that do not support estimate consistency and accuracy can be significant in terms of cost and schedule impacts. Two methods that experienced estimators often use when implementing new tools are testing new tools in parallel with existing tools and conducting pilot studies on appropriate projects.

For example, if an agency wishes to implement new conceptual estimation software, it might first test the software by running it in parallel with the existing method to determine if the software will yield reasonable results. The agency can continue to run this software in parallel with their existing approach until consistent results are achieved and the staff is trained on the new software. If the change to this new conceptual estimation software is a significant departure from the agency's standard practices, it can consider implementation through a formal pilot study. The pilot study should be conducted on an appropriate project, and the study should produce an objective review of the software's performance, benefits, deficiencies, and perspectives on future implementation. This effort will take time and resources.

Develop Agency-Specific Tools

The final activity in project-level implementation involves the development of agency-specific tools. Each agency has its own unique cost estimation practice and cost estimation management needs because of issues as diverse as the physical, geographic, and climatic conditions of the state or its local and stakeholder involvement. Some of the tools presented in Appendix A were developed through national initiatives sponsored by AASHTO or the NCHRP, but the majority of tools were developed within individual agencies. State highway agencies should strive to continuously develop and improve on their suite of cost estimation practice and cost estimation management tools. When, due to a specific project requirement, new tools are developed, agency management should consider implementation of the tool across projects.

Step 4: Integrating the System—A Strategic Plan

Implement the Long-Term Strategic Plan

The previous sections described the implementation of strategies, methods, and tools at the organization, 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.

Table 8.4 provides an implementation framework to integrate the strategies, methods, and tools. The previously mentioned cost estimation practice and cost estimation management steering committee can use this framework and update it on a periodic basis, as depicted in Figure 8.1. Table 8.4 provides an example of the framework for only the management strategy. A template for Table 8.4 can be found in Appendix B.

The first column of Table 8.4 is simply a listing of the strategies. All eight strategies should be considered. If the steering committee believes that some of the strategies are more critical than others, they may wish to delay immediate implementation of certain lower-ranked strategies to conserve resources, but all strategies should be considered.

The second column of Table 8.4 is a listing of performance improvement opportunities as generated by an assessment of the methods that need to be addressed. These opportunities should be generated from an evaluation of the agency's current practices, as described in Table 8.2. When considered in conjunction with the strategies, the methods can be used as a checklist of performance improvement opportunities. For instance, Table 8.4 provides an example of an opportunity to improve estimate communications as part of an overall management strategy. Chapter 5 provides the details on the various methods under that management strategy, one of which is communication.

The third column of Table 8.4 provides for implementation steps through a strategic organization of tools. The list of tools should be assembled from an assessment of current agency practices, as previously described in Table 8.3. The list of tools

Table 8.4. Implementation framework.

Cost Management Strategy (Strategies)	Performance Improvement Opportunity/Action (Methods)	Implementation Steps (Tools)	Responsible Party and Performance Measurement
Management—Manage the estimation process and costs through all stages of project development.	Communication—Develop estimate communications tools.	Management plan—Develop a definitive management plan for the oversight of estimates. Public information plan—Develop a definitive public information plan for communicating cost estimates to the public. Training—Develop estimation training modules for all branches of the agency that communicate (1) the importance of accurate cost estimate communication and (2) uncertainty involved in cost estimation.	Program or party responsible for implementation with performance measurement
Continue with Strategies 2 to 8…	*Continue with opportunity/actions from methods…*	*Continue with implementation steps from tools…*	*Continue with assignment of responsibilities and measures…*

will form a set of implementation activities that provide an actionable path forward. For example, Table 8.4 provides a set of three tools that can be implemented to improve the communication of estimates.

The fourth column of Table 8.4 provides for the assignment of responsible parties, which will most likely come from the subject matter experts identified in Table 8.3. This column also provides for a noting of performance measures. While all tools should contribute to greater estimate consistency and accuracy, the performance measures should be specific to each tool. For example, a performance measurement for the management plan tool could be the percentage of management plans that contain specific references to cost management procedures.

Using a structure similar to that shown in Table 8.4 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.

Summary

This chapter illustrates a purposeful approach to integrating and implementing the concepts found in this Guidebook. The framework proposed in the previous section is one method for creating a strategic path forward with the goal of improving cost estimation practice and cost estimation management. There is no one correct path to success. Agencies can develop other approaches that use the methods and tools presented in this Guidebook. However, to repeatedly achieve accurate and consistent cost estimates, agencies should adopt a systematic approach to cost estimation practice and cost estimation management that addresses cost escalation factors across the entire planning and project development process spectrum.

CHAPTER 9

Path Forward

Industry Problem

State highway agencies face a major challenge in controlling project budgets over the time span between project initiation and the completion of construction. Project cost increases, as reflected by budget overruns during the course of project development, are caused by any number of factors, such as an inadequate project scope definition at the time of planning or programming, insufficient information on the extent of utility relocation requirements, insufficient knowledge of right-of-way costs, added environmental mitigation costs necessary to avoid impacts, traffic control requirements, and work-hour restrictions. The objective of this Guidebook is to assist state highway agencies in achieving better estimate consistency and accuracy during planning and project development.

Guidebook Development

The Guidebook was developed after a focused review of current state highway agency estimation practices and an extensive examination of recent estimation research. Over half of the state highway agencies, representing all parts of the country, provided input on their current estimation practices and the problems they are experiencing. By a critical review of the literature and state highway agency information, the root causes of problems in cost estimation practice and cost estimation management were identified. The information also permitted the identification of viable and successful approaches to cost estimation practice and cost estimation management.

An analysis of estimation literature and the information provided by the state highway agencies led to the development of eight strategies to address 18 factors that cause cost increases as experienced by state highway agencies during planning and project development. These eight strategies are linked to over 30 recommended methods for implementing the eight strategies and to over 90 tools for executing the specific methods.

A Strategic Approach

The cost escalation factors that lead to project cost increases have been documented through a large number of studies and matched to cost estimate changes that occur during project development. Each factor presents a challenge to a state highway agency seeking to produce accurate project cost estimates and managing project costs. These factors can all be addressed by using a strategic approach to estimation and cost management that is structured around the eight strategies and the following three elements:

- Planning and project development process phases,
- Project complexity, and
- Basic cost estimation practice and cost estimation management steps.

Cost estimation practice and cost estimation management are processes that require the completion of a number of specific cost estimation steps. The cost estimation process necessitates completion of four basic steps that are applicable to the process across each development phase. These cost estimation steps are usually preformed sequentially and repeatedly as project development proceeds:

1. Determine estimate basis.
2. Prepare base estimate.
3. Determine risk and set contingency.
4. Review total estimate.

There are five cost estimation management steps. Implementation of these steps varies by project phase. The cost estimation management steps are also preformed repeatedly as project development proceeds:

1. Obtain appropriate approvals.
2. Determine estimate communication approach.

3. Monitor project scope/project conditions.
4. Evaluate potential impact of change.
5. Adjust cost estimate.

Keys to Success

Disciplined cost estimation management and cost estimation practices should be applied in the context of the eight global strategies. This research has determined that 10 key principles must be followed 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 10 key principles are incorporated into the agency's business practices throughout the organization. Within each group, the key principles are prioritized as follows.

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 this estimate 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 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 that the estimate is accurate and fully reflects project scope.

Challenges

Implementing new concepts involves facing the challenges that accompany change. State highway agencies must consider several challenges when deploying this 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 processes 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 state highway agency practices is difficult when resources are scarce.
- **Dedicating sufficient human resources** to cost estimation practice and cost estimation management beyond the resources that have previously been allocated to estimation processes.

Meeting these challenges will ultimately require a commitment by the agency's senior management to direct and support change. The benefit of this commitment will be manifested in projects that are consistently within budget and on schedule and that fulfill their purpose as defined by their scope. This benefit will also improve program management by allowing for better allocation of funds to projects to meet the needs of the ultimate customer, the public.

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APPENDIX A: TOOLS

CONTENTS

B1 Budget Control

Budget control tools assist in providing a disciplined approach to scope decisions that impact project cost. Budget control must begin early in project development. Two simple but essential principles of the budget control process must be clearly understood: (1) there must be a basis for comparison, and (2) only future costs can be controlled.

B1.1 Budget by Corridor

Budget control tools assist in providing a disciplined approach to scope decisions that impact project cost. Budget control must begin early in project development. Two simple but essential principles of the budget control process must be clearly understood: (1) there must be a basis for comparison, and (2) only future costs can be controlled.

What Is It?

Budgeting by corridor involves estimating and managing logical groups of smaller projects in transportation corridors. Transport corridors link major articulation points (e.g., hubs) on which freight and passenger movements converge. Most often, they lie at the intersection of economic, demographic, and geographic spaces as they perform both market-serving and market-connecting functions.

Why?

Developing estimates and budgets by corridors can assist with the challenges of long-range planning. First, projects in a corridor can be closely related in their physical and temporal characteristics. There is a link between transportation corridors and economic activities that can help to predict the needs, and thus the cost, of transportation projects. Estimating the need for improvements and reconstruction of corridors can be more accurate than estimating smaller projects individually. Additionally, long-range planning tools (i.e., conceptual estimation tools) are aligned with corridor-scale estimates rather than smaller individual projects.

What Does It Do?

In addition to providing a logical grouping of projects with similar physical and temporal characteristics for more accurate estimates, budgeting by corridor allows planners and estimators to better manage cost because they can budget a portfolio of projects rather than a single project. Project needs will change over time within the corridor. Budgeting by corridor allows planners to reallocate moneys from one project to another within the corridor as needs dictate and better scope information becomes available over time. Used in conjunction with the constrained budget and/or design to cost tools, budgeting by corridor can provide a means to manage a portfolio of projects in a logical manner.

When?

This tool is used for preparing long-range estimates during the planning phase of project development.

Examples

The Washington State DOT has created an Urban Corridors Office in the Seattle Metro area to manage the state's largest corridors. The Seattle-based Urban Corridors Office directs six of the DOT's largest projects, including the SR 99 (Alaskan Way Viaduct and Seawall Replacement Project), SR 520 (Bridge Replacement and HOV Project), and SR 509 (I-5 Freight and Congestion Relief, Access Downtown [Bellevue], I-90 Two-Way Transit and HOV, and I-405 Congestion Relief and Bus Rapid Transit Projects). More information can be found at http://www.wsdot.wa.gov/consulting/Ads/UrbanCorridors/Misc/UCOOrganization.pdf.

Tips

A state highway agency may need to reorganize its management structure to effectively budget and control costs by corridor. This tool should be used in conjunction with other tools, such as constrained budget and design to cost.

Resources

Washington State DOT Urban Corridors Offices: http://www.wsdot.wa.gov/consulting/Ads/UrbanCorridors/Misc/UCOOrganization.pdf.

B1.2 Constrained Budget (Also See B2.2)

Budgeting is a balancing act of meeting the agency's objectives—responding to transportation needs—to the fullest extent possible within the limits of its financial capacity. To purposely budget a deficit results in the agency's goals not being fully realized. The result is also the same when project estimates and, therefore, project budgets are at risk to grow over the approved baseline budget as development progresses. Prudence requires that individual project budget growth not destroy the agency's total program by requiring the diversion of funds to cover the deficit in a project. To optimize the agency's programs, it is better to establish budget constraints early in the project development process and to demand that cost-effectiveness be a critical component of all project decisions.

What Is It?

Highway projects often are authorized with resource limitations, particularly budget limitations. The projects are usually reconstructions, extensions, or additions to existing roadways. State highway agencies are often willing to undertake these projects with a specific cost commitment approach, which typically means that these projects have to be completed within a fixed budget. Scope definition for such projects is directly related to the funds available. The constrained budget tool is perceived as a regulatory mechanism to evaluate and limit project scope to the absolutely necessary items alone and prevent any cost overruns.

Why?

Highway projects involve a huge sum of monetary resources, which often involve a significant amount of consideration and give and take by legislators. The need and feasibility of a project has to be adequately justified while funds are being sought. In a resource-limited environment, some projects may be approved based on a limited resource allocation—budget. A mechanism is required to carefully monitor and use resources for such projects. The constrained budget tool was developed with these requirements in mind.

What Does It Do?

This tool is used to constantly evaluate whether or not the total project cost is within a predefined or mandated budget while attempting to scope and design the project within the fixed budget. The tool can also be perceived as a cost-cutting technique. The tool also ensures that critical elements of the project are sufficiently included in the scope. This tool causes designers to seek innovative and low-cost designs as a means of meeting the cost restraints.

When?

This tool is used early in the project development process—in the programming and preliminary design phase. The tool is needed when a budget has been mandated and when no increases will be allowed.

Examples

The state of Washington has recently passed several gas taxes that included legislated line-item budgets for different projects. These budgets are considered fixed and cannot be increased. Cost estimates for many of these projects were prepared based on limited scope. WSDOT has initiated project control and reporting procedures to ensure that these constrained budgets are met.

Tips

When developing a project under a constrained budget, the state highway agency should use a number of different tools to support this method. For example, Tool D3.1, design to cost, is an excellent tool to help ensure that the design is constantly being assessed from a cost estimate perspective. Tool V2.1, value engineering, should be used to evaluate different design alternatives to determine the lowest-cost option that provides the most scope for a project. Other budget control tools should also be used in conjunction with this tool.

One issue that state highway agency estimators have to carefully consider under the constrained budget tool is artificially reducing costs to maintain the budget as the design is developed. The integrity strategy should be followed to prevent this pressure from occurring.

Resources

WSDOT (2006). *Project Management On-Line Guide.* www.wsdot.wa.gov/Projects/ProjectMgmt.

Project Management Institute (2004). *A Guide to the Project Management Body of Knowledge: PMBOK Guide,* Third Edition, Project Management Institute.

B1.3 Standardized Estimation and Cost Management Procedures (Also See C4.6)

The objective of standardizing procedures is to establish a common basis for all state highway agency project participants to follow when preparing cost estimates and to manage costs in a similar manner over the project development process. Change occurs frequently on projects as they are developed. Changes come from, for example, added scope, design development, and different site conditions than anticipated. Adopting standard procedures will aid project participants when making decisions regarding potential changes to current budgets, with the goal of controlling the project baseline budget. The integration of both cost estimation practice and cost estimation management through standardized procedures is a critical feature to successfully managing cost escalation.

What Is It?

This tool establishes a set of standards and procedures within a state highway agency to guide the preparation of estimates and management of costs through the various stages of project development. The objective is to provide a coherent policy basis for alleviating cost escalation by consistently providing timely feedback on the potential impact of changes to project budgets. Procedures provide a basis for how costs are managed, including who has authority to make decisions regarding changes to current budgets.

Why?

Changes often impact costs, and the necessity to constantly monitor these impacts in relation to the budget is necessary to control cost escalation. The most effective cost management system is one that will allow the project team to develop designs and make decisions regarding design alternatives with full knowledge of the cost impact of their decisions. Standardized cost management procedures should facilitate controlling cost escalation throughout programming and design of project development. They also can help establish a cost-conscious atmosphere within the project team environment.

What Does It Do?

These procedures formalize project cost control approaches that will be followed throughout the project development phases through a standardized process for (1) monitoring project development for potential changes to the budget, (2) submitting potential changes, and (3) obtaining management approval of these changes. This cost control process aids the project team in monitoring costs and alerts the team to any major impacts with regard to the current budget.

When?

Standardized procedures must be established at an agency level for guiding project development work, specifically for cost estimation and cost management. The procedures should be applied throughout the project development process. However, cost management can only begin when a baseline scope, cost, and schedule are set.

Examples

The Missouri DOT has developed a set of estimation and cost management procedures that are applied from need identification through to the final design stages. These procedures are closely tied to the Missouri DOT project development process. There are clear definitions of terms and the identification of a timeline for the different steps to be followed for a project to be realized. As a need is transformed into a real project, based on available information, appropriate estimation techniques are indicated to accurately derive cost estimates. Further, significant tasks—such as public input, environmental considerations, and the proper channels to obtain approvals as cost estimates are developed—have been incorporated into the Missouri DOT procedures (see C4.6 example). An outline of the contents of the Missouri DOT procedure is provided below:

1-02.1 PURPOSE
1-02.2 GENERAL OVERVIEW
1-02.3 NEEDS INDENTIFICATION
1-02.4 NEEDS PRIORITIZATION
1-02.5 INITIAL PROJECT ESTIMATES
1-02.6 PROJECT SCOPING
1-02.7 PROJECT SCOPING MEMORANDUM
1-02.8 PROJECT SCOPING CHECKLISTS
1-02.9 PROJECT PRIORITIZATION
1-02.10 STIP COMMITMENTS
1-02.11 SCOPE CHANGES
1-02.12 PROJECT COST ESTIMATES
1-02.13 ENGINEER'S ESTIMATE
1-02.14 BID ANALYSIS PROCESS
1-02.15 RECOMMENDATION FOR AWARD OR REJECTION OF BIDS

A tracking system for potential amendments to budgets is also covered in the Missouri DOT procedures to monitor changes and update the estimate accordingly. A set of submittal and approval forms indicating changes and justification of these changes to current budgets keeps key personnel informed of cost variations. An example of a project control form for scope changes included in the Missouri DOT procedure can be found under Tool C6.3, scope change form.

Tips

Budget control can only begin once a baseline cost estimate is prepared for a project. Cost management procedures should include project control forms and directions on when and how to complete these forms. Further, the procedures should identify levels of approval for accepting changes to the budget based on dollar size of the change. Smaller cost changes can be approved at the project level, while larger cost changes would require region/district or headquarter's management approval.

Resources

Becker, Daniel (2003). "Controlling Construction Costs During Design," *AACE Transactions,* AACE International, Vol. F-5, 1–4.

Schloz, Michael J. (1977). "Project Cost Management During Conceptual Engineering," *AACE Transactions,* AACE International, 167–172.

Sturgis, Robert P. (1967). "For Big Savings—Control Costs while Defining Scope," AACE 11th National Meeting, AACE International, Vol. 67-C.3, 49–52.

Missouri DOT (2004). "Chapter 1, General Information: Needs Identification Project Scoping and STIP Commitments," Section 1-02, *Project Development Manual,* Revision April, 12, 2004. www.modot.org/business/manuals/projectdevelopment.htm.

Project Management Institute (2004), *A Guide to the Project Management Body of Knowledge: PMBOK Guide,* Third Edition.

B1.4 Summary of Key Scope Items (Original/Previous/Current)

Developing and tracking key scope items can aid in budget control by immediately indicating changes in those items as the project progresses through project development. Listing these key items at each project development phase and with each estimate assists in communication among all team members.

What Is It?

A summary of key scope items is a list or outline of the most important elements of a project. These items should be identified early, during the project scoping process (see also C6.4 and P2.2). These items ultimately define the project budget and schedule.

Why?

Defining project scope clearly lays the groundwork for accurate estimation and more efficient project delivery by defining and setting project limits. Communication of these items allows for tracking of project scope changes, as well.

What Does It Do?

Summarizing key scope items makes team members aware of the estimate basis and fundamental project assumptions. Each key scope item will represent a group of smaller tasks and scope components. Estimates can be prepared according to each key scope item or division of the project. When a new scope item arises, the team will be immediately aware of the change.

When?

The list of key scope items should be done as early as possible in the project development process, preferably during the scoping process. If a project does not use a formal scoping process, a list can typically be completed during the conceptual estimation process. The summary of key scope items should be used for conceptual estimation, budget control, and project control.

Examples

The Minnesota DOT uses a summary of key scope items to clearly define the project (see Figure B1.4). Although simple, the summary of key scope items can be used extensively throughout project development to track budget and schedule progression.

Tips

As a means to monitor budget and schedule variances, compare original and current project scopes at key project development milestones and when changes arise.

Resources

California DOT Division of Design. *Project Development Procedures Manual.* www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm.

South Dakota DOT. Scope Summary—*Road Design Manual.* www.sddot.com/pe/roaddesign/docs/rdmanual/rdmch03.pdf.

B1.5 Variance Reports on Cost and Schedule

Variance reports on changes in cost and schedule provide a mechanism for budget control through tracking changes and alerting project personnel of changes.

What Is It?

This is a tool for alerting project personnel, particularly management, to deviations from the project budget or plan. It enhances management's ability to control project cost and schedule.

Why?

Early identification of differences in project cost and schedule can help to ensure proper resource allocation. Discrepancies between estimated or planned costs or schedule can be harmful to the project. If a project's costs increase, additional funds will need to be allocated. If a project's schedule increases, additional funds may also have to be allocated to compensate for inflation, rising land values, or other time-related factors. If the project costs decrease, the additional resources can be allocated elsewhere; however, care should be taken to not redirect money that will have to be requested later due to not realizing that the deviations were inaccurate or not recognizing that unfavorable differences in funds (an increase in funding needs) were a possibility in the future. If the project schedule decreases, the availability of funds and other resources needs to be assessed given the new time frame.

What Does It Do?

Variance reports create a transparent notification system for alerting project personnel of deviations in project costs or schedule.

When?

Variance reports need to be completed regularly throughout project development.

PROJECT SCOPE SUMMARY FORM
FOR COST ESTIMATES

Purpose of this Form: To provide a summary record of the project scope associated with each project cost estimate Mn/DOT prepares.

Directions for Completing this Form: This form is set up as a checklist of the possible elements, which may be included in a roadway/bridge construction project. The checklist also includes a column/space for approximate quantities and/or comments regarding each element. The **L**ength **W**idth **D**epth (LWD) method for early project cost estimates requires very specific quantities in specified units for these project elements. In this form units and quantities should be identified in general terms which define the project in a way which can be easily understood by people who currently are not directly working on the project.

Date:
T.H.
S.P., if known:
From:
To:
Brief Project Description:
Cost Estimate Total:
Summary Author/Estimator:

	Project Scope		
Element	Includes	Doesn't Include	Quantity/Comment
Grading	☐	☐	
Aggregates	☐	☐	
Paving	☐	☐	
Bridge Approach Panels	☐	☐	
Mobilization	☐	☐	
Removal/Salvage	☐	☐	
Drainage	☐	☐	
Traffic Control	☐	☐	
Turf/Erosion	☐	☐	
Signing	☐	☐	
Lighting	☐	☐	
Temporary Construction	☐	☐	
Utilities	☐	☐	
Aesthetics	☐	☐	
Retaining Walls	☐	☐	
Noise Walls	☐	☐	
Bridges	☐	☐	
Signals/Traffic	☐	☐	
Management Systems	☐	☐	
Right of Way	☐	☐	
Project Development/ Delivery	☐	☐	

Figure B1.4. Minnesota scope summary form.

Examples

Cost containment tables are a simple but powerful form of variance reporting. Sections C6.1 and I1.1 contain excellent descriptions and examples of cost containment tables. Figure C6.1 can be used to create a variance report, which is simply a report that documents variances in cost to management as a project progresses through the development process. Variance reports are generated at key project milestones or when significant changes in the project occur.

Tips

Consider different variance report details and intervals depending on the level of complexity of the project or phase of project development. Intervals should be closer together on highly complex projects or projects that are in a phase of high activity. Even during periods of inactivity, projects should be regularly examined to ensure that there are no variances in project costs or schedule.

Variances should be reported to appropriate levels of management if the magnitude of the deviation warrants.

Consideration should be given to the impact of multiple small deviations that alone do not account for much difference from the budget or schedule but collectively amount to a problem. Safeguards should be in place to watch for this type of activity.

Resources

FHWA (2004). "Lessons Learned: Federal Task Force on the Boston Central Artery/Tunnel Project (Summary of 34 Rec-

ommendations).” www.fhwa.dot.gov/programadmin/mega/lessonsa.htm.

Federal Aviation Administration (FAA) uses “baseline instability” or variance from an origin to determine cost and schedule deviations. See www.faa.gov/acm/acm10/reports/Instability/introduction.htm.

Metropolitan Transportation Authority of New York, Sample of Variance Report can be found at www.mta.net/board/Items/2005/04_April/20050407OtherSectorWES_Item2D.pdf

Washington DOT, Set of Deviation Guidelines: www.wsdot.wa.gov/NR/rdonlyres/76FAB4F0-7EBD-4104-9441-B80D690DE4C1/0/DVP.pdf.

B2 Buffers

The objective of buffers is to protect the state highway agency and particularly estimators from outside pressure that could bias or manipulate a project estimate. Buffers take the form of structured estimate approval processes. These formal estimate approvals obligate management and external parties to recognize and acknowledge changes in project scope and schedule.

B2.1 Board Approvals

On larger projects or on groups of smaller projects, a board will review and approve the estimate and schedule while representing all parties involved. Requiring board approval of all major decisions throughout project development, especially when defining the project scope, can help to contain project cost growth.

What Is It?

This is a tool commonly used to ensure that the focus and scope of a project remains clear and is understood by all parties, thereby providing guidelines and priorities to keep mangers and estimators on target.

Estimators can feel pressure to maintain a project budget, particularly as scope changes or scope creep occurs. Requiring board approval for scope changes and cost increases can take some of this pressure off of the estimator and possibly prevent any optimistic biases from entering into the estimate. An estimator’s job is to estimate and support design. Estimators should not be asked to make large scope assumptions or to respond to outside requests for additions to scope. Board approvals help to ensure that scope responsibility is the purview of management.

What Does It Do?

The practice of using board approvals counters the internal and external pressures that often coerce project managers to make scope changes. Thus, the estimators have a clear understanding of the project scope at all times.

When?

Board approvals can and should be used at key points during the development phase. Board approvals not only help to maintain clear scope definition, they also improve general communication between parties. (Also see C1.1, Communication of Importance.)

Examples

Washington State DOT uses board approvals to increase communication between the state and local agencies as well as all other parties involved with the project. For instance, board approvals are often used to discuss and decide upon deviations from standard procedures or varying design options. Table B2.1 is an example of choices that would need to be considered during a board meeting for approval.

Involving key parties in scope decisions through a board approval process from the start of the design process can deter conflicts that may surface later in project development and place undue pressure on estimators to maintain unrealistic budgets.

Tips

Use a facilitator to ensure that board meetings progress following the agenda and cover all of the required topics in a timely manner. Be prepared and take a proactive role; do not use board approvals as a crutch.

Resources

Washington State DOT, *Design Manual.* An online PDF version can be found at www.wsdot.wa.gov/fasc/EngineeringPublications/Manuals/DesignManual.pdf. This file is very large (70 MB) and may take a long time to download.

Washington State DOT, “Building Projects That Build Communities,” Chapter Three: Working Through Design, Review and Approval. An online PDF version can be fount at www.wsdot.wa.gov/biz/csd/BPBC_Final/#BPBC_Final.

B2.2 Constrained Budget (Also See B1.2)

Typically, an agency’s program of required projects outpaces its funding year after year. In such a fiscally constrained environment, it is inevitable that tough decisions have to be made, and the decision process becomes more difficult if funds must be reapportioned to pay for individual project cost growth during the development process. Therefore, one control approach is to push fiscal constraints down to the project or corridor level. Thus, it is better to establish budget constraints early in the project development process and to demand that evaluating cost effectiveness is a critical component of all project decisions. This requirement is especially important when a budget is fixed due to some legislative constraint.

Table B2.1. Sample of board meeting considerations.

Slower speeds – using traffic calming techniques to reduce severity of collisions.	Less efficient movement of traffic/increased congestion/increased variability in vehicles speed.
Lower speed limits – to encourage motorists to stop and shop; allow people to safely cross streets.	Fewer speed limits that reflect current operating speeds. Reduced enforceability and compliance.
Bulb-outs at intersections – to make pedestrians more visible to motorists and delineate parking; **raised medians** to reduce collision points, manage access and provide refuge for crossing pedestrians	Less consistent facility; less consistency with design requirements; more obstructions on highways; increased liability; increased maintenance work; less efficient freight movement.
Roundabouts – to reduce delay, improve capacity and reduce maintenance cost.	Inconsistent facilities: safety and mobility may be compromised; reduced emergency service speed; reduced service to pedestrians and bicyclists.
Landscaping and aesthetic improvements – to visually enhance community.	Increased maintenance costs and worker exposure to traffic; reduced safety to motorists: less visibility of pedestrians.
Roadside trees – to absorb storm water runoff; add shading and visual value to community.	Reduced safety clear zone (speed dependent) or protection; increased severity of accidents. Increased environmental related accidents.
More crosswalks – to indicate pedestrian crossing areas to motorists and channelize pedestrians.	Increased pedestrian "false sense of security."

What Is It?

The constrained budget tool restricts the project cost to a predefined limit and confines scope development within this cost constraint.

Why?

Scope development is often subject to external or internal pressures to maximize the scope for a project, which may have an impact on the estimator's decisions when preparing cost estimates. The constrained budget tool reduces the impact of such potential barriers for an estimator by setting cost constraints up front and then ensuring that the design is constantly tested against these cost constraints through frequent estimate updates.

What Does It Do?

This tool will require that the project team and estimators closely monitor project costs to keep costs within the fixed budget, as there is no possibility for seeking additional funds. This tool acts as a buffer because it, by default, protects the estimator from pressure to artificially reduce cost.

When?

This tool is used in programming and early in preliminary engineering and consistently acts a budget control mechanism throughout the design process.

Examples

The State of Washington has recently passed several gas taxes that included legislated line-item budgets for different projects. These budgets are considered fixed and cannot be increased. Cost estimates for many of these projects were prepared based on limited scope. WSDOT has initiated project control and reporting procedures to ensure that these constrained budgets are met. As part of project control and reporting procedures, quarterly reports are presented to region and headquarters management with the intent to provide the most current cost and reveal any potential cost increases so decisions can be made to realign cost estimates with the fixed budgets. This is an effort to reduce surprises and, in this way, protect the project team from downward biasing of costs simply to meet a given budget.

Tips

When developing a project under a constrained budget, the state highway agency should use a number of different tools to support this method. For example, Tool D3.1, Design to Cost, is an excellent tool to help ensure that the design is constantly being assessed from a cost estimation perspective. Tool V2.1, Value Engineering, should be used to evaluate different design alternatives to determine the lowest-cost option that provides the most scope for a project. Other budget control tools should also be used in conjunction with this tool.

One issue that state highway agency estimators have to carefully consider under the constrained budget tool is artificially reducing costs to maintain the budget as the design is developed. Management can play an important role in reducing pressures to estimate on the low side.

Resources

Washington State DOT (2006), *Project Management Online Guide.* www.wsdot.wa.gov/Projects/ProjectMgmt.

Project Management Institute (2004). *A Guide to the Project Management Body of Knowledge: PMBOK Guide,* Third Edition.

B2.3 Management Approvals

Departments should establish a formal estimate approval process that requires all major project cost and schedule increases/decreases to be approved by at least two members of the department's senior management.

What Is It?

This is a tool that supports the estimate integrity strategy by shielding the state highway agency estimators and consultant estimators from external and internal pressures to manipulate an estimate.

Why?

Two of the root causes of project cost growth and estimate inaccuracies are scope changes and schedule growth. If state highway agencies truly want accurate project estimates, especially in the case of large or complex projects, they must have management structures in place that screen and control changes to project scope and schedule.

What Does It Do?

State highway agencies can protect designers and estimators from outside pressures that cause project cost growth by requiring senior management approvals of project scope (design) and schedule changes. This tool promotes estimate quality by establishing an organizational structure that shields lower-level designers and estimators from influences that can cause scope and schedule growth. It places the authority and responsibility for project scope and schedule changes where there is a much broader knowledge base of the project and its environment. The tool's other important function is to ensure that management is kept appraised of a project's current scope, cost, and schedule—*no surprises.*

When?

Before a project's scope or schedule can be changed, management must be made aware of the impacts of the change and provide formal (documented) approval.

Examples

Scope changes usually drive cost changes, so those authorized to sign off on scope changes need to know the cost impacts. Therefore, the agency may structure the approval process based on the effect of the requested change on estimated project cost. To do this, it is necessary that an estimate of the cost effects of any scope change be submitted with the approval request.

All major scope changes to a project must be approved by at least two members of the agency's senior management, and a copy of the scope change approval letter is retained in the project estimation file.

All major cost increases/decreases to a project must be approved by at least two members of the senior management. Such approvals must be in writing, and copies of the approval letters must be maintained both by project management and by those responsible for developing the project estimate (there should also be a copy in the estimation file).

Tips

An agency can set dollar limits that determine when agency management approval is required. These dollar limits can be graduated and tied to different levels of responsibility within the project team, within the management hierarchy of a region/district, or within the headquarters at a senior management level.

Resources

Missouri DOT (2004). "Chapter 1, General Information: Needs Identification Project Scoping and STIP Commitments," Section 1-02, *Project Development Manual,* Revision April, 12, 2004. www.modot.org/business/manuals/projectdevelopment.htm.

C1 Communication

Proper communication of project cost estimates can help to solve many cost escalation problems. Key communication points are the *communication of importance* and the *communication of uncertainty.* A key question that must be communicated with each estimate is "what decisions will be made from this estimate?" Estimators need to know the purpose of an estimate to know the appropriate level of effort to expend on an estimate. The decisions that will be made from the estimate must be communicated at the time the estimate is being generated. Likewise, estimators have an obligation to communicate the level of uncertainty associated with an estimate so that inappropriate decisions are not made from the estimate.

C1.1 Communication of Importance

Every project estimate is important because cost is integral to project scope, and together cost and scope drive many of the project team's design and schedule decisions. Cost estimation must be viewed as an important and integral part of the project development function. Cost estimators should understand how their estimates are going to be used to support the project development process. Additionally, the estimated costs that are presented to stakeholders outside of the project team create third-party expectations, and these expectations can have many positive and negative implications to the project and the state highway agency.

What Is It?

This is a tool that ensures that all project team members understand the importance of a given cost estimate and/or the cost estimation function. This understanding is necessary if costs are to be managed appropriately. Communication of importance serves to correctly convey the accuracy and variability of an estimate.

Why?

During project development, team members and a variety of stakeholders need cost information to make decisions. Estimators should understand the nature of the decisions that will be made from their estimates. For example, a different level of importance—and a corresponding level of effort—should be placed on an estimate that is supporting a decision when comparing options versus an estimate that is being released to external stakeholders as an ultimate project cost.

What Does It Do?

The communication of importance creates an understandable and open communication path between all project participants. It lets estimators know the amount of effort they should expend on the estimate. It creates a transparency in the purpose of the estimate and helps to ensure that the wrong number will not be used for critical budgeting or design decisions.

When?

Communication of importance should happen throughout all phases of project development. It is particularly important during milestone updates and at critical points in the project development process.

Examples

The communication of importance is as much a philosophy as it is a tool. The simplest example is to always ask, "What decisions will be made from this estimate?"

The use of milestone estimates to convey importance is also very helpful. Pennsylvania DOT uses the following milestones in their estimating process:

- Program amount (amount approved by the Program Management Committee [PMC])
- Engineering and environmental (E&E) scoping field view
- 30% (design field view)
- 75% (after final design field view)
- 95% (engineer's estimate)
- Bid amount

By using these critical milestones, Pennsylvania DOT can convey the importance of these estimates. They know what decisions will be made at each of these milestone and what the current estimate is to communicate to external stakeholders. Estimates in support of design decisions will not be confused with milestone estimates. For more information on the Pennsylvania DOT system, see C6.1, Cost Containment Table.

Tips

Through workshops and continued reinforcement of the concept, develop an agency understanding of accurate estimate importance and the impact that inaccurate estimates may have on a project and program.

Resources

The Construction Industry Institute has numerous tools available on its website. Search for "communication of importance" at www.construction-institute.org.

C1.2 Communication of Uncertainty

Properly communicating the uncertainty involved in an estimate will help to ensure that appropriate decisions are made from the estimate. Estimate uncertainty can be communicated by providing a range estimate rather than a point estimate. Communication of estimate uncertainty can also be conveyed by simply listing the assumptions, allowances, unknowns, and contingencies included in an estimate.

What Is It?

Communication of estimate uncertainty involves an explicit means of conveying the accuracy of an estimate. There are numerous means of conveying uncertainty. Presenting a cost range is common early in project development, and presenting a contingency is common during final engineering. At any point in the process, list of allowances or project unknowns can be used to convey uncertainty. All means are intended to let designers and decision makers know the accuracy of, or potential error in, a cost estimate.

Why?

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 estimated costs will help in managing project expectations.

What Does It Do?

Communication of uncertainty creates transparency in the estimation process. It buffers estimators by conveying that estimates are not absolute, but rather predictions based upon the best information known at the time. This tool allows for more prudent decisions to be made from cost estimates.

When?

The identification and communication of the uncertainty in relation to project scope and cost unknowns helps in managing project cost in all phases of project development, but particularly in the programming and preliminary design 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.

Examples

Examples of communication of uncertainty can be seen under the risk analysis method, R3.1.

The following illustration from Washington State DOT's Cost Estimate Validation Process (CEVP) program is an excellent example of how to convey uncertainty concisely to the project team and any number of stakeholders.

The Washington State DOT CEVP summary example (Figure C1.2) is an excellent demonstration of how to convey estimate uncertainty. It provides a cost range, rather than a point estimate, for both cost and schedule. It lists the risks associated with the project so that readers understand what is driving the uncertainty in an estimate. It also lists changes from periodic or milestone estimates.

While the CEVP example may be too elaborate for most projects, the point of communicating estimates with a range or with a list of risks is applicable to most projects.

Tips

Transparently convey the uncertainty of each estimate. An estimate with uncertainty is not a bad estimate; it is a realistic estimate. Conveying uncertainty will allow better decisions to be made from estimate information.

Resources

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook.*

FHWA (2004). "Major Project Program Cost Estimating Guidance." http://www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3.

Washington State DOT (2006). Cost Estimating Validation Process (CEVP) website. www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

C1.3 Communication within State Highway Agency

Developing a project-specific communication plan that includes all types of internal communication among project team members is required for successful project execution. This communication plan should include issues related to cost estimation practice and cost estimation management.

What Is It?

Communication is the exchange of specific information. Both cost estimation management and cost estimation practice involve many information exchanges. Timely and accurate information transmission is often attributed to efficient project organizational structures. Cost estimation management and cost estimation practice involve multiple participants within a state highway agency, often at different locations, such as in regions/districts or headquarters. Even within regions/districts, there may be multiple office locations. Hence, there is a need to establish channels for efficient communication.

Why?

Communication tools and techniques ensure the timely and appropriate generation, collection, storage, and retrieval of project information. A project communication plan has to be developed identifying who is responsible for what information or data, and how and when this project participant can be reached to obtain that specific information. State highway agencies have different teams working on different aspects of a project, such as pavement design and estimation, right-of-way estimation, bridge design and estimation, and project risk analysis. The estimator must consult with such teams to incorporate current cost into the estimate. This communication interaction should be covered in the project communication plan.

I-405 Congestion Relief and Bus Rapid Transit Projects

Revised July 2003

Scenario

Tukwila to Bothell
(Option C)

Project Descriptions:

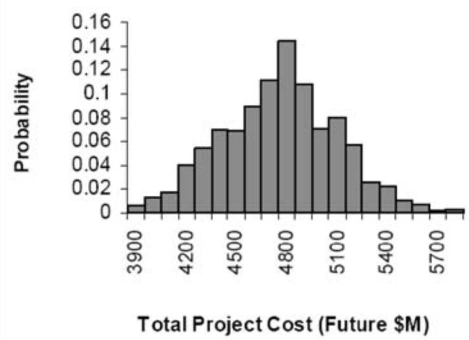
- Continuous multi-modal corridor improvement projects from I-5 in Tukwila to SR 522 in Bothell.
- Adds one lane each direction from I-5 to SR 181 in Tukwila.
- Adds two lanes each direction from SR 181 in Tukwila to I-90 in Bellevue.
- Adds one lane each direction from I-90 in Bellevue to SR 522 in Bothell.
- On SR 167, adds one lane between I-405 and S. 180th St.
- Constructs Bus Rapid Transit system with stations, HOV direct access ramps and Park & Ride lots and coaches.
- Expands the vanpool program.

Schedule:

Begin Construction
Range: 2006-2007

End Construction
Range: 2013-2014

CEVP Result:



Project Benefits:

- Reduces congestion and improves freight movement.
- Provides bus rapid transit system from SeaTac to Lynnwood.
- Constructs 2300 new Park & Ride spaces.
- Adds 600 new vanpools and increases commute reduction programs.
- Improves water resources.

Project Cost Range:

10% chance the cost < $ 4.2 Billion

50% chance the cost < $ 4.7 Billion

90% chance the cost < $ 5.1 Billion

Project Risks:

- Changing environmental requirements for project mitigation (stormwater, wetlands, fish resources and streams) may increase project costs--primarily for added right-of-way purchases.
- Delays in right-of-way purchases may result in construction delays and project cost increases.
- Early stage of project development leads to scope uncertainty.
- Legal challenges and delays in obtaining environmental permits may result in project delay.
- Utility relocations may require extra time to negotiate and complete.

What's Changed Since 2002:

- Scope: Project limits are smaller.
- Schedule: Begin construction range has been delayed up to one year. End construction range has been accelerated two years.
- Costs: Costs have gone down approximately $1 billion due to scope revisions.
- Risk Management: Identifying new strategies for improved environmental clearances and right-of-way processes. Coordinating decision strategies with FHWA.

Financial Fine Print (Key Assumptions):

- Full project funding becomes available in July 2005. State I-405 Nickel funds will roll-over into this package.
- Inflation escalation is to 2010, the approximate midpoint of construction.
- Additional federal, state, regional and local money may be needed.
- Project cost range includes $18.5 million in past expenses, beginning in 1999.
- Assumes funding decisions do not interrupt or cause construction delays.

Level of Project Design: Low — Medium — High

July 16, 2003

Washington State Department of Transportation

Figure C1.2. WSDOT CEVP summary example.

What Does It Do?

A communication plan establishes a logical channel for project participants internal to the state highway agency to interact with each other. A good plan will eliminate ambiguities like where to find what information and whom to consult for a specific problem in relation to the many different aspects of the project (including cost estimation management and cost estimation practice). In particular, the communication plan should identify who needs to be notified when changes are made that impact scope, cost, and/or schedule.

When?

An internal communication plan is used during all phases of the project development. However, this plan must be created as early as possible and may have to be updated as newer participants join the project team. The project team must be informed of any changes.

Examples

Lead project personnel can assign team members to create a stakeholders analysis with input from all participants, and then a communication matrix can be formulated. This process involves collection of data, such as different modes of communicating with different stakeholders (stakeholders as used in this example means project team members), period of unavailability, and alternative contact information. The top of Figure C1.3 shows a sample stakeholder analysis.

Subsequently, a communication matrix is formulated matching the work breakdown structure (WBS) with all deliverables and timelines clearly indicated, as shown in the bottom of Figure C1.3. This will help eliminate ambiguities in determining responsible participants at any point in the project and will help reduce any delays caused by a communication blackout.

Table C1.3 shows the table that Washington State DOT uses to structure the internal communication plan. The table addresses communication between and among the teams as well as communication protocols. The table helps to ensure that communication is open, honest, continuous and efficient.

Tips

A formal list of all project participants and their contact information must be created for every project, along with the participants' duties and responsibilities. A portion of this list must be dedicated to communication related to cost estimation practice and cost estimation management.

Educate and train project participants within a state highway agency on the importance of efficient communication. Ensure project participant awareness of the project communication plan.

Resources

Harder, Barbara T., Neil J. Pedersen, Tom Warne, and Barbara Martin (July-August 2005). "On Budget and On Time," *TR News,* Transportation Research Board.

Caltrans (2003). *Project Communication Handbook.* www.dot.ca.gov/hq/projmgmt/documents/pchb/project_communication_handbook.pdf. Additional information can be found at www.dot.ca.gov/hq/projmgmt/guidance_pchb.htm.

Project Management Institute (2004), *A Guide to the Project Management Body of Knowledge* (PMBOK Guide).

Washington State Project Management Process, Communication Plan Template, can be found at www.wsdot.wa.gov/Projects/ProjectMgmt/OnLine_Guide/Tools/Communication_Plan.doc.

C1.4 Definitive Management Plan

A primary function of state highway agencies is project management. Cost estimation management can be considered a subset of project management. Project management requires the application of skills, knowledge, tools, and techniques to deliver the project on time, within budget, and according to specifications. Communication is arguably one of the most important elements of project management. Successful project management involves discipline. The creation of definitive project management plans is a critical element of project management. It helps to communicate management objectives, strategies, project control requirements, project milestones, and project personnel. Project management plans will vary based upon project type, project complexity, and point in project development. This variation is a primary reason why definitive project management plans can help communicate estimates and cost management procedure effectively.

The definitive management plan describes how the processes and activities of a project will be managed. A cost estimation management plan is a subset of this definitive project management plan. The primary objective of a definitive project management plan is to create a consistent, coherent document that can be used to guide the project execution and project control and communicate the essential functions of estimation management.

Why?

Each project is unique. Projects vary by the complexity of their physical, temporal (i.e., schedule), and sociopolitical characteristics. While some projects require elaborate project management plans and actions, others can be managed by planning a concise set of actions at critical times in the process. The purpose of the definitive project management plan is to clearly define management roles and responsibilities, struc-

Stakeholders Analysis

EA Number: 34040K
District/Cty/Rte/PM: 08-SBD-395-0.5
Project Manager: Lisa Gonzales

RBS Group	Function	Name	Telephone	Stakeholders Goals on this Project	Preferred Method of Communication	Second Preferred Method of Communication	Preferred Method for Rewarding the Team
106	Project Management	Lisa Gonzales	(909) XXX-XXXX	Efficient project completion	email	cell phone	Team Celebration
140	Project Management	Peggy Wright	(909) XXX-XXXX	Project completed within cost, scope and schedule	email	telephone	Team Celebration
146	Program Management	Robert Johnson	(909) XXX-XXXX	Keep project on track	email	telephone	Certificate
147	Capital Outlay Mgmt	Fred Carter	(909) XXX-XXXX	Secure funding	email	telephone	Team Celebration
168	Envr-Biological/Permits	Slandra Vijay	(909) XXX-XXXX	Having all mitigation	email	telephone	Team Celebration
170	Envr-Mgmt	Jim Black	(909) XXX-XXXX	Environmental requirements covered	email	cell phone	Team Award
178	Envr-Cultural	Paul Hernandez	(909) XXX-XXXX	Complete mitigation	email	cell phone	Team Award
195	Forecasting	David Blake	(909) XXX-XXXX	To produce accurate data	email	in person	Team Celebration
233	Design P	Fathi	(909) XXX-XXXX	plans	telephone	email	Team Celebration

WBS Code	WBS Title	Sub-Product	Product Required on this Project? (Y/N)	Product Produced by (Task Manager Name)	Product Received by (Name of person receiving the product)	Method of Transmittal (mail, e-mail, fax, etc.)	Date of Submittal (one-time product) or Frequency (repetitive products)	Uniform Filing System Location	PHF
165. . .	**Perform Environmental Studies And Prepare Draft Environmental Document (DED)**								
165.05. .	*Perform Environmental Scoping and Select Alternatives for Study*								
165.05.05.	Review Project Information	• Initial Environmental Project File Setup	Y	Jane Moore	Jane Moore/Wendy Young	mail		421.01	
165.05.10.	Public and Agency Scoping Process	• Draft Notice of Intent for FHWA publication	Y	Jane Moore	Rich Williams/FHWA	mail		331.09	X
165.05.10.	Public and Agency Scoping Process	• Published Notice of Preparation with mailing list and State Clearinghouse documentation.	Y	Jane Moore	Rose Wilson	mail		231.1	X
165.05.10.	Public and Agency Scoping Process	• Public Participation Plan	Y	Public Affairs	Lisa Gonzales	e-mail		233.01	X
165.05.10.	Public and Agency Scoping Process	• MPO/APCD comments on and concurrence with Public Participation Plan.	Y	Slandra Vijay	FHWA/SCAG	mail		231.09	X

Figure C1.3. Sample stakeholder analysis (above) and communication matrix (below) (Caltrans Project Communication Handbook).

ture of work, and execution required by the executive management and project teams to complete a quality project on time, within budget, and safely.

What Does It Do?

The communication of a definitive project management plan can help to clarify project objectives, strategies, cost control requirements, project milestones, and project personnel. It can ultimately help state highway agencies to manage taxpayer resources for the highest possible return on value. It communicates that each project is unique and requires individual project management attention.

When?

This tool can be used during all phases of project development. In planning, it will likely be most effective on large projects with clearly defined boundaries. The tool will be most helpful from preliminary engineering through final engineering and into construction.

Examples

There are proven industry standards for project management. Perhaps the most pervasive standard is the Project Management Body of Knowledge (PMBOK) from the Project

Table C1.3. Template for documenting communication among teams.

WHAT	WHO	HOW	WHEN
Communicate project progress to senior management			
Communication among all teams.			
Distribute & maintain schedule Base Schedule Date:			
Create an organizational chart that identifies Team Structure			
Set guidelines			
Clarify chain of command guidelines with other agencies and contractors			
Set protocols			
Team member Communication			
How do project teams & resource agencies communicate?			
Communication between P/M Team and Production/Supervision Team			
Define internal (WSDOT) communication roles and responsibilities			
Facilitate distribution of information on other relevant agency projects to all production team members			
Communication between P/M Team and Consultant or Contractor			
At technical/field level			
At admin/regional level			

Management Institute (PMI). According to the PMBOK, the organization and presentation of the project plan should include the following:

1. Project charter
2. A description of the project management strategy
3. Scope of work, with the project's objectives
4. Define quality-level analysis
5. Cost estimates, schedule start and finish dates, and responsibility assignments
6. Performance measurements and baselines for technical scope, schedule, and cost
7. Major milestones and the corresponding dates
8. Required personnel and their expected cost
9. Risk management plan (including main risks) and planned strategies, solutions, and contingencies for each risk
10. Subsidiary management plan, including:
    - Scope management plan
    - Schedule management plan
    - Cost management plan
    - Quality management plan
    - Staffing management plan
    - Communications management plan
    - Risk response plan
    - Procurement management plan
11. Open issues and pending decisions

A second example comes from Washington State DOT. In July of 2005, the secretary of transportation issued Executive Order E 1032 to address project management at the agency level. The executive order contained guiding principles for the agency to follow. It provides an excellent point of discussion for this tool. The introduction of the executive order states as follows:

> The Washington State Department of Transportation (WSDOT) has refined its project management process for delivery Capital Transportation projects. This process includes "best practices," tools, templates and examples and will enhance the communication process for both pre-construction and construction project management. The Process, tools and templates can be found at www.wsdot.wa.gov/Projects/ProjectMgmt.

The project management website contains tools, templates, and examples that help project managers create definitive management plans. The website is extremely detailed. It covers tools and training in such areas as project management, cost risk assessment, cost estimate validation, value engineering, project control and reporting, and innovative project delivery. Figure C1.4 provides a concise overview of the process.

Communicating a definitive project management plan will assist in project estimation management and has proven successful in assisting to deliver projects on budget.

Tips

Intuition and numerous research studies have shown the benefits of pre-project planning. A definitive management plan should be created early and revisited at key milestones throughout the project lifecycle.

Resources

Project Management Institute (2004). *Project Management Body of knowledge* (PMBOK Guide). www.pmibookstore.org/PMIBookStore/productDetails.aspx?itemID=358&varID=1.

C1.5 Proactive Conveyance of Information to the Public

Proactive conveyance of information to the public is an important tool in cost estimation management. An informed public can become partners in cost estimation management. Additionally, state highway agencies are entrusted with resources from the public and have the responsibility to communicate how they are managing the resources to maximize a state's transportation system. Cost estimation practice and cost estimation management are vital processes to manage these resources. Transparency and proactive conveyance of estimate information can assist in cost estimation management.

What Is It?

This tool is a proactive approach for conveying cost estimate information to the public. It includes an action plan established for taking a proactive rather than defensive (or reactive) posture in gathering and transmitting information.

Why?

Public input can be vital to successful project completion. The public is the customer of every state highway agency. If the public does not agree with the project or some aspects of the project, there can be major impacts to project cost, schedule, and scope. Open and honest communication with the public can limit problems that impact project development.

What Does It Do?

A communication plan and the activation of the plan can create an open and honest dialogue between the agency and public. It creates accountability in cost estimation management for both the state highway agency and the public. This open exchange

The 5-step Process	Initiate and Align the Team	Plan the Work	Endorse The Plan	Work the Plan	Transition and Closure
Who is responsible?	*Project Manager	*Project Manager	*Project Manager	*Project Manager	*Project Manager
Who is involved?	**Project Team	**Project Team	**Project Team	**Project Team	**Project Team
What is it?	This step defines the what, identifies who is on the team and how and what are they going to contribute to completing the assignment	A work plan that specifically identifies who will do the work and mutually agreed upon time frames and budgets to get the work done.	An agreement of what is to be completed and by whom	Actively managing the work plan	A completed project or phase
What are the steps?	• Project Description • Team Mission / Assignment • *Team member identification and roles and responsibilities • Measures of success • Major Milestones • Boundaries • Operating Guidelines	• Task Planning using MDL • Schedule • Budget • Risk Management Plan • Communication Plan • Change Management Plan • QA/QC Plan • Transition/Closure Plan	• Project Team Commitment • Management Endorsement	• Manage the scope, schedule and budget • Manage risks and opportunities • Managing change • Communicate progress, issues and lessons learned	• Implement transition plan • Review Lessons Learned • Reward and Recognize • Archive
What it looks like to team members?	Attends and participates in a general project kick-off and review.	Participates in development of schedule at the task and deliverable level, develops budget for deliverables they are responsible for, participates in a risk assessment. Participates in development of communication and change management plans	Reviews schedule and estimate for consistency with earlier input and says "can do" A project management plan approved by the team and ARA or equivalent.	Regularly contacted by project manager or representative to review adherence to the project plan. Initiates contact with project manager upon discovery of potential change. Actively monitors key milestone dates for dependant activities that initiates his or her work.	Participates in lessons learned and development of phase transition plan
What is the outcome or work product?	An understanding of what is to be produced by whom and how they will work together. A document describes who is to be included on the team and what their responsibility is. A list of the milestones and critical success factors this team will accomplish.	A refined scope of work, a baseline schedule, a current estimate, a risk register that identifies and quantifies risk, a document on what information will be communicated to whom and when, and a document on what the team will do when change occurs.	A commitment by the individual team members and management agreeing to the: who, what, when and for how much.	Actively managed scope, schedule and budget, monthly status meetings to communicate progress and any changes to scope, schedule or budget, quarterly reports, and change management plans. Clear understanding of project status. Documents that communicate scope schedule and budget status.	A completed project phase, a transition (archive and hand off) document, a list of lessons learned.

* The Assigned Project manager is responsible for assuring total team participation **(Including Specialty Groups).**

**A project team consists of the project manager, team members from their project office, team members from specialty groups such as Real-Estate Services, Environmental, Hydraulics, Traffic, Operations, Geotech, Bridge, Utilities, and any others that are needed to deliver the project.

Figure C1.4. WSDOT project management process.

creates a positive atmosphere in which the agency and public can express goals, questions, comments, and concerns. Not only does this allow for an exchange of information, but it also produces an air of accountability. The plan needs to be developed and followed actively throughout project development.

When?

To be effective, the plan needs to be instituted in the earliest stages of project development. Communication plans may be standard for all projects, but large, complex, and sensitive projects require more extensive information exchanges than small, simple projects.

Examples

Some state highway agencies have public awareness plans that include websites for larger projects. While this may be very beneficial, state highway agencies should also make information available to the public regarding smaller, less controversial projects. This does not have to be a high-cost initiative on all projects. Consider using local and regional media, local schools, fairs, malls, focus groups, sponsorship of teams in walk-a-thons or benefit races, advisory groups, town hall meetings sponsored by local organizations, billboards, flyers, logo design competitions, or appearances at local civic club meetings.

Virginia DOT (VDOT) has created a "Dashboard" website, shown in Figure C1.5, which provides a wide variety of information to the general public regarding VDOT operations. The VDOT Dashboard site allows the public access to information on the number of projects in each phase of development, real-time information on specific projects, and milestone accountability of project development and engineering project activities. Information is transmitted using a traffic signal framework. The website enables the public to track any project. The website allows open communication between VDOT and the public and creates accountability to the public.

Resources

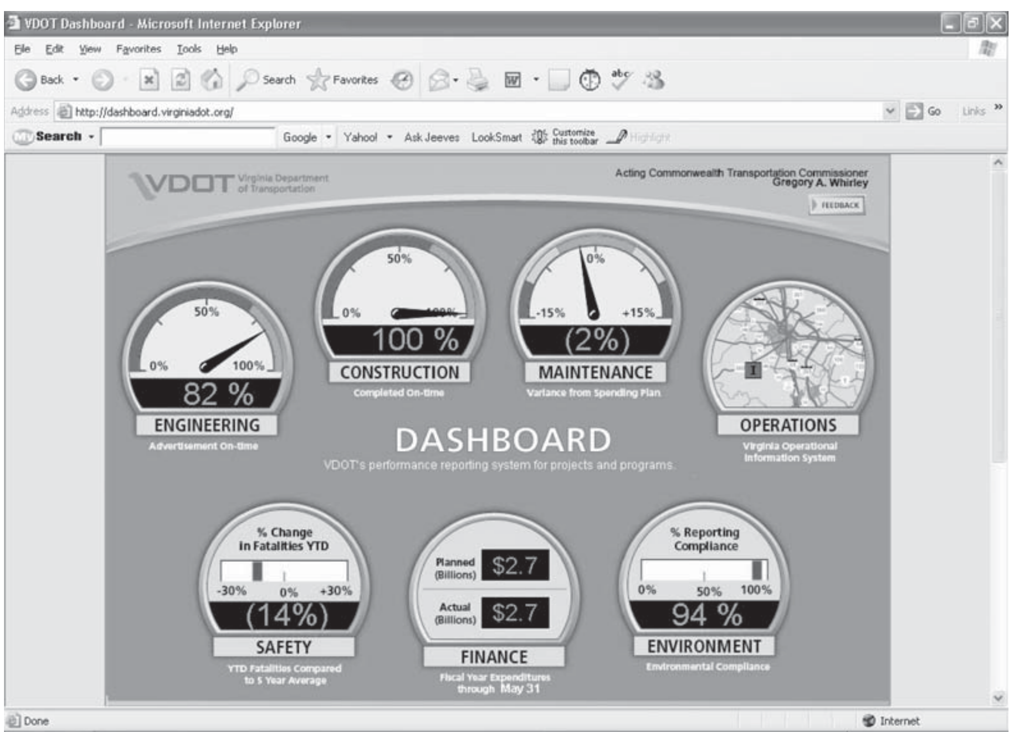
The VDOT Dashboard website: www.virginiadot.org.

Scenario Planning: www.fhwa.dot.gov/planning/scenplan/index.htm.

Public Involvement Techniques for Transportation Decision-Making: www.fhwa.dot.gov/reports/pittd/cover.htm.

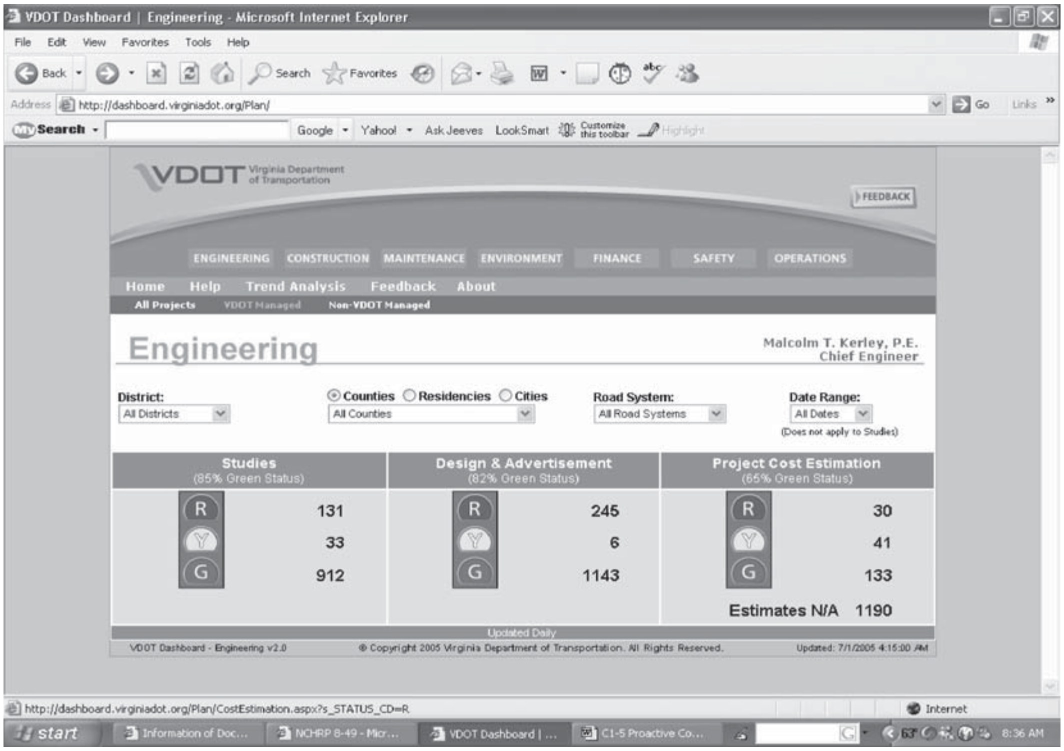
Bell, J. (1998). "Public Involvement, Low Budget Can Mean High Effectiveness," *Proceedings: National Conference on Transportation Planning for Small and Medium-Sized Communities,* http://ntl.bts.gov/card_view.cfm?docid=703.

O'Dowd, Carol (1998). "A Public Involvement Road Map," *Proceedings: National Conference on Transportation Planning for Small and Medium-Sized Communities.* http://ntl.bts.gov/card_view.cfm?docid=701.

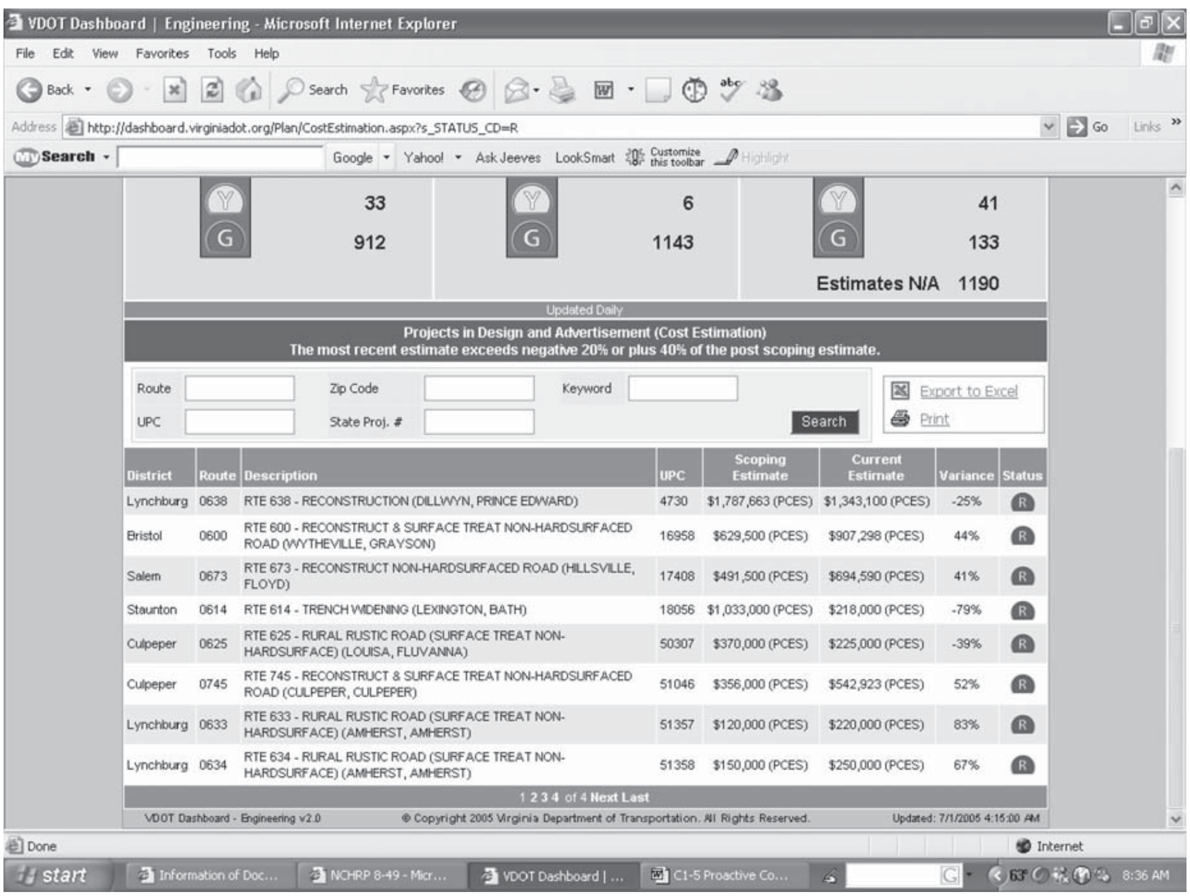


(a) Homepage

Figure C1.5. Virginia DOT "Dashboard" website.



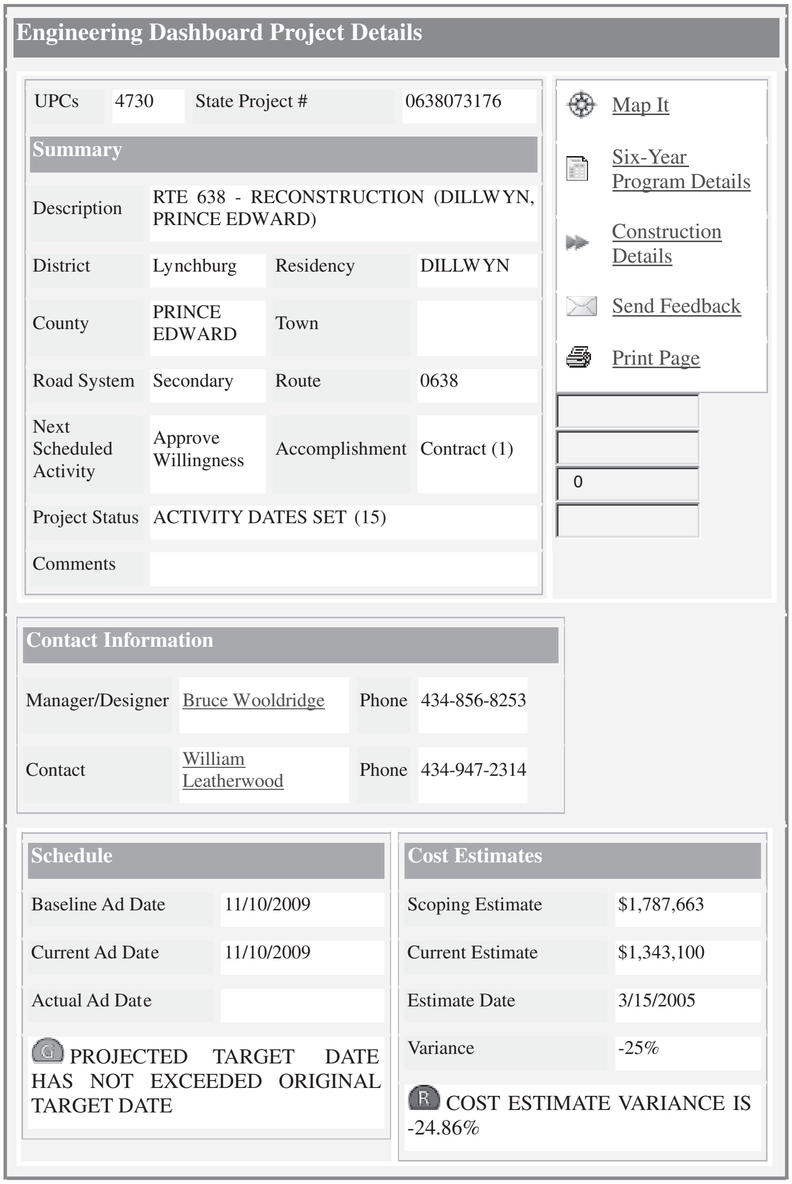
(**b**) Traffic signal information framework



(**c**) Project-specific information

Figure C1.5. (Continued).

(continued on next page)



Engineering Dashboard Project Details

UPCs	4730	State Project #	0638073176

Summary

Description	RTE 638 - RECONSTRUCTION (DILLWYN, PRINCE EDWARD)		
District	Lynchburg	Residency	DILLWYN
County	PRINCE EDWARD	Town	
Road System	Secondary	Route	0638
Next Scheduled Activity	Approve Willingness	Accomplishment	Contract (1)
Project Status	ACTIVITY DATES SET (15)		
Comments			

Map It
Six-Year Program Details
Construction Details
Send Feedback
Print Page

0

Contact Information

Manager/Designer	Bruce Wooldridge	Phone	434-856-8253
Contact	William Leatherwood	Phone	434-947-2314

Schedule

Baseline Ad Date	11/10/2009
Current Ad Date	11/10/2009
Actual Ad Date	

G PROJECTED TARGET DATE HAS NOT EXCEEDED ORIGINAL TARGET DATE

Cost Estimates

Scoping Estimate	$1,787,663
Current Estimate	$1,343,100
Estimate Date	3/15/2005
Variance	-25%

R COST ESTIMATE VARIANCE IS -24.86%

(**d**) Engineering-specific information

Figure C1.5. (Continued).

Shoemaker, Lee, and Tom Schwetz (1998). "Sustaining Public Involvement in Long Range Planning Using Stakeholder Based Process: A Case Study from Eugene-Springfield, Oregon," *Proceedings: National Conference on Transportation Planning for Small and Medium-Sized Communities.* http://ntl.bts.gov/card_view.cfm?docid=702.

C1.6 Simple Spreadsheet (Also See C2.4, D2.8)

Spreadsheets and checklists are excellent and simple methods for ensuring that all components of project cost have been considered and accounted for in the estimate. Spreadsheets and checklists, which identify the elements and activities included in (and excluded from) the estimate, can effectively communicate project cost and the distribution of that cost.

What Is It?

Spreadsheets are formatted standard lists of items that an estimator should consider when calculating the cost of a project. Because spreadsheets are usually straightforward documents, they are very good tools in communicating estimate completeness and the allotment of costs to the different portions of work.

Activities					
Activity	Code	Begin Date		End Date	
		Scheduled	Actual	Scheduled	Actual
AUTHORIZE PE	12	05/16/1987	05/16/1987	05/18/1987	05/18/1987
SERP-NOTICE TO STATE AGENCIES	18	04/01/2004	04/07/2004	07/30/2004	06/11/2004
SCOPE PROJECT	22	04/01/2004	04/01/2004	08/31/2004	06/11/2004
CONDUCT LOCATION SURVEY	31S	03/16/2001	03/16/2001	11/30/2001	03/20/2002
PLAN DESIGN/PRELIMINARY F.I.	36F	07/16/2004	07/16/2004	12/13/2004	12/13/2004
R/W&UT DATA-HEARING/PUBLIC INV	44	12/13/2004	12/13/2004	09/28/2007	
APPROVE WILLINGNESS	47	10/07/2007		02/04/2008	
FURNISH R/W&UT PLANS	51	02/04/2008		04/04/2008	
NOTICE TO PROCEED/RW ACQUIS	60P	04/04/2008		04/19/2008	
UTILITY RELOCATION BY UTILITY	67U	04/14/2009		10/13/2009	
ACQUIRE RIGHT OF WAY	69	04/19/2008		04/14/2009	
APPROVED CONSTRUCTION PLANS	71	07/01/2009		10/13/2009	
ADVERTISE PROJECT/BEGIN CN	80	10/20/2009		11/10/2009	

Figure C1.5. (Continued).

Why?

A well-designed spreadsheet will clearly communicate the total estimated cost of the project, as well as what is included in the estimate and what the various categories of work are expected to cost. A secondary objective is to guide organizations toward improved estimation processes and practices.

What Does It Do?

The objective of a spreadsheet is to provide guidelines that (1) facilitate creation of a complete estimate and (2) support the evaluation of cost and schedule credibility. Spreadsheets serve to document estimate completeness in an easy-to-read format, which facilitates project cost communication in a uniform and structured manner.

When?

Different spreadsheet formats (with different levels of detail) are used in the course of project development as project scope is quantified and additional information becomes available. However, spreadsheets should be designed so that major categories can easily be expanded as project detail is better defined.

Examples

The detail of an estimation spreadsheet will vary by project type and by the point in time when the estimate is being created.

In the earliest stages of project development, there is limited project definition and design knowledge. One state highway agency's early stage spreadsheet has only five cost categories:

1. Grading and drainage
2. Base and pavement
3. Lump items
4. Miscellaneous
5. Engineering and construction

The sheet also requires calculation of a total cost and a total cost per mile to provide transparency in comparing the cost to similar projects, thereby assessing reasonableness. These basic categories can be expanded as additional information about the project is developed.

Sheets from Georgia DOT spreadsheets are shown in Table C1.6.

Tips

The calculation of estimated costs during the early phases of project planning usually employs parametric techniques based on historical cost data. Therefore, to be truly effective, the agency must have cost databases for organizing and retaining information on completed projects.

Resources

Michigan DOT's Road Cost Estimating Checklist can be found at www.michigan.gov/documents/MDOT_0268_Road_Cost_Est_120543_7.pdf.

Table C1.6. Georgia DOT spreadsheets.

Project #	Enter project number Here
PI #	Enter PI number Here

Project Length 2.11 (Enter Length in Miles)	North Georgia Region						
	Grad & Drain Project	Base & Pave Project	Lump Items Project	Misc. Project	E & C 10% Project	Total Cost Per Mile	Project Total Cost
					Month	Year	
			Created Spring			1999	
Rural New Location							
4 lanes with 44' grassed median	8,506,929	1,861,442	605,781	459,558	1,143,371	5,960,702	$12,577,081
4 lanes with 20' Raised Median	8,016,734	1,796,454	617,386	364,397	1,079,497	5,627,710	$11,874,468
4 Lanes with 0' Median (48' Pavement)	7,120,596	1,796,454	373,681	192,643	948,337	4,943,939	$10,431,711
4 Lanes with 4' Flush Median (52' Pavement)	7,240,592	1,938,035	373,681	208,890	976,120	5,088,776	$10,737,317
4 Lanes with 12' Flush Median (60' Pavement)	7,480,583	2,216,555	373,681	241,384	1,031,220	5,376,030	$11,343,423
4 Lanes with 14' Flush Median (62' Pavement)	7,534,198	2,286,185	373,681	248,347	1,044,241	5,443,911	$11,486,652
3 Lanes with 36' Pavement	6,760,609	1,378,674	306,372	139,260	858,491	4,475,548	$9,443,406
2 Lanes with 24' Pavement	6,395,516	963,215	280,841	174,075	781,365	4,073,465	$8,595,011
Urban New Location							
4 lanes with 20' Raised Median	7,511,220	1,912,504	596,497	364,397	1,038,462	5,413,782	$11,423,080
4 Lanes with 0' Median (48' Pavement)	6,602,317	1,912,504	287,804	250,668	905,329	4,719,726	$9,958,622
4 Lanes with 4' Flush Median (52' Pavement)	6,758,056	2,077,295	287,804	271,557	939,471	4,897,717	$10,334,183
4 Lanes with 12' Flush Median (60' Pavement)	7,074,640	2,395,272	287,804	313,335	1,007,105	5,250,311	$11,078,156
4 Lanes with 14' Flush Median (62' Pavement)	7,151,233	2,474,186	287,804	324,940	1,023,816	5,337,431	$11,261,979
2 Lanes with 24' Pavement	5,869,577	960,894	234,421	136,939	720,183	3,754,509	$7,922,014
3 Lanes with 36' Pavement	6,237,223	1,436,699	234,421	192,643	810,099	4,223,263	$8,911,085
Rural Widening							
2 to 4 Lanes with 44' Grassed Median	2,300,343	1,360,106	338,866	150,865	415,018	2,163,601	$4,565,198
2 to 4 Lanes with 20' Raised Median widen Symmetrical	852,735	1,659,515	473,484	317,977	330,371	1,722,314	$3,634,083
2 to 4 Lanes with 20' Raised Median widen on one Side	1,445,055	1,260,303	369,039	201,927	327,632	1,708,036	$3,603,956
2 to 4 Lanes with 0' Median (48' Pavement)	1,102,939	1,260,303	315,656	146,223	282,512	1,472,812	$3,107,633
2 to 4 Lanes with 4' Flush Median (52' Pavement)	1,156,554	1,436,699	315,656	157,828	306,674	1,598,773	$3,373,411
2 to 4 Lanes with 12' Flush Median (60' Pavement)	1,273,997	1,791,812	315,656	183,359	356,482	1,858,439	$3,921,306
2 to 4 Lanes with 14' Flush Median (62' Pavement)	1,296,975	1,882,331	315,656	188,001	368,296	1,920,028	$4,051,259
3 to 4 Lanes with 14' Flush Median (62' Pavement)	880,820	1,348,501	315,656	150,865	269,584	1,405,415	$2,965,426
Urban Widening							
2 to 4 Lanes with 20' Raised Median widen Symmetrical	1,580,369	1,754,676	429,385	457,237	422,167	2,200,869	$4,643,834
2 to 4 Lanes with 20' Raised Median widen on one Side	1,817,807	1,181,389	362,076	271,557	363,283	1,893,892	$3,996,112
2 to 4 Lanes with 0' Median (48' Pavement)	949,753	1,181,389	306,372	239,063	267,658	1,395,372	$2,944,235
2 to 4 Lanes with 4' Flush Median (52' Pavement)	1,028,899	1,380,995	306,372	278,520	299,479	1,561,263	$3,294,265
2 to 4 Lanes with 12' Flush Median (60' Pavement)	1,197,404	1,770,923	306,372	359,755	363,445	1,894,739	$3,997,899
2 to 4 Lanes with 14' Flush Median (62' Pavement)	1,238,254	1,870,726	306,372	378,323	379,367	1,977,745	$4,173,042
3 to 4 Lanes with 14' Flush Median (62' Pavement)	906,351	1,281,192	306,372	259,952	275,387	1,435,665	$3,029,253

(a) Conceptual estimate spreadsheet

Table C1.6. (Continued).

ESTIMATE SUMMARY			
A.	Right of Way		$2,454,000.00
B.	Reimbursable Utilities		$0.00
C.	Clearing and Grubbing		$416,000.00
D.	Earthwork		$565,000.00
E.	Base and Paving		$3,302,000.00
F.	Drainage		$255,000.00
G.	Concrete Work		$563,000.00
H.	Traffic Control		$225,000.00
I.	Erosion Control		$113,000.00
J.	Guardrail		$20,000.00
K.	Signs, Striping, Signals, Lighting		$353,000.00
L.	Grassing/Landscaping		$17,000.00
M.	Miscellaneous		$46,000.00
		Roadway Subtotal	$5,875,000.00
N.	Major Structures		$200,000.00
		Construction Total	$6,075,000.00
	4 years of inflation at 5%		$1,309,200.47
	10% Engineering and Contingency		$738,420.05
		Construction Estimate Subtotal	$8,122,620.52
		Total Construction Estimate	$8,123,000.00

(**b**) Summary conceptual estimate spreadsheet

C1.7 Year-of-Construction Costs (Also See E3.5)

Project cost estimates are created at a specific point in time. The estimated cost is typically based on prices as of the date on which the estimate is created, while construction is to occur at some future date. Economic comparisons between options are most commonly done in present values during planning and preliminary engineering. However, estimates should be communicated to project stakeholders in year-of-construction costs because that is what the project will actually cost when it is complete and that is the number that many stakeholders will use to measure success. Therefore, for the estimate to reflect actual construction cost, there must be an adjustment for inflation between the two points in time.

What Is It?

Year-of-construction cost is the estimated cost adjusted for the difference in time between when the estimate is created and when the project is to be constructed. Year-of-construction cost estimates take the “time value of money” into account. Project costs should be adjusted for inflation or deflation with respect to time due to factors such as labor rates, material cost, and interest rates. Estimated cost is most commonly inflated to the expected midpoint of construction date.

Why?

Using year-of-construction cost will more accurately reflect the future project cost. Funds available for projects often do not increase with inflation, but actual project costs do. Inflation continually reduces the agency’s capacity to preserve, maintain, and modernize the transportation system. While it is common to communicate a net present value for estimates when comparing projects or design options, it is not a good idea to communicate the estimate to external parties in anything but year-of-construction costs.

What Does It Do?

State highway agencies can be prepared in advanced to evaluate the construction cost for the project at its programmed date. This tool improves estimate accuracy by identifying the effect of inflation on project cost. Implications for decision making regarding transportation infrastructure based on budget will be clear to the public, and concerns about strategic misrepresentation (or lying) will be dismissed. It defines an estimated cost made in current dollars in terms of cost at the time of construction.

When?

Year-of-construction cost recognizes the cost escalation effect of inflation across the period of development and construction. Estimates should be communicated in year-of-construction costs from the earliest points in the project development process. This is very important for projects having long development and/or construction periods.

Examples

The year-of-construction cost will vary depending on when the estimate is created and the year-of-construction and economic variations caused by external factors, such as inflation. To calculate the year-of-construction cost, adjustments should be made from current dollar estimates by applying a cumulative inflation factor for the year of construction. MnDOT applies inflation factors as developed by the Office of Investment Management and approved by the Transportation Program Investment Committee.

Table C1.7, which is a MnDOT table, illustrates a consistent standard to be applied in adjusting project estimates. Short-term inflation rates are higher because they can be more volatile. Long-term rates are lower because the economic cycles are expected to dampen the rates over time. The table has limited life and must be updated on a periodic basis.

Similarly to other state highway agencies, the Washington State DOT maintains it own Construction Cost Index (CCI) that is applied to projects across the state. WSDOT also maintains inflation rates for right-of-way costs (R/W Cost Index) because these costs can increase at substantially higher rates than general construction inflation depending upon the location of the parcels. WSDOT maintains these values internally, but the values can be obtained by contacting the WSDOT Strategic Planning and Programming—Systems Analysis and Program Development Office.

The FHWA also tracks cost changes that can be used to project future inflation on federal aid projects. This information can be found at www.fhwa.dot.gov/programadmin/pricetrends.htm.

Tips

Project costs estimates provided in the Statewide Transportation Improvement Plan (STIP) should be calculated in year-of-construction costs. Use discipline in communicating year-of-construction costs at each phase of the project development. Federally funded local projects may either be adjusted for inflation as described above or capped at a fixed level of federal funds.

Resources

FHWA price trends for federal aid highwy construction: www.fhwa.dot.gov/programadmin/pricetrends.htm.

Minnesota DOT (2002). *Ten Year Highway Work Plan* http://www.leg.state.mn.us/docs/2004/other/040069.pdf.

Washington State DOT Strategic Planning and Programming website: http://www.wsdot.wa.gov/planning.

C2 Computer Software (Also See C3, D2, V1)

Computer software provides state highway agencies the ability to manage large data sets that support estimate development for all project types and across the range of project complexity. Estimation programs with preloaded templates for creating cost items help project teams define the project scope, cost, and schedule. Computer software eases the task of tracking project estimates through all phases of development and can assist in estimate and schedule reviews. In the case of state highway agencies, the most widely used estimation software is Estimator by InfoTech.

Project development and management are team efforts. Computers and software can be a part of the team. But the state highway agency has to set high standards for the software if it is to be an effective member of the team.

C2.1 Agency Estimation Software (Also See C3.1, D2.2, P1.1)

Some state highway agencies have taken the initiative to develop their own estimation software. This has been accomplished using internal resources in many cases, but external contractors have also been employed in software development. A survey in 2002 found that 18 state highway agencies are using software programs that were developed within the agency. These are not commercially available and are used either as

Table C1.7. Inflation factors for current WP/SP to be consistent with 02-04 STIP guidance.

STATE FISCAL YEAR										
	01	02	03	04	05	06	07	08	09	10
Current WP/SP	--	--	.06	.06	.0325	.0325	.0325	.03	.03	.03
FY 02-04 STIP		--	.06	.06						
CUMULATIVE			1.06	1.1236	1.160	1.1978	1.237	1.274	1.312	1.351
				1.12	1.16	1.20	1.24	1.27	1.31	1.35

WP/SP = work plan/strategic plan

stand-alone systems or in conjunction with other software. These programs generally have limited capabilities and were designed to run on mainframe computer systems.

Additionally, many state highway agencies and individual estimators have not gone as far as developing software but have created spreadsheet programs to support estimate development (see Sections C1.6 and C2.4).

What Is It?

The various software packages developed by state highway agencies are designed to address very explicit agency estimation approaches and satisfy discrete agency objectives. Some agency software has been created for use exclusively during specific project development phases (also see Section E3.1).

Why?

Due to the computer's ability to handle large data sets and its calculation flexibility, the estimator can easily adjust unit costs or percentages to match each project's unique conditions and can generate answers to specific agency questions. Many agency-developed estimation software programs are connected to other management software that the agency employs.

What Does It Do?

Computer software allows the user to readily employ several different estimation databases for parametric or line-item estimation and for performing "what-if" analyses. The programs typically allow the user to draw prices from historical bid data, historical cost data, reference tables, or a collection of price derivations. All of the data used to generate an estimate—such as historical costs, crew wages, equipment and material costs, production rates, and assumptions—can be stored to provide a sequential record of estimate development.

When?

To address very specific estimation requirements, custom agency software may be the only solution. Agency software can be very good in addressing distinctive requirements imposed on any individual state highway agency; however, software development is tedious and costly, and continuing support is a critical issue. Agencies should first look to commercially developed and supported software such as the AASHTO Trns•port, which has been developed specifically to meet the needs of state highway agency estimation.

Examples

North Carolina DOT approaches project estimation by building estimated cost from the bottom up currently uses a slightly modified commercial estimation program. This program is used by many contractors and was originally developed to facilitate detailed estimation by a large contracting organization. This program and similar ones of this type enable state highway agencies to development estimates from the bottom up based on crew productivity, construction methods, and selected equipment.

Virginia DOT (VDOT) expanded an in-house-developed software system that was initially created through the combined efforts of two districts. The VDOT Project Cost Estimate System (PCES) is currently being used during the middle stages of project development (see Figure C2.1). Virginia is looking to expand its use of the system to the earlier stages of project development. The initial software system specifically guided the estimator through decisions about the following:

- Costs common to every project (i.e., the costs of every "usual element" averaged and factored according to geometric classification), such as stone, asphalt, grading, pipes, erosion control, pavement markings, and moderate shoulder widening
- Costs specific to each project that are typically overlooked, such as crossovers, turn lanes, and curb and gutter
- Costs of unique or unusual items requiring a specific dollar input determined by a specialist in a particular field

That original template was modified to include the following:

- Data from the entire state rather than just a few districts
- Interstate projects
- Right-of-way
- Utilities
- Estimation curves and relationships based on a wider variety of projects
- Construction engineering and inspection at a variable rate based on project cost
- A wider range of bridge estimates

This software is not only an estimation tool, but also a management tool in that a number of items must be checked off, dated, or entered before a project can continue to the next level of development.

Tips

Many times, estimators spend more time with the tools they use to create the estimate (computers and software) than studying and analyzing the project. It is important that agency-developed software be user friendly and structured so that it is easy to input the required data into the system.

Resources

Kyte, C. A., M. A. Perfater, S. Haynes, and H. W. Lee (2004). *Developing and Validating a Highway Construction Project Cost Estimation Tool,* Virginia Transportation Research Council, Charlottesville, Virginia, December 2004, VTRC 05-R1. Can

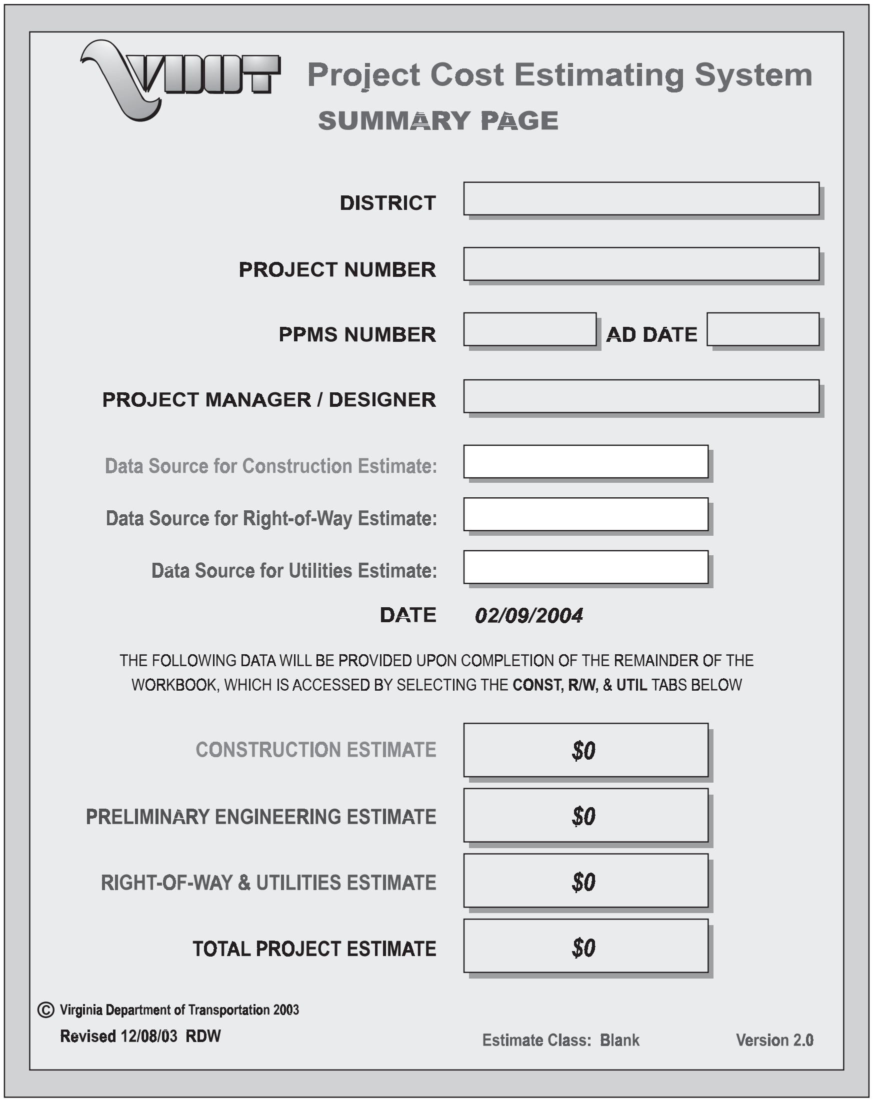


Figure C2.1. Example of summary page available in VDOT's Project Cost Estimating System.

be found at www.virginiadot.org/vtrc/main/online%5Freports/pdf/05-r1.pdf.

Barlist is a reinforcing steel quantity-estimating tool developed at the Washington State DOT. It can be found at www.wsdot.wa.gov/eesc/bridge/software/index.cfm?fuseaction=download&software_id=45.

Trns•port is AASHTO's transportation software management program. It is an integrated construction contract management system that has been developed based on the experience and needs of AASHTO's member agencies.

The New York State DOT (NYSDOT) and the New York State Thruway Authority (NYSTA) developed a website to support their transition to the Trns•port system. This website can be found at www.dot.state.ny.us/trns-port/index.html. The "About Trn•sport" page of the website describes how, in years past, the NYSDOT used the mainframe versions of Trns•port Proposal and Estimates System (PES), Letting and Awards System (LAS), and Decision Support System (DSS), but as other agencies moved from the mainframe to the client/server versions, AASHTO decided to drop support of the mainframe version:

> NYSDOT's options were to run the mainframe system without vendor support (a risky proposition), replace Trns-port with a new system, or migrate to the client/server version. The decision was made to migrate to the client/server version, and to implement additional modules, to provide a more functional and integrated system which covers the full lifecycle of capital projects.

Similarly, the NYSTA had been using BIDLET, a Clipper-based estimation and bid management system developed in house. As stated in the same website,

> As computer technology and operating systems have advanced BIDLET has required increasingly greater resources to maintain its'

[sic] operation. The decision was made to replace BIDLET with the client/server version of Trns-port. The NYSDOT and the Thruway Authority investigated and have subsequently been working on a joint implementation of Trns-port to take advantage of the cost savings and efficiencies that could be realized from utilizing a single common installation.

C2.2 Commercial Estimation Software (Also See C3.2, P1.2)

In the case of state highway agencies, the most widely used computer estimation software is Estimator by InfoTech. Estimator is a module of Trns•port. Trns•port is owned by InfoTech, Inc., and fully licensed by AASHTO under that name. Using this software, state highway agencies 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 are derived from bid histories and cost-based estimation techniques. Cost-based estimates use material, equipment, and labor costs.

What Is It?

Estimation software systems are the computer program tools that assist the state highway agencies in developing their project estimates. Estimation software systems have preloaded templates that help the state highway agency 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. There are several very good commercial programs available and being used by a large number of state highway agencies.

Why?

By using commercial software, the state highway agency avoids responsibility for updating or modifying the estimation programs as technology advances. Responsibility for matching the software with current protocols remains with the software provider. Additionally, the software provider works with many agencies and estimators and, therefore, has a broad knowledge of software issues.

What Does It Do?

Computers and estimation software enhance the ability of engineers to manage large data sets that are used in developing estimates for all types of projects. Definite advantages include the following:

- Ability to develop an unlimited number of estimates matched to project complexity and level of design, whether from scratch, other current estimates, or historical backups
- Ability to easily change, back up, and restore estimates
- Ability to draw from unlimited amounts of historical cost data and/or labor and equipment rate tables
- Ability to quickly copy entire estimates, individual or multiple work (bid) items, and/or activities from previous estimates
- Ability to track all changes made to the estimate and who made the change

When?

Commercial estimation software offers the most effective means of preparing and managing estimates for medium to large projects involving multiple cost items. For very large, complex projects, computer software may be the only effective and efficient method for handling large amounts of information.

Examples

The Trns•port Estimator module is used by 22 state highway agencies (as of August 7, 2002). Historic bid price databases can be created using Decision Support System module of the construction contract information historical database.

Another commercially available system that is used by several state highway agencies is Bid Tabs by Oman systems. This system is used as a stand-alone system or in conjunction with Trns•port by seven state highway agencies (as of August 7, 2002). Two other state highway agencies are in the process of testing this software (as of August 7, 2002).

One state highway agency (as of August 7, 2002) uses Heavy Construction Systems Specialists (HCSS) Heavy Bid, which is a program used by many contractors and was originally developed to facilitate detailed estimation by a large contracting organization.

One state highway agency (as of August 7, 2002) uses AutoCAD to perform quantity takeoff for project estimates by combining plan views of the project area with elevation information to get a three-dimensional view of the project.

Tips

The effectiveness of any computer software program is directly related to product support and training. When selecting software, always ensure that product support will be available and that training and training material will be provided.

Resources

For more information about Trns•port Estimator, contact the AASHTOWare contractor: Info Tech, 5700 SW 34th Street, Suite 1235, Gainesville, FL 32608. Phone 352-381-4400; Fax 352-381-4444; info@infotechfl.com; www.infotechfl.com.

Oman Systems, Inc., P.O. Box 50820, Nashville, TN 37205. Phone 800-541-0803; Fax 615-385-2507; www.omanco.com.

Heavy Construction Systems Specialists, Inc. (HCSS), 6200 Savoy, Suite 1100, Houston, TX 77036. Phone 800-683-3196 or 713-270-4000; Fax 713-270-0185; www.hcss.com; info@hcss.com.

C2.3 In-House Conceptual/Parametric Estimation Software

Parametric estimation methods are defined as estimation techniques that rely on relationships between item characteristics and the associated item cost. Early estimates developed during planning or during the initial stages of programming and preliminary design are typically based on a limited definition of project scope. The usual approach used to address these estimation difficulties is reliance on some form of conceptual estimation methodology. Parametric models can be developed internally by an organization for unique estimation needs, or they can be obtained commercially. One key reason state highway agencies develop their own parametric models is that they have specific estimation needs that cannot be achieved by using a commercial parametric model.

What Is It?

A parametric cost estimate is one that uses cost estimation relationships and associated mathematical algorithms (or logic) to establish the cost estimate for a project. Parametric estimation using statistical techniques can produce a range of probable costs rather than a single deterministic cost. The method can be applied to develop an estimate before design is complete.

Why?

During the early stages of project development, it is difficult to develop definitive cost numbers based on material quantities or specific work items, as these have not yet been defined. Conceptual estimation methodologies and parametric estimation tools can bring speed, accuracy, and flexibility to estimation processes that are often bogged down in unnecessary and really unknown project detail at this point in project development.

What Does It Do?

The cost of a project element is based on relevant independent variables, or cost drivers. Mathematical expressions, or formulas, are used to express the functional relationship between the cost drivers and the elements of a project being estimated. These techniques are often referred to as cost estimation relationships.

Parametric models are more complex than cost estimation relationships. They can be used to prepare estimates for an entire project. Parametric models incorporate many equations, ground rules, assumptions, logic, and variables that describe and define the particular situation being studied and estimated. Parametric models make extensive use of cost history databases.

In addition, organizations use parametric estimation techniques to develop estimates that serve as "sanity checks" on the primary estimation methodology.

Because these estimates can be prepared based on only a limited amount of definitive project information, they support the following:

- Scope development tasks
- Investigation of alternative design concepts
- Examination of alternative proposals for enhancements and upgrades
- Identification of key design elements
- Recognition of key project parameters
- Prioritization of needs versus wants
- Disclosure of key assumptions

When?

Early in project development, it is usually not possible to create a bottom up estimate based on a fully developed scope of work. Conceptual estimation is an excellent estimation methodology that can provide reliable estimates based on limited scope definition. Parametric estimation techniques can also use validated change order request pricing.

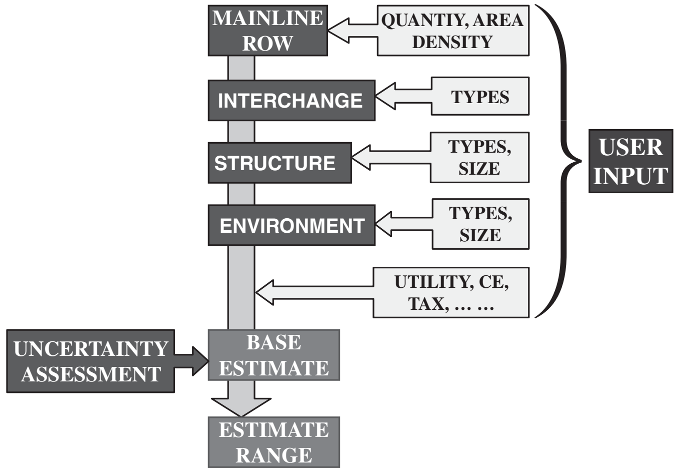
Examples

Pennsylvania DOT (PennDOT) uses parametric values in determining cost estimate at planning and early design stages.

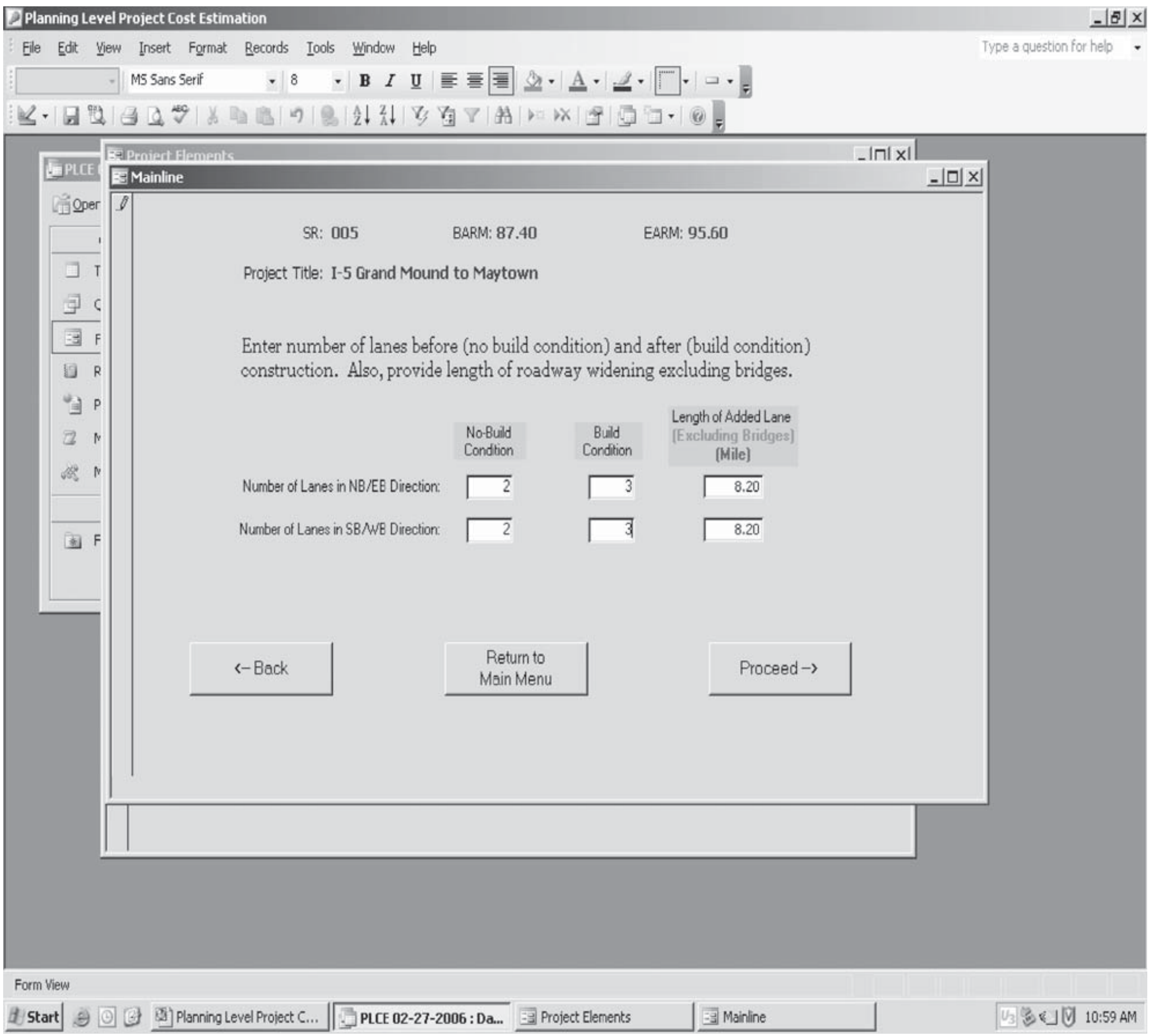
The Washington State DOT (WSDOT) Urban Planning Office has developed a tool termed "Planning Level Cost Estimation" (PLCE). The PLCE tool is a parametric estimation tool created to help plan and budget for large improvement projects. The output of this tool is a range of total project costs, including preliminary engineering, right-of-way (if applicable), and construction. The tool focuses on major project elements and creates costs for other minor elements using factors. This program is based on WSDOT data for large projects using recent cost data. The tool can reflect regional differences. The output needs to be reviewed carefully by planners and other disciplines. The tool uses Microsoft Access as the database. Figure C2.3 shows a flowchart of the process, a typical screen capture for the mainline add of two lanes, and a typical summary output.

Tips

All parametric estimation techniques, including cost estimation relationships (CERs) and complex models, require credible data before they can be used effectively. Data should be collected and maintained in a manner that provides a complete audit trail with expenditure dates so that dollar-valued costs can be adjusted for inflation. While there are many formats for collecting data, an example of one commonly used by state highway agencies would be the standard contract pay items. Technical noncost data that describe physical, performance, and engineering characteristics of a project must also



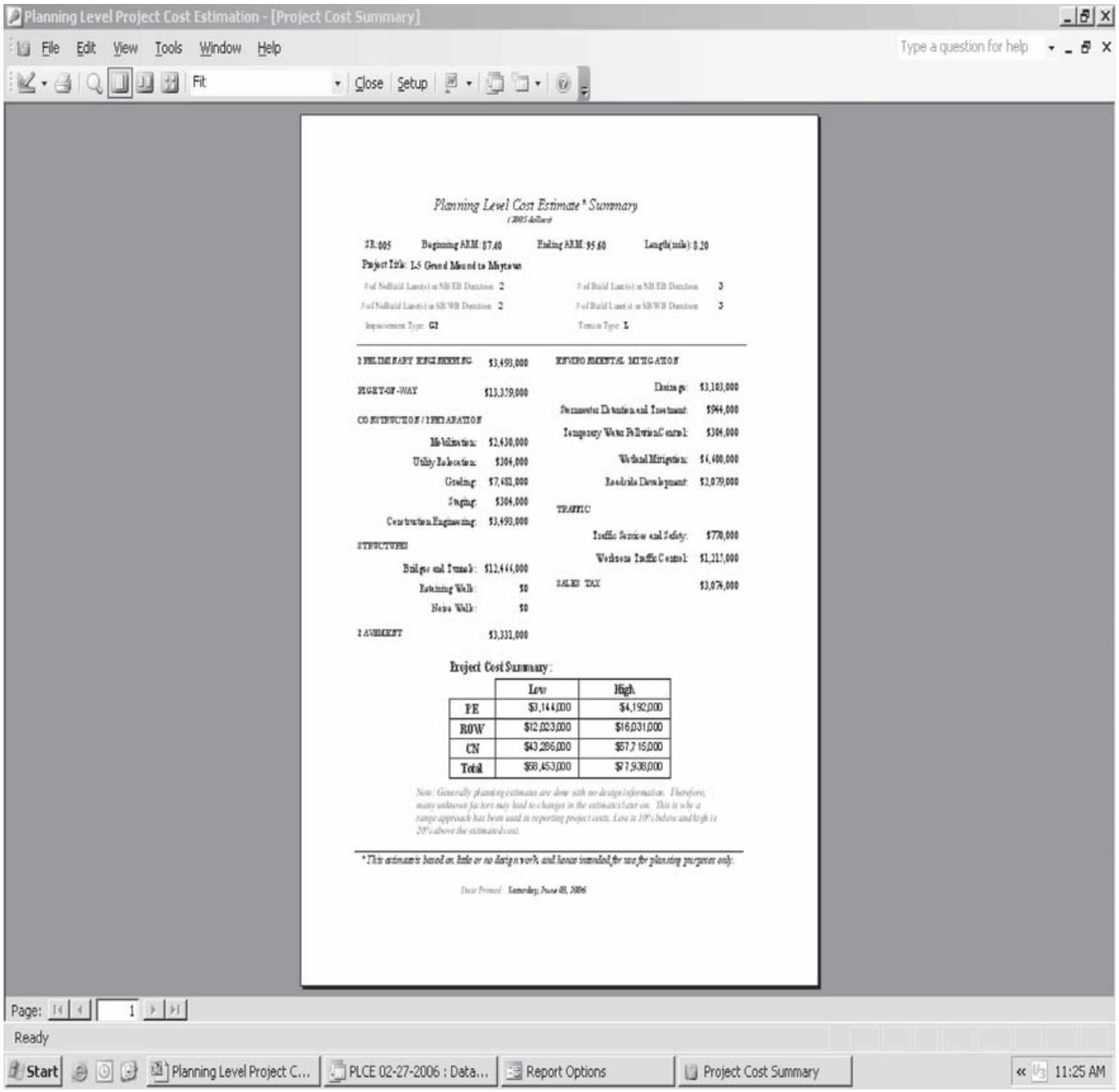
(**a**) Flowchart



(**b**) Input for added lanes

Figure C2.3. WSDOT's "Planning Level Cost Estimation" tool.

(continued on next page)



(c) Summary cost estimate generated

Figure C2.3. (Continued).

be collected. Once collected, data need to be adjusted for items such as production rate, improvement curve, and inflation. This is also referred to as the data normalization process.

CERs are analytical equations that relate various cost categories (in either dollars or physical units) to cost drivers, or variables. CERs can take numerous forms, ranging from informal rules of thumb to formal mathematical functions derived from statistical analysis of empirical data. Developing a CER requires a concerted effort to assemble and refine data. In deriving a CER, assembling a credible database is especially important and, often, the most time-consuming activity.

Resources

The paper "Parametric Estimating Methodology for Transit Project Planning," by Robert H. Harbuck, PE CCE, which is part of the *2001 AACE International Transactions,* provides an overview for transit project applications. A copy can be found on the Parsons Brinckerhoff website at: www.pbworld.com/library/technical_papers/pdf/46_ParametricEstimating.pdf.

The Association for the Advancement of Cost Engineering (AACE International) *Professional Practice Guide #6, Construction Cost Estimating,* presents information on conceptual and parametric estimation.

NASA has a *Parametric Cost Estimating Handbook.* This handbook is intended to be used as a general guide for implementing and evaluating parametric-based estimation systems and as the text material for a basic course in parametric estimation techniques. It can be found at http://cost.jsc.nasa.gov/PCEHHTML/pceh.html.

Washington State DOT, Urban Planning Office, Seattle, Washington.

C2.4 Simple Spreadsheet (Also See C1.6, D2.8)

An estimator or state highway agency typically creates simple spreadsheets using Excel or some similar user-friendly computer software. They provide a rapid and easy means for organizing numbers and making calculations (also see C1.6). These are really computer worksheets, but the name from the old pencil-and-paper days—spreadsheet—is retained.

What Is It?

Electronic spreadsheet programs offer the computing power of the computer and text editing and formatting capabilities at high speed and low cost. The electronic spreadsheet can store both the formulas and the computed values returned by the formulas and, therefore, provide great economies when there are numerous repetitive calculations to be made.

Why?

Electronic spreadsheet programs speed up estimate calculations and will automatically update all calculations when values are changed. In the case of repetitive calculations, there is only the need to formulate the mathematics once. The other advantage of using such spreadsheets is that everyone is already familiar with how the software works, so training time is almost nonexistent.

What Does It Do?

Simple electronic spreadsheets can generate documents that use text and number entries and that require performance of calculations on the inserted values. Monte Carlo simulation can also be added to spreadsheets for doing probabilistic estimation or risk analysis.

When?

Simple electronic spreadsheets can be developed to estimate small projects or they can be created to support other estimation programs. Spreadsheets are also excellent tools for supporting and documenting quantity takeoff work.

Examples

Virtually any estimation process can be successfully automated with a well-designed Excel template. Spreadsheets are excellent tools for calculating material areas, volumes, and summing by type of material.

New Jersey DOT has posted on the Internet (www.state.nj.us/transportation/eng/CCEPM/) a preliminary estimate spreadsheet.

Tips

Computer spreadsheets such as Excel require less initial investment than commercial estimation software and tend to be very flexible. The list of included items on spreadsheets is often not exhaustive, and space should be provided in each section of the spreadsheets to allow the entry of additional cost items that may be unique to a particular project.

Resources

Georgia DOT (GDOT) has posted on the Internet (www.dot.state.ga.us) the format for submitting scope and cost estimates for GDOT projects in the form of Excel workbooks to expedite the review and approval process. Type "GUIDELINES FOR SCOPE & COST ESTIMATE WORKBOOKS" in the search box on the home page.

There are also commercial estimation programs that have seamless integration with Microsoft Excel. See Hard Dollar Construction Estimating Software at www.harddollar.com/software/Take-Off-Analysis.asp.

C3 Conceptual Estimation

During the earliest stages of project development, prior to any design work, there is limited information about the project. However, there is the need to establish the approximate cost in order to evaluate options and to make choices between transportation needs and feasibility. Because there is very little project definition at this point in time, conceptual estimates usually rely on parametric techniques to extrapolate from past experience the economic impact cost of future projects. These techniques are applied using custom cost estimation relationships or commercially available tools.

Such estimates are normally prepared prior to the National Environmental Policy Act (NEPA) decision document. The accuracy of these estimates is directly related to the specificity of project definition. These techniques are used to determine the approximate cost of the project. In some cases, the estimated dollar amount is expressed as a range; this is a very good practice.

C3.1 Agency Estimation Software (Also See C2.1, D2.2, P1.1)

Based on schematic information, the intent of a conceptual estimate is to provide a *realistic* cost assessment so that decision makers can judge the relative merits of the project. The usual approach to doing that is reliance on some form of parametric estimation approach. Parametric estimation methods are defined as estimation techniques that rely on relationships between item characteristics and the associated item cost. One key reason state highway agencies develop their own parametric models is that they have specific estimation needs that cannot be achieved by using a commercial parametric model.

What Is It?

A parametric cost estimate is one that uses cost estimation relationships and associated mathematical algorithms (or logic) to establish the cost estimate for a project. Parametric estimation using statistical techniques and historical databases can produce a range of probable costs rather than a single deterministic cost. The method can be applied to develop an estimate before design is complete. The conceptual estimation techniques with 1% to 15% project definition can produce a project estimate with an accuracy range of +40/–20% to +120/–60% according to the Association for the Advancement of Cost Engineering International (AACE).

Why?

During the early stages of project development, it is difficult to develop definitive cost numbers based on material quantities or specific work items, as these have not yet been defined. Computer-driven conceptual estimation tools can bring speed, accuracy, and flexibility to estimation processes. They are also applicable for projects of an emergency nature that must be completed rapidly and for which there is limited scope definition.

What Does It Do?

When the only definitive information about a project is general parameters such as location, length, and maybe the number of roadway lanes an estimate can be derived from a weighting of historical cost records from previous projects.

The technique uses cost estimation relationships to build the cost of individual parts of the project and parametric models to prepare estimates for an entire project. Parametric models incorporate many equations, ground rules, assumptions, logic, and variables that describe and define the particular situation being studied and estimated. Parametric models make extensive use of cost history databases.

When?

Early in project development, it is usually not possible to create a bottom up estimate, as a fully developed scope of work is yet to be created. Conceptual estimation is an excellent costing methodology that can provide reliable estimates based on a limited definition of project scope.

Conceptual estimation techniques can also be used to price validated change order requests.

Examples

Penn DOT uses parametric values in determining the cost estimate at the planning and early design stage.

Tips

All parametric estimation techniques, including cost estimation relationships and complex models, require credible data before they can be used effectively. Data should be collected and maintained in a manner that provides a complete audit trail with expenditure dates so that dollar-valued costs can be adjusted for inflation. While there are many formats for collecting data, an example of one commonly used by state highway agencies would be the standard pay items. Technical noncost data that describe physical, performance, and engineering characteristics of a project must also be collected. Once collected, data need to be adjusted for items such as production rate, improvement curve, and inflation. This is also referred to as the data normalization process.

Cost estimation relationships are analytical equations that relate various cost categories (either in dollars or physical units) to cost drivers, or variables. They are created in a stepped process involving development of a unit cost by a weighting of historical data to which appropriate corrective adjustments are applied.

Inflation/deflation adjustment. The unit cost must be adjusted for the time difference between the historical projects and the estimated project. Various indexes of economic trends are available to support a correction. See the *Engineering News Record* quarterly construction indexes.

Location adjustment. The historical cost data are only reliable for the specific locations of the encompassed projects. Consequently, the relative difference in the cost of materials, equipment, and labor between locations of past projects and the current project requires an adjustment in unit cost.

Project size adjustment. Project size can affect cost; therefore, in developing a cost estimation relationship, size of the historical projects compared with the estimated projects must be factored in.

Unit cost adjustments. The cost of certain items (e.g., specific hardware) is independent of project size; as a result, it is necessary that the estimator have a clear understanding of the proposed project scope.

In deriving a cost estimation relationship, assembling a credible database is especially important and, often, the most time-consuming activity.

Resources

The paper "Parametric Estimating Methodology for Transit Project Planning," by Robert H. Harbuck, which is part of the *2001 AACE International Transactions,* provides an overview for transit project applications. A copy can be found on the Parsons Brinckerhoff website at www.pbworld.com/library/technical_papers/pdf/46_ParametricEstimating.pdf.

The Association for the Advancement of Cost Engineering's (AACE International's) *Professional Practice Guide #6: Construction Cost Estimating* presents information on conceptual and parametric estimation.

NASA has a *Parametric Cost Estimating Handbook.* This handbook is intended to be used as a general guide for implementing and evaluating parametric-based estimation systems and as the text material for a basic course in parametric estimation techniques. It can be found at http://cost.jsc.nasa.gov/PCEHHTML/pceh.html.

C3.2 Commercial Estimation Software (Also See C2.2, P1.2)

The intent of a conceptual estimate is to provide a *realistic* cost assessment so that decision makers can judge the relative merits of the project. These estimates are generally based only on schematic information. The usual approach to address such an estimation situation is reliance on some form of conceptual estimation. These are estimation techniques that rely on relationships between item characteristics and the associated item cost. Writing good software is extremely time intensive and requires a qualified staff of professional programmers who are also knowledgeable about the task the software is to perform. These two reasons cause many agencies to use commercial estimation software that has been validated and documented before release.

What Is It?

A conceptual cost estimation software system, whether it is a commercial product or agency-developed product, uses cost estimation relationships and associated mathematical algorithms (or logic) to establish the cost estimate for a project. These statistical techniques, together with historical databases, can produce a range of probable project costs. The method can be applied to develop an estimate before design is complete. Table C3.2 is from the Association for the Advancement of Cost Engineering (AACE) International. The table provides a sense of the accuracy that can be achieved using a conceptual estimation methodology in relation to the amount of project definition. During early project development, scope definition and design will be limited. Under the AACE International matrix, early estimates would be either Class 5 or 4.

Why?

During the early stages of project development, it is difficult to develop definitive project cost numbers based on material quantities or specific work items, as these have not yet been defined. Computer-driven conceptual estimation tools can bring speed, accuracy, and flexibility to estimation processes. Because development and maintenance of individual or specialized software packages can be expensive and requires special talents, it is often more economical to use commercially available software, which spreads the product cost over a larger user base.

In the case of conceptual estimation, commercial software providers often also have extensive databases that can be provided with the product.

What Does It Do?

When the only definitive information about a project are general parameters such as location, length, and maybe the number of roadway lanes, an estimate can be derived from a weighting of historical cost records from previous projects.

Table C3.2. AACE International generic cost estimate classification matrix.

	Primary Characteristic	Secondary Characteristic		
Estimate Class	**Level of Project Definition** Expressed as % of complete definition	**End Usage** Typical purpose of estimate	**Methodology** Typical estimating method	**Expected Accuracy Range** Typical +/– range
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgment	+40/–20 to +200/–100
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	+30/–15 to +120/–60
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed, but Primarily Stochastic	+20/–10 to +60/–30
Class 2	30% to 70%	Control or Bid/ Tender	Primarily Deterministic	+10/-5 to +30/-15
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	+10/-5

The technique uses cost estimation relationships to build the cost of individual parts of the project and parametric models to prepare estimates for an entire project. Parametric models incorporate many equations, ground rules, assumptions, logic, and variables that describe and define the particular situation being studied and estimated. Parametric models make extensive use of cost history databases.

When?

Early in project development, it is usually not possible to create a bottom-up estimate, as there is no fully developed scope of work. Conceptual estimation is an excellent costing methodology that can provide reliable estimates based on a limited definition of project scope.

Conceptual estimation techniques can also be used to price validated change order requests.

Examples

Trns•port cost estimation relationships is a job and program cost estimation and planning tool that provides a highly productive environment to prepare parametric, cost-based, and bid-based job cost estimates.

Tips

The estimator is the key to any estimation process and must know the software being used, its capabilities, and its limitations. To become proficient at any task, training is required. This is especially true with estimation software. Training will greatly enhance the proficiency and efficiency of estimators using any software.

One of the greatest benefits of computer estimation is the storage and retrieval of historical data. All parametric estimation techniques, including cost estimation relationships and complex models, *require credible data* before they can be used effectively. Data should be collected and maintained in a manner that provides a complete audit trail with expenditure dates so that dollar-valued costs can be adjusted for inflation. While there are many formats for collecting data, an example of one commonly used by state highway agencies would be the standard pay items. Technical noncost data that describe physical, performance, and engineering characteristics of a project must also be collected. Once collected, data need to be adjusted for items such as production rate, improvement curve, and inflation. This is also referred to as the data normalization process.

Cost estimation relationships are analytical equations that relate various cost categories (in either dollars or physical units) to cost drivers, or variables. Cost estimation relationships are created in a stepped process involving development of a unit cost by a weighting of historical data to which appropriate corrective adjustments are applied.

Inflation/deflation adjustment. The unit cost must be adjusted for the time difference between the historical projects and the estimated project. Various indexes of economic trends are available to support a correction. See the *Engineering News Record* quarterly construction indexes.

Location adjustment. The historical cost data are only reliable for the specific locations of the encompassed projects. Consequently, the relative difference in the cost of materials, equipment, and labor between locations of past projects and the current project requires an adjustment in unit cost.

Project size adjustment. Project size can affect cost; therefore, in developing a cost estimation relationship, size of the historical projects compared with the estimated projects must be factored in.

Unit cost adjustments. The cost of certain items (e.g., specific hardware) is independent of project size; as a result, it is necessary that the estimator have a clear understanding of the proposed project scope.

In deriving a cost estimation relationship, assembling a credible database is especially important and, often, the most time-consuming activity.

Resources

The paper "Parametric Estimating Methodology for Transit Project Planning," by Robert H. Harbuck, which is part of the *2001 AACE International Transactions,* provides an overview for transit project applications. A copy can be found on the Parsons Brinckerhoff website at www.pbworld.com/library/technical_papers/pdf/46_ParametricEstimating.pdf.

The Association for the Advancement of Cost Engineering International's (AACE International's) *Professional Practice Guide #6: Construction Cost Estimating* presents information on conceptual and parametric estimation.

NASA has a *Parametric Cost Estimating Handbook.* This handbook is intended to be used as a general guide for implementing and evaluating parametric-based estimation systems and as the text material for a basic course in parametric estimation techniques. It can be found at http://www1.jsc.nasa.gov/bu2/PCEHHTML/pceh.htm.

AASHTOWare is AASHTO's transportation software solutions. See http://aashtoware.org/?siteid=28.

C3.3 Cost/Parameter Using Similar Projects

This tool is based on the concept of using the cost of projects that are similar to the project being estimated as the basis for developing the estimate. The similar project has a known cost and scope. The similar project cost is converted into some reasonable cost parameter, such as dollars per centerline-mile or dollars per square foot of decking and is used in conjunction with an order-of-magnitude quantity parameter of the project being estimated, such as centerline-miles, to provide a basis for approximating the total cost of the facility.

What Is It?

Early in program (or project) development, there is very limited scope definition as to how a transportation need should be addressed. Because there are often similarities between a current need and a recently programmed, designed, or completed project, the cost basis for estimating the future program area (a project or groups of projects) is the relationship to the similar project for which there are cost data. The cost of the similar project is often expressed in terms of a cost per mile.

Why?

The purpose of this tool is to rapidly assess the approximate costs for addressing a transportation need or needs.

What Does It Do?

This tool provides an easy way to quickly approximate the order-of-magnitude cost of a potential transportation program (project or groups of projects). The concept is based on identifying an existing project that is *almost identical* in scope to the project that is being estimated. The tool relies on historical cost data. The historical data have to be modified to fit any differences in scope, location, and other project characteristics that might exist between the similar project and the new project or program area.

When?

This tool is used for preparing conceptual estimates during the planning phase of program (or project) development.

Examples

Several state highway agencies use historical cost data from similar projects 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 data could be obtained from a single programmed project or from a number of similar programmed projects. The key to this estimation practice is using similar projects that have a more defined scope than the project in the long-range planning phase. The planning engineers in the respective districts provide the estimators with the current cost-per-mile estimate for the programmed projects, which were created using parametric and line-item historical bid-based estimation tools. Thus, the conceptual estimates reflect all project cost elements, including costs for design, utilities, construction, and right-of-way. If the project includes structures, the estimator attempts to separate and remove the structure cost in the programming phase estimates and then estimates the current project's structures separately. Other state highway agencies develop lane-mile factors in a similar manner as the one describe here, but they use costs for projects that have already been let instead of projects still in the programming phase.

Tips

Applying this tool requires the user to match basic scope items to projects that are deemed similar in scope to the transportation program or project being estimated. The user must ensure that all scope items are covered in relation to the similar project. If there is not a perfect match, appropriate adjustments in cost should be made. For example, if the similar project has fewer structures than the transportation need being estimated, an appropriate adjustment in the cost estimate should be made to account for fewer structures. There may also be location differences that must be accounted for when using costs of similar projects. Costs should be adjusted to include future dollars—that is, the time at which the transportation need is likely to become a project with a construction target date.

This tool is useful for developing quick estimates for a program or project *provided that the level of scope similarity is very high.* The cost of the similar project should include all elements, including preliminary design costs, right-of-way, utility adjustments, contract administration, and construction. If one of these elements is not in the scope of the new transportation need, then the cost for this element must be deleted from the similar estimate. Alternatively, cost for elements could be added to adjust for differences between a similar project and a new transportation need. Contingencies should be included to cover uncertainties in the cost estimate. Simple spreadsheets can be used to summarize cost estimation elements when using this tool.

Resources

The data for the Wisconsin DOT method of calculating construction costs for a roadway improvement project based on "controlling cost items" (these are the certain bid items that comprise the majority of total construction costs) can be found at www.dot.wisconsin.gov/localgov/highways/docs/district-controlling.pdf.

C3.4 Cost/Parameter Using Typical Sections

This tool is based on the concept of using typical sections/components representing common types of facilities and historical cost data to derive key cost parameters. These cost parameters, such as dollars per centerline-mile or dollars per square foot of decking, are used in conjunction with gross quantities to provide a basis for approximating the partial cost of a facility.

What Is It?

Early in program (or project) development, very limited scope definition is available for solving a potential transportation need. The proposed facilities are often described in terms of a parameter such as a centerline-mile of roadway improvement, the number of lanes, and the type of construction (new or reconstruction) or number of bridges. For example, typical-pavement-type sections are used as the basis for estimating pavement construction cost for a given or standard pavement length and thickness or for a typical shoulder width. Historical cost data are provided in terms of cost factors (e.g., dollars per centerline-mile) and percentages for certain scope categories. Historical data reflect average costs and are not necessarily specific to any one area within a state.

Why?

The purpose of this tool is to develop approximate capital costs for a transportation need or needs so that estimates of funds required for long-range programs can be determined.

What Does It Do?

This tool is easy to use and provides a quick approximation of the magnitude of the cost for addressing a transportation need or correcting a deficiency. The concept is based on identifying those cost elements that are likely to be a substantial portion of a project's capital cost. The tool relies on historical data for developing standardized or typical configurations that represent types of transportation facilities.

When?

This tool is used for preparing a transportation program (or project) conceptual estimate during the planning phase of program (or project) development.

Examples

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

This estimation method provides the state highway agency with a consistent and transparent approach to estimating the cost of transportation needs. Consistency of approach continues as the project is further developed because the state highway agency 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, estimate development 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.

Two state highway agencies reported using lane-mile cost factors with typical sections for their planning estimates, but their methods were not consistently used within the state highway agency as the procedure previously described. One state highway agency uses three spreadsheet templates specifically for its central, northern, and southern regions. The templates categorize typical projects into rural or urban location and into new or widening projects. The number of roadway travel lanes and the median type is used to further define each typical section. The spreadsheet templates have columns associated with costs for grading and drainage, base aggregate and pavement, lump-sum items (e.g., 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 state highway agency with different design alternatives along with an estimate for each design so that designs can be compared.

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

Two illustrations of typical cost data that support this tool are shown here. The first illustration (Table C3.4-1) relates to bridge costs and shows typical structural sections. The second illustration (Table C3.4-2) shows typical costs for roadway sections, bridge types, and other relevant costs such as right-of-way and construction engineering.

Tips

Applying this tool requires the user to match basic scope items to typical configurations and/or sections representing different types of transportation need solutions. The user also must ensure that all scope items are covered and that the database provides sufficient information to estimate all pertinent scope elements for the proposed solution, such as right-of-way, preliminary engineering, and utility relocation. If necessary, costs should be adjusted to include future dollars, adjusted to time-of-construction dollars. Cost adjustments may also be necessary when the scope is different form that used to make the estimate or unique conditions exist. Simple spreadsheets can be used to make calculations and summarize cost estimation elements.

Resources

Florida DOT Office of Planning Policy (March 2003). "Policy Analysis and Program Evaluation, 2002 Transportation Costs."

Caltrans Division of Engineering Services, Structure Office Engineer (2003). "Comparative Bridge Costs." http://www.dot.ca.gov/hq/esc/estimates.

The Wisconsin statewide average costs per mile for various roadway improvement projects based upon the state's classification such as a resurfacing, pavement replacement, reconditioning or reconstruction project can be found at www.dot.wisconsin.gov/localgov/highways/docs/statewide-cost permile.pdf.

C3.5 Trns•port (Also See D2.9, P1.5)

Trns•port is the AASHTO-sponsored transportation agency management software. It is a robust transportation program management system. It uses the most current information systems technology and is based on the experience and needs of AASHTO's member agencies.

Trns•port capabilities encompass the full functionality of a construction contract management system. It is an integrated system consisting of 11 modular components, which can be used individually or in combinations as appropriate. Each module (see Figure C3.5) addresses the needs of the highway agency at a particular milestone in the construction contracting life cycle, representing three functional areas: preconstruction, construction, and decision support.

What Is It?

The Cost Estimation System (CES) is the primary Trns•port module, and, as shown in the estimation workflow schematic, it is most appropriately used in the conceptual estimation stage. It provides a highly productive environment for preparation of parametric, cost-based, and bid-based project cost estimates.

The CES module, when used in a conceptual estimation context, estimates the cost of parameters involved in the breakdown of a project. A parameter could be general characteristics such as project type, length, and location, or more specific information such as quantities and prices of major items. Parametric estimation uses three statistical modeling techniques: (1) project breakdown estimation, which determines the major cost drivers, called "major items," for the breakdown; (2) major item quantity estimation, which determines appropriate quantities of major items; and (3) major item price estimation. Adjustment of any of the calculated values to better reflect estimator knowledge of the project is possible, and CES will recalculate the estimate by using the refined data. A very popular calculating approach among state highway agencies is the lane-mile historic cost averages, which is an inbuilt feature of this module backed by the Bid Data Analysis and Decision Support System (BAMS/DSS) historic database feature of Trns•port.

Why?

At the conceptual estimation stage, it is an ordinary practice for state highway agencies to use lane-mile costs to estimate a project. The lane-mile cost parameter is a built-in feature of the Trns•port CES module. The CES module, however, emphasizes an item-level-quantity-based approach as opposed to estimating at a project level using a cost-per-lane-mile parameter. This approach may improve early estimate accuracy. Developing quantities early may enable continuous tracking and control by initiating quantity estimates at the outset. To efficiently perform these functions, a comprehensive project breakdown schematic is necessary, along with the ability to correlate them to historical databases. The CES module of Trns•port can be used to accomplish this correlation.

Table C3.4-1. Comparative bridge cost data.

JANUARY 2003

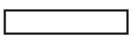
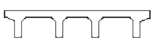
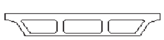
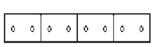
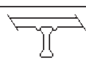
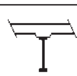
The following tabular data gives some **general guidelines** for structure type selection and its relative cost. These costs should be used just for **preliminary estimates** until more detailed information is developed.

These costs reflect the **'bridge costs'** only and ***do not*** include items such as: bridge removal, approach slabs, slope paving, soundwalls or retaining walls.

The following factors ***must*** be taken into account when determining a price within the cost range:

Factors for Lower End of Price Range	Factors for Higher End of Price Range
Short Spans, Low Structure Height, No Environmental Constraints, Large Projects, No Aesthetic Issues, Dry Conditions, No Bridge Skew	Long Spans, High Structure Height, Environmental Constraints, Small Project, Aesthetic Issues, Wet Conditions (cofferdams required), Skewed Bridges
Urban Location	Remote Location
Seat Abutment	Cantilever Abutment
Spread Footing	Pile Footing
No Stage Construction	2 Stage Construction

Factors That Will Increase the Price Over the High End of the Price Range
Structures With More Than 2 Construction Stages
Unique Substructure Construction
Widenings Less Than 5M

STRUCTURAL SECTION	(STR. DEPTH/MAX SPAN) SIMPLE	(STR. DEPTH/MAX SPAN) CONTINUOUS	COMMON SPAN RANGE (meters)	COST RANGE ($ / M2)	REMARKS
RC SLAB 	0.06	0.045	5-13	800 - 1,200	THESE ARE THE MOST COMMON TYPES AND ACCOUNT FOR ABOUT 80% OF BRIDGES ON CALIFORNIA STATE HIGHWAYS.
RC T-BEAM 	0.07	0.065	12-18	850 - 1,400	
RC BOX 	0.06	0.055	15-37	950 - 1,450	
CIP/PS SLAB 	0.03	0.03	12-20	950 - 1,300	
CIP/PS BOX 	0.045	0.04	30-76	800 - 1,200	
PC/PS SLAB 	0.03 (+75 mm AC)	0.03 (+75 mm AC)	6-15	1,300 - 1,950	NO FALSEWORK REQUIRED
PC/PS 	0.06 (+75 mm AC)	0.055 (+75 mm AC)	9-37	1,100 - 1,800	
BULB T GIRDER	0.05	0.045	27-44	1,100 - 2,100	
PC/PSI 	0.055	0.05	15-37	1,300 - 1,700	
PC/PS BOX 	0.06	0.045	37-61	1,500 - 2,700	
STRUCT STEEL I-GIRDER 	0.045	0.04	18-91	1,625 - 2,300	NO FALSEWORK REQUIRED

NOTE: Removal of a box girder structure costs from $160 - $215 per square meter.

COSTS INCLUDE 10% MOBILIZATION AND 25% CONTINGENCY

Table C3.4-1. (Continued).

JANUARY 2003

The following tabular data gives some **general guidelines** for structure type selection and its relative cost. These costs should be used just for **preliminary estimates** until more detailed information is developed.

These costs reflect the **'bridge costs'** only and ***do not*** include items such as: bridge removal, approach slabs, slope paving, soundwalls or retaining walls.

The following factors ***must*** be taken into account when determining a price within the cost range:

Factors for Lower End of Price Range	Factors for Higher End of Price Range
Short Spans, Low Structure Height, No Environmental Constraints, Large Projects, No Aesthetic Issues, Dry Conditions, No Bridge Skew	Long Spans, High Structure Height, Environmental Constraints, Small Project, Aesthetic Issues, Wet Conditions (cofferdams required), Skewed Bridges
Urban Location	Remote Location
Seat Abutment	Cantilever Abutment
Spread Footing	Pile Footing
No Stage Construction	2 Stage Construction

Factors That Will Increase the Price Over the High End of the Price Range
Structures With More Than 2 Construction Stages
Unique Substructure Construction
Widenings Less Than 15 ft.

STRUCTURAL SECTION	(STR. DEPTH/MAX SPAN) SIMPLE	(STR. DEPTH/MAX SPAN) CONTINUOUS	COMMON SPAN RANGE (feet)	COST RANGE ($ / FT2)	REMARKS
RC SLAB	0.06	0.045	16-44	75-110	THESE ARE THE MOST COMMON TYPES AND ACCOUNT FOR ABOUT 80% OF BRIDGES ON CALIFORNIA STATE HIGHWAYS.
RC T-BEAM	0.07	0.065	40-60	80-130	
RC BOX	0.06	0.055	50-120	90-135	
CIP/PS SLAB	0.03	0.03	40-65	80-100	
CIP/PS BOX	0.045	0.04	100-150	75-110	
PC/PS SLAB	0.03 (+3" AC)	0.03 (+3" AC)	20-50	120-180	NO FALSEWORK REQUIRED
PC/PS	0.06 (+3" AC)	0.055 (+3" AC)	30-120	100-170	
BULB T GIRDER	0.05	0.045	90-145	100-200	
PC/PS I	0.055	0.05	50-120	120-160	
PC/PS BOX	0.06	0.045	120-200	140-250	
STRUCT STEEL I-GIRDER	0.045	0.04	60-300	150-215	NO FALSEWORK REQUIRED

NOTE: Removal of a box girder structure costs from $15 - $20 per square foot.

COSTS INCLUDE 10% MOBILIZATION AND 25% CONTINGENCY

Table C3.4-2. Highway cost per centerline-mile.

State Rural Roads

2 Lanes

New Construction With 5' Paved Shoulders	$2,172,300
Milling & Resurfacing With 5' Paved Shoulders	$477,800
Routine Maintenance (Annual)	$21,700

4 Lanes

New Construction (Interstate) With 10' Paved Shoulders	$4,018,600
New Construction (Undivided) With 5' Paved Shoulders w/12' Aux. Ln.	$3,317,700
New Construction (Divided) With 5' Paved Shoulders	$3,240,700
Milling & Resurfacing (Arterial) With 5' Paved Shoulders w/12' Aux. Ln.	$686,900
Milling & Resurfacing (Interstate) With 10' Paved Shoulders	$777,700
Add 2 Lanes (To Existing 2 Lane) With 5' Paved Shoulders	$2,381,600
Routine Maintenance (Annual)	$40,700

Source: Long Range Estimate System, Maintenance Offices - Florida Department of Transportation.

Notes:

Before using the cost information provided herein, please contact the FDOT District Offices to see if district estimates are available. A list of the district contacts is provided in the Introduction of this report.

Figures are for 2002 construction costs for one centerline mile of roadway including structures up to 20 feet in length; they may not be comparable to prior year figures in all cases.

These figures **exclude costs** for intersections/interchanges/structures over 20 feet, right-of-way, landscaping, traffic signals, preliminary engineering, and construction engineering inspection.

The cost-per-centerline mile figures are based on general, statewide averages. They are not to be used for Work Program estimating because they are not job specific.

What Does It Do?

The CES module of Trns•port provides a full range of cost estimation capabilities from conceptual estimation to the engineer's final estimate required for final approval. Estimators can migrate their work through each stage of estimation, splitting and combining projects as required, moving smoothly from each stage of estimation. This tool allows import of data from other design software, such as computer-aided design and drafting (CADD).

The parametric estimation capability of CES is, however, of particular interest for this application. The CES module creates estimates using item-based historical prices from the BAMS/DSS module. It permits the creation of estimates from scratch or by importing older project estimates from existing Trns•port modules that may have similar parameters, such as project type, length, and location, or more specific information such as quantities and prices of major items. Estimates are created and categorized on a project-by-project basis using an item-based approach. Predefined line items that are built into the program are directly linked to historical databases. The module also permits customization for unique items. It also facilitates the listing and tracking of sources of funding on each project. Item pricing can be based upon equipment and labor, previous bid and regression analysis, references to similar projects, and ad hoc. As items are added, CES automatically calculates and updates the estimate based on the pricing method chosen. This computer-based tool allows customization to improve accuracy and also generates an array of reports to help document and track project costs.

When?

This tool can be used in the planning phase of project development to create early estimates based on major project parameters and other factors. In this way, CES can be an efficient tool for quickly estimating project costs for purposes of long-range planning.

Table C3.4-2. (Continued).

State Urban Roads

2 Lanes

New Construction With 5' Sidewalk, Curb, Gutter and 10' Refuge Ln.	$,2821,800
Milling & Resurfacing Curb to Curb	$422,100
Routine Maintenance (Annual)	$26,300

4 Lanes

New Construction (Interstate) With 10' Paved Shoulder	$4,765,100
New Const. (Undivided) With 5' Sidewalk, Curb, Gutter & 12' Aux. Ln.	$3,305,100
New Const. (Divided) With 5' Sidewalk, Curb, Gutter & 9' Refuge Ln.	$4,273,200
Milling & Resurfacing (Arterial) Curb To Curb w/12' Aux. Ln.	$541,200
Milling & Resurfacing (Interstate) With 10' Paved Shoulder	$785,200
Add 2 Lns (Existing 2 Ln.) W/5' Sidewalk, Curb, Gutter & 12' Aux. Ln.	$2,812,900
Routine Maintenance (Annual)	$58,500

Source: Long Range Estimate System, Maintenance Office - Florida Department of Transportation.

Notes: Before using the cost information provided herein, please contact the FDOT District Offices to see if district estimates are available. A list of the district contacts is provided in the Introduction of this report.

Figures are for 2002 construction costs for one centerline mile of roadway including structures up to 20 feet in length; they may not be comparable to prior year figures in all cases.

These figures **exclude costs** for intersections/interchanges/structures over 20 feet, right-of-way, landscaping, traffic signals preliminary engineering, and construction engineering inspection.

The cost-per-centerline mile figures are based on general, statewide averages. They are not to be used for Work Program estimating because they are not job specific.

(continued on next page)

Examples

In years past, the NYSDOT used the mainframe versions of Trns•port PES, LAS, and DSS, but as agencies moved from the mainframe to the client/server versions, AASHTO decided to drop support of the mainframe version. NYSDOT then migrated to the client/server version.

Tips

This tool can be used at all stages of estimation, bridging easily from one Trns•port module to another module that has been developed to be used at different stages of project development. These features help improve accuracy and handle more complex circumstances. Thus, the user can start with the planning estimate developed in CES and then move to estimation in the other project phases.

The estimator should check the output of the CES model to ensure that the estimate is consistent with estimated costs using other agency historical data. The estimator must ensure that all project costs are covered, such as right-of-way and preliminary engineering. These costs may not be generated by CES.

Additional information can be found using the following website dot.state.ny.us/trns-port/about.html.

Resources

The Technology Implementation Company, in Gainesville, Florida. See website addresses www.infotechfl.com and www.cloverleaf.net.

AASHTOWare, the transportation software system of AASHTO. See website at www.aashtoware.org.

C4 Consistency

The estimate is the beginning and the foundation of the entire project cost control process. All project estimates should be developed and treated as permanent documents that function as a basis for business decisions. Therefore, an estimate must be in a form that can be understood, checked, verified, and corrected. There must be consistency of presentation within an individual estimate and consistency across all estimates prepared by an agency. Consistency is an important feature of all estimates, but its impact on performance increases with project complexity. The consistent presentation of state highway agency estimates supports avoidance of duplications, omissions, and errors within an estimate and strengthens the estimate review processes. Successful estimation improvement is not so much about "computers and data" per se, as it is about

Table C3.4-2. (Continued).

New Construction
(Cost Per Square Foot)

Bridge Type	Low	High
Short Span Bridges:		
Reinforced Concrete Flat Slab Simple Span	$50	$65
Reinforced Concrete Flat Slab Continuous Span	$60	$80
Medium Span Bridges		
Steel Deck/Girder - Simple Span	$62	$75
Steel Deck/Girder - Continuous Span	$70	$90
Prestressed Concrete Deck/Girder - Simple Span	$50	$70
Prestressed Concrete Deck/Girder - Continuous Span	$65	$110
Long Span Bridges		
Steel Box Deck/Girder - Span Range from 150' to 280' (for curvature, add a 15% premium)	$76	$120
Segmental Concrete Box Girders - Cantilever Construction, Span Range from 150' to 280'	$80	$110
Movable Bridge - Bascule Spans and Piers	$900	$1,500
Demolition Cost		
Typical	$9	$15
Bascule	$63	$63

Source: Structures Design Office - Florida Department of Transportation.

Notes: Figures are for 2002 construction costs per square foot of deck area, including allowance for handrails; they may not be comparable to prior year figures in all cases.

Costs of preliminary engineering, right-of-way, bridge approaches, mobilization, and construction engineering inspection are **not** included.

The cost-per-square foot figures are based on general, statewide averages. They are not to be used for Work Program estimating because they are not job specific.

creating an organizational culture and climate that support state highway agency estimators and the estimation process.

C4.1 Cradle-to-Grave Estimators

When the same estimator or estimation team is assigned to a project from programming through plans, specifications, and estimates (PS&E), the retention of historical knowledge about cost drivers and why decisions were made is more easily maintained and considered during later phases of project development.

What Is It?

Under the cradle-to-grave concept, the same estimator is responsible for the estimate during all phases of project development. As a project moves through its development stages, a single estimator or estimation team is responsible for developing and updating the estimate. There is no “over-the-wall” (i.e., team to team) passage of scope, schedule, and estimation responsibility as the project passes from one development stage to another.

Why?

When project development is a stepped process with stage responsibility passing from one team to another (i.e., over-the-wall deliverables) there is always the possibility that critical knowledge will be lost during a hand-off between teams. One approach used to avoid this problem of lost project knowledge is the reliance on a dedicated team to move the project through all development phases. This approach would also place estimation responsibility with the same person or persons during all of the project’s development stages.

What Does It Do?

The use of cradle-to-grave estimators improves the knowledge base of the estimator or estimation team concerning all

Table C3.4-2. (Continued).

Cost of Traffic Signals

Activity	Rural	Urban	Average
Installation (Mast Arm)	$129,400	$113,300	$121,400
Installation (Strain Pole)	$68,700	$60,300	$64,500
Maintenance (Excluding Power)	--	--	$2,150*

*Per Intersection/Year

Source: Traffic Engineering Office - Florida Department of Transportation

Ratio of Right-of-Way to Construction Costs
Statewide Averages

Type of Right-of-Way Activity	Ratio
Total Right-of-Way/Construction	20%
Resurfacing Only	1%
Bridge Only	4%
Interstate Only	14%
Other Capacity Only	40%

Note: Right of way costs vary considerably, depending on the location. District information is available for some areas. Please contact the District Office where the project will be located before developing project estimates. A list of the district contacts is provided in the Introduction of this report.

Statewide averages for right-of-way as a percentage of construction costs for six year period between fiscal years 1997 and 2002. Right-of-way costs vary based on factors such as production mix and location, so historic averages may not be representative for future or individual construction projects.

Ratio of Engineering to Construction Costs

The relationship between the Florida Department of Transportation's engineering to construction costs (including right-of-way) varies. Engineering costs include preliminary engineering, construction engineering inspection, right-of-way support, and related overhead costs. For the past five fiscal years, the ratio of engineering to construction costs has been approximately 36% on average.

Source: Program Development Office - Florida Department of Transportation.

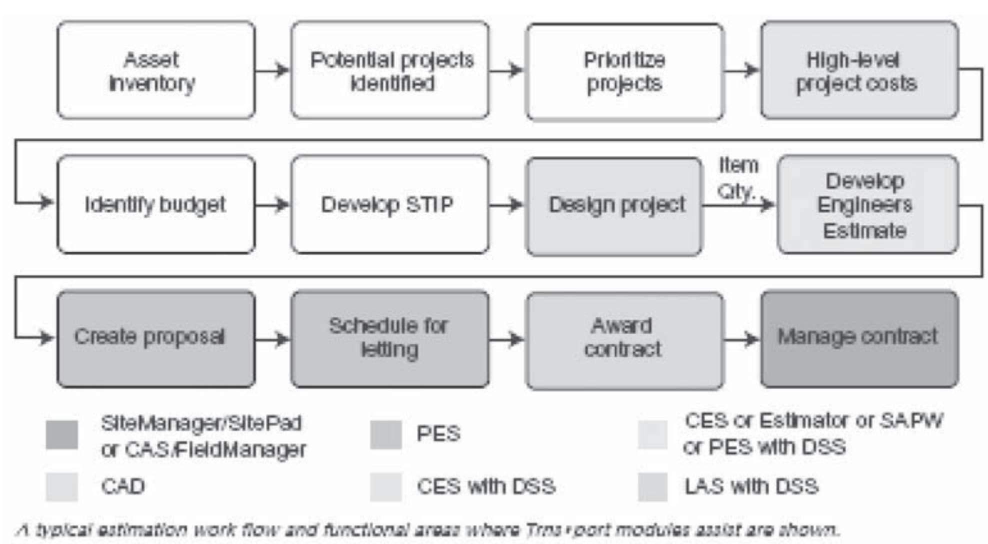


Figure C3.5. Estimation workflow and functional areas where Trns•port models assist.

project details. With this approach, estimators gain knowledge about the reasons for revisions, the existence of constraints, the required coordinate with other schedules, and the regulatory procedures that affect the project. When estimators possess such knowledge, estimate quality is improved because there is a better understanding about external cost drivers.

When?

The use of cradle-to-grave estimators can be very beneficial in the case of projects that will be impacted extensively by third-party agreements, utility conflicts, coordination issues, and scheduling uncertainty. Even with simple and straightforward projects, the use of cradle-to-grave estimators will work, but the realized benefits are usually not as significant.

Examples

The use of cradle-to-grave estimators is found more in the private sector of the construction industry, where the estimator is a member of the project development team and not an auxiliary or separate support staff. It has been reported by engineering firms working for the chip and technology industry that, by making the estimator a member of the project development team, the firms are saving to the original budget because of early value engineering and cost input.

Tips

To realize the full potential of this estimation approach, the estimator must become an integral part of the project development team and be fully informed about coordination issues, external agreements (environmental, utility, and societal), and schedule constrains.

Resources

The Trns•port Estimator and CES modules are both cost estimation systems. CES is a client/server system that is tightly integrated with Trns•port PES, sharing databases and supporting direct project import/export and check-in/check-out processes. CES supports cradle-to-grave project estimation.

C4.2 Estimation Checklist (Also See P2.1, V3.1)

Checklists are intended to serve as guides in preparing, checking, and reviewing cost estimates for errors and omissions. Effective use of estimation checklists will minimize omissions and duplications. They are not, however, a substitute for the exercise of sound engineering judgment by the estimator or the reviewers. The estimation professionals must independently evaluate supporting data upon which the estimates are based, but the checklist helps to ensure estimate completeness.

What Is It?

Checklists are templates that estimators and reviewers use to ensure a complete estimate. They guide the estimator through suggested items and consideration of factors that impact project cost.

Why?

While estimators and project managers are generally very familiar with assembling cost data and developing an estimate, the estimation process requires consideration of a very large number of work items and the factors that impact the cost of individual items, as well as factors that impact the cost of the project in general. Checklists serve to delineate the large number of factors, which must be considered during estimate preparation. Therefore, they are an excellent means of avoiding omissions and for calling attention to the interaction between factors that can impact cost.

What Does It Do?

Checklists guide the estimator through suggested work items and cost factors. A checklist serves to ensure that all cost categories are accounted for in an estimate. The answers to the checklist questions will provide an overview of the estimate's completeness and focus the estimator's attention on critical questions. The checklists can be divided into major work areas, such as roadway and structural, to support specific parts of project estimate development.

When?

Checklists can support estimate creation at all stages of project development. The purpose of a checklist is to assist the estimator in planning, formatting, and developing a complete estimate. Checklists should be as inclusive as possible, with questions that specifically probe the estimate at the different stages in project development.

Examples

North Carolina DOT has an estimation checklist for functional and preliminary estimates. The list, which contains the various items included on a project, as well as the units of measurement to be used in estimating the items, is as follows:

- Clearing and grubbing (acre or hectare)
- Earthwork (cy or m3)—unclassified, borrow, undercut, etc.

- Fine grading (sy or m2)
- Drainage (per mile or kilometer)
- Paving (ton or mtn, w/pavement design, or sy/m2 without)
- Stabilization (sy or m2)
- Shoulder drains (lf or meter)
- Curb and gutter (lf or meter)
- Guardrail (lf or meter)
- Anchor units (each type)
- Fencing (mile or kilometer)
- Interchange signing (type and location)
- Traffic control plan (TCP) (per mile or kilometer)
- Thermo and markers (per mile or kilometer)
- Utilities (lf or meters)
- Erosion control (acres or hectares)
- Traffic signals (each and location)
- Retaining walls/noise walls (sf or m2, with avg. height)
- Bridges (individual location)
- Reinforced concrete (RC) box culverts (individual location)
- Railroad crossing (each—with or without gates)

Tips

There can be many individual checklists to support different phases of estimate preparation and specific cost areas—a plan review checklist; a site checklist; a checklist for developing quantities; and a checklist to consider construction noise, dust, and other construction nuisance issues.

Resources

The following list is from the FHWA's *Engineer's Estimate Checklist for Full Oversight Projects:*

- Check approximately 15–20% (more if possible) of the bid items against the plan quantities for accuracy.
- Do the items checked correspond with the plans and plan quantities?
- Do the pay items correspond to the type of work proposed?
- Are the units of measure appropriate for the pay item?
- Is the quantity for the pay item reasonable for the project?
- Does the unit price seem reasonable for the type, size, and location of the project?

The FHWA also has posted on the web a checklist document: "Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications." The PS&E portion of the checklist applies to specific geotechnical features, such as pile foundations, embankments, and landslide corrections. This checklist can be found at www.fhwa.dot.gov/bridge/checklist.htm.

The U.S. Army Corps of Engineers estimate review checklist from ER1110-1-12 requires that the reviewer verify the following:

- Estimates are based on an approved scope of work and the latest available design data.
- Estimates are developed from Corps unit price book (UPB) or approved construction cost data (e.g., the General Construction Cost Engineering Standards published annually by Richardson Engineering Services or the price data published by R. S. Means Company).
- Basis for estimates is provided or explained; all assumptions, quotes, crew sizes, and other cost factors are documented.
- Estimates are escalated to the expected midpoint of construction using the latest approved management control plan or Office of Management and Budget (OMB) (for Civil Works projects) index.
- Estimates are prepared in accordance with latest Corps cost engineering regulations and technical manuals.
- Estimates include risk analysis to cover unknown conditions or uncertainties on work schedules.
- Estimates are internally reviewed prior to submittal.

This checklist could serve as review guidance for any state highway agency.

Defense Logistics Agency's "In-House Cost Estimate Checklist" (available online at www.dla.mil/j-3/a-76/IRLine02.html) is not designed for projects of the type that state highway agencies usually handle, but it does contain some very good questions that a state highway agency might want to include in its own checklist, including the following:

- Is inflation calculated correctly?
- If costs are based on historical data, are appropriate adjustments included?

C4.3 Estimation Manual (Guidelines)

The foundation of a good estimate is composed of the formats, procedures, and processes used to arrive at project cost. Consistency is measured by the ease with which an estimate can be checked and the ability of several estimators to work together to complete a single estimate. Every state highway agency should have a published estimation manual of standard formats, procedures, and processes to be used by both state highway agency estimators and design consultants retained for estimation purposes. This guidance document should be specifically written for those responsible for preparing the state highway agency's estimates.

What Is It?

An estimation manual is a set of standard operating procedures that guide the preparation of cost estimates. By establishing standard operating procedures for estimate preparation, state highway agencies can enhance estimate completeness and accuracy. An estimation manual should also address wide-ranging issues of estimation practice, such as consideration of external factors that affect construction cost and how to accommodate project risk in contingency amounts.

Why?

The foundation of a good estimate is the formats, procedures, and processes used to arrive at project cost. A survey of state highway agencies in 2003 found that only 16 had manuals that provided formal guidance for preparing estimates, and most of these tended to describe how to use the particular state highway agency's estimation system and failed to address broader issues of good estimation practice, such as consideration of external factors that affect project cost. Estimate consistency and accuracy is achieved by instituting procedures that serve as guides for all parties engaged in the estimation processes.

What Does It Do?

An estimation manual provides guidelines for the preparation of all project estimates developed by the state highway agency. It should provide information on a range of processes and techniques matched to varying project types (straightforward to complex) and to project development stage.

When?

The manual should address estimate preparation during all phases of project development, not just during plans, specifications, and estimates (PS&E).

Examples

Examples of estimation manuals can be found at www.state.nj.us/transportation/eng/CCEPM/ and www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap65.pdf.

The Queensland Government of Australia has its manual online at www.mainroads.qld.gov.au/MRWEB/Prod/Content.nsf/0/02c5ce00d16de3764a256e4000101970?OpenDocument.

Tips

The following ideas should be part of the estimation manual:

- All estimates should be prepared electronically and stored in a centralized database.
- Estimators should become familiar with the project site. A formal site review helps in identifying constructability issues that can be overlook during a paper plan review.
- Prime estimators should obtain written estimates from supporting units, including
  - Traffic engineering,
  - Environmental compliance, and
  - Right-of-way.
- The designer should confirm that the estimate is consistent with the project scope.
- Estimates should be updated at design milestone points: preliminary design, 30%, 60%, and final design.
- All support units should be required to update and submit their portion of the estimate at the milestone points.
- The 60% and final design estimates should be based on actual quantity take-offs.
- There should be consistent methods for estimating both the quantities and prices of minor items.
- There should be a standard method for handling inflation and a defined inflation percentage that is applied to the estimate. The estimate for long-duration projects should be stated in year-of-construction costs.
- The estimation manual itself should be updated annually in the areas of inflation factors, contingency amounts or percentages to be used, and possibly other factors that change with time and market conditions.

Resources

Visit these sites for additional information and guidance on cost estimation practices:

- Transportation Estimators Association (TEA): tea.cloverleaf.net/.
- FHWA "Guidelines on Preparing Engineer's Estimate, Bid Reviews, and Evaluation": www.fhwa.dot.gov/programadmin/contracts/ta508046.htm.
- FHWA's "Major Project Program Cost Estimating Guidance": www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

C4.4 Estimator Training

Human error in anticipating and properly considering project cost drivers is an important factor in the failure to producing quality estimates. This often happens because of a de-emphasis on engineering/estimation experience and judgment in the light of increasingly sophisticated numerical techniques/software. Estimate accuracy and quality will only be achieved when the analytical, numerical, and computational tools are supplemented with improved thinking skills.

What Is It?

Estimators come from many different specialties within the state highway agency, including engineering, construction, contracting, and occasionally from the operations and maintenance areas. Estimator training can be attendance at formal classes; mentoring among the estimators in the state highway agency; or support for estimators to attend off-site conferences, seminars, or classes pertinent to their work. These activities should support estimation skill in using techniques for achieving accurate estimates and knowledge about the state highway agency's estimation procedures.

Why?

Cost estimators must be able to interpret details from scoping documents during early phases of project development or from the plans as design progresses and then make sound and accurate judgments using poorly defined information or only minimal information. To do these things, estimators must receive formal training in (1) estimation methods appropriate to different levels of project detail and (2) methods for properly using the estimation software that is available.

What Does It Do?

Formal training programs can provide state highway agency estimators with a solid background in methods, materials, and regulations, including methods to analyze bid documents (reading and understanding contracts, plans, and specifications); methods to evaluate special conditions affecting project cost; and methods to analyze project risk for developing realistic contingency amounts. Training programs will serve to maximize the potential of software programs for improving estimation processes by providing estimators with a broader understand of how these systems can be used.

Training should also provide opportunities to obtain practical construction experience because such experience is an important component of estimator training. Field experiences enhance knowledge about construction methods and provide awareness of the on-site construction difficulties that impact job cost.

When?

Training must be continuous because new construction techniques are always being introduced and the cost of work changes with economic conditions. Additionally, new computer systems are constantly being introduced and the potential of these systems is dependent on knowledge of how to use them effectively. But maybe most important is the issue of accounting for new rules and regulations that impact project costs.

Examples

One state highway agency (New York) has developed a computer-based training CD with training modules for each phase of project development. The agency has central office training sessions for the estimating engineers and conducts an annual class to bring the estimators together to discuss issues.

Tips

If the agency uses the AASHTO Trns•port estimation software, the agency should support estimator participation in the Trns•port Users Group (the TUG), which seeks to provide a forum for a unified voice to direct the course of Trns•port development. The TUG additionally provides input to the Product Management Task Force on product effectiveness, deficiencies, and needed enhancements and helps to define product training and support needs.

Resources

To expand the knowledge base of department estimators, their participation in the Transportation Estimators' Association (TEA) should be supported. TEA publishes guidelines used by transportation estimators (cost based, historical based, and parametric), publishes a newsletter for transportation cost estimators, sponsors an annual cost estimation workshop, and seeks to achieve the following goals:

- Advance cost estimation techniques;
- Develop new, innovative cost estimation techniques; and
- Disseminate information about cost estimation experiences and new practices.

The homepage for the TEA can be found at http:tea.cloverleaf.net/.

The homepage for the TUG can be found at www.tug.cloverleaf.net/default.htm.

C4.5 Major Project Estimation Guidance

This guidance is provided by the FHWA for the preparation of a total program cost estimate for a major project. For the purpose of this guidance, a major project is defined by the FHWA as a project that

- Receives any amount of federal financial assistance and has an estimated total program cost greater than $500 million (expressed in year-of-expenditure dollars) or
- Has an estimated total cost approaching $500 million, with a high level of public or Congressional intent.

The total program cost estimate includes engineering, construction, right-of-way, and related costs, which will be identified by this guidance. Although this guidance is for major projects, it may also be applied to other projects.

What Is It?

The major project estimation guidance is a compilation of key principles to be followed when preparing a cost estimate for significantly large projects. The magnitude of investment on such projects is associated with greater risks, which have to be carefully monitored. These guidelines provide a complete overview of all critical elements that must be estimated and included in the cost estimate and their importance.

Why?

Estimates are central to establishing the basis for key project decisions, for establishing the metrics against which project success will be measured, and for communicating the cost status of a project at any given point in time. Logical and reasonable cost estimates are necessary in maintaining public confidence and trust throughout the life of a major project. Cost increases over and above the early planning and environmental estimates for major transportation projects have become an increasing concern to Congressional and political leaders, federal and state executive management, and auditing agencies.

Major projects by nature are usually more complex and contain more risk elements than other projects. Careful attention must be provided when preparing cost estimates for major projects. Traditional estimation methods may not be appropriate in all cases. This guidance is intended to assist state highway agencies, the FHWA, and other sponsoring agencies to ensure that all program cost estimates are prepared using sound practices that result in logical and realistic initial estimated costs of the projects, thereby providing a more stable cost estimate throughout the project continuum.

What Does It Do?

Major projects are associated with greater risks and require more effort to properly estimate project cost. There are many aspects of major projects that must be considered when preparing cost estimates. These guidelines, hence, familiarize estimators with the requirements of such estimates and provide a standardized framework and checklist of items to be included in the estimate.

When?

These guidelines indicate how to maintain consistency in estimation through all project development process phases, but the guidelines are most extensively and appropriately applied in the programming and preliminary design phase. These guidelines could be referred to as late as during plans, specification, and estimates (PS&E) phase.

Examples

The key principles for project cost elements are as follows.

- 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
- Release of estimates and estimation information
- Program cost estimation elements
- Preliminary engineering
- Right-of-way
- External third-party (e.g., utilities and railroad adjustments)
- Transportation demand and management and transportation system management
- Construction estimate
- Construction contingencies
- Construction administration
- Public outreach
- Management reserve
- Integration of program costs estimates throughout the project continuum
- Quality assurance/quality control

Tips

State highway agencies should incorporate these procedures into their cost estimation process by adapting them to fit into agency approaches for estimating major projects. Developing checklists based on such guidelines and other input from within the state highway agency or from experts outside of the state highway agency, as applicable to major projects, would improve estimates in terms of consistency. Continuous improvement of such checklists through lessons learned from past major projects can help in improving accuracy.

Resources

More information is available from the FHWA publication, "Major Project Program Cost Estimating Guidance," June 8, 2004: www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

C4.6 Standardized Estimation and Cost Management Procedures (Also See B1.3)

The objective of standardizing procedures is to establish a common basis for all state highway agency project development participants to follow when preparing cost estimates and when managing costs over the project development process. The integration of both cost estimation practice and cost estimating management through standardized procedures is a critical feature to achieving consistent project results.

What Is It?

This tool establishes a set of standards and procedures within a state highway agency to guide the preparation and management of costs throughout the various phases of project development. The objective is to provide a coherent policy basis for alleviating cost escalation by consistently applying tools used for cost estimation practice and cost estimation management. These procedures typically include standard formats for summarizing costs estimates and for tracking changes.

Why?

In many state highway agencies, projects are estimated and managed in regions or districts. However, final project approval of estimated costs and changes is often made at the state highway agency headquarters. Standard procedures can provide estimate and cost management consistency across the different regions or districts within a state. Using common formats will make review and approval processes more efficient.

Projects are often similar, and past projects provide valuable input for future projects. However, projects must be compared on a common basis. A common basis is achieved by following similar procedures for every project. Standardized procedures facilitate this. Standardized procedures help in establishing familiar estimation and cost management processes for project participants, which, in turn, should improve proficiency over a period of time and minimize errors.

What Does It Do?

By following standardized procedures, project managers and estimators apply consistent approaches to estimating cost and controlling costs. These approaches will likely generate more accurate and realistic estimates with less room for errors. Standardized procedures also help in documenting previous projects in a format that permits easy extraction of necessary information in future.

When?

Standardized procedures must be established at an agency level for guiding project development work and specifically for cost estimation and cost management. They should be applied throughout the project development process. However, cost management can only begin after the project's baseline scope, cost, and schedule are set.

Examples

Missouri DOT has developed a list of items to be considered during design that is followed for every project to prevent omissions. Similarly, they have standard lists for procedures to be followed while estimating for right-of-way, environmental, utilities, and bridge considerations. There are also guidelines on acceptable estimation approaches to adopt based on the information available during different periods when estimates are developed. Given that, for many highway projects, 80% of the cost is often attributed to 20% of the line items, which often constitute grading, drainage, and paving quantities, elaborate and updated cost databases on these items have significant impact on cost estimate accuracy.

Missouri DOT has developed a list of items to be considered during design that is followed for every project to prevent omissions. Similarly, it has standard lists for procedures to be followed while estimating for right-of-way, environmental, utilities, and bridge considerations as shown below:

> **1-02.12 (10) (b) DESIGN CONSIDERATIONS.** Below is a partial list of design items. Other items may be considered and included in the estimate, as necessary.
>
> - Grading (Class A, Class C Excavation, Borrow)
> - Pavement design—include curb and gutter if applicable. (See Section 6-03 for pavement design considerations)
> - Drainage—stream crossings, closed systems, open channel
> - Detention storage basins
> - Shoulder widening
> - Resurfacing
> - Signals, lighting, signing (include temporary signals)
> - Temporary by-pass
> - Traffic control, detours, etc.
> - Construction incentives
> - Pavement edge treatment
> - Guardrail items
> - Urban contingencies (i.e., enhancements, landscaping, etc.)
> - Erosion control (seed and mulch, rock ditch liner, paved ditch, rock blanket)
> - Temporary erosion control
> - Mobilization
>
> **1-02.12 (10) (c) RIGHT-OF-WAY CONSIDERATIONS.** If right-of-way acquisition is involved, a written request for an estimate should be made to the district right-of-way manager with the following information:
>
> - Latest available plans
> - Tentative or actual right-of-way required
> - Access controls
> - Anticipated improvements to be taken
> - Proposed borrow areas
> - Proposed mitigation sites for parklands, wetlands, etc.

Right-of-way personnel should develop the estimate according to the guidelines and policies of the right-of-way manual.

1-02.12 (10) (d) ENVIRONMENTAL CONSIDERATIONS. The Environmental Section of GHQ [General Headquarters] design should be consulted to determine if there are any environmental or cultural resource issues that may affect the cost of the project. They will also be able to provide assistance in determining any associated costs. The Environmental Section should be furnished with the following applicable items:

- Request for Environmental Studies (RES) form (see Subsection 2-03.2)
- Latest available plans
- Location layout of structures, suspected wetlands and unusual features
- Photographs

Environmental staff should give consideration to how the following items will impact the project costs:

- Parklands
- Wetlands
- Historic structures (include bridges)
- Hazardous waste sites
- Threatened and endangered species
- Archeological sites
- Noise mitigation
- Socio-economic impacts

1-02.12 (10) (e) UTILITIES CONSIDERATIONS. The district utility engineer should be furnished with the following applicable items:

- Latest available plans
- Photographs

The district utility engineer should consider the following in developing the associated utility cost estimate for the project:

- Known major utilities
- Railroad crossings
- Determine if existing utilities are on existing highway right-of-way or private easement
- Coordinate with appropriate utility companies

1-02.12 (10) (f) BRIDGE CONSIDERATIONS. GHQ Bridge will provide cost estimates for the bridge structures associated with a project. Upon receipt of the bridge survey, GHQ Bridge will review the bridge survey data and make an in-depth analysis of the proposed crossing. The analysis will include hydraulic design of the waterway opening for stream crossings, geometric layout for grade separations, economic analysis of structure types and span lengths, and investigation of any special features evident from the bridge survey data. A tentative bridge layout will be prepared. The following bridge-related items should be considered by the core team when developing costs for bridges and other drainage structures:

- Number of major stream crossings
- Flood plain proximity to crossing location
- Earthquake design necessity
- Nearby structures that are similar
- Number of bridge rehabilitations
- Clearance requirements
- Enhancements (Special aesthetics—railing, lighting, girders, concrete surface texture, etc.)

Missouri DOT process also addresses quality control and quality assurance as these two functions relate to ensuring estimate consistency across Missouri DOT's planning and project development process. The following parts of their procedure highlight their approach to quality control and quality assurance.

> **1-02.12 (6) QUALITY CONTROL.** The district engineer is responsible for maintaining the consistency of the estimates and their documentation within each district. The district engineer should establish a district Cost Estimate Quality Control Review Team that will implement a plan to ensure quality control of all project estimates. It is recommended this team include the district's transportation planning coordinator, project development engineer, right-of-way manager, transportation project managers, and other personnel deemed necessary. This team is not expected to inspect each estimate in detail, but rather establish consistent procedures for the appropriate preparation and updating of the project estimates.
>
> **1-02.12 (7) QUALITY ASSURANCE.** The GHQ design technical support engineers will provide quality assurance to their assigned districts to ensure consistent cost estimates are produced throughout the department. This will be accomplished through periodic reviews of selected project estimate files, the district's project estimation process, the district's quality control plan, and the district's plan for review and updating of the STIP [state transportation improvement plan] estimates.
>
> The results of all quality assurance reviews should be reported on the quality assurance form, Figure 1-02.8, and submitted to the district engineer and the Chief Engineer. Reviews may be conducted by the district review team, the GHQ design technical support engineer, or jointly performed by both parties. The participation of other GHQ personnel, including a bridge structural liaison engineer and structural project manager, a right-of-way field liaison, and other project core team members, should be required as appropriate.

Tips

Identifying tasks that are repeated for every project and adopting an efficient method to accomplish these tasks are necessary for this tool to be successful. Also, adequate training and awareness among participants is also essential for this tool to be successful.

Resources

Missouri DOT (2004). "Chapter 1, General Information: Needs Identification Project Scoping and STIP Commit-

ments," Section 1-02, *Project Development Manual.* www.modot.org/business/manuals/projectdevelopment.htm.

C4.7 State Estimation Section

Estimators come from many different specialties within the state highway agency, including engineering, construction, contracting, and occasionally the operations and maintenance areas. In 26 state highway agencies, estimation personnel are consolidated in a dedicated estimation section where their primary responsibility is the production of estimates. In the other 24 state highway agencies, personnel prepare estimates as an ancillary duty while their primary responsibilities are likely to be either design or contract preparation.

What Is It?

To achieve consistency in estimation processes and techniques from programming through plans, specifications, and estimates (PS&E), some state highway agencies have centralized estimation functions. Such an approach provides a central point of contact for designers and allows experience staff to mentor new, less experienced estimators. Centralized estimation can bring rigor and discipline to project estimation, which in turn means estimate reliability.

Why?

Cost estimation for large projects or for complex projects is inherently challenging. In a 2003 survey, several state highway agencies reported having estimators with minimal experience and stated that in recent years they had lost their most experienced personnel to retirement. A number of state highway agencies have therefore recognized the benefit of having estimation personnel at all stages of professional development working as a consolidated group in a single location.

What Does It Do?

When the state highway agency's estimation functions are centralized in a single location with a dedicated team, less experienced estimators can be mentored by those having a broader range of knowledge. The principle advantages of a centralized state estimation section are that it

- Improves corporate memory,
- Facilitates the use of experienced staff and their individual knowledge,
- Achieves better estimated documentation,
- Makes possible interaction between estimators to discuss approaches, and
- Enhances the ability to support externally imposed schedule constraints by sifting the workload of collocated estimators.

When?

Consolidation of project estimation functions in a single location is usually the result of personnel issues, such as lack of qualified staff and limitations on the number of staff positions. But consolidation can also be driven by the need for estimators to interact with multiple sections within the state highway agency.

Examples

The California DOT (Caltrans), which has 12 districts, has consolidated all estimation structures into a single office in the Engineering Service Center located in Sacramento. The districts take the lead in developing all project estimates, but the estimation group, which is in the Engineering Service Center, provides the bridge cost part of an estimate. This group also produces conceptual estimates for alternatives during the early stages of project development.

Tips

One of the problems with having a single estimation group is establishing good communication with the state highway agency's districts that are being served. For a consolidated estimation group to be effective, there needs to be good communication between the project's designer and the estimation group so that the experience of both groups can be fully used.

Resources

Florida Dot State Estimates Office: www.dot.state.fl.us/estimates.

The Caltrans Division of Engineering Services, Cost Estimates Branch, web page is located at www.dot.ca.gov/hq/esc/estimates. This page provides access to Caltrans's Bridge Construction Cost Index, Construction Statistics, and Comparative Bridge Cost in both English and Metric units.

The Caltrans estimation portion of the bridge design manual is found at www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/bridge-designaids/page/bda_11.pdf.

C5 Constructability

In a broader context, the intent of constructability is to apply construction knowledge and experience during all phases of project development to help achieve the project objectives. The application of construction knowledge and experience can occur in a number of ways depending on the project phase and complexity of the project. The ultimate goal of constructability is to enable cost-effective construction by improving the efficiency of construction through better project designs. If properly implemented on projects, the design intent should be clear to the contractor through the contract plans and specifications, and the design should be constructable, thereby improving the likelihood of receiving consistent bids when the project is advertised for construction. During construction, fewer claims should result in problems with the design.

Constructability is formalized through a review process. This process determines when reviews will occur, who will perform the reviews, what level of review is necessary, and how recommended changes will be incorporated into project designs. The tool involves constructability reviews. With respect to cost estimation practice and cost estimation management, constructability reviews will have their most significant impact if performed during the programming and preliminary design phase in support of improving document quality while preventing and/or reducing the impact of scope and schedule changes. This tool can also ensure that final design documents are clear and error free.

C5.1 Constructability Reviews

Constructability reviews can occur during any phase of a project, although they are most likely to occur during preliminary engineering and final design. Constructability reviews provide an independent and detailed analysis of all project drawings and construction-related project information. These reviews can be conducted at design milestones and also just prior to release of plans and specifications for construction. This critical review evaluates the "ability to construct" the proposed highway project.

What Is It?

The production of an accurate, well-coordinated set of plans and specifications is very important to minimize change orders and optimize field contract administration. Constructability reviews are performed as a means to assess critical construction issues early in design so as to provide an opportunity to improve the efficiency of construction. Later in design, constructability reviews assess the construction documents for accuracy, completeness, and systems coordination issues. This latter review occurs as construction documents are nearing completion and prior to advertising the project for bid. During this review, potential coordination issues, missed details, time delays, potential liability, and inter-contractor coordination items are identified prior to publishing bid documents. The design team then reviews and implements appropriate changes to the documents.

Why?

During a project, the design phase can take months or even years to complete. If construction knowledge and expertise are introduced at the end of the design phase, potential changes may be difficult to incorporate into the design in a timely manner. Delaying this vital and project-critical review can lead to inefficiencies. At worst, the lack of a timely constructability review will lead to cost overruns, time overruns, and possibly substandard quality. Using constructability reviews early will ensure high-quality project design documents and reduce the potential for change.

What Does It Do?

A constructability review helps in determining whether a contractor can ultimately submit a competitive bid based on what is shown in the contract plans and specifications. Constructability reviews provide an opportunity to remove many common problems with plans and specifications. A constructability review concentrates on whether the information shown on drawings and within specifications can be constructed. Further, constructability reviews can aid in suggesting improvements to designs that support efficient construction methods, phasing and sequencing, and site access approaches.

When?

Constructability reviews can be applied during each phase of the project development process. Maximum benefits occur when people with construction knowledge and experience become involved from the very beginning of the project life cycle.

Examples

Enhanced Constructability Review is a new Caltrans pilot project whereby the highway construction industry can review preliminary design plans and submit comments to Caltrans regarding the constructability of a project. The intent is to draw on the vast experience of the industry to ensure that plans and specifications are biddable and buildable. Contractors can review the draft project plans and specifications provided on this Caltrans website and voluntarily provide comments. Comments submitted through the website are forwarded to Caltrans designers and may be incorporated into the final design. Comments that are submitted may be posted on the website.

A sample agenda for constructability review meetings from one state highway agency is presented in Figure C5.1.

Tips

Conducting a constructability review incorporates contractor knowledge into the total construction project develop-

Constructability Review Meeting Agenda

Project: ____

Project No.: ____ Date: _____________________

Meeting Location: ____

Agenda Item	**Speaker Time**	**Frame**
Introduction		
I Traffic		
A. Design office specific items of concern		
B. Traffic office specific issues of concern		
C. Stage construction		
II Environmental		
A. Design office specific items of concern		
B. Environmental office specific issues of concern		
III Hydraulics/Utilities		
A. Design office specific items of concern		
B. Hydraulic/Utilities specific issues of concern		
IV Structures/Geotechnical		
A. Design office specific items of concern		
B. Structures/Geo. specific issues of concern		
V Right-of-Way		
A. Design office specific items of concern		
B. Right-of-way specific issues of concern		
VI Traffic Control		
A. Design office specific items of concern		
B. Traffic control specific issues of concern		
VII Construction/Maintenance		
A. Design office specific items of concern		
B. Construction/Maintenance issues of concern		
VIII Recap of issues		
A. Issues		
B. Responsible parties for resolution		
C. Deadlines dates		

Figure C5.1. Constructability review meeting agenda.

ment process. This review provides the state highway agency with the following advantages:

- Many problems can be identified before the construction phase. This can prevent costly change orders, extra work orders, and financial bombshells.
- Plans and specifications can be improved.
- Contractor claims can be reduced.
- Building quality can be enhanced.
- Cost can be reduced.
- Project schedules can be shortened.
- Environmental permit violations and/or noncompliance can be reduced.
- There can be cooperative team relationships between all parties involved in a project.
- All parties can gain more time to concentrate their efforts on producing a high-quality, cost-effective project.

Constructability reviews are not intended to replace or change a designer's duties or the handling of a value engineering program; rather, they are intended to review projects during the design phase for constructability issues.

The constructability review should concentrate on quantities for each item of work called for in the plans and specifications. What is material used for? How much? Where does it go on the project? Are the quantities correct? Reasonable? Misleading? Duplicated? Unnecessary? Contingent?

Resources

Anderson, S, and D. Fisher (1997). *NCHRP Report 391: Constructability Review Process for Transportation Facilities*, Transportation Research Board.

Oregon DOT Constructability Review Process, www.oregon.gov/ODOT/CS/OPO/construction/constructability_reviews.shtml#Constructability_Review_Process.

C6 Creation of Project Baseline

Cost estimation is continuous and repetitive during the project development process. Cost estimates must be created to support the various alternative solutions that are being explored at the earliest stages of design. When the preferred design becomes apparent or when project-funding limits are set, a baseline cost estimate should be established. That baseline can best be defined as the estimate that is used to manage change and make design decisions that affect project cost. The baseline estimate sets the basis for funding and for measuring project performance. It is important to note that the baseline refers to a project of a certain scope and dimension; any future design or scope changes that alter the actual capacity of the project *by definition* change the project and require a new baseline, and not just an adjustment to the existing cost and schedule estimates. Four tools have been identified in this research to assist in the creation of a project baseline: cost containment tables, an estimation scorecard, a scope change form, and scoping documents.

C6.1 Cost Containment Table (Also See I1.1, G1.2)

Cost containment is an objective of cost estimation management. Managing to a baseline cost estimate is one of the most common measures of estimation management success. As a project moves forward through its development stages, cost containment tables provide a benchmark against the project baseline. They create a standard tool that can be used by team members to track cost growth and provide immediate feedback for executive management.

What Is It?

A cost containment table is an estimate reporting system that requires project team members to document summary-level estimates at critical points in the project development process. It provides executive management with estimate totals as the project moves through critical milestones during its development. These milestones will vary from state highway agency to state highway agency, but they can include scoping, programmed amount, preliminary engineering, final engineering, award, and closeout. They can also include estimate subtotals for items like engineering, right-of-way, and construction.

Why?

Cost containment tables provide a simple and concise tool for managers and project team members to monitor and react to cost escalation as projects transition through critical phases in their development process.

What Does It Do?

Cost containment tables create transparency and accountability in the management of a baseline. The use of cost containment tables permits quick identification of cost escalation as it occurs. When standardized in a state highway agency, cost containment tables allow for comparison of cost escalation by the variables captured in the tables. The use of the cost containment table establishes minimal milestones that are consistent throughout the state highway agency. They create accountability for the project team for changes in the estimates from one milestone to the next.

When?

The effort to manage project costs continues from the programming and advanced planning/preliminary design stage through final design until the project letting. The cost containment table should only be used when a project baseline estimate is established.

Examples

Pennsylvania DOT developed a cost containment form that provides information on cost breakdown and milestone estimates. This table is shown in Figure C6.1. Pennsylvania DOT has found that this table creates accountability and transparency. If costs escalate from one milestone to the next, the project teams are charged with bringing the project back into budget or justifying the reason for this escalation (i.e., right-of-way cost escalation, varying material prices, other scope change, or estimate error).

Tips

A cost containment table requires updating at each predetermined project milestone. At each project milestone where the table is used, the estimate must be broken down into specified items. If substantial changes are present, they can be easily identified to indicate a need for further review.

Cost containment tables should be only one tool in managing cost escalation. A drawback of the cost containment table is that it only provides a "rearview mirror" look at cost escalation. While knowing that there is a problem at critical project milestones is essential, project teams should strive to anticipate cost escalation whenever possible and mitigate their effects before they occur.

Resources

Pennsylvania DOT (2001). *Estimating Manual.* ftp://ftp.dot.state.pa.us/public/Bureaus/design/PUB352/inside_cover_page.pdf.

C6.2 Estimation Scorecard (Also See I1.2)

While the use of estimation scorecards is not prevalent with state highway agencies, scorecards are good tools for evaluat-

Cost Containment Table						
District:		Program Yr:				
County:		Project:				
		Short Title:				
Cost Containment	Milestone Estimate					
	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
Cost Breakdown	$	$	$	$	$	$
Engineering:						
Preliminary Engineering						
Final						
Design						
R/W						
Utilities						
Construction						
Total Cost:						
Scope						
Comments						

Figure C6.1. Cost containment table.

ing cost estimation management throughout the project development process. An estimation scorecard is an objective measure of estimate accuracy or project scope growth. It should be created by the entire team and aligned with the project objectives that will ultimately drive the perceived project success.

What Is It?

An estimation scorecard is an evaluation tool to measure the success of cost estimation practice and cost estimation management during the project development processes. The format of the scorecards can vary depending upon individual agency objectives, but the goal is to create an objective score for performance in cost estimation practice and/or cost estimation management.

Why?

Early identification and measurement of the project success criteria helps to ensure that there is no miscommunication regarding functionality and physical structure of the completed project. This helps to clearly align project scope with expectations, thereby limiting scope changes.

What Does It Do?

Estimation scorecards are commonly used when consultants are preparing the project design and estimate, but they can also be used internally for agency evaluations. Estimation scorecards indicate the measures that will be used at project completion to evaluate success. During various points in the project development or once the project is complete, performance measures can be derived from comparison of target values designated during project development and the achieved values measured after project completion.

When?

The evaluation criteria of the estimation scorecard are developed early in the project development process and used in the latter phase to determine the success of the project.

Examples

Coors Brewing Company has found it beneficial to develop benefit and execution scorecards to evaluate the benefit of the project as well as execution. These scorecards are completed early in project development and are used at project completion to evaluate success of the project. This tool is also used for payment of services. Figure C6.2 shows the Coors Brewing Company benefit scorecard and execution scorecard. The scorecard is developed for each project, one for execution and another for benefit.

The benefit scorecard communicates the benefits of the project. The elements of the benefit scorecard for determining project success are defined based on the project. The weights for each benefit are determined by the project team that develops the benefit items as well as how the results will be measured early in project development. After the project is completed, these benefits are assessed. The result for each benefit can either be above the target value (AT), on target (OT), or below the target value (BT). The success of the project is dependent on the evaluation of the perceived benefits.

The execution scorecard is similar to the benefit scorecard in that the weights of the given evaluation items, project cost, schedule, and quality/performance are determined early in project development by the project team. The elements of the execution scorecard for determining project success are cost, schedule, and quality/performance. The measurement characteristics are also defined. Once the project is completed, these characteristics are assessed. The results for each can either be above target (AT), on target (OT), or below target (BT).

While the example above was created by a private-sector company for a process facility, the concept can easily be translated to public-sector transportation projects. State highway agencies should develop clear and concise project goals at the beginning of each project. These goals can be used to measure project success, either internally for the state highway agency or externally for consultants. An example of project goals, which relate to benefits in the scorecard, is taken from Colorado DOT's Colorado Springs Metro Interstate Expansion Project (COSMIX; http://www.cosmixproject.com):

1. Maximize capacity and mobility improvements in the corridor within the program budget.
2. Minimize inconvenience to the public during construction.
3. Provide a quality project.
4. Complete by the end of calendar year.
5. Provide a visually pleasing final product.

A benefit scorecard can be created in a fashion similar to Figure C6.2 using the project goals above. The weighted goals can be scored and used in an execution scorecard to measure cost estimation performance and overall management performance.

Tips

The use of the scorecards can ensure that all team members are clear about the expectations for a successful project. The tool will help to facilitate a structured discussion about what will define success on each project, and it will provide an objective measurement for this success.

Develop the scorecard as a team. Consider developing an overall project scorecard as well as discipline-specific scorecards.

Resources

U.S. Department of the Interior (2005). "The Quarterly Scorecard and Corrective Actions Reports for Constructed Asset Investments." www.doi.gov/pam/QuarterlyReportGuidance61605.pdf.

C6.3 Scope Change Form (Also See I1.4)

Although managing a project to the baseline estimate is the goal of every project manager, scope changes are sometimes unavoidable. Changes in scope should be documented and justified. A scope change form is an estimation tool that creates a standard procedure for reporting scope changes. It creates transparency and accountability. It also allows agencies to view trends in scope changes that may allow for better scope definition on future projects and in future estimates.

What Is It?

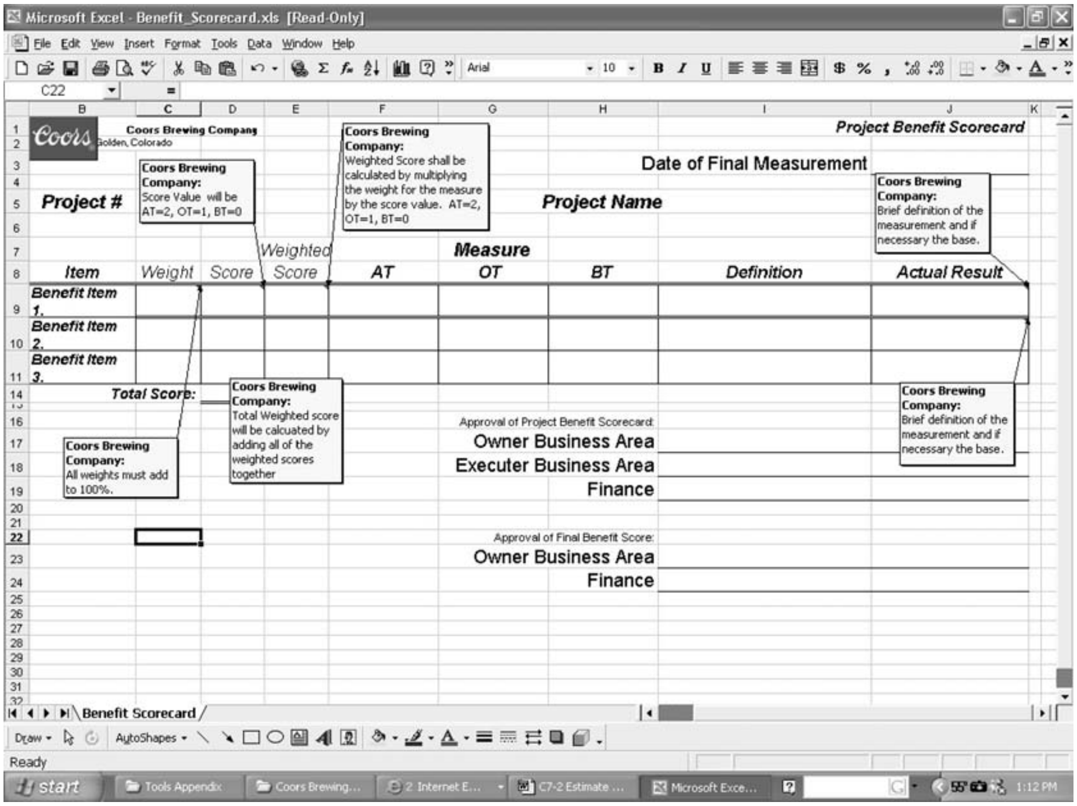
This form provides a permanent record of the scope changes that occur during the project development. To create accountability, it also records who authorized the changes.

Why?

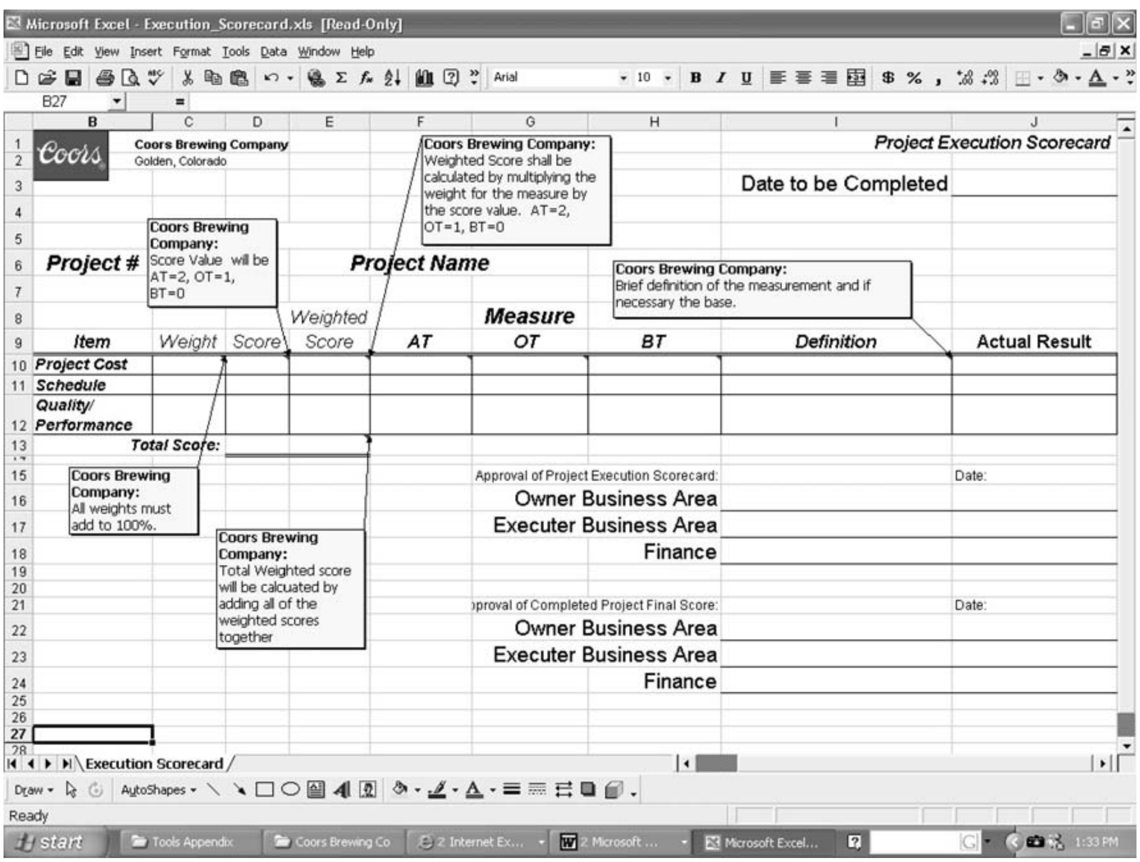
Changes to project scope almost always cause cost increases. Therefore, the requirement for formal management approval of any scope change serves to limit change, because all such proposals must be carefully reviewed and controlling scope change serves to control cost growth. An additional reason for tracking changes to the project is to ensure that no changes take place without the full knowledge of the project team, including designers, managers, and estimators.

What Does It Do?

Scope change forms make possible easy comparison of the current project scope, schedule, and cost with the established baseline of the project. The form should require that the documented change—as well as any impacts of the change to project scope, schedule, and cost—be specifically acknowledged. An explanation is required with each change. Appropriate approvals should be required depending on the size and nature of changes.



(a) benefit scorecard



(b) execution scorecard

Figure C6.2. Coors brewing company scorecards.

When?

Changes should be tracked throughout project development. The form may change slightly and require more detail as the project progresses through development; however, the concept and purpose of the form remains constant. The usefulness of the scope change form in regards to cost will be more beneficial after the project baseline is set.

Examples

Missouri DOT (MDOT) has created a form for tracking both scope and estimate changes. The form and the instructions for how to complete it are shown in Figure C6.3.

Tips

Scope change forms should explicitly require all the information needed to track project changes, including scope, schedule, and cost impacts, as well as explanations and approvals. Forms should be standard; however, there should be the ability to deviate from the form for special project circumstances.

Resources

California State DOT *Project Development Procedures Manual* (PDPM) Chapter 6 addresses project cost, scope, and schedule changes: dot.ca.gov/hq/oppd/pdpm/chap_htm/chapt06/chapt06.htm.

MEMORANDUM

Missouri Department of Transportation

Project Development
District

TO: (District Engineer)

FROM: Your Name
Project Manager

Date:

Subject: Route _, ___________ County
Job No. _________________
Non-Major Project Scope/Estimate Change

Project Stage:

_____ Annual Review/Milestone Completion

_____ Submittal of P,S,&E

Scope Change:

(Describe the elements and details of the project that have changed since the project initially included funds in the STIP for right of way or constriction or since the last scope/estimate change was approved)

(If a project scope/estimate memorandum has not previously been approved for the project, the details of the project that have changed since approval of the original project-scoping memorandum should be documented here.)

(Projects that require submittal of this letter due solely to a change in cost may not necessarily include a change in the project's scope.)

Reason for Change:

(Provide the reasons that the change in the project's scope is necessary. The information provided should be detailed enough to allow someone unfamiliar with the project details to gain a general understanding of why the recommended change is necessary.)

(Projects that require submittal of this letter due solely to a change in cost may not necessarily include a change in the project's scope. However, the reasons for the cost change shall be fully described in adequate detail to allow someone unfamiliar with the project details to gain a general understanding why the recommended change is necessary.)

Figure C6.3. Missouri DOT non-major project scope/estimate change form.

Source of Additional Funding:

(This section is only required if the project scope/estimate change results in an increase in the total project cost.)

(If the change results in an increase in cost, the source of the additional funds should be identified. Any associated impacts to other STIP commitments should also be discussed in this section, if applicable.)

Project Estimate Change: Approved STIP Amount: $__________ ($1,000's)

Revised Cost Estimate: $__________ ($1,000's)

Amount of Change: (+/-) $__________ ($1,000's)

Percent Change: (+/-) __________ %

(The estimate amounts shown here should reflect the total amounts included in the STIP for right of way and construction as compared to the revised estimates for the same items. For example, if a project only has right of way funds included in the latest approved STIP then the cost comparison only needs to include the revised right of way costs. If right of way and construction funds are both included in the latest approved STIP then the revised total of these costs should be compared to the previous total of these costs.)

(In order to ensure an accurate comparison of the project costs, the revised costs should be compared to the latest approved amounts found in District STIP database. Any amounts obtained from the database should be obtained from the Internal Report category since these amounts do not include any inflation factors.)

Change in Construction Award Date:

Approved STIP Construction Award Date: _____ Quarter of FY ____

Revised Construction Award Date: _____ Quarter of FY ____

Approved: ______________________ Date: __________________

(District Engineer)

Figure C6.3. (Continued).

Chapters 2 and 3 in the New York State DOT's *Project Development Manual* (PDM) discusses changes in project cost, scope, and schedule: www.dot.state.ny.us/cmb/consult/dpm1/pdm_01_30_04.html.

C6.4 Scoping Documents (Also See P2.2)

State highway agencies throughout the country have created scoping documents to support the project definition (i.e., scoping) process. These documents are used at project initiation to define project scope. These scoping documents provide an excellent tool for project estimators to define the basis of an estimate. The documents are also excellent tools for understanding the uncertainty involved in a project; thus, they are very helpful in setting an appropriate project contingency early in the project development process.

What Is It?

Scoping documents are standardized forms that state highway agencies use to explicitly define and document the scope of a project. They are often developed in the form of a checklist. They represent past project experience and list key scope items and lessons learned from past projects.

Why?

Scoping documents are a tool to aid in project scope definition and documentation. They can be used before any major engineering efforts take place. They can also be used in the cost estimation process to define the estimate basis and aid in the establishment of an appropriate level of contingency.

What Does It Do?

The development of a standard scoping document provides consistency in project scope definition early in the project development process. Completion of a scoping document for each project assists in documenting the estimate basis, defining the baseline estimate, defining contingency, and tracking scope changes. This document will aid in identification of the true purpose of the project and serve as a reminder of project intentions throughout project development. The document aids in identification of elements to be included in estimate and schedule considerations.

When?

The scoping document should be completed early in project development to establish a baseline scope of the project and basis for the early project estimates. The document should be reviewed throughout the development of the project to check for changes in scope.

Examples

Many state highway agencies use some sort of scoping document. The documents range in complexity and specificity. Some state highway agencies use a simple memo as their scoping document, while other agencies have longer, more detailed forms.

Figure C6.4-1 provides an example of a scoping document from Virginia DOT.

Figure C6.4-2 provides an example of a scoping document from the Missouri DOT.

Tips

A scoping document is an excellent tool to define an estimate basis. Use the scoping document in a team environment with all of the appropriate disciplines represented whenever possible to minimize the chance of any oversights. Scoping documents should permit some flexibility for special-case projects, both the very straightforward and the more complex.

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VIRGINIA DEPARTMENT OF TRANSPORTATION
LOCATION AND DESIGN DIVISION
INITIAL FIELD REVIEW AND SCOPING REPORT

NOTE: A project location map (USGS) and written report of the initial field review should be attached to this form.

PART A Date of Review:

Route ____ or Name of Facility ____

Project ____ PPMS ID ____

From: ____ FHWA - 534 ____

To: ____

County, City or Town ____, Virginia

District ____ 6 Year Plan(Year) ____ Page ____ Line ____

Type of Facility: (Interstate, Primary, Urban, Secondary, Bridge, Bicycle, Other) ____

PE Authorization Date ____ Type Plan Assembly (C,M,N) ____

Scheduled Advertisement Date ____

Amount Authorized for PE ____

Type of Financing: State ____ Federal ____ Other ____

6 Yr. Plan Est.: PE ____ R/W ____ (Incl. Utilities) Const. ____ Total ____

Engineer's Est.: PE ____ R/W ____ (Incl. Utilities) Const. ____ Total ____

Railroad Force Account Est.: ____

Description of Work: ____

Design Speed ____ Functional Class. ____

Existing Traffic ____ ADT (Yr. ____) % Trucks ____

Design Year Traffic ____ (if available) ADT (Yr. ____) DHV ____

Project Length ____ Alignment Length ____ Should utilities be designated? ____

3R Guidelines Used? ____ If no, explain ____

Are you aware of the need for any 3R waivers or design exceptions? ____ If yes, attach separate documentation for approval with this LD-430 form.

Are you aware of any sinkholes along the project corridor? ____

Figure C6.4-1. Example scoping document from Virginia DOT.

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PART A (cont.)

Widening Existing Pavement ________ (one side, both) Existing Pavement Width ________ m/ft

Widening Lt. ________ m/ft. Widening Rt. ________ m/ft.

Does the locality have a biking or walking accommodations plan? ________

Sidewalk: Width ________ Location ________

Shared Use Paths: Width (10' or 12') ________ Location ________

Bicycle Lanes: (yes or no) ________ Location ________

Wide Outside Lane: Width (14' or 15') ________ Location ________

No. Bridges Req'd. ________ Suff. Rating Exist. Bridges ________

R/W Width ________ Purchase ________ Donation ________

Perform Recoverable Slope Study? (Y or N) ________ If no, explain ________

List Necessary Design Exceptions: ________

Should a value engineering study on this project or specific elements be facilitated by Management Services Division? ________

Design services provided by (Central Office, District, Consultant or other)? ________

Project Assigned to ________ Phone No. ________

Members of the Initial Field Review Team are as follows:

- District Utilities Engineer ________
- Residency ________
- Location and Design ________
- Location and Design (Public Involvement) ________
- Location and Design (Survey) ________
- Location and Design (Hydraulics) ________
- Locality (if applicable) ________
- Programming Division ________
- Local Assistance Division (if applicable) ________
- Environmental (address items found on Form EQ-429) ________
- Right of Way and Utilities ________
- Mobility Management Division ________
- District Traffic Engineer ________
- Transportation and Mobility Planning Division ________
- Structure and Bridge Division ________
- Department of Rail and Public Transportation (if applicable) ________
- Scheduling & Contract Division ________
- Area Maintenance Engineer ________

Figure C6.4-1. (Continued).

Resources

The Vermont Agency of Transportation Project Development Process is online at www.aot.state.vt.us/progdev/Sections/PDManual/01mantabl.htm.

The New York State DOT Design Quality Assurance Bureau scoping process can be found in the first three chapters of the Project Development Manual: www.dot.state.ny.us/cmb/consult/dpm1/pdm_01_30_04.html.

Project initiation documents mark the transition from planning and programming to advanced planning (using the terms in NCRHP Project 8-49). These documents are described in Chapter 9 of the California DOT Project Development Procedures Manual (PDPM), which is on the Internet at www.dot.ca.gov/hq/oppd/pdpm/chap_htm/chapt09/chapt09.htm.

D1 Delivery and Procurement Method

The selected contracting method is a critical factor impacting the project estimate because it definitively states how project risk is distributed between the state highway agency and the contractor. The distribution of risk directly impacts the cost of the project. Additionally, it is clear today that market forces have a substantial impact on the cost of a project. How market forces impact a particular project depends on the specific dates

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PART A (cont.)

Survey Information Required

Provide a letter size map or photo showing the location of project. If possible, please include a large scale photo (minimum plan ratio 1:2000 or scale 1" – 200') to show the scope of the project.

Average width of terrain information required ______________________

List connections with length of survey needed ______________________

____

____

____

Does this project tie to or cross any other existing projects that are now in the survey, design, R/W. or Construction phase Y ______ N ______

If yes, provide the following information:

Project ______________________
From: ______________________
To: ______________________
Project Manager ______________ PPMS No. ______________

Project ______________________
From: ______________________
To: ______________________
Project Manager ______________ PPMS No. ______________

Project ______________________
From: ______________________
To: ______________________
Project Manager ______________ PPMS No. ______________

Any other information which should be included with survey request ______________

____

____

Figure C6.4-1. (Continued).

on which a project is advertised and bid (are there many projects being advertised by other agencies during the same time frame?) and on the manner in which the work is packaged into individual contracts (what is the size of a single contract, and is there coordination between adjoining contracts?).

D1.1 Contract Packaging

On December 13, 2001, Maryland DOT opened bids for the Woodrow Wilson Bridge superstructure contract. A single bid, 75% higher than the engineer's estimate for the contract, was received. In reviewing the situation, it became clear that market forces had a substantial impact on the bid prices, a much greater impact than anticipated by the project planners and estimators. The manner in which work is packaged into individual contracts affects contract prices and must be accounted for when estimating project cost. State highway agencies should seek to package projects in such a way that there is effective management of cost, schedule, and risk. Heeding the recommendations of an independent review committee, Maryland DOT repackaged the contract into three contracts and rebid the project approximately a year later. The first rebid contract came in 11% over the estimate, but there were five bidders and it was a workable bid, and the other two contracts both came in below the estimates, one by 28% and the other by 25%.

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PART B (cont.)

Environmental impacts that may accrue on this project ______________________________

____

Are you aware of any sinkholes along the project corridor? ______

Are major utility conflicts or problems anticipated? ____ Yes ____ No. If yes, please explain ____

____

Are utilities present that may be attached to bridges? ____ Yes ____ No

Would this project be affected by any other project? If yes, please explain ______________

____

Recommended Public Involvement for this project:

None ________ Explain ______________________

Information meeting (s) ______________________

Post Willingness ______________________

Public Hearing ______________________

Will maintenance of traffic be necessary for this project? (Y or N) ______

Can a detour to another road be used? ______________________

Figure C6.4-1. (Continued).

Contract packaging is important for maintaining competition and receiving competitive bids.

What Is It?

In packaging contracts, there must be a weighing between economy (usually measured as competition) and work efficiency. Based on thoughtful analysis and consideration of a program or project's physical work elements and on the market conditions existing at the work location, contract packages are developed that minimize the total cost of construction. Contract packaging, which is based on such forethought, requires interaction between estimators, the project development team, and the state highway agency personnel responsible for managing project construction as the estimator and construction management personnel will be able to call attention to packaging affects on project cost.

Why?

Project size (contract dollar), equipment requirements, physical features, and the responsibilities (i.e., risk) imposed on the contractor are all critical factors impacting the bid price of work. There are opportunities to reduce contract cost by conscientiously considering the contract package in respect to these factors. At the same time, estimators must consider the impacts of contract packaging when developing the project estimate.

A California DOT (Caltrans) study on the impact of competition on final bid results found a clear and undeniable relationship between the number of bids received and the contact low bid compared with the engineer's estimate. Strategies that increase competition (i.e., the number of bidders per project) will lower project cost. Contract packaging is particularly important in the case of large aggregate dollar value work and work of a specialized nature. The geographical location of a contract or work sites is an additional factor that should be considered. Any factor that affects the number of bidders that can be expected on a project should be evaluated.

Caltrans found that the relationship between the average number of bidders and the bid price changes based on project dollar size, as shown in Table D1.1. This table makes it clear that even for small dollar jobs, it is important to consider the effects of competition.

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PART C (cont.)

Transportation and Planning __________

Structure and Bridge __________

Rail and Public Transportation (if applicable) __________

Area Maintenance Engineer __________

FHWA __________

Other __________

Scope Approval

Approved by: __________ Date ______
Resident Engineer (Secondaries Only)

Approved by: __________ Date ______
District Administrator

Approved by: __________ Date ______
State Location & Design Engineer

Approved by: __________ Date ______
Programming Division Director

Approved by: __________ Date ______
Local Assistance Division Director (if applicable)

Comments: __________

After approval by Scoping Group please return completed form to:
__________ Project Manager

The Project Manager will distribute copies of this report to the following upon completion:

Figure C6.4-1. (Continued).

What Does It Do?

Contract packaging affects project cost; therefore, knowledge of such impacts can result in contracting packages structured to achieve the work at lower cost. By structuring contracts to facilitate maximum participation by the contracting community, state highway agencies can often lower bid prices. Increasing competition also leads to the continued potential for long-term savings by maintaining a viable base of competition.

When?

The contract packaging control procedures should be established from the initial conceptual phase through bidding.

Examples

A review of the Maryland DOT estimate compared with the single bid for the Woodrow Wilson Bridge superstructure contract found the following:

- Only a small number of contractors had the ability to undertake a project of such magnitude.
- Several other major bridge projects were being bid concurrently with the Woodrow Wilson project.
- The size of the project necessitated that joint-venture teams be formed, thereby further reducing the competition.

The work was repackaged into three contracts. The first contract was successfully bid with five contractors competing. The second contract had six bidders and came in 28% below the engineer's estimate. The third contract had four bidders and was 25% below the engineer's estimate.

Tips

State highway agencies should consider the following when packaging contracts:

- Contracting method (the history of design-build projects by state highway agencies indicates that change orders average 2%, while design-bid-build contract change orders average 5%)

MEMORANDUM
Missouri Department of Transportation

Project Development
District

TO: (Director of Project Development)

FROM: Your Name
Project Manager

Date:

Subject: Route _, ___________ County
Job No. _________________
Draft Project Scoping Memorandum

(The information provided in the draft project scoping memorandum should be detailed enough to allow someone unfamiliar with the project details to gain a general understanding of the recommended actions that will be taken to address the need.)

Need:

(This should include a description of the deficient items that indicate the initial need for the project. In addition any other deficient items or safety needs that are identified through the initial stage of the project scoping process should be included.)

Scope:

(The description of the project's scope should be as complete as possible at this early stage of the project development process. However, it is reasonable to assume that level of detail that is available will be limited to describing broad concepts and general details of the project.)

Figure C6.4-2. Example scoping memorandum from Missouri DOT.

- Potential high mobilization costs for bridge structure or earthmoving equipment
- Coordination with adjacent contracts
- Traffic control limitations
- Utility relocation activities (Can this work be accomplished before the prime contract [advance utility relocation] or will there be extensive coordination of work?)
- Accomplishment of hazardous remediation work as a separate contract in advance of the prime contract
- Large-dollar contracts (Such contracts can limit competition because contractors are not able to obtain bonding. In the case of mega-dollar projects, there is a limit to the risk that the bonding community is willing to assume. To protect themselves, the bonding companies join together to write large bonds. This practice further limits the availability of a contractor to obtain a bond.)

During the design phase of project development, there should be a strategic separation of projects within a corridor, thereby allowing for efficient use of earthwork (balancing cut and fill requirements).

In respect to all these considerations, there must be a balance between the cost of administration for multiple contracts and the potential benefits from having multiple contracts.

Resources

While the California DOT report is specific to conditions in that state, it provides a good indication of competition impacts on project cost (see “Impact of Competition on Final Bid Results for Transportation Related Construction Project,” Nov. 15, 2001, Caltrans, Division of Engineering Services).

Maryland DOT (MDOT) information on the Woodrow Wilson Bridge contract packaging can be found at www.mdot.state.md.us/News/2003/May2003/Wilson%20Bridge.

Former Utah DOT chief Tom Warne led the Independent Review Committee (IRC) that MDOT established to examine the Wilson Bridge situation. The IRC recommendations for

Budget:

Grading & Drainage +	Base & Surface +	Bridges +	Misc. +	Estimated Contract Total =	
$0	$0	$0	$0	$0	
				Construction Contingency (est. @ 3% of contract total)	Contract Total+ Construction Contingency=
				$0	$0
				Utilities	
				$0	
				Non Contractual Items	Total Construction Cost=
				$0	$0
R/W Incidentals +	Preliminary Engineering Incidentals +	Construction Engineering (est. @ 7% of contract total) +		Total Incidentals	
$0	$0	$0		$0	
				Construction Incentives/ Contract Acceleration	
				$0	
				Program Estimated Total =	
				$0	

Schedule:

Milestone	Schedule
Initial Concept Approval	
Environmental Document Approval	
Preliminary Plans Approval	
Project Scoping Memorandum Approval	

Implementation Plan:

(The implementation plan should include a discussion of how development of the project will proceed beyond this stage. This should include the time frame for developing the project to enough detail to allow completion of the project scoping memorandum. Any other pertinent information related to implementation of the project should also be included. Projection of the project schedule beyond the project scoping memorandum will not be possible at this point in the process since the project prioritizations process will be used to determine priority for the fully scoped project.)

Figure C6.4-2. (Continued).

advancing the project included: value-engineering opportunities, contract modifications, review of bonding/surety issues, and project modifications to enhance competition. The full report is available from MDOT.

There is also a TRB paper, "Adventures in Building Another Washington Monument: Woodrow Wilson Bridge Project Re-Bidding Outcomes," by Robert Douglass, Robert Healy, Thomas Mohler, and Shirlene Cleveland, which was presented in the 2004 TRB Annual Meeting.

D1.2 Delivery Decision Support

The selection of a project delivery system can affect both cost estimation practice and cost estimation management. The design-bid-build delivery system approach, in which unit price construction contracts are awarded to the lowest bidder, is the traditional method for delivery of U.S. highway projects and is used in the majority of cases today. However, this traditional project delivery method has received criticisms stemming from long delivery times, excessive cost growth, and litigious relationships. Continuing to face increasing demands of the traveling public with declining staffs, federal, state and local agencies are employing alternative project delivery, procurement, and contracting methods to improve the efficiency and effectiveness of public-sector project delivery.

What Is It?

Project delivery decision support is a tool that assists state highway agencies in choosing the appropriate project delivery

I have reviewed the scope of this project and offer the following comments:

____

____

(Design Technical Support Engineer)

I recommend proceeding with the development of this project subject to the following comments:

____

____

(District Engineer)

Approved Subject to the following comments:

____

____

(Director of Project Development)

Approved subject to the following comments:

____

____

(Transportation Planning Director

Figure C6.4-2. (Continued).

Table D1.1. Relationship of bid price to estimate considering project size (Caltrans study).

Project Size, $	Ave. No. Bids	Percent over PS&E if only one bid	Expected reduction by increasing the average by one bidder
Less than 1 Mil.	5.2	+17%	-2.3%
1 to 5 Mil.	5.3	+5%	-2.0%
5 to 10 Mil.	5.0	+5%	-2.1%
Greater than 10 Mil.	5.7	+3%	-1.8%

method. It provides a clear understanding of the advantages and disadvantages of alternative delivery methods so that state highway agencies can make informed decisions about the most effective choice for the available alternatives to meet the specific project goals. The following is a sample of alterative project delivery methods in use by state highway agencies at the time that this document was being prepared.

Project delivery methods:

- Construction management at risk
- Design-build (and variations, such as design-operate-maintain and design-warranty)
- Indefinite quantity/indefinite delivery
- Job order contracting
- Public-private partnerships

Procurement methods:

- Cost + time bidding (A+B)
- Multi-parameter bidding (A+B+C)
- Best-value procurement
- Alternate designs
- Alternate bids
- Additive alternates
- Negotiated or qualifications-based selection (for construction)

Contracting and payment methods:

- Lane rental
- Incentive/disincentive payments
- Warranty contracting
- Lump sum payment methods

When selecting alternative project delivery methods, state highway agency personnel should consider such issues as risk allocation, legal implications, statutory restrictions, and administrative issues. The decision to use an alternative delivery method invariably involves a tradeoff between cost and other factors such as time, user delays, or quality. Delivery decision tools can help to define and quantify the tradeoffs.

Why?

The choice of project delivery method often hinges on a project's cost or time constraints, and estimators must understand how to estimate the cost tradeoffs involved in the decision to use an alternative delivery method. For example, the design-build project delivery method can be used to award a lump-sum contract for both the design and construction of a project much earlier in the project development process than the traditional design-bid-build method. This early award offers a high potential for project delivery time savings and, in essence, fixes a project's cost earlier in the project development process than the traditional process. When design-build is selected, different approaches must be taken for cost estimation practice and cost estimation management. Cost estimation practice may require the use of more rigorous conceptual estimation tools and a more rigorous risk analysis because designs will not be complete and quantities will not be known at the time of project award. Cost estimation management will require different change management procedures because the design-builder is responsible for the final project design (including final quantities) and changes in cost estimates due to scope additions or deletions can be more difficult to manage.

What Does It Do?

Project delivery decision support provides an understanding of why an alternative delivery method might be appropriate for a project given a set of unique project goals. It provides guidance for cost estimation practice and cost estimation management.

When?

Project delivery decisions should be made as early as possible in the project development process to optimize their impact. Decisions for the overall project delivery method (i.e. design-build, public-private partnership, etc.) should preferably be made during the project scoping process or shortly thereafter. Decisions regarding innovative procurement methods such as best-value or qualifications-based procurements should be made as early as possible as well. Other, less significant procurement and contracting decisions (e.g., A+B bidding, additive alternates, and lane rental) can be made sometime in the preliminary engineering development.

Examples

There are numerous examples of project delivery decision tools. Five national examples are provided here, but numerous states have developed decision support tools as well.

Utah State University Innovative Contracting Website. The Federal Highway Administration sponsored the development of an innovative contracting website to provide decision support for innovative contracting methods. A screen clip of the website is provided in Figure D1.2. The Utah State University's Innovative Contracting website includes information concerning various construction contracting methods, such as design-build, warranties, cost-plus-time bidding, lane rental, and job order contracting. State DOT work plans and evaluation reports from FHWA's

Special Experimental Project No. 14, "Innovative Contracting," are provided. The site also features a best practices guide and a decision tree for selecting the appropriate contracting technique.

NHI Alternative Contracting Course (Course No. 134058). The Federal Highway Administration's National Highway Institute (NHI) is offering a course on "Alternative Contracting" (Course No. 134058). A short description of the course is listed below, and more information on the course availability can be found on the NHI website at www.nhi.fhwa.dot.gov.

Course Objective

The estimated 2-day training course will teach participants how to select the appropriate projects for alternative project delivery strategies, choose the correct alternative contract provisions, and recognize the legal and programmatic implications associated with these techniques. The course design is to be flexible, allowing the requesting agency to customize the presentation for increased emphasis on topics of interest to the agency.

The target audience includes personnel working in contract administration, project development and design, and the management of highway construction, including contribution of information in contract provisions.

Upon completion of the course, participants will be able to:

- Identify alternative project delivery, procurement, and contract management methods for highway construction
- Identify objectives for the use of alternative project delivery, procurement, and contract management methods
- Differentiate among traditional design-bid-build and alternative project delivery, procurement, and contract management methods based on relative advantages and risks

AASHTO Primer on Contracting for the 21st Century. The Primer on Contracting for the 21st Century is an updated version of the Primer on Contracting 2000, which was published in 1997. The new primer describes various contracting and contract administration methods that are currently being used by contracting agencies in their transportation programs and provides contacts within these agencies for use in obtaining additional information. This report was prepared by the Contract Administration Task Force of the AASHTO Highway Subcommittee on Construction. The document can be found in the references section of the AASHTO Subcommittee on Construction's website http://construction.transportation.org.

NCHRP Project 10-49, "Improved Contracting Methods for Highway Construction Projects." The project reviewed relevant domestic and foreign literature; surveyed the construction industry; identified and evaluated contract-

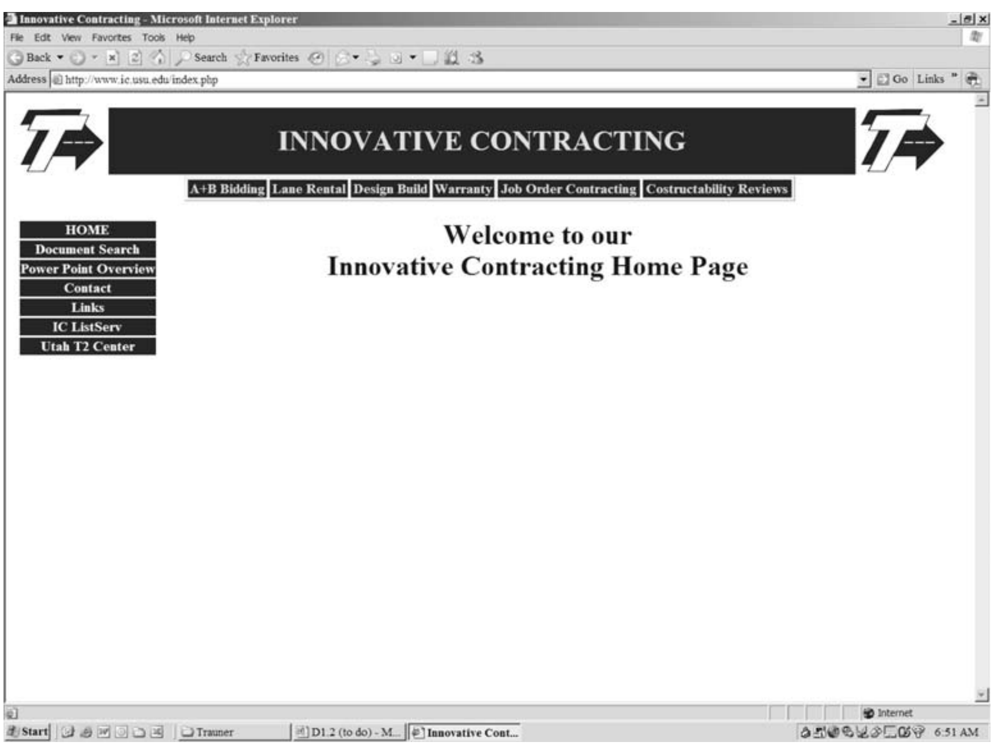

Figure D1.2. Utah State University Innovative Contracting Website (www.ic.usu.edu).

ing practices with consideration to compatibility with the low-bid system, impact on state highway agency resources, product quality, and risk allocation; and developed guidelines for three nontraditional contracting methods: warrant, multi-parameter, and best value. The agency's final report that contains the findings of the literature review, discussions of current use, and analysis of survey results has been distributed to all state highway agencies. The guidelines for nontraditional contracting methods have been published as *NCHRP Report 451* (http://www.trb.org/news/blurb_detail.asp?id=5476)

NCHRP Project 10-61, "Best Value Procurement Methods for Highway Construction." NCHRP Project 10-61 provides decision support for best-value procurement of U.S. highway construction. The resulting report outlines a comprehensive process that state transportation agencies can use to create best-value methods in their individual states. The research effort investigated best-value concepts currently in use in the construction industry, evaluated their relative effectiveness, and recommended a best-value system or systems that may be used in conjunction with a traditional design-bid-build delivery system for highway construction. The research products include:

- A common definition and a conceptual framework for the use of best-value procurement methods for highway construction projects
- A best-value procurement system that allows for flexibility in the choice of parameters and award methods
- An implementation plan that includes both a project screening system for selecting candidate projects and a step-by-step process for selecting appropriate parameters, criteria, and award algorithms
- Recommendations regarding models to use for legislation and procurement regulations
- A compendium of case studies for best-value procurement in the highway construction industry
- A training tool to assist agencies with implementation

The results of NCHRP Project 10-61 have been published as *NCHRP Report 561: Best-Value Procurement Methods for Highway Construction Contracts.* (http://www.trb.org/news/blurb_detail.asp?id=6903).

Tips

Choose delivery methods that better align goals and that allocate risk properly. The U.S. highway industry must evolve from the traditional "one size fits all" project delivery method. A renewed focus should be given to alternative delivery methods that promote early industry involvement and life cycle design solutions to maximize the entire project team's input into meeting customer needs.

Resources

AASHTO Subcommittee on Construction's website. See references for *Primer on Contracting for the 21st Century* (http://construction.transportation.org).

Anderson, S. D., and J. S. Russell (1998). *NCHRP Report 451: Guidelines for Warranty, Multi-Parameter and Best-Value Contracting,* Transportation Research Board. http://www.trb.org/news/blurb_detail.asp?id=5476.

FHWA's National Highway Institute, www.nhi.fhwa.dot.gov.

NCHRP Project 10-49 website, http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=266.

NCHRP Project 10-61 website, http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=281.

Scott, S., K. R. Molenaar, D. D. Gransberg, and N. Smith (2006). *NCHRP Report 561: Best-Value Procurement Methods for Highway Construction Contracts,* Transportation Research Board. http://www.trb.org/news/blurb_detail.asp?id=6903.

Utah State University, Technology Transfer (T2) Center, Innovative Contracting website, www.ic.usu.edu.

D2 Design Estimation

Design estimation commences when a project enters into the programming phase and continues throughout preliminary engineering. Design estimation is critical during programming because during programming is often when a baseline scope, cost, and schedule are determined. Design estimation tools must produce consistent and accurate estimates. However, the use of these tools will vary depending on the level of project scope definition, the project type, and the complexity of the project. Computer software is used to facilitate the application of these types of estimation tools.

A variety of tools can be used to support design estimation:

- **Analogous or similar project:** This tool relies heavily on one project that is very similar to the project being estimated. The reference (i.e., analogous or similar) project is typically one that was previously constructed; is currently under construction; is bid for construction; or has a completed plans, specifications, and estimates (PS&E) level estimate. Line items, quantities, and unit costs are used as a basis for estimating the current project. Similar costs from the reference project are used to estimate preliminary engineering and construction engineering costs.
- **Cost-based, bottom up:** This tool relies on the cost-based estimation approach, wherein construction costs, based on a selected productivity, are estimated for labor, material,

equipment, contractor overhead, and contractor profit for each major line item. Estimates of preliminary engineering and construction engineering are estimated from the bottom up. This means that resources are specifically identified for each element and tied to time—productivity—when these resources will be engaged on the project.

- **Historical bid based:** The use of historical data from recently bid contracts is the most common state highway agency estimation approach. Under this approach, bid data are summarized and adjusted for project conditions (project location, size, quantities, etc.) and the general market conditions. Line items are developed for major elements of work so that quantities and historical unit prices can be applied to these line items. Often, percentages are used to estimate items where little or no definition is available. Standard percentages are used to estimate preliminary engineering and construction engineering costs.
- **Historical percentages:** This tool is used in conjunction with other tools such as historical bid-based estimation. Historical percentages are used to estimate costs for items that are not typically defined early. A percentage is developed based on historical cost information from past projects to cover certain items. This percentage is based on a relationship between the selected items and a total cost category such as direct construction. Contractor mobilization, construction engineering, and preliminary design (often referred to as preliminary engineering) are often estimated based on a historical percentage of construction.
- **Major cost items using standard sections:** Typical sections are developed for different roadway or bridge types. These typical sections are tied to cost data that reflect the work to be completed for each section. As a project scope is developed, typical sections that are similar to the project being estimated are used to generate a new cost estimate for a project. Standard percentages are used to estimate other costs associated with the typical sections, such as traffic control items and preliminary engineering and construction engineering costs.
- **Parametric estimation:** Parametric estimation techniques are used primarily to support development of programming or early preliminary engineering estimates, which are developed when very little project scope definition is available. Major project parameters are identified. Statistical relationships and/or nonstatistical ratios between historical data and other parameters (e.g., tons of asphalt and square footage of bridge deck) are used to calculate the cost of various items of work.

D2.1 Analogous or Similar Project

This tool relies heavily on matching a previous project that is very similar to the project being estimated. The reference (i.e., analogous or similar) project is typically one that was previously constructed; is currently under construction; is bid for construction; or has a completed plans, specifications, and estimates (PS&E) level estimate. Line items, quantities, and unit costs are used as a basis for estimating the current project. Similar costs from the reference project are used to estimate preliminary engineering and construction engineering costs.

What Is It?

Analogous estimation is an estimation tool that uses the values of parameters (such as scope, cost, and time) or measures of scale (such as size, quantities, and complexity) from a similar previous project as the basis for estimating the same parameters or measures for a future project. This tool is a form of expert judgment. It is most reliable when previous projects are in fact similar in terms of major parameters and not just in appearance. Future projects often have common elements associated with other completed or ongoing projects.

Why?

This tool provides a quick and cost-effective approach for developing a programming-type estimate or to prepare an estimate during the early phases of preliminary engineering. The availability of information based on real project experience is an invaluable input for determining future project cost. Identifying similarities in a completed or current project and comparing that project to one that is being estimated can provide excellent cost history for estimation purposes. Further, using lessons learned to adjust a project estimate that is based on a similar past project can improve estimate accuracy.

What Does It Do?

This tool provides an approach to preparing an early estimate that has sufficient reliability and accuracy for use in programming a project. Further, the tool provides sufficient detail to subsequently track changes in quantities and unit costs as the project is designed.

When?

Analogous or similar project estimation is perhaps best used during programming and early in preliminary engineering. It can also be used in planning in a slightly different form (see C3.3).

Examples

In late 2003, when Caltrans received a single bid for the self-anchored-suspension (SAS) span of its San Francisco-

Oakland Bay Bridge Project, the upper levels of California government seriously considered going forward with a skyway-type structure instead of the costly SAS. Caltrans therefore had to prepare an early estimate for a Skyway Extension Bridge span. At the time of this estimate preparation, the design was only 5% complete. The proposed project was very similar in scope to the existing Skyway Extension Bridge work that was under construction at that time. Further, the foundation system was also very similar to cost data that were available from a bid on another type of bridge to be located at the same location. These two past projects were used to develop the cost estimate for the Skyway Extension Bridge span project estimate. The estimator used both quantities and unit costs from the two similar projects. Appropriate adjustments were made to both quantities and unit costs to fit the current bridge situation and reflect the unique site conditions for the proposed bridge as well as current market conditions. These adjustments were extremely important for this billion-dollar project. Cost estimates for preliminary engineering, environmental impacts, and construction engineering were also based on costs from the similar bridge projects.

The Washington State DOT prepared an estimate for another component of a pavement project on an existing state route. The project increases the capacity of the route by adding two lanes to an existing two-lane highway. This current estimate was based on a previously completed estimate for an earlier stage of a project on the same road. The estimator used the previous estimate that was based on an approximately 1-mile section of roadway to estimate another 2 miles of roadway for the next stage of the project. The estimator used ratios to adjust quantities for the new project estimate. Unit prices were also used, but were adjusted to reflect current dollars and several slight differences in complexity of the new project in the earthwork category.

Tips

The user of this tool must understand that the reference project is in fact similar to the project being estimated and not just similar in appearance. Thus, the estimator must make a careful assessment of the scope and site conditions of both the project being estimated and the reference project. Adjustments may be required to the reference project scope and cost data to fit the project being estimated.

Differences between the reference (or analogous/similar) project and the current project should be carefully documented as part of the estimate back-up calculations.

Resources

Project Management Institute (2004). *A Guide to the Project Management Body of Knowledge* (PMBOK Guide).

D2.2 Agency Estimation Software (Also See C2.1, C3.1, P1.1)

Some state highway agencies have taken the initiative to develop their own estimation software. This has been accomplished using internal resources in many cases, but external contractors have also been employed to support state highway agency software development. Most of the software programs have limited capabilities and were designed to run on mainframe computer systems. Additionally, many state highway agencies and individual estimators have not gone as far as developing software but have created spreadsheet programs to support estimate development. See Sections C1.6, C2.4, and D2.4.

What Is It?

Agency estimation software is specifically designed to serve the estimation practice of a specific state highway agency. This includes the capability to use the agency's existing historical data files on project components and costs. The software may include logic to establish the cost of items that are not fully defined using parametric techniques combined with the use of historical databases to produce costs for fully scoped items. The combination of these methods can be applied to develop an estimate before design is complete.

Why?

During the early stages of project development, it is difficult to develop definitive cost numbers based on material quantities or specific work items because they have not yet been defined. Because of the computer's ability to handle large data sets and its calculation flexibility, the estimator can easily search historical databases to parametrically estimate those items for which there is still limited scope development and can also adjust unit costs or percentages to match each project's unique conditions. Additionally, agency estimation software is designed to be compatible with other management software used by the agency.

What Does It Do?

Computer software allows the user to employ different estimation databases for parametric or line-item estimation and for performing "what-if" analyses. The programs typically allow the user to draw prices from historical bid data, historical cost data, reference tables, or a collection of price derivations. All of the data used to generate an estimate (such as historical costs, crew wages, equipment and material costs, production rates, and assumptions) can be stored to provide a sequential record of estimate development.

When?

To address very specific estimation requirements, custom agency software may be the only solution. Agency software can be very good in addressing distinctive requirements imposed on any individual state highway agency; however, software development is tedious and costly, and continuing support is always a critical issue. Agencies should first look to commercially developed and supported software such as the AASHTO Trns•port product, which has been developed specifically to meet the needs of state highway agency estimation.

Examples

Virginia DOT expanded an in-house-developed software system that was initially created through the combined efforts of two districts. This Project Cost Estimate System (PCES) is currently being used during the middle stages of project development. Figure C2.1 is a sample summary page from PCES. The state is looking to expand its use to the earlier stages of project development. The initial software specifically guided the estimator through decisions about the following:

- Costs common to every project, such as stone, asphalt, grading, pipes, erosion control, pavement markings, and moderate shoulder widening (i.e., the costs of every "usual element" averaged and factored according to geometric classification)
- Project-specific costs that are typically overlooked, such as crossovers, turn lanes, and curb and gutter
- Costs of unique or unusual items requiring a specific dollar input determined by a specialist in a particular field

The initial software was modified to include the following:

- Data from the entire state, rather than just a few districts
- Interstate projects
- Right-of-way
- Utilities
- Estimation curves and relationships based on a wider variety of projects
- Construction engineering and inspection at a variable rate based on project cost
- A wider range of bridge estimates

This software is not only an estimation tool, but also a management tool in that a number of items must be checked off, dated, or entered before a project can continue to the next level of development.

Tips

Many times, estimators spend more time with the tools they use to create the estimate (computers and software) than with studying and analyzing the project. It is important that agency-developed software be user friendly and structured so that it is easy to input the required data into the system.

Resources

Kyte, C. A., M. A. Perfater, S. Haynes, and H. W. Lee (2004). "Developing and Validating a Highway Construction Project Cost Estimation Tool," *Transportation Research Record 1885: Transportation Management and Public Policy 2004,* Transportation Research Board. http://www.trb.org/news/blurb_detail.asp?id=4517.

Barlist is a reinforcing steel quantity-estimating tool developed at the Washington State DOT. It can be found at www.wsdot.wa.gov/eesc/bridge/software/index.cfm?fuseaction=download&software_id=45.

D2.3 Cost Based, Bottom Up

Cost-based, bottom-up estimation is a tool similar in concept to the cost-based estimation tool described in Section P1.3. The application under design estimation *is extended to not only cover construction costs but also other project costs, such as preliminary engineering (PE) and construction engineering (CE).* During programming and preliminary design, this tool is often used to estimate unique items and not necessarily used to estimate all construction-related costs, such as the cost-based estimation tool in Section P1.3. Nineteen state highway agencies perform detailed bottom-up estimates for major work items, using historic databases to track costs based on crews, equipment, and production. Further, this tool may be used when PE and CE costs are difficult to estimate using a percentage.

What Is It?

Cost-based, bottom-up estimation is a tool to compute project costs by estimating the cost of each component required to complete the work. In the case of construction, costs are estimated based on crew sizes, wage rates, and production rates for labor, material and construction equipment. A reasonable amount for a contractor's overhead and profit is added. In the case of PE and CE costs, these costs would be estimated based on anticipated resource levels (e.g., the number of design personnel or construction inspectors) and the deliverables (e.g., number of plans needed or quality assurance tests) based on the time required to perform the work.

Why?

This tool is especially applicable for very large and complex projects. The unique character of these projects, geographical influences, market factors, and the volatility of material prices can make historical bid pricing an unreliable method of estimating project costs. In addition, long design and construction durations for these projects make the use of percentages for estimating PE and CE costs potentially unreliable. Hence, cost-based, bottom-up estimation can provide more accurate and defendable estimates.

What Does It Do?

Bottom-up estimates are, as the term suggests, developed from the bottom up. Costs are estimated based on the lowest component level of work, such as identifying crews, production rates, materials, and equipment for construction items; assigning resource requirements for detailed design elements; and estimating agency construction staff support for administering the construction contract. Costs at the lowest levels are estimated and then summarized to different levels to ultimately generate a total project cost estimate.

When?

This tool can be used for large projects that are in the programming phase or early in the preliminary design phase of project development. The tool can be used to estimate components of projects that are not that large but still complex. It is a very good method for developing plans, specifications, and estimates (PS&E) when final plans and quantities are known.

Examples

When Caltrans was attempting to estimate the capital outlay support (COS) cost or what could be referred to as the department's overhead cost for the Skyway Extension Bridge, the project's design was in its infancy (5%). A bottom-up approach was used to provide an independent validation of the initial numbers developed using a percentage estimation approach. Six functional areas were identified and solicited to provide COS workload estimates based upon their anticipated relevance on this project. The primary functional areas were project management, environmental, structure design, roadway design, construction, and materials engineering and testing services (METS). Within these primary functional areas, subfunctions such as surveys, hydraulics, and electrical were represented by the primary function they support.

The functional groups submitted hours by the work breakdown structure for the Skyway Extension Bridge through all phases of the work. The COS dollar estimate was calculated using the workload estimates provided by the functional experts and applying the present associated state personnel rates and consultant rates. The consultant rates were from existing consultant contracts. To better capture the effects of escalation as a function of resource types, an escalation of 3.5% was applied to state resources, and an escalation of 5% was applied to consultant resources.

Follow-up interviews were conducted with the functional experts to clarify assumptions used in building the workload estimates. This effort resulted in the identification of specific line-item contingencies not captured in the workload estimates.

Rather than apply an across-the-board contingency factor to the entire COS estimate to account for unknowns, specific percentages were used depending upon the phase of the project. A 35% contingency was applied during the design phase to provide for potential added costs associated with major design modifications and unknown special studies that may be needed. This unknown potential added cost was not captured in the 6-month design delay calculation. The 6-month design delay calculation was based solely upon the concept of extended review times due to public scrutiny resulting in minimal design changes. A 20% contingency was applied to the construction phase to account for potential added cost associated with use of additional expert consultants or independent analysis for construction engineering. A lower percentage was used during the construction phase because the costs for a 1-year construction delay reflected the extended use of all support staff in the construction phase.

The delay costs were calculated by preparing two separate scenarios: (a) a 6-month design delay during design and (b) a 12-month construction delay. The worst-case situation of both design and construction delay combined was evaluated. For simplicity, delays were applied at the peak workloads and for a sustained duration.

The bottom-up estimate more accurately reflected the impact of delays because it took into consideration the resource type and the work being performed. A relatively lower delay cost during design was indicative of the ability to quickly mobilize and demobilize consultant design staff. Higher delay costs during the construction phase reflected the fact that mobilization and demobilization of staff are not a viable option for short-term sporadic delays in a construction environment. The bottom-up delay costs captured the higher end of delay costs by applying a sustained level at the peak staffing level. Delay costs may actually be lower if the delays occur earlier in the project, when staffing levels are much lower.

The bottom-up method segregated the specific costs and clarified the relationship between the functional components of the estimate and the contingency components.

Tips

Detailed cost-based bottom-up estimation requires a great deal of knowledge about construction methods, supply systems, labor markets, and method productivity specific to the area where the work is being performed. It also requires more time to prepare a detailed estimate than that which is needed for estimation methods that simply apply bid averages to work items. This is because the estimator must conceptualize the construction process in order to prepare an accurate estimate.

Most state highway agencies that do this kind of estimation have dedicated estimation sections whose personnel have the necessary construction experience. State highway agencies that do perform detailed estimates typically use computer software that supports estimate development, but the software is not critical to the estimation process itself. The software may be used to track cost trends or simply allow the estimator to report the estimate to other sections of the state highway agency more efficiently. The basic information that is necessary to perform a detailed estimate—such as crew sizes, equipment types, production rates, and labor and material costs—can be derived from a variety of resources. This may require contacting local contractors or using a database such as RS Means Heavy Construction Cost Data (see Section P1.3). The estimator will have to call suppliers of materials to obtain unit costs for materials and similar resources for determining equipment production and rental rates. It is important that the estimator be familiar with available resources, know how to find the resources, and most importantly has a competent knowledge of construction processes. All of these elements are necessary in order to develop an accurate cost-based, bottom-up estimate.

Resources

The AASHTO Subcommittee on Design, Technical Committee on Cost Estimating is developing guidance on historical cost-based estimation. Draft papers are prepared, but not approved for release. If interested, contact the chair of this technical committee. See this website for key contact persons: http://design.transportation.org/?siteid=59&pageid=756.

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Means, R. S., and M. A. Kingston (2006). “Heavy Construction Cost Data,” www.rsmeans.com.

Oberlender, Garold D., and Steven M. Trost (2001). “Predicting Accuracy of Early Cost Estimates Based on Estimate Quality,” *Journal of Construction Engineering and Management,* Vol. 127, No. 3.

Parker, Albert D., Donald S. Barrie, and Robert M. Snyder (1984). *Planning & Estimating Heavy Construction,* McGraw-Hill Book Company.

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D2.4 Historical Bid Based (Also See P1.4)

Historical bid-based estimation is the most common estimation approach used by state highway agencies. This approach relies heavily on line items with quantities and good historical bid data for determining line-item cost. The historical data normally are based on bids from recent projects. The estimator must adjust the historical data to fit the current project characteristics and location.

What Is It?

The most common method used by state highway agencies in developing estimates for transportation projects is historical or bid-based estimation. This tool is more often associated with the engineer’s estimate, but can be used during programming and preliminary design. The tool requires the estimator to identify line items and quantities for each line item so that historical unit prices can be used to calculate line-item costs for the project.

Why?

Historical bid-based estimation is an efficient method for developing an estimate for line items that have adequate historical pricing data available. Implementing a bid-history-based estimation process enables an agency to estimate the cost of proposed work using a minimum of resources. Similar projects with similar line items, quantities, and locations can generally be estimated quickly using historical bid data and engineering judgment. Preparing estimates quickly may be important when the agency is developing a number of project estimates for programming purposes. The tool can be used at this stage in project develop for standard-type projects where the scope is relatively consistent, such as hot mix asphalt pavement overlay projects.

What Does It Do?

Creating cost estimates from historic bid prices is a relatively straightforward and quick process. After determining the quantities from the project plans, the estimator simply matches those quantities to the appropriate historical unit-bid prices or average historic unit-bid prices. To generate unit price data, departments systematically compile bid data from past project lettings. The data are broken down by bid line item. Average prices can also be calculated for the estimator’s use. State highway agencies reported several different methods for sorting the data collected from bid documents.

When?

Historical bid-based estimation can be used during programming and throughout preliminary engineering as long as the project scope can be described in terms of line items for which quantities can be developed.

Examples

The first decision is how many bids from each project should be included in the data. There is significant variance as to how state highway agencies approach this issue. All 50 state highway agencies responded to this question because even those state highway agencies that use a detailed estimation procedure track historical bid average costs for minor work items. Among the 50 states,

- 20 state highway agencies use low bid only
- 1 state highway agency uses low and second bid
- 15 state highway agencies use the three lowest bids
- 11 state highway agencies use all bids, but may exclude single bids that are very high or low
- 2 state highway agencies use all bids except high and low
- 1 state highway agency uses bid analysis to determine a reasonable bid amount for each line item

Table D2.4 summarizes the estimation performance of the above practices. The one agency using a reasonable price and the two agencies using all bids except high and low reported the best performance. The one agency that used reasonable price to create its estimates did not have any experience using the approach for projects valued at more than $100 million, and, as with the two agencies that use all bids except high and low, this agency's total project experience over a 5-year period was limited. Of the remaining practices, using the three low bids produced the best results.

Tips

After it is decided which bid prices will be used to create the average price, a timetable must be established that specifies the frequency of data updates. Databases can be refreshed and updated after each letting or on an annual or on some other recurring basis.

In addition to these two factors (i.e., how many bids to use and how often to make system updates), the department must decide for what period of time data will be retained in the database 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 2 years for use in averages. Nine state highway agencies retain data for as long as records exist. Estimators can examine and use the data for items that are not frequently encountered or items that have seasonal price swings. An averaging of data would obscure seasonal pricing.

Estimators should know exactly how the prices they are using were created, because there are multiple mathematical methods to arrive at an index value or average value. Three common methods of deriving an index value are:

$$\text{Index value (average)} = \frac{\sum_{i=1}^{n} C_i}{n}$$

$$\text{Index value (inverse)} = \frac{n}{\sum_{i=1}^{n}\left(1/C_i\right)}$$

$$\text{Index value (root of the product)} = \left(C_1 \times C_2 \times C_3 \times \cdots \times C_n\right)^{1/n}$$

where

C = the individual costs elements and
n = the numbers of cost elements.

Such information should be part of the state highway agency's estimation manual. Connecticut has several different sets of bid data information that the estimator can use as the situation dictates, as shown in Figure D2.4. A three low-bid printout is created for each project bid. At the end of each calendar year, average prices are computed, and every 2 years weighted unit prices are prepared.

Resources

The AASHTO Subcommittee on Design, Technical Committee on Cost Estimating is developing guidance on historical

Table D2.4. Number of bids used for historic bid price estimation.

Number of bids used	Number of DOTs	Reported projects	Number reported more than 5% over estimate	%
Reasonable price	1	24	1	4.2
All except high and low	2	64	3	4.7
Three lowest	15	497	88	17.7
Low only	20	755	169	22.4
All	11	260	74	28.5
Low and second	1	24	13	54.2

CONNECTICUT DEPARTMENT OF TRANSPORTATION

COST ESTIMATING PROCESS

PRICE COST DATA:

The primary method used is pricing from a history of bid prices. This entails a review of past project prices that are assembled into three categories as follows:

A. Three low bid printout. About three weeks after a project is bid, the three low bidders are printed on a form with the item description, quantity, unit price and amount. This information is used for similar items and projects. This information is fresh in the estimator's mind and is easily used.

B. At the end of each calendar year the estimator prepares a list of recent projects for computer compilation of average prices for all items bid. The computer printout is a page for each item bid with the quantity and unit price for the three low bidders on all projects that were asked for. These prices are averaged for each project and for all projects that used the item. This provides current prices. (Typical page attached)

C. Every two years weighted unit prices are prepared for all projects bid in the last two calendar years. This list is separated into wide categories by type of project; for example, Major Bridge, Commuter Parking Lot. The listing contains all bid items separated according to category and contains a weighted unit price for low bidders only.

Figure D2.4. Connecticut price cost data guidance.

cost-based estimation. Draft papers are prepared, but not approved for release. If interested, contact the chair of this technical committee. See this website for key contact persons: http://design.transportation.org/?siteid=59&pageid=756.

The data for the Wisconsin DOT method of calculating construction costs for a roadway improvement project based on controlling cost items (these are the certain bid items that comprise the majority of total construction costs) can be found at: www.dot.wisconsin.gov/localgov/highways/docs/district-controlling.pdf.

D2.5 Historical Percentages

Historical percentages are used to estimate costs for items that are not typically defined early. A percentage is developed based on historical cost information from past projects to cover certain items. This percentage is based on a relationship between the selected items and a total cost category, such as direct construction. Contractor mobilization, construction engineering, and preliminary design (often referred to as preliminary engineering) are often estimated based on a historical percentage of construction.

What Is It?

During the early phases of project development, not all line items can be identified sufficiently to be quantified. Estimating quantities and unit prices for these line items is difficult due to this lack of definition in the design. One tool that is often used to estimate known but not quantified line items is developing historical percentages to cover those items. Historical percentages can be developed using projects that are relatively similar in scope and complexity. This tool relies on an agency having standard line-item numbers to aid in preparing such percentages. Historical percentages are typically developed for estimating contractor mobilization, construction engineering, and preliminary engineering costs.

Why?

There are circumstances when the estimator simply does not have sufficient time and information to detail all line items and develop quantities for these line items. With a good database of historical bid prices used on past projects, combined with standard line items for reference, developing percentages for a group of similar line items may take less time and be just as accurate as trying to estimate quantities for these line items.

What Does It Do?

Cost estimates contain many line items when fully detailed through the engineer's estimate at the end of final design. However, early in project development, identifying and quantifying all line items is difficult at best. This tool provides a methodology for estimating costs for these unidentified line items.

When?

Historical percentages are best applied when there are many small items that cannot be quantified due to lack of design. This tool can also be used when time to prepare the estimate is a constraint. Historical percentages are commonly used for estimating contractor mobilization, construction engineering, and preliminary engineering costs. This tool is most applicable in the programming and early design phases of project development.

Examples

On a recent Washington DOT (WSDOT) project that is early in preliminary engineering, a historical percentage was used to determine the estimated costs for erosion control and planting. This category of work has a set of standard line items under Section 17 of WSDOT's Standard Item Table. In this case, several similar projects, both completed and recently estimated, were used to develop a percentage range for the erosion control and planting component of the estimate. The percentages were based on a ratio of costs for this section to total direct construction costs without mobilization. The range varied from 2% to 9%.

WSDOT provides guidance on some historical percentages. For example, mobilization, construction engineering (CE), and preliminary engineering (PE) costs are estimated typically using this approach. Mobilization is a percentage of direct construction cost. Suggested percentages based on construction cost are provided in the WSDOT Plans Preparation Manual, Division 8. Typical percentages used on recent projects have varied from 7% to 12%. Typically, ranges for CE costs are also shown in the Plans Preparation Manual, Division 8. These ranges are based on program type (preservation and improvement) and construction cost. The range for PE cost is typically between 7% and 15%.

Tips

The project from which historical percentages are developed should be very similar in scope and complexity to the project being estimated. The following approach to developing and applying this tool may be useful:

1. Identify components or project elements that can be estimated using a percentage.
2. Find several different projects that are similar.
3. Identify line items and actual cost for those items.
4. Calculate the sum cost of these items and determine the ratio percentage of the sum to total costs for several projects (e.g., percent of construction).
5. Select percentage that best fits the project being estimated.
6. Apply the percentage to the project, and incorporate the item into the cost estimate.

The percentage selected must be consistent with the scope, complexity, and schedule for the project being estimated. As the dollar size of the project increases, historical percentages normally decrease. Construction execution can also impact mobilization and construction engineering costs.

Resources

Washington State DOT *Plans Preparation Manual,* Standard Item Table, can be found on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev.

D2.6 Major Cost Items using Standardized Sections

Developing accurate estimates early in programming or preliminary design is a requirement of all state highway agencies. In many cases, these estimates must be developed quickly based on limited scope definition, and often these early estimates become the baseline from which the project is managed. As the design develops, estimates are prepared and compared with the baseline. If these early estimates are developed on a consistent basis using the same tools, then changes can easily be identified and reported to management. Preparing estimates based on major cost items using standardized sections is a technique that can provide accurate baseline estimates and allow for tracking of cost changes as the design is developed.

What Is It?

Early in programming and preliminary engineering, very limited scope definition is available on a potential transportation need, such as urban and rural roads, bridges, and related highway facilities. Often a transportation need is very similar to a project under design, under construction, or recently completed. One approach to bridge available information with ambiguous project conditions is to adapt standardized sections. Typical section models can be developed with major cost elements as a standard. Agencies will have a basis for developing an estimate using a limited pool of successful designs and will improve the level of proficiency over a period of time by working on similar models.

Why?

The purpose of this tool is to develop accurate estimates based on information from previous projects that have been completed by adapting similar sections for major cost items. The availability of previous data enhances the credibility of the estimate generated. The concept of working with a smaller number of designs but having the flexibility to customize components improves the efficiency of estimate development.

What Does It Do?

This tool is feature driven and template based to match the conceptualized project scope. It consists of a limited number of models conceptualized on standard roadways. The concept is to identify and group all major roadway types in terms of magnitude and allocate minimum design elements to each type. Each design element is further associated with parameters such as dimensions, pavement designs, and pay items. Similar standardized sections can be developed for structures.

A model is chosen from the available list as appropriate to the project requirements and customized for any additional facility components that may be required. The tool should be able to generate multiple versions based on design refinement and be used for tracking changes. The tool also should have default values based on historical databases and predetermined formulas. Validation and customization of values are permitted to produce more accurate estimates.

When?

This tool is used in programming when a project is being scoped for inclusion in an authorized program. Design is typically between 5% and 25%. The tool is used to update estimates periodically as design progresses (25% to 80%) until adequate information is generated from final plans and specifications to develop plans, specifications, and estimates (PS&E) using line items and historical bid pricing.

Examples

Florida DOT (FDOT) has pioneered this concept by developing long-range estimates (LRE), which have four hierarchical levels: project, version, sequence, and component. The project level contains general information like the project, location, key personnel, time periods, budgeted costs, and project delivery. A number coding is further associated with each project to distinguish between official and unofficial projects. The version level allows for coding the projects in multiple ways, for alternative designs. But, a primary version has to be designated for reporting and reviews. Costing information is summarized back to the version level. The sequence level accommodates choice of alternative designs from 12 section models representing type of construction, median, and shoulder type. Each model has default values that represent average conditions. These values can be modified to reflect current conditions. Multiple sequences are possible when there are changes in the characteristics of the typical section. The component level relates to specific pay items, groups, and types of work. These pay items, groups, and types of work can either be optional or required. The latter are generated automatically, while the former are at the discretion of project requirements.

A tab system facilitates easy navigation through the levels. The virtual private networking feature of the LRE enables remote operation. For bridges, a cost reference sheet based on most common sections, designs, and spans is developed on a unit basis and incorporated at the preliminary design phase. Also, additional costs such as mobilization and contingency can be attributed on a percentage basis.

The LRE provides for customization in terms of additional or extra items with relevant input from the estimator on parameters such as unit costs, quantity, and dependencies. This can also be calculated on a percentage basis of some dependent standard element. Figures D2.6-1 through D2.6-6 show various screen captures of the FDOT LRE.

Tips

Applying this tool requires the standardization of roadway sections by the agency. Care must be taken to include all major elements into each standardized model and to allow for flexibility to adjust sections to fit unique project conditions. Generating and maintaining bid history databases from previous projects are also essential elements for this tool. The user has to understand what is covered in the estimate using this approach and what must be added to cover all components of the project.

Resources

FDOT State Estimates Office, 605 Suwannee St., MS 34, Tallahassee, FL 32399-0450.

D2.7 Parametric Estimation

Parametric estimation techniques are primarily used to support development of programming or early preliminary engineering estimates, when very little project scope definition is available. Statistical relationships and/or nonstatistical ratios between historical data and other parameters (e.g., tons of asphalt and square footage of bridge deck) are used to calculate the cost of various items of work.

What Is It?

Early in programming and preliminary engineering, project scope definition is usually very ambiguous. However, it is often the case that the project is similar to previous projects that are under design, are under construction, or have recently been completed. The cost history from these projects can serve as a basis for developing a uniform, repeatable estimation tool. Parametric estimation provides reasonable estimate accuracy in a timely manner. Statistical relationships and/or nonstatistical ratios between historical data and other parameters form the basis for parametric estimation.

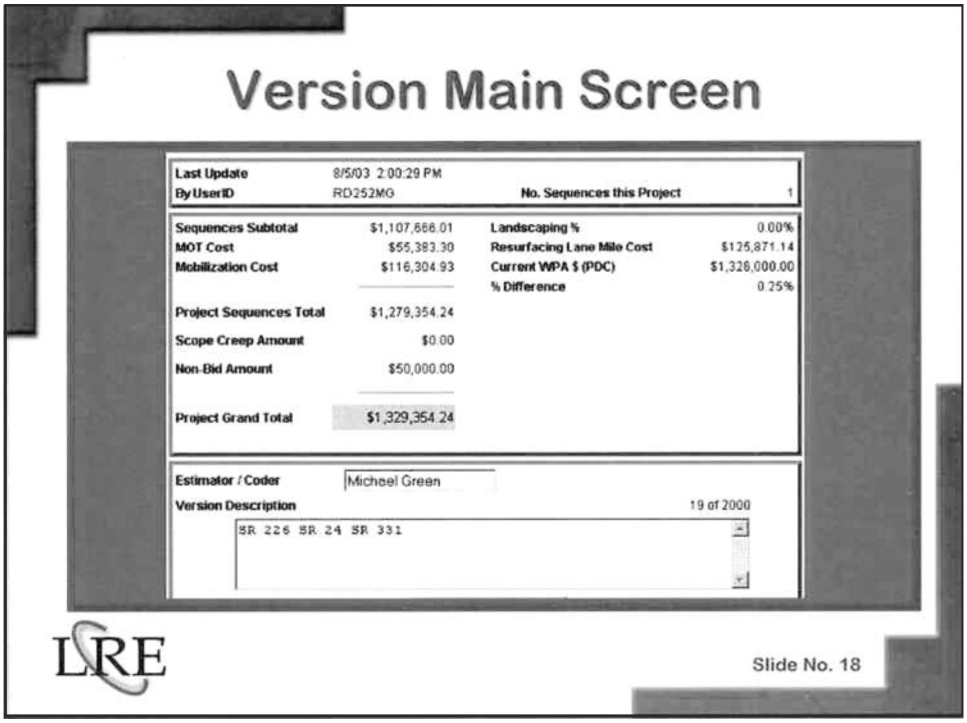


Figure D2.6-1. Screen capture of the FDOT LRE (showing main screen).

Why?

The purpose of parametric estimation is to develop early project estimates when information is restricted to only gross dimensions work features. An item-level quantity approach based on predicting item quantities from preliminary quantity information is another potential parametric approach. While parametric estimation can be used in the planning phase, this tool can provide a more detailed cost breakup than the traditional cost-per-lane-mile estimation. This more detailed cost breakup should improve accuracy and alleviate cost overruns. The tool is developed to provide simplified, reliable, early estimates that are based on current prevailing costs. The potential to separate quantity uncertainty from price uncertainty provides a better platform to track and analyze the effects of changes during project development.

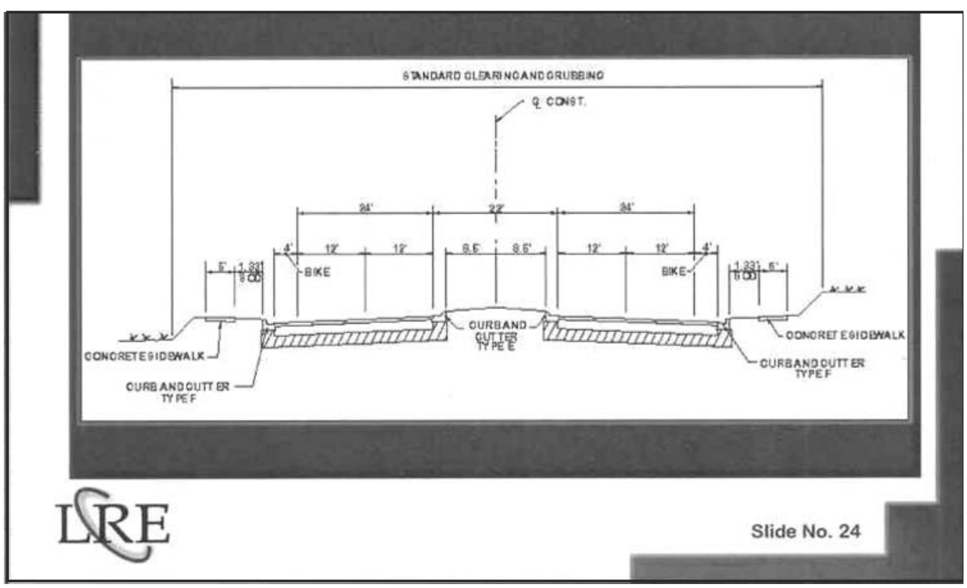


Figure D2.6-2. Screen capture of the FDOT LRE (showing one of the standard sections).

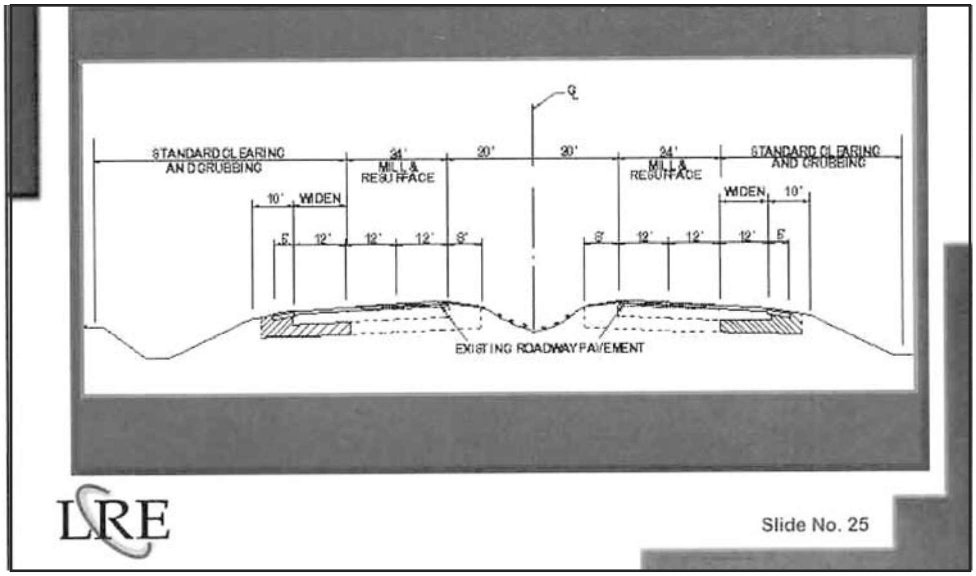


Figure D2.6-3. Screen capture of the FDOT LRE (showing another standard section).

What Does It Do?

A major fraction of a transportation project's costs is often attributed to one component, and many projects may have a common critical cost component. One parametric approach takes advantage of this fact and seeks to quantify the critical component in a unit volume. All pavements are three-dimensional (length, width, and depth), and these parameters are typically known fairly early in project development. The concept is to develop factors based on roadway sections for different dimensions and associate them with a historical cost database considering all major items to construct the roadway. The individual factors are extracted as applicable to the project and are then cumulated for all elements in the

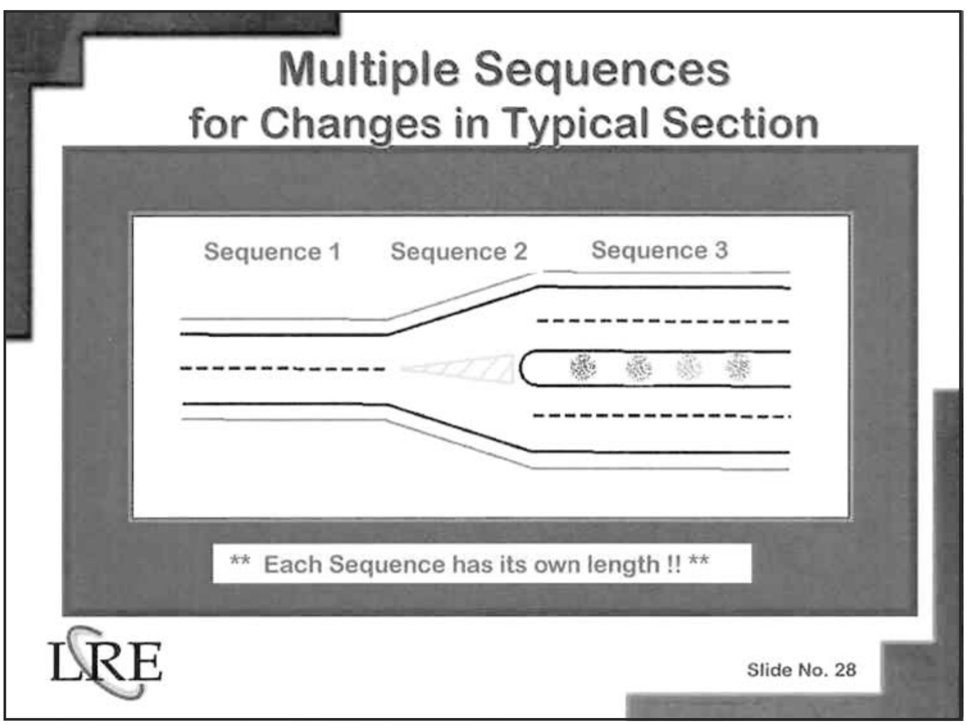


Figure D2.6-4. Multiple-sequence feature of the FDOT LRE.

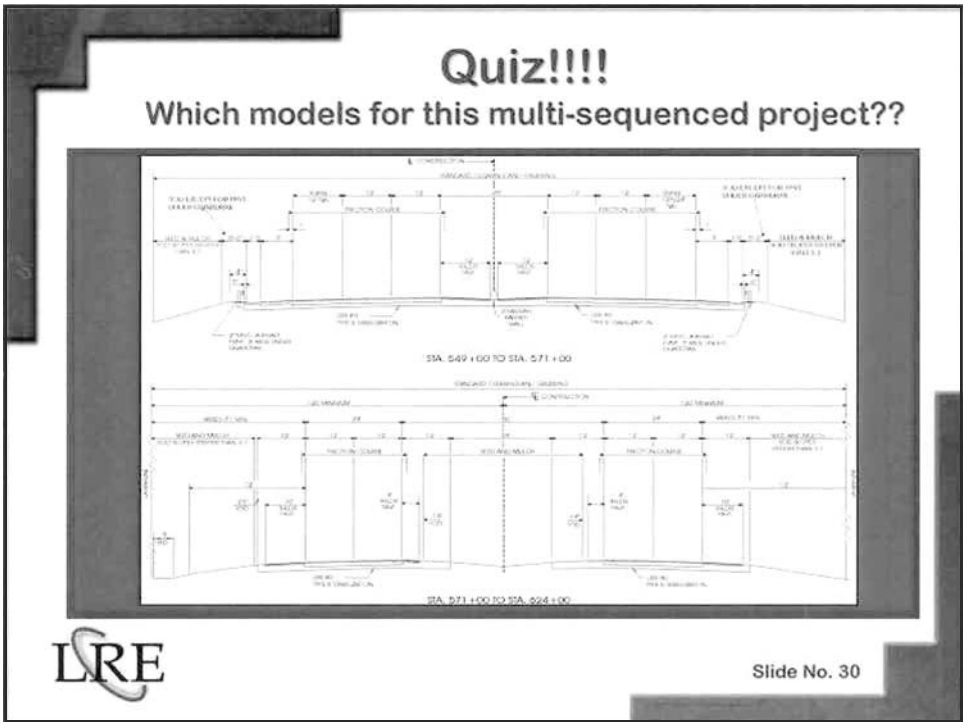


Figure D2.6-5. Screen capture of the FDOT LRE (showing multiple-sequence section selection).

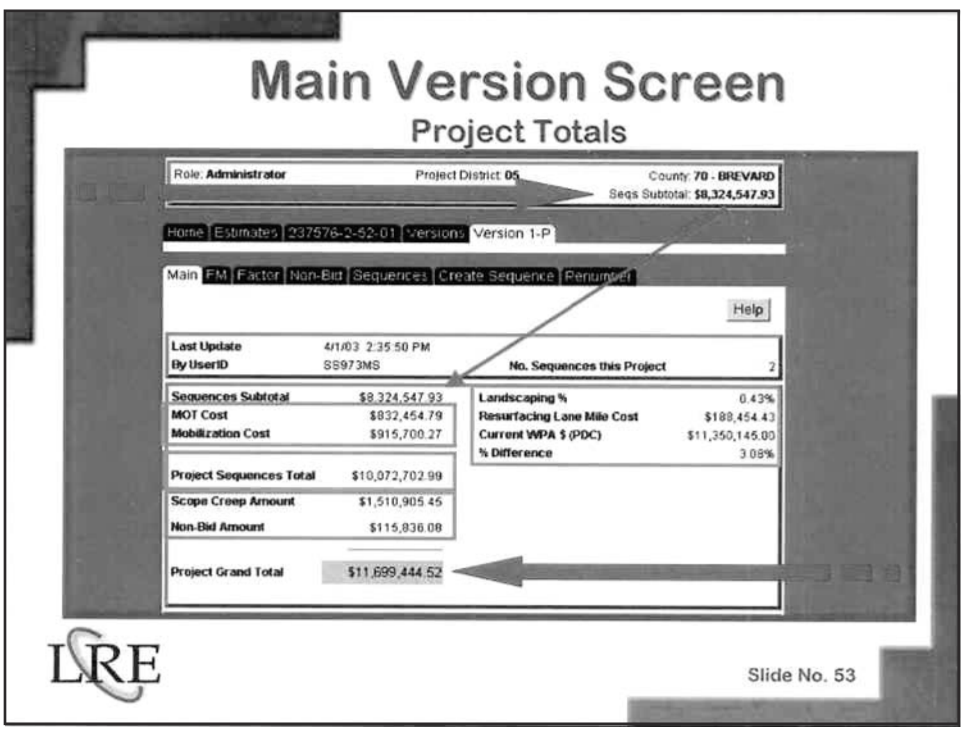


Figure D2.6-6. Screen capture of the FDOT LRE (showing project totals).

estimate to derive a single factor, which is multiplied with a cost multiplier (i.e., ratio) representing closely a past project of similar type and scope. This tool, however, estimates cost for roadway construction only and does not include other project elements such as right-of-way or bridges.

In another example, the item-level, quantity-based estimation approach enables continuous tracking and control by initiating quantity estimates at the outset. The basic estimation parameters, as derived from the statistical analysis, are then documented for future input in quantity calculation. The concept behind this tool development is to match historical data with current project elements and subject them to quantity model development using statistical techniques. Such analyses will provide estimators with cost-sensitive project elements, which can be closely monitored for improving estimate accuracy. Several parameters based on design, project locations, and other topographical and geographical conditions that may influence project costs are incorporated into such modeling to improve accuracy. Major cost elements are hence identified, and a standard can be established for future reference with constant validation for current markets.

When?

This tool is used early in project estimating, through programming and early into the preliminary engineering phases of project development. Parametric estimation may be best used on less complex projects that tend to be more standard in terms of project components such as preservation projects (i.e., overlays) or bridge rehabilitation projects.

Examples

Minnesota DOT has developed a cost estimation tool based on the physical dimensions of the roadway using the length, width, and depth (LWD) methodology. The DOT uses a LWD factor, which is a cumulative computation of each roadway, shoulder, or ramp's LWD volume. A project LWD factor is multiplied by a selected multiplier/LWD cost multiplier, which constitutes all major items to construct a roadway only, 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. Items such as bridges, signals, noise and retaining walls, traffic management systems and other special constructions are not included in the LWD cost multiplier and have to be estimated separately. ROW cost is also not included. A scope form is completed for every project at its inception. This form is used for extracting information revolving mainly around pavements for the three dimensions. It is preferred to have a separate entry for different depths along with areas.

A centralized database is maintained to generate cost multipliers calculated from past and current projects within a 5-year time frame. These cost multipliers are supplied on a project-by-project basis. The estimator requests these multipliers when they are required.

The combination of the LWD factors and the cost multipliers culminate in a roadway cost, to which other costs, such as bridges and signals, are added to determine project totals.

The tool inputs are through Excel spreadsheets and Word templates, while databases are queried with Access. Figures D2.7-1 and D2.7-2 show screen captures of the LWD tool.

Texas DOT supported a study to develop an item-level, quantity-based estimation method. This method was developed on the belief that it was possible to segregate unit prices from estimates. The method is schematically represented in the flow chart shown in Figure D2.7-3.

An overview of the systematic procedures for the quantity-based approach is illustrated in Figure D2.7-4.

The approach was based on identifying factors affecting an item-level quantification from literature survey combined with experience obtained from past projects. These factors were then formulated along statistical techniques to establish correlations and develop models based on several assumptions. Several iterative steps refined the model to an acceptable computational program, which was then verified with current prices to validate the model. Another key aspect of this method was effective use of work breakdown structures, which are often the framework of estimates.

The item-level, quantity-based approach employs quantity estimation models at project inception to produce preliminary estimates. Items comprising 80% of project costs based on historical data were identified as major work items. For each major work item, a statistical parametric model was developed to predict the quantity during the conceptual planning phase of the project. The results of the statistical analysis show a strong relationship between the item quantities and the parameters adopted in the models. The quantity prediction models are being integrated into an item-level cost estimation system to predict both major item costs and total project cost. By segregating unit prices from item quantities, the quantity-based approach provides an opportunity to document both price inflation over time and changes in project scope.

Sample outputs from such statistical analysis that aid in predicting costs based on quantities are shown in Figure D2.7-5.

Tips

The estimator needs to ensure that all project costs are covered, especially costs that may not be generated using the parametric approach, such as right-of-way.

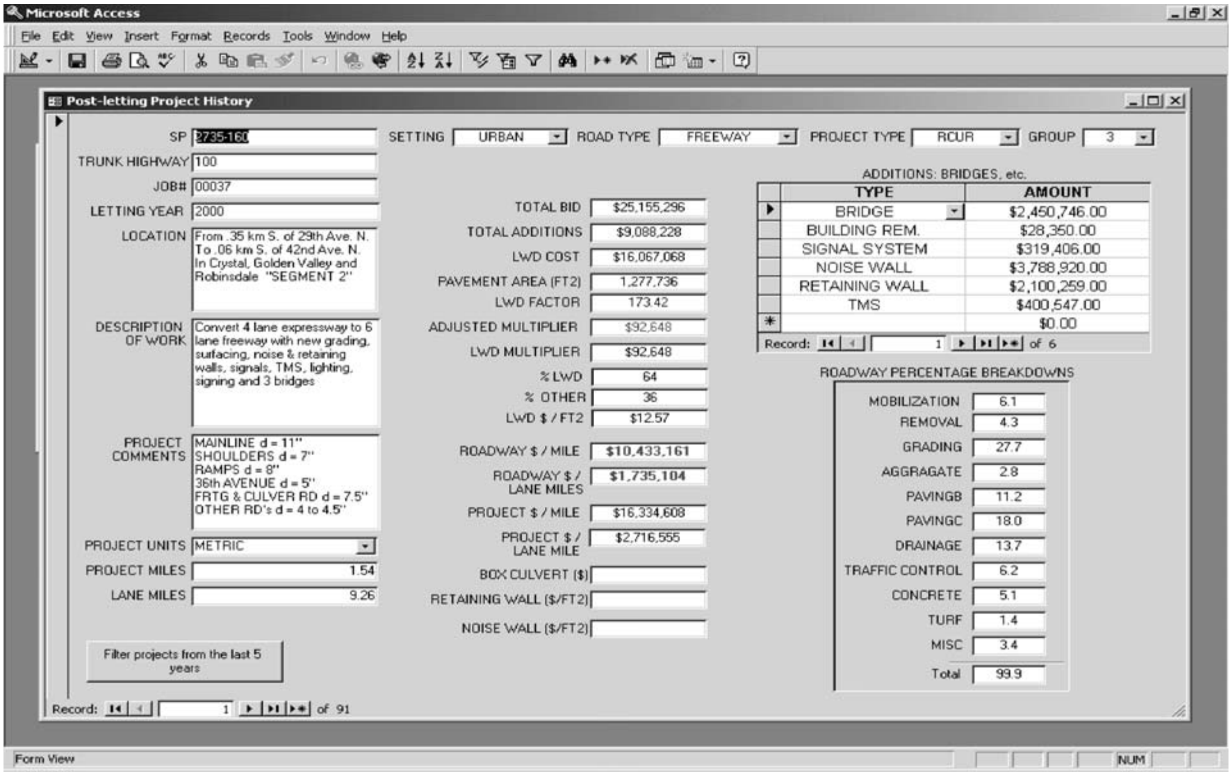


Figure D2.7-1. Screen capture of the LWD tool showing post letting project history.

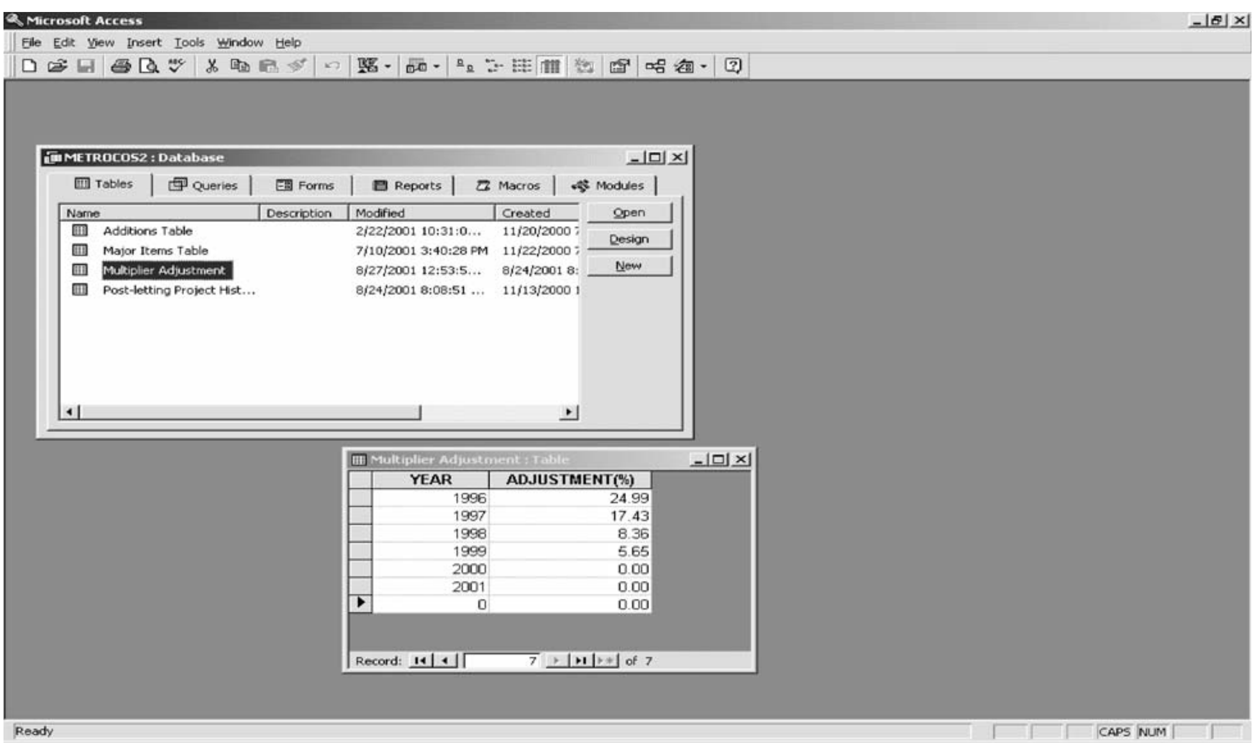


Figure D2.7-2. Screen capture of the LWD tool showing multiplier adjustment options.

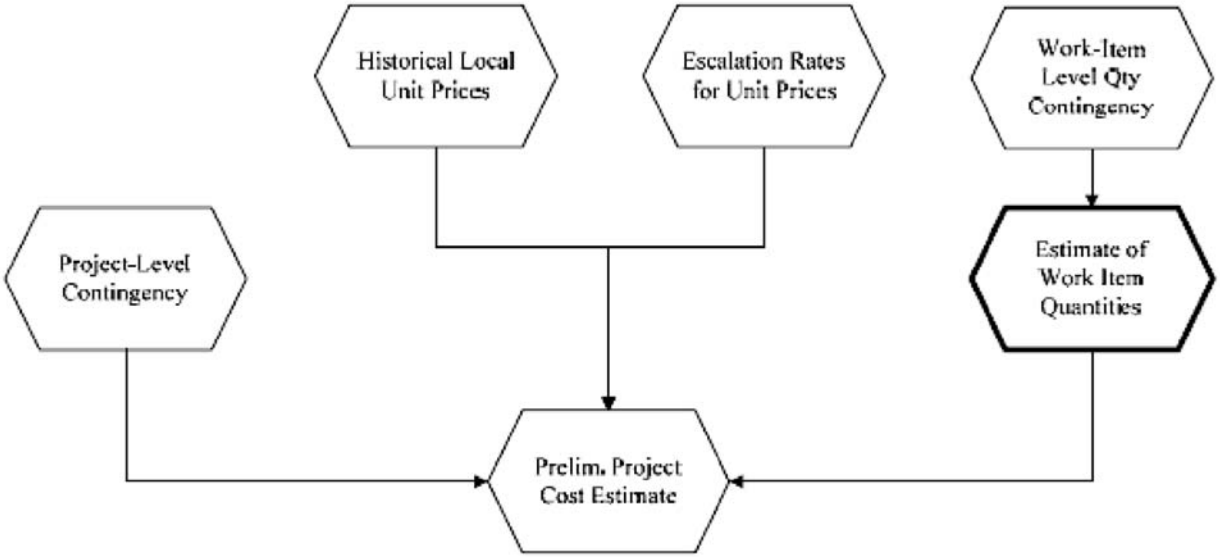


Figure D2.7-3. Influence diagram of preliminary project cost estimate.

Identification of those elements that contribute to the major fraction of a project's total cost is critical to this tool. The tool relies on cost predictions for items of work based on statistical predictions. Hence, identification and inclusion of cost items that contribute to 80% of the cost for each estimate is crucial for the tool's success. The standardization of such elements in relation to project types is to a large extent the basis of implementing this tool. The tool can model additional items that may not be standard as long as historical information is available.

Resources

Minnesota DOT (2002). "Documentation of Guidelines for Statewide Uniform Cost Estimates."

Chou, Jui-Sheng, Min Peng, Khali Persad, and James T. O'Connor (2006). "Quantity Based Approach to Preliminary Cost Estimates for Highway Projects," *Transportation Research Record 1946: Construction 2006,* Transportation Research Board. http://gulliver.trb.org/news/blurb_detail.asp?id=6858.

Project Management Institute (2004). *A Guide to the Project Management Body of Knowledge* (PMBOK Guide), Third Edition.

D2.8 Spreadsheet Template (Also See C1.6, C2.4)

Spreadsheet templates provide a rapid and easy means for organizing estimate data and formulating repetitive calculations. Templates are excellent and simple tools for ensuring

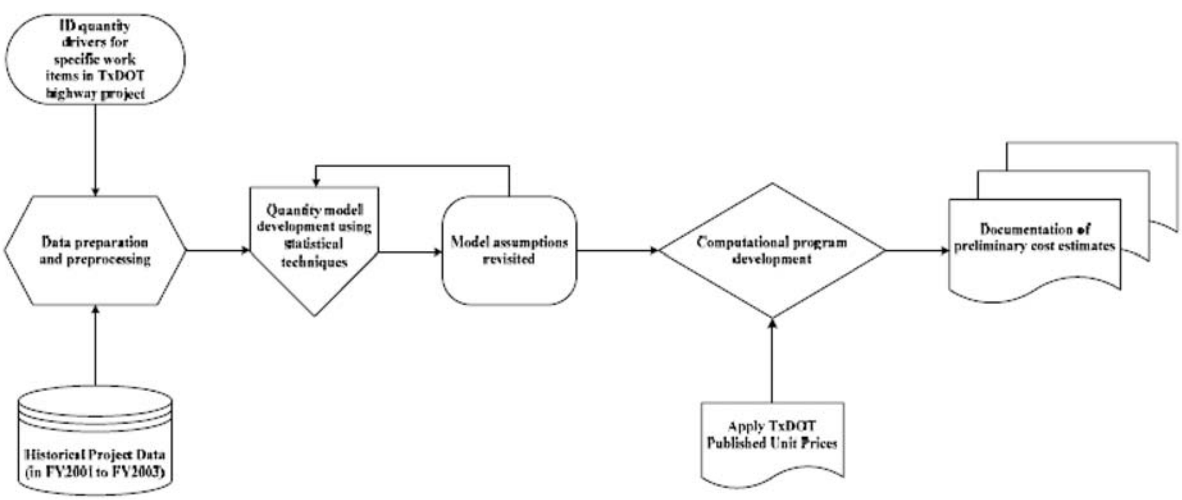


Figure D2.7-4. Overview of item-level quantity model development and application.

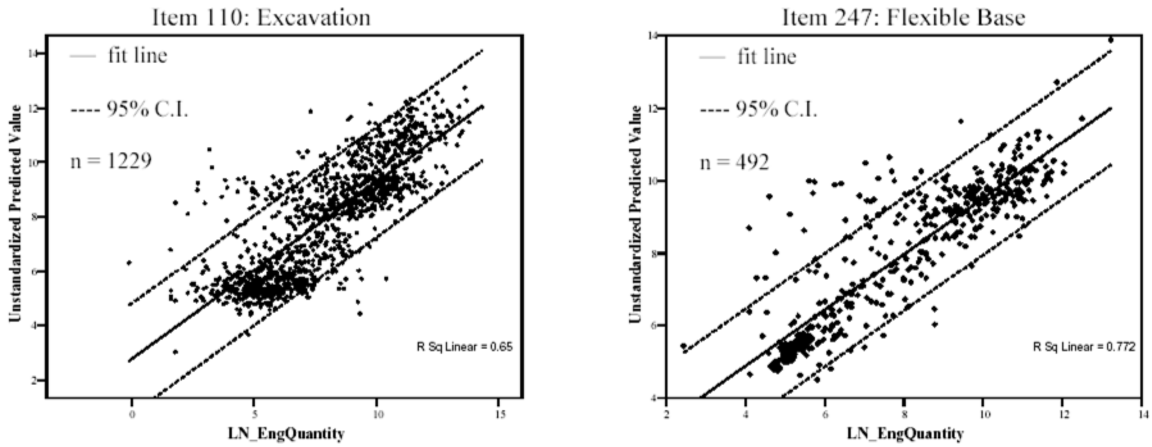


Figure D2.7-5. Sample predicted values of logarithmic engineering quantity versus historical values for representative work items.

that all components of project cost have been considered and accounted for in the estimate. Because these are usually straightforward documents they are good tools for communicating estimate completeness and the allotment of cost to the different portions of work.

What Is It?

Spreadsheet templates are standard item lists of things an estimator should consider when calculating the cost of a project. When constructed in an electronic spreadsheet program, they provide computing, text-editing, and formatting capabilities at high speed and low cost. Electronic spreadsheet templates can store both the formulas and the computed values returned by the formulas.

Why?

By using a spreadsheet template to guide estimate development, state highway agencies can improve estimate accuracy by ensuring that critical cost items are included in the cost total and that the estimator considers significant impacting factors when preparing the estimate. Furthermore, a well-designed spreadsheet will clearly communicate the total estimated cost of the project, as well as what is included in the estimate and what various categories of work are expected to cost. This allows easy comparison to historical values for making rapid “sanity checks” of estimated costs.

What Does It Do?

Spreadsheet templates (1) provide estimate development guidelines that facilitate creation of a complete estimate and (2) support the evaluation of cost and schedule credibility. They serve to document the estimate and provide an easy-to-read format, which facilitates communication about the project costs in a uniform and structured manner. Monte Carlo simulation can also be added to spreadsheets for doing probabilistic estimation or risk analysis.

When?

Different spreadsheet templates can be used in the course of project development as scope is quantified and additional information becomes available. However, templates should be designed so that major categories can easily be expanded as project detail is better defined. Spreadsheet templates are also excellent tools for supporting and documenting quantity takeoff.

Examples

The detail of a spreadsheet template will vary by project type and by the point in time when the estimate is being created.

In the earliest stages of project development, there is limited project definition and design knowledge. One state highway agency’s early-stage spreadsheet has only five cost categories:

1. Grading and drainage
2. Base and pavement
3. Lump items
4. Miscellaneous
5. Engineering and construction

The sheet also formulates calculation of a total cost and a total cost per mile, which provides transparency in comparing the cost with similar projects. These basic categories can be expanded as additional information about the project is developed.

Tips

Computer spreadsheets such as Excel require less initial investment than commercial estimation software and tend to be very flexible. The list of included items on spreadsheets is often not exhaustive, and space should be provided in each section of the spreadsheets to allow the entry of additional cost items that may be unique to a particular project.

Resources

Michigan DOT's "Road Cost Estimating Checklist" can be found at www.michigan.gov/documents/MDOT_0268_Road_Cost_Est_120543_7.pdf.

New Jersey DOT has posted on the Internet (www.state.nj.us/transportation/eng/CCEPM/) a Preliminary Estimate (English or Metric) Spreadsheet (zip 85k).

Georgia DOT has posted on the Internet (www.dot.state.ga.us/) the format for submitting scope and cost estimates for GDOT projects in the form of Excel workbooks to expedite the review and approval process. Type "Guidelines for scope & cost estimate workbooks" in the search box on the home page.

D2.9 Trns•port (Also See C3.5, P1.5)

Trns•port is the AASHTO-sponsored transportation agency management software. It is a robust transportation program management system. It uses the most current information systems technology and is based on the experience and needs of AASHTO's member agencies.

Trns•port capabilities encompass the full functionality of a construction contract management system. Trns•port is an integrated system consisting of 11 modular components that can be used individually or in combination as appropriate. Each module addresses the needs of the highway agency at a particular milestone in the construction contracting life cycle, representing three functional areas: preconstruction, construction, and decision support.

AASHTO recently introduced another software to the suite of estimation tools. TRAnsportation Cost EstimatoR (TRACER) software is a parametric cost estimation tool created to help plan and budget for highway and bridge construction/renovation projects at the predesign and preliminary design phases. TRACER was developed by Earth Tech.

What Is It?

Trns•port has three modules (Cost Estimation System, Estimator, and Proposal and Estimates System) that interact with each other or work independently, as applicable, to produce design estimates. Figure D2.9-1 shows the interaction of these modules. The Cost Estimation System (CES) and Estimator modules are the most popular modules among state highway agencies that use Trns•port for design estimation.

The CES module is a network-dependent module that is fully integrated with the other database-oriented Trns•port modules. It provides a highly productive environment in which to prepare parametric, bid-based, or cost-based estimates.

The Trns•port Estimator module is a highly interactive, PC-based, stand-alone estimation system for highway construction that uses a graphic user interface to prepare detailed estimates. It is well suited for distributing the estimation function both throughout the agency and to the supporting consulting community.

The Proposal and Estimates System (PES) module is designed for use at relatively advanced design stages, when more project data are available. This module accepts data in a project, category, and item level, and grouping of multiple projects is allowed to track all related costs and sources of funding. The ability of this module to interact with the Bid Data Analysis and Decision Support System (BAMS/DSS) module of Trns•port and the exchange of this function with the CES module are the key attractions in parametric estimation.

TRACER is a new computer-based tool developed to support parametric estimation. The database that supports this tool is the RS Means Heavy Construction Cost Data manual.

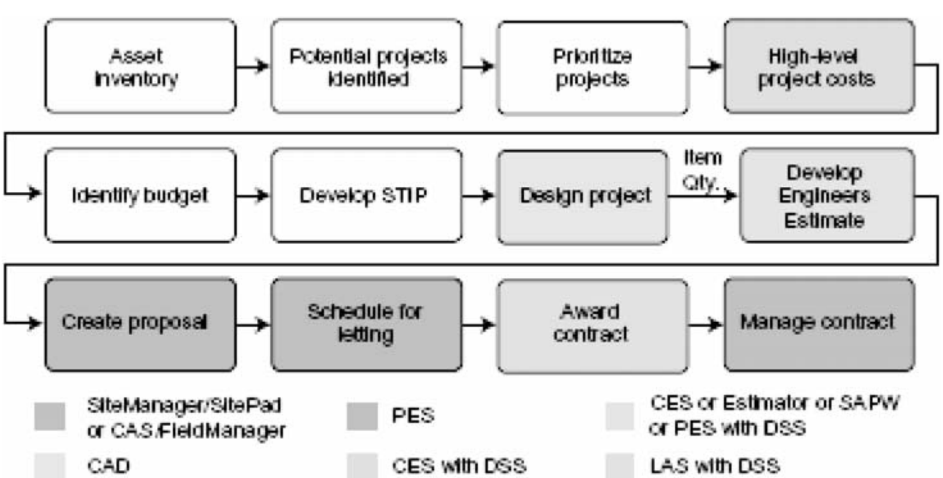


Figure D2.9-1. Interaction of Trns•port modules.

Why?

During programming and preliminary design, specific elements are defined for a project, and cost estimates are prepared using a number of different tools. The Trns•port estimation software can facilitate the use of several design estimation tools, such as historical bid-based and cost-based, bottom-up approaches. This software allows the estimator to build up an estimate as the design progresses. When software is linked to a historical cost database, selecting unit cost information can be more efficient because the user works within the software to find the appropriate historical bid costs that fit the element being estimated. Further, changes in the cost estimate can be made easily as new information or modifications to existing information are made. The software can be used to eventually develop the engineer's estimate and support preparation of bid documents.

In programming, if quick estimates are desired using major project parameters, TRACER can be used. Minimal input is required to generate a construction cost estimate.

What Does It Do?

The CES module contains a standard set of cost groups for parametric estimation. It is also equipped with tools that, coupled with its integration with the other Trns•port components, permit the uploading of historical labor, equipment, material and crew data for more detailed estimates. Its parametric estimation strategy uses cost groups that are based on major project types. They are groupings of items that are usually known early in the planning process for the type of project.

Trns•port's Estimator module supports generation of cost estimates using cost-based or bid-based techniques. Hybrid estimates are easy to create, allowing cost- and bid-based methodologies to be used in the same project estimate. Estimator can also reference a price lookup table if data are lacking or can perform ad hoc data entry of unit prices.

The reference data used to generate estimates, including wages, equipment costs, material costs, production rates and historical bid data, are stored and maintained in the computer. Estimator will automatically apply the weighted average price to line items, providing statistically valid estimates. If the historical data set is sufficiently large, regression coefficients can be calculated and applied. Estimator can also bridge between the other modules and design systems to enhance data exchange.

TRACER uses statistical relationships between major systems of a highway project, termed "modules," and the details that describe that system. For example, a bridge module is available to estimate the cost of a bridge. The user then provides the system definition for the bridge. In this case, three basic elements are required—bridge size (length and width), separation type (over highway and height), and definition (superstructure and substructure type). This is the only input required. TRACER then generates all direct construction costs. Contractor overhead and profit must be added. A template is provided to insert these values. TRACER costs can be adjusted for different locations.

When?

These modules of Trns•port can be used in both programming and preliminary engineering. CES can be used in programming to create a parametric estimate. It can also be used for bid-based estimation at the programming phase if sufficient design details are available to support line-item-type estimates. All three modules can be used during preliminary engineering to support on-going design estimates.

TRACER is probably most applicable during programming.

Examples

In the past, the NYSDOT used the mainframe versions of Trns•port PES, LAS, and DSS, but as agencies moved from the mainframe to the client/server versions, AASHTO decided to drop support of the mainframe version. NYSDOT's migrate to the client/server version.

Figure D2.9-2 shows the interaction of estimation-related Trns•port modules.

A CES product tour is available at https://www.nysdot.gov/portal/page/portal/main/business-center/trns-port/modules/ces (click on "CES Product Tour" at the bottom).

An Estimator product tour is available at http://www.infotechfl.com/software_solutions/estimator.php (click on "Product Tour" on the left).

When using TRACER, the estimator needs to check the results against past history to verify the estimate. Several screen captures are shown in Figures D2.9-3 through D2.9-5.

Tips

Estimators who have access to the Trns•port database should use CES, while estimators without a connection to the network should use Estimator.

The information generated by the CES module for cost-based estimation includes the following:

- Detailed job estimate snapshots
- Labor
- Equipment
- Materials
- Cost sheets
- Crews
- Programs

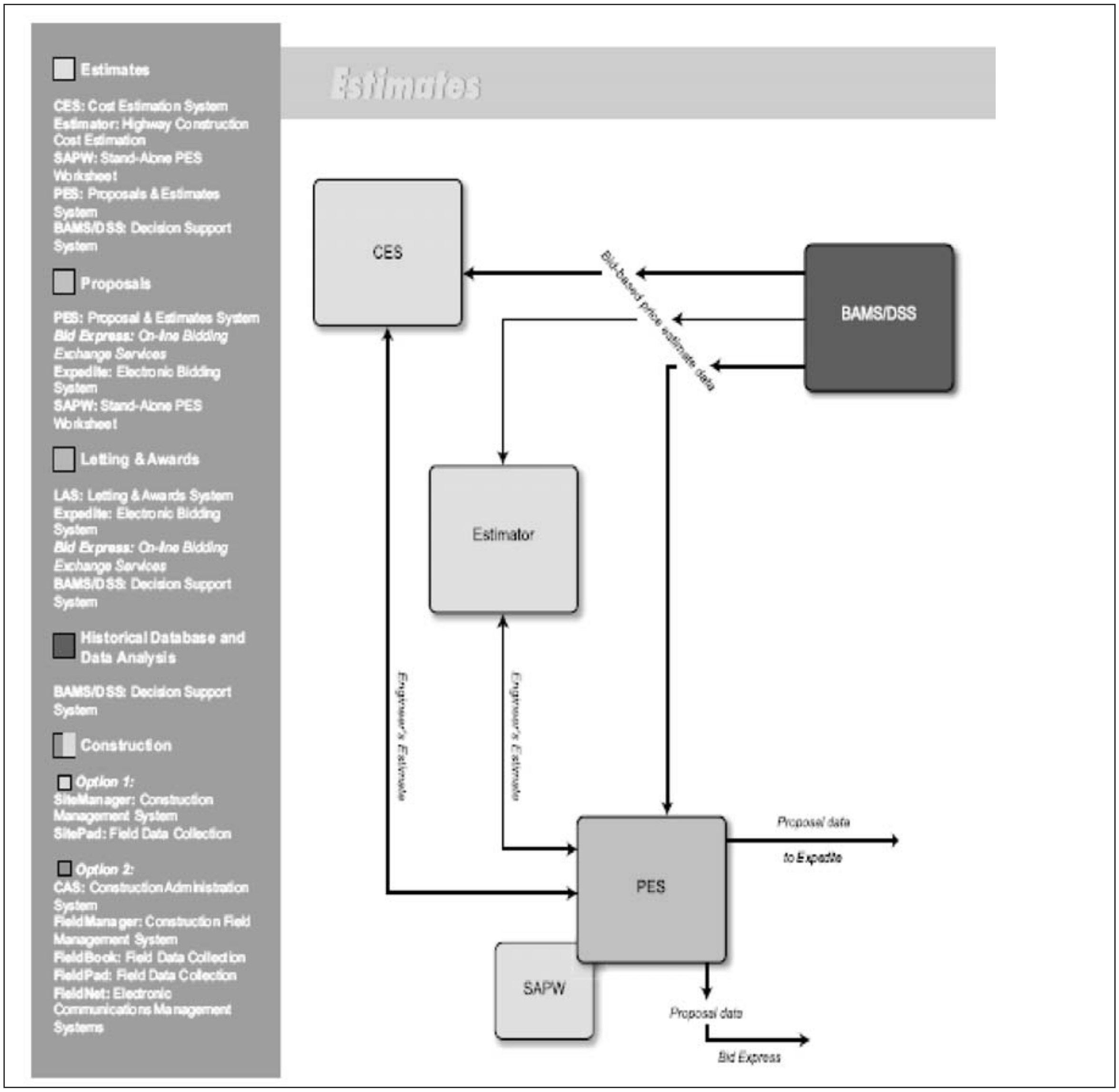


Figure D2.9-2. Interaction of estimation-related Trns•port modules.

The Estimator module has the following features:

- Master data for producing estimates are stored and maintained in catalog forms.
- Reference data are easily shared among several project participants using the same platform.
- Historical pricing information can be applied automatically when Estimator is properly configured with BAMS/DSS, another Trns•port module.
- Reference prices or ad hoc data entry is permitted when historical data are not available.
- Cost-based estimation techniques are flexible, yet structured and simple.
- In-built Estimate verification processes improve accuracy.

The estimator must ensure that all project costs are covered, such as right-of-way and preliminary engineering costs. These costs may not be generated by CES.

The estimator must check all input and output to ensure that the estimated costs for major line items are within expected agency tolerances for the project type being estimated. This check can follow the Puerto principle: 80% of the estimated cost of construction is covered in 20% of the items. Comparing the overall estimate with estimates from similar-type projects that are recently bid or completed is another method of checking an estimate. Finally, using the statistical techniques in CES and Estimator may help identify line-item estimates that are outside normal cost ranges for that item.

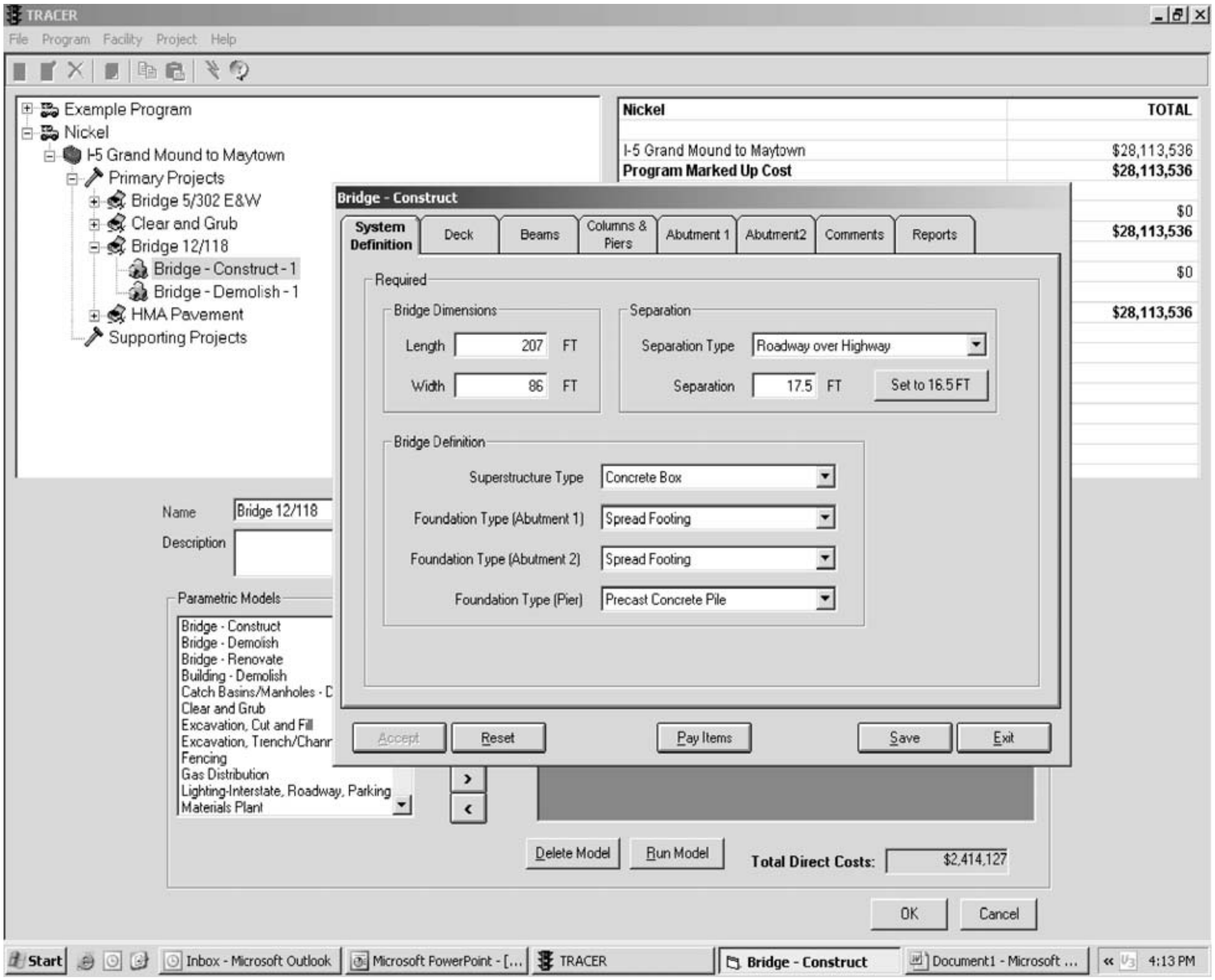


Figure D2.9-3. TRACER system definition input for a bridge over a roadway.

Additional information can be found using the following website: dot.state.ny.us/trns-port/about.html.

Resources

The Technology Implementation Company, Gainesville, Florida, see website addresses: www.infotechfl.com or www.cloverleaf.net.

AASHTOWare, Transportation Software Solutions, American Association of State Highway and Transportation Officials, www.aashtoware.org.

D3 Design to Mandated Budget

Budgeting is a balancing act of meeting the agencies' objectives (i.e., responding to transportation needs) to the fullest extent possible within the limits of its financial capacity. Typically, an agency's program of required projects outpaces its funding year after year. Budgets for projects that move into the state highway agency's program are sometimes fixed independently of the scope of the project. When this scenario occurs, the preliminary engineering effort is substantially influenced by the dollars available for construction and right-of-way. Project scopes must be tailored to fit the budget; thus, the focus of engineering becomes a constant tradeoff between costs and scope.

D3.1 Design to Cost

In some cases, funding for a project is fixed by an external source, such as the state legislature. The scope of work may be congruent with the allocated project funds. The design-to-cost method is often used when a project team encounters a predetermined fixed budget, but it can also be used by the state highway agency management to control project scope growth. The design-to-cost estimate and the budget cost of the project are compared. If the estimated cost during design exceeds the budget cost of the project, then one or both need to be reevaluated before continuing with further project development.

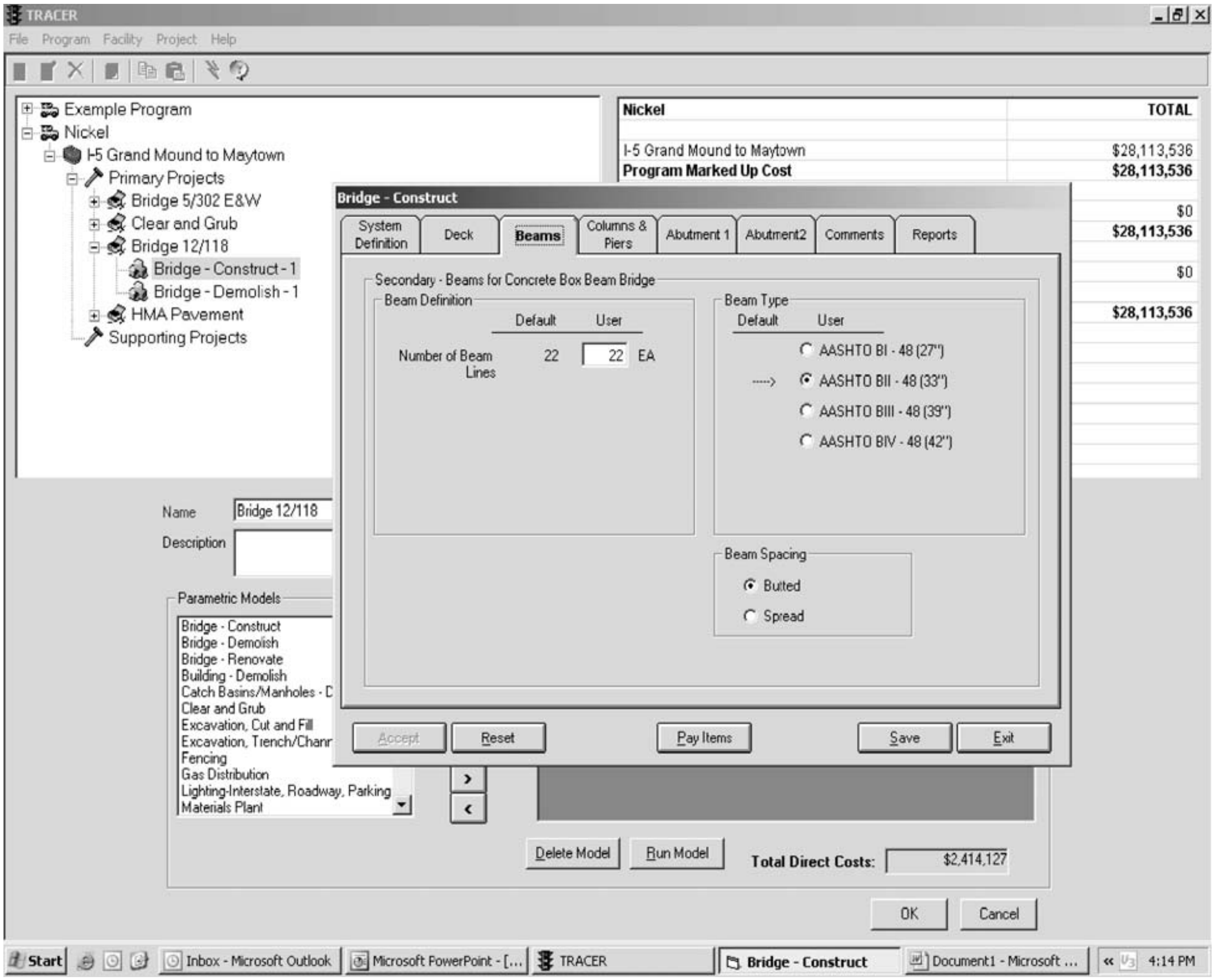


Figure D2.9-4. Additional TRACER information created by the bridge system definition (beams).

The scope will be reduced if the current cost estimate is higher than the fixed budget. Scope may be added if the current estimate is substantially less than the fixed budget.

What Is It?

Design to cost is a method of controlling project cost by establishing cost goals at specified levels of a project work breakdown structure and then requiring the project to make scope tradeoffs during the engineering process. These tradeoffs will ensure that the facility built will meet the cost goals. In design to cost, the cost goals are added to the existing design requirements to form additional requirements of the project.

Why?

This tool is used most often when external sources mandate a fixed budget for a project. The budget may have been prepared with little or no information on the project or may be based on cost information that has not been recently updated. If there is little or no possibility of obtaining additional funding, then the project team must develop a design that meets the mandated budget. This often will lead to a scope that is less than that which was envisioned by the external source.

What Does It Do?

This tool is based on constant evaluation of different scope options available to construct a project while continuously checking cost ramifications of these scope options in order to not exceed the predefined total project cost. This tool can foster innovative design solutions, which can help in alleviating cost overruns.

When?

This tool should be used early in programming or preliminary engineering, when design criteria and basis are being

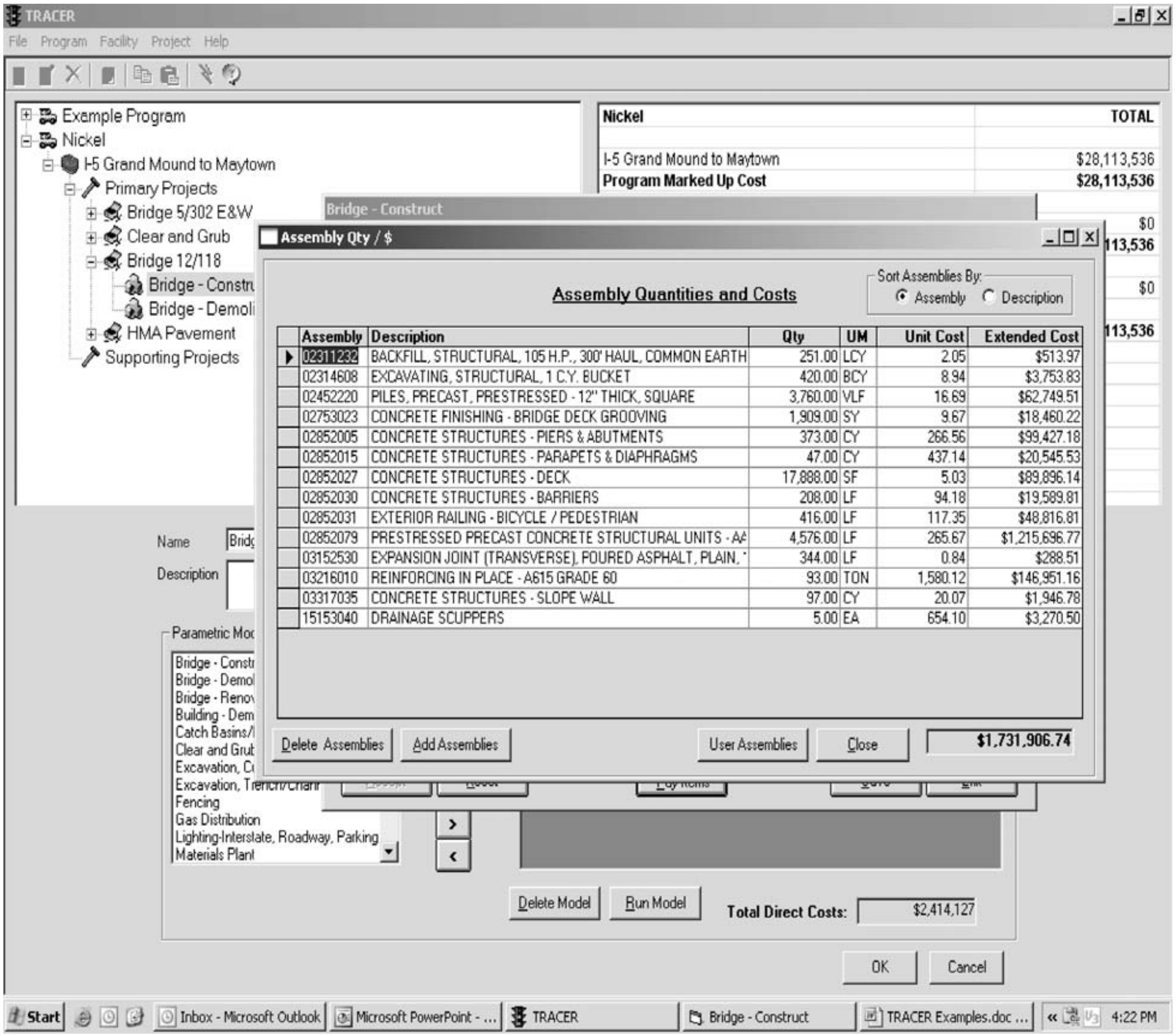


Figure D2.9-5. TRACER direct construction cost output for this bridge (without markups).

established. The project design team will need adequate time to explore alternative design solutions in an attempt to maintain the project within the mandated budget.

Examples

The flow chart in Figure D3.1 illustrates typical steps followed to implement the design-to-cost tool. The process is iterative until the estimate cost of the project is aligned with the established budget. This alignment process fixes the scope of the project.

Tips

Several factors are important when using the design-to-cost approach:

- An understanding of state highway agency affordability or competitive pricing requirements by the key participants in the development process
- Establishment and allocation of target costs down to a level of the construction cost components where costs can be effectively managed
- Commitment by estimators to match development budgets and target costs
- Stability and management of requirements to balance requirements with affordability and to avoid creeping elegance
- An understanding of the highway construction cost drivers and consideration of cost drivers in establishing highway specifications and in focusing attention on cost reduction
- Creative exploration of concept and design alternatives as a basis for developing lower-cost design approaches

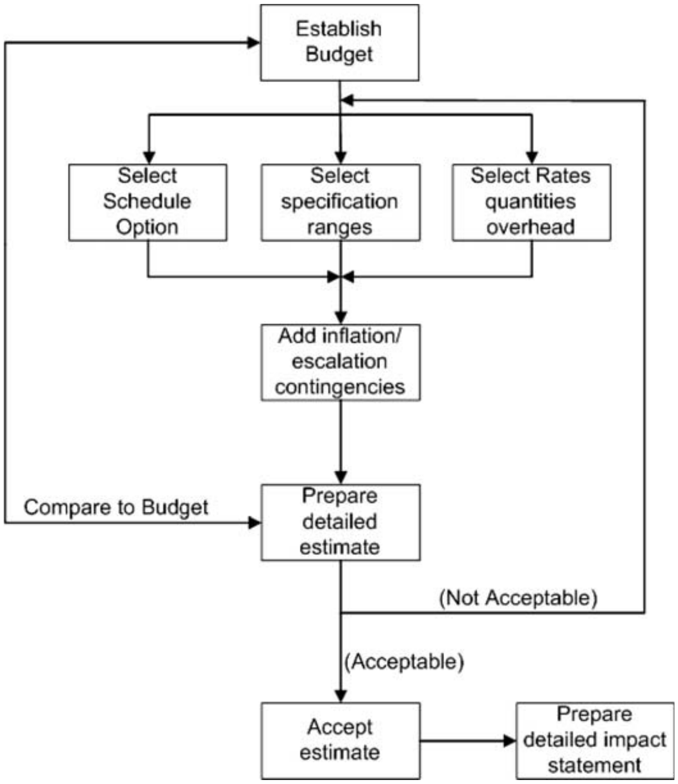


Figure D3.1. Flow chart of a typical design-to-cost process.

- Access to cost data to support this process and empower project team members
- Meaningful cost accounting systems using cost techniques to provide improved cost data
- Continuous improvement through value engineering to improve product value over the long term

Resources

Crow, Kenneth (2000). "Achieving Target Cost/Design-to-Cost Objectives," SAS Institute. http://www.bettermanagement.com/library/library.aspx?l=12369.

D4 Document Estimate Basis and Assumptions

Project complexity and the size of many projects today means that more issues must be considered in preparing the estimate. Additionally, estimates are commonly prepared in collaboration among many individuals and departments within the state highway agency. The decisions and assumptions behind the decisions that drive the estimate must be clearly stated and communicated to management and to those reviewing the estimate.

D4.1 Project Estimation File

Estimates are usually created by the collaborative effort of many individuals. To be able to follow the assumptions upon which the estimate is based and to preserve the information for future efforts, there should be a structured system for accumulating all estimates and their supporting documentation. Construction contractors use their project estimates both to create the budgets for successful bids and as reference sources for developing future estimates. State highway agencies need information systems that allow easy retrieval of historical estimate information and that allow multiple individuals to work productively on a single estimate.

What Is It?

The development team and the estimators prepare and maintain a master reference file that contains the critical scope, policy, and supporting information (assumptions, methods, and procedures) that are used to prepare the project estimate. This master file is maintained as a permanent reference file. The estimator, when costing an item, must reference specific cost-impacting information documented in the file.

Why?

Good documentation supports the cost estimate's credibility, aids in the analysis of changes in project cost, enables reviewers to effectively assess the estimate, and contributes to the population of state highway agency databases for estimating the cost of future projects.

Each project should have an individual project estimation file that is separate from the general project file or the correspondence file. The primary purpose of this requirement is to ensure that each project has a well-documented and easily retrievable history of the assumptions, methods, and procedures used to estimate the costs associated with the project's specific scope of work. Having this information contained in one location and separated from other project documentation will help ensure that the estimate information is readily accessible and uncluttered with other project information.

What Does It Do?

A project estimation file provides a corporate memory and historical database for cataloging the basic reasons behind the original estimated cost, as well as reasons for subsequent cost revisions. Additionally, it usually provides other project descriptive information, such as trends that affect the item cost, cost from similar past projects, and external factors that limit construction operations. This historical file allows easy comparison of the current estimate with previous estimates and resolution of discrepancies

When?

The project estimation information should be retained in the central filing system from the time the initial project estimate is prepared until project close-out. The project estimation file should include all cost estimates prepared for the project up to and including the completed contract plans, specifications, and estimates (PS&E). Archiving the cost estimation files is a good practice because these files can be useful in reconciling completed project cost and responding to inquiries.

Examples

For each bid item element, there should be a description of the derivation of its estimated cost in sufficient detail to allow an independent reviewer to determine whether the estimate is complete, accurate, and realistic. The following information should be provided:

- Item number and title.
- Item description and any tailoring used for this estimate.
- Methodology. Describe how the item's costs were estimated. Depending on the choice of methodology, the estimator could include one or more of the following practices:
  - The use of unit prices from the department's historical bid tab database. This is the most common approach. Under this approach, bid data are summarized and adjusted for project conditions (project location, size, quantities, etc.) and the general market conditions.
  - The actual cost approach (i.e., a bottom-up estimate). This approach takes into consideration factors related to actual performance of the work (i.e., cost of labor, equipment, and materials; sequence of operations; and production rates). This approach requires the estimator to have a good working knowledge of construction methods and equipment.
- How lump-sum items are handled.
- Base year of the cost calculation. For long-duration projects it is a good practice to present the item's estimated cost in constant year dollars, both total dollars and distributed across fiscal years.
- Detailed, clear environmental items (requirements).
- How indirect costs are determined.
- Each contingency allowance assigned to the various parts of the estimate. If extraordinary conditions exist that call for higher contingencies, the rationale will be documented.
- All uncertainties and risks associated with the estimate.
- Level of knowledge about scope.
- Level of risk.
- Level of estimate detail.
- Techniques used to compete the estimate.
- Experience of those who developed the estimate.
- Cost tractability. When a prior cost estimate exists, a cost track should be prepared. The cost track should provide a concise explanation for any cost change to an item from the prior estimate.
- Who participated in the development of the estimate.

A description of an approach used by the Missouri DOT regarding estimate documentation is shown below:

> **1-02.12 (5) DOCUMENTATION OF PROJECT ESTIMATES.** Each project will have an individual project estimate file that is separate from the general project file or the correspondence file. The purpose of this requirement is to ensure that each project has a well documented and easily retrievable history of the assumptions, methods and procedures used to estimate the right of way and construction costs associated with the specific scope of work identified for the project. Having this information contained in one location and separated from other project documentation will help ensure that the estimate information is readily accessible from a known location and uncluttered with other project information.
>
> At a minimum the project estimate file should include any assumptions that have been made, the current project scope, maps, photos, as-built plans, functional classification, design criteria and a copy of or reference to the cost data used to support the estimate. This basic information should be included in each project estimate file regardless of the stage of project development. A sheet should be placed in the front of each estimate file so the project manger can record the date and current project milestone or project development stage each time the project estimate is changed, updated or reviewed. A signature line should also be included to document the project manager's review of the estimate file.
>
> Depending on the level of project development that has occurred on the project, the amount and type of documentation contained in the project estimate file will vary. For projects that do not have clearly defined scopes and in the absence of other estimating methods, the cost-per-mile type of estimates described in Section 1-02.5 are suitable and acceptable to develop the initial project estimate.
>
> Cost-per-mile factors may be developed from a previously constructed project of similar type and conditions or the generic cost per mile factors included in Figure 1-02.1 may be applied to the estimated project length to develop an initial project cost. Information used to develop the project specific cost per mile factors or the generic factors from Figure 1-02.1 that are used should be well documented and included in the project estimate file.
>
> This information may consist of items such as estimate software, bid tabulation data from similar projects, unit bid price books, or some other reputable resource. Additionally any deviations from the generic cost per mile factors, that are determined to be warranted by the estimator, shall have well documented reasons included in the project estimate file.

The district may prepare a master reference file that contains the cost-per-mile, unit costs, accepted PE [preliminary engineering] and CE [construction engineering] cost as a percentage and other critical policy and procedures that are used to prepare project estimates on an annual basis in order to avoid duplication of the information in multiple project estimate files. However, this master file must be kept as a permanent reference file that can be cited and reference to. It must be included in each individual project estimate file.

Variations of the Miscellaneous and Utility Costs percentage (see Figure 1-02.1) should also be documented in the project estimate file. As discussed in Subsection 1-02.6(4) some projects that are not complex and have a small scope of work may warrant the inclusion of a cost adjustment factor to compensate for the short project development time and project uncertainties. These cost adjustment factors shall be well documented in the project estimate file and have a reproducible basis. These factors should only be applied to projects that fall into the small noncomplex category. They shall not be applied to all project estimates as a matter of district practice. A cost adjustment factor will never be considered as an acceptable substitute for preparing a well documented and accurate estimate if adequate project information is available.

Once the project scoping phase of the project is completed and estimates are being produced for inclusion in the STIP [statewide transportation improvement program], cost-per-mile type estimates will no longer be acceptable. All estimates made beyond this stage of project development shall be based upon estimated pay item quantities and unit costs. Copies of all pertinent information related to the project estimate, including all documentation of the quantities and unit costs used, shall be included in the project estimate file. All estimate data sheets should include the date of preparation and the estimator's name.

Each time a final Project Amendment Tracking System (PATS) form is prepared for the project a copy should be placed and retained in the project estimate file. Another copy of the PATS form will be provided to the district transportation planning coordinator, who will be responsible for ensuring a copy is also immediately submitted to GHQ [General Headquarters] Transportation Planning. This procedure should be followed for all projects, whether designed internally or by a consultant. The documentation included in the estimate file must substantiate the latest final PATS form that has been submitted to GHQ Transportation Planning. In addition, any project scope change approval letters required by Sections 1-02.11 and 1-02.12(9) shall also be retained in the project estimate file.

The project estimate files for all projects under development in the district should be located in one central location. District management is responsible for establishing estimating procedures, within their district, that will indicate the person responsible for maintenance of the project estimate files and the central location for the files. The district estimating procedures should also establish general guidelines for the contents that should be maintained in the file.

The project estimate information should be retained in the central filing system from the time the initial project estimate is prepared until after the project has been included in the Accountability Report to the Legislature. The project estimate file should include all cost estimates prepared for the project up to and including the completed Contract Plans (PS&E) Estimate. Cost data following submission of Contract Plans to GHQ is not required in the project estimate file. Once the project data has been included in the accountability report, there is no requirement to archive the cost estimate files. However, the district may wish to retain cost data longer for purposes such as reconciling completed project cost with GHQ Transportation Planning, responding to additional inquiries related to the Accountability Report, or until there is a final payout on the project by FHWA, etc.

Tips

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

When items are estimated by percentages of other costs, as is often done for miscellaneous and utility costs, the percentage should also be documented in the project estimation file. Some projects that are not complex and have a small scope of work may warrant the inclusion of a cost adjustment factor to compensate for the short project development time and project uncertainties. These cost adjustment factors shall be well documented in the project estimation file and have a reproducible basis. These factors should only be applied to projects that fall into the small noncomplex category. They should not be applied to all project estimates as a matter of common practice. A cost adjustment factor will never be considered an acceptable substitute for preparing a well-documented, accurate estimate if adequate project information is available.

Depending on the level of project development that has taken place, the amount and type of documentation contained in the project estimation file will vary. Information used to develop the initial estimate, such as cost-per-mile factors or the generic factors, should be well documented and included in the project estimation file. This information may consist of references to software databases, bid tabulation data, unit bid price book data, or some other reputable resources. Additionally, any deviations that are determined to be warranted by the estimator from the generic cost factors shall be well documented in the project estimation file.

The estimation procedures manual should also establish general guidelines for the contents of the file.

The documents that serve as the basis of the estimates should do the following:

- Provide a description of site conditions (railroad through or adjacent, utilities, need for stage construction, etc.)
- Describe assumed construction methods and alternatives considered
- Explain the decision criteria used for evaluating alternatives
- List and explain all general assumptions that apply to all alternatives
- List and explain all specific assumptions (e.g., excavation costs assume 30% rock)
- Include a full listing of the item take-offs (quantities)

Resources

Missouri DOT (2004). "Chapter 1, General Information: Needs Identification Project Scoping and STIP Commitments," Section 1-02, *Project Development Manual.* www.modot.org/business/manuals/projectdevelopment.htm.

Many state highway agencies use the commercial estimation software Trns•port Estimator by InfoTech. This software requires the estimator to input much of the data that should be in a project estimation file. See the NYSDOT Trns•Port Estimator Guidelines, Draft May 6, 2004 version, which can be found at www.dot.state.ny.us/trns-port/files/nysdotestguide.pdf.

E1 Estimate/Document Review

In the construction world, designers provide contractors and subcontractors with graphical and written representations (i.e., the project plans and contract documents) that describe what is to be constructed, the required quality, and sometimes how it must be constructed. The constructors must transform these concepts into physical reality. The quality of this transformation from abstraction to reality not only determines the quality of design work provided by the designers, but also impacts how the work is priced. Baffling drawings or any ambiguous wording as to what quality or limitations to construction activities are expected affects project cost.

E1.1 Estimate/Document Review—External

The design and contract documents for all projects should be subjected to an internal review and compared with the estimate assumptions; however, in the case of very large and complex projects, the design drawing and contract documents should additionally be subjected to an external review and comparison with the estimate.

What Is It?

This tool consists of an external estimate/document review process structured to minimize or eliminate contractor-perceived project risk by ensuring that the construction documents are fully coordinated, complete, and buildable. It should be employed after the agency's own internal estimate/document review. Specifically, it adds an important dimension to estimate/document reviews because the reviewers have not been privy to how the plans and project documents were developed. Therefore, the reviewers shape their opinion of the work strictly by what is presented in the documents.

Why?

Many times, the agency personnel who regularly review project documents are so familiar with the project or how the state highway agency describes project elements that their historical knowledge prevents them from completing a valid review of the project's documents compared with the estimate. This can be a serious problem in the case of very large or complex projects where a critical review of the documents is most important for ensuring clarity of plans and specifications. The primary method used by contractors to cover document ambiguity is adding dollars to the bid prices, and that creates a disparity with the state highway agency's estimate.

What Does It Do?

External estimate/document reviews support the development of accurate cost estimates for large and complex projects by bringing an independent perspective to the quality of the project documents, particularly in terms of their relationship to the assumptions upon which the estimate is based. It is a process that ensures that construction requirements are complete and not in conflict.

When?

The FHWA believes that an external review is appropriate prior to the first release of an estimate to the public for large and complex projects. External estimate/document reviews should also be conducted for large and complex projects during the latter stages of design development. It is important to conduct such a review prior to advertising a project, and such a review must use the final project documents. Therefore, the review must be scheduled with sufficient time after the review for making any necessary corrections to the documents.

Examples

While no external estimate/document review examples exist that strictly match the tool outlined here, research has repeatedly indicated the need for such a process.

Many agencies do have review formats in place for the documents in general that could be used as the starting point for developing this tool. The Central Federal Lands Highway Division, in the Design Resources section of its website, has a "Document Review Comment and Response" form (www.cflhd.gov/design/_documents/misc_forms/design/PSE_CMT.doc).

Tips

The most important factor in the success of this tool is engaging independent external experts, who could be retired construction professionals or construction professors who have had actual field experience.

These reviews should evaluate all project documents because many times geotechnical, hazardous material, and environmental reports, which are included only by reference in the bid package, contain information or directions that affect how the work must be conducted and therefore influence bid prices, particularly if there is a conflict between these reports and the project plans and specifications.

The design engineers should provide a written response to all project estimate/document review comments. Responses to review comments must be available to the project team prior to production of the bid documents so as to allow sufficient time for the estimators to properly prepare the PS&E.

For projects that will be constructed using multiple contracts, a phasing or staging plan should be provided to delineate the boundaries of each phase. The same would be true of multiple projects in a corridor.

Additional tips can be found in Tool E1.2, Estimate/Document Review—Internal.

Resources

Alaska Division of Legislative Audit (1994). "Department of Transportation and Public Facilities Highway Design Cost and Quality Comparison." http://www.legaudit.state.ak.us/pages/audits/1995/pdf/4472.pdf.

Tilley, P. A., A. Wyatt, and S. Mohamed, S. (1997). "Indicators of Design and Documentation Deficiency," *Proceedings of the Fifth Annual Conference of the International Group for Lean Construction,* 16–17 July, Australia, 137–148.

The Massachusetts Highway Department and the American Consulting Engineers Council of Massachusetts (1998). "Measuring Design Quality."

E1.2 Estimate/Document Review—Internal

Design quality for highway construction has been defined by the Massachusetts Highway Department as a totality of characteristics and features of all preconstruction engineering processes, tasks, and deliverables that bear on satisfying stakeholders' needs. A critical stakeholder is the future project constructor who will be submitting a price to perform the work.

What Is It?

This tool consists of a structured agency estimate/document review process to minimize or eliminate contractor-perceived project risk by ensuring that the construction documents are fully coordinated, complete, and buildable. It can be implemented either as part of the agency's normal document reviews or as a separate review. Specifically, it adds an important dimension to estimate/document reviews by purposely checking the project plans and contract documents for completeness, ambiguous language, and conflicts between contract clauses and the plans, because such problems cause contractors to perceive increased project risk and add dollars to their bids and it is very difficult for state highway agency estimators to quantify such perceived risk when they prepare their estimates.

Why?

Contractors are quite often supplied with project documentation that is incomplete, conflicting, or erroneous, which causes pricing tribulations. Contract document quality is important to controlling project cost and accurate estimation because document conflicts and/or ambiguous language increase the builder's perception of project risk, and such issues lead to higher bid prices as the contractor attempts to cover risk with dollars. Deficiencies in the project documents also have the potential to cause change orders and delay claims, which can have serious detrimental effects on the project budget.

What Does It Do?

Estimate/document reviews seek to ensure that there is continuity and conformance in expressing the scope of the project and between individual clauses in the documents. It is also an ordered process that ensures that construction requirements are definitively stated and that the plans and specifications are complete and not in conflict. In practical terms, it seeks to eliminate subjective and arbitrary requirements, such as the following:

- "The engineer assumes *no responsibility* for the completeness of the plans."
- "Provide item X *as required.* Provide item Y *if necessary*."

- "Contractor to provide item Z *as needed.*"
- "If phased construction is required by the agency, the agency will allow a *30-day time extension* for the contract."

Most state highway agencies have policies and procedures in place for the review of project plans and contract documents. However, most of these processes have as their purpose to ensure that the project has been properly designed and that all necessary contract language is included in the document package. These existing reviews are for the purpose of checking completeness to general agency standards, whereas the reviews developed under this tool seek to establish clarity and eliminate presentation-related conflicts.

When?

Estimate/document reviews should be conducted at each design development phase (30%, 60%, 90% design). A cost estimate should be provided along with the intermediate design phase documents. At 100% design and prior to advertising a project, there should be a comprehensive in-house review of the project plans and all contract documents. All projects receive the same type of reviews; however, larger projects usually warrant a more in-depth review.

Examples

While no estimate/document review examples exist that match the strict purpose of this tool, many agencies have review formats in place for the documents in general. The Central Federal Lands Highway Division, in the Design Resources section of its website, has a "Document Review Comment and Response" form: www.cflhd.gov/design/_documents/misc_forms/design/PSE_CMT.doc.

Georgia DOT has the material for "Field Plan Review Inspections" posted in the Transportation Online Policies and Procedures System (TOPPS) section of its website: www.dot.state.ga.us/topps/ss/engserv/2440-1.htm.

Tips

The methodology for conducting an estimate/document review should be to focus on project buildability from a contractor's perspective of risk.

The project manager should immediately arrange a meeting with the designers to resolve issues if any review comments indicate a conflict between the design documents and the project's scope and/or standards of practice or conflicts within the documents.

The design engineers should provide a written response to all project estimate/document review comments. Responses to all project estimate/document review comments must be submitted prior to production of the bid documents so as to allow sufficient time for the estimators to properly prepare the PS&E.

The project manager should immediately arrange a meeting with the designers to resolve issues when review comments indicate a conflict between the design documents and the project's scope and/or standards of practice.

Each contract requirement should be stated only one time and in the most logical location in the contract documents. Information in one document should not be repeated in any of the other documents. Each document has a specific purpose and should be used precisely for that purpose. This simplifies the retrieval of information and substantially reduces the possibility of conflicts and discrepancies. Everyone involved with a project benefits from this standardized approach to the placement of information within the construction documents.

Resources

Alaska Division of Legislative Audit (1994). "Department of Transportation and Public Facilities Highway Design Cost and Quality Comparison." http://www.legaudit.state.ak.us/pages/audits/1995/pdf/4472.pdf.

Tilley, P. A., A. Wyatt, and S. Mohamed (1997). "Indicators of Design and Documentation Deficiency," *Proceedings of the Fifth Annual Conference of the International Group for Lean Construction,* 16–17 July, Australia, 137–148.

The Massachusetts Highway Department and the American Consulting Engineers Council of Massachusetts (1998). "Measuring Design Quality."

E2 Estimate Review—External

The most effective means of improving estimate quality is to refine the methods of identifying errors and omissions, not to refine estimation methods or computer software. No estimate should be released without review. Estimate reviews should be conducted at strategic times during estimate preparation to improve accuracy and completeness. The formality of a project estimate review and the depth of the review at each stage in project development will vary depending on the type of project and project complexity.

The first review of the estimate should be conducted by the team that prepared the estimate. This is essentially a screening review that ensures that the math is correct, the process is documented, and agency guidelines were followed.

When very complex projects or projects involving new construction methods are being estimated, management should require that there be an external review of the estimate by qualified professionals.

E2.1 Expert Team

Very complex and high-profile projects should have an external review of the estimate by qualified professionals. The most indispensable tool for estimate review is judgment. Judgment is what identifies mistakes, detects flawed assumptions, and identifies where the process has missed critical cost drivers. The surest way of conducting a successful external review is by selecting a panel of independent reviewers that have as broad a range of engineering experience as the project demands.

What Is It?

External reviews concentrate on the estimation process and methodology. They are applied based on project scope and design development at the point in time when the review is conducted. An external review should include a risk analysis that identifies the critical elements of the estimate and possible impacting risks.

Why?

Large projects with multiple interacting activities, urban projects with numerous stakeholders, and projects using new technology all test the estimator's ability to properly account for all cost drivers when developing a project estimate. Therefore, a review that brings a viewpoint completely external to that of the state highway agency should be part of an inclusive review process. This includes a requirement for internal reviews of the estimate calculations and the applied unit costs.

What Does It Do?

The reviewers seek to assess the reasonableness of the assumptions supporting the cost and schedule estimates and assess the rationale for the methodology used. Reviewers receive a briefing from the project team and the estimators and are given access to all available project documentation. By applying parametric techniques or ratios to analyze costs and schedule reasonableness, they check the completeness of the estimate. However, they usually do not perform quantity takeoffs or estimate individual items. The result is a report that details findings and recommendations.

In the case of a very complex project with critical cost drivers, it is sometimes necessary for the reviewers to develop an independent, bottom-up estimate of their own to ensure estimate reasonableness. This may or may not involve quantity takeoffs, but usually does necessitate vendor quotations and productivity analysis of the critical cost items.

When?

Independent external reviews are more typically employed on PS&E of large complex projects. However, having such reviews conducted much earlier in the design process can provide real benefits because they often discern cost drivers that can be addressed by design changes, thereby reducing project cost.

Examples

Several state highway agencies have used retired heavy construction personnel to conduct estimate reviews and in some cases have even staged mock bids.

As an after-the-fact example, on December 13, 2001, Maryland DOT opened bids for the Woodrow Wilson Bridge superstructure contract. A single $860 million bid was received. That amount was more than 75% higher than the engineer's estimate for the contract. Maryland formally rejected the bid because it far exceeded the project's budget. An independent review committee (IRC) was organized to identify and evaluate the reasons for the large discrepancy between the engineer's estimate and the bid submitted.

The IRC determined that the owner-produced estimate was technically solid, based on the tangible factors like the cost of steel, concrete, and other materials. But certain significant factors, particularly for large construction projects, are difficult to quantify in an estimate. The IRC went on to state that the estimate did not sufficiently take into account the intangibles of market factors, specifically the following:

- Contractors capable of bidding a project of that size were seeking larger margins to protect themselves due to recent experiences on other mega-projects and to associated project risks.
- There were several other large bridge projects bidding in the same period, a completely external factor that caused a lack of competition.
- Equipment demands on projects of this size are substantial.

Maryland DOT took the advice of the IRC and repackaged the contract and rebid the project approximately a year later as three independent contracts. The first contract rebid came in 11% over the estimate, but there were five bidders and it was a workable bid. The other two contracts both came in below the estimates, one by 28% and the other by 25%.

Tips

The reviewers need to be experienced professionals who have an understanding of engineering and construction complexities. 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 handle the construction tasks 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 state highway agency receives for the work. External independent reviews are usually more attuned to the impacts of such factors on project cost.

Resources

Maryland DOT (March 1, 2002). "Summary of Independent Review Committee Findings Regarding the Woodrow Wilson Bridge Superstructure Contract." The full report is available from the MDOT.

Woodrow Wilson Bridge Project Bridge Superstructure Contract (BR-3): Review of the Engineer's Estimate vs. the Single Bid, February 28, 2002. This report is available from Maryland DOT.

Douglass, Robert, Robert Healy, Thomas Mohler, and Shirlene Cleveland (2004). "Adventures in Building Another Washington Monument, Woodrow Wilson Bridge Project Re-bidding Outcomes," presented at the 2004 TRB Annual Meeting.

E3 Estimate Review—Internal

Estimate reviews should be conducted at strategic times during estimate preparation to improve accuracy and completeness. The formality of a project estimate review and the depth of the review at each stage in project development will vary depending on the type of project and project complexity.

No estimate should be released without internal reviews. The team that prepared the estimate should conduct the first review of the project estimate. This is essentially a screening review that ensures that the math is correct, the process is documented, and department guidelines were followed. In the case of a straightforward overlay project, a formal review may not be necessary. However, as project complexity and scope increase, it is necessary to conduct formal reviews with either an in-house/peer review or a formal committee review. When very complex projects or projects involving new construction methods are being estimated, management should require that there be an external review of the estimate.

There can be several different approaches to estimate reviews: (1) a review of calculations and applied unit costs, (2) a review of the process and methodology, or (3) a very complete review that encompasses evaluation of both calculations and mythology. All reviews must closely examine the assumptions that form the basis of the estimate, internal logic, completeness of scope, and estimation methodology.

E3.1 Formal Committee

Certain state highway agencies use an "estimate review committee" approach to enhance estimate accuracy. The formal committees review each estimate at different stages in project development and prior to the bid letting. The committee structure used by the Georgia DOT consists of six people, including the state construction engineer, an FHWA representative, a contract administration engineer, a state maintenance engineer, and two project/field engineers.

What Is It?

A formal committee estimate review is a cost estimate validation tool. This cost validation tool entails an objective review of the estimate by a group of experienced third-party state highway agency individuals who did not participate in development of the estimate.

Why?

The most effective means of improving estimate quality is, not to refine estimation methods or computer software, but to refine the methods of identifying errors and omissions. This is a tool to ensure that estimation criteria and requirements have been met and that a well-documented, defensible estimate has been developed.

What Does It Do?

The review committee seeks to subjectively determine estimate accuracy, based on the totality of the information available. In particular, the committee:

- **Determines whether the estimate satisfies the project criteria:** The committee seeks to ensure that the estimate conforms to the project scope and design documents.
- **Appraises the estimate methodology:** The committee must be able to follow and check the estimate methodology. Steps to do this would include verifying estimation techniques and sources of estimate data. The committee should be able to clearly understand the origin of all numerical data in the estimate.
- **Identifies uncertainties:** The committee should confirm all uncertainties documented in the estimate and identify other uncertainties in the estimate that were missed or glossed over. It is good to note these uncertainties at this time so that an accurate estimate can be developed.
- **Documents the finding:** The findings of the estimate review must be documented. The committee may use an estimate review checklist or prepare a concise written report that documents the findings. A sample estimate review checklist is present here in the example part of this section.

When?

Reviews are typically employed on plans, specifications, and estimates (PS&E). However, as the project design is developed and the revised estimates are generated, it is good practice to conduct a review of the revised estimate, particularly at the major design development stages, 30% and 60%. These earlier reviews can provide real benefit because they often discern cost drivers that can be addressed by design changes and, in so doing, reduce project cost.

Example

Here is an example of a checklist used by a formal committee when conducting a review.

REVIEW CHECKLIST

Review Date:
Review Location:
Project Name:
Reviewers' Names and Organizations:
Background Data and Conditions:

Is there complete technical scope documentation, including the following elements?

____ Description of the work to be performed;
____ Performance criteria and requirements;
____ Discrete tasks and deliverables;
____ Resource requirements;
____ Sequence of events and discrete milestones;
____ Work not included in the scope.

Have milestone descriptions been developed for each milestone associated with the project?

Does the technical scope documentation for the estimate include descriptions of support associated with the work to be performed?

Is the technical scope for the estimate consistent with the site, regulatory requirements and constraints (e.g., permit conditions, regulations) identified during the planning process?

Cost Estimate

Are appropriate historical cost data used in the estimate?

Are direct costs that are associated with individual activities included in the cost estimate clearly and individually identified?

Are indirect, overhead, or other costs clearly and individually identified?

Has the cost estimate been updated in a timely manner in response to relevant changes in its basis, background data, or assumptions?

Are an appropriate change control document and an estimate development history attached to the cost estimate?

Does the estimate development history include an itemized and chronological list of the changes made to the cost estimate since initiation of its preparation, and the rationale for each change?

Are activities, quantities, and unit costs associated with the work to be performed clearly identified and defined in the cost estimate?

Are the assumptions and exclusions upon which the cost estimate is based clearly identified and defined in the estimate?

Are time and cost assumptions and cost elements associated with each activity clearly identified, defined, and documented in the estimate? Cost elements for program activities include:

Quantities

Unit of measure
Material cost
Overhead rate
Total overhead allocated

Are significant estimator findings identified during preparation of the estimate documented?

Have factors been used to adjust the costs? If so, have they been adequately documented and appropriately applied?

Have escalation factors been used to escalate the estimate?

Are the escalation factors adequately documented and appropriately applied?

Are indirect rates used in the estimate adequately documented and appropriately applied?

Are estimate summary and detailed reports included, and do they provide cost totals for each cost element in the estimate?

Is a schedule included with the estimate?

Are activities included in the schedule consistent with those included in the technical scope?

Are milestones and deliverables included in the schedule consistent with those included in the technical scope documentation and the estimate?

Tips

The reviewer must try very hard to eliminate confusion in the contract documents and specifications. Check the estimated cost of any items that represent unfamiliar work or items for which there is only a limited database of historical information. Investigate whether the percentages used to estimate overhead and other costs besides the direct cost are realistic.

It is good practice to include younger state highway agency staff as members of the committee so that they can learn from the discussion, but many times they will also contribute a completely new perspective.

Resources

FHWA (2004). *Major Project Program Cost Estimating Guidance.* While aimed at estimation for major projects, this document does contain many ideas that can be incorporated into a review process and stresses the need for review teams to have diverse membership composition.

E3.2 Off-Prism Evaluation (Also See I3.2)

In the case of most conventional projects, engineers focus on technical solutions with little attention to community interest or the macroeconomic environment. Market forces and third-party interventions can have a major impact on project cost and must be accounted for in the estimation process.

What Is It?

This is an estimate review that seeks to provide management with assurance that cost impacts driven by macroeconomic and market conditions have been considered in developing the project's estimated cost.

Why?

Every project is executed in the context of a particular political, economic, and cultural environment. The legal system, labor practices, and even the global demand for construction materials are manifestations of a project's macroeconomics. The macroeconomy 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 understanding other aspects of project planning and estimation, understanding the macroenvironment has never been standardized as a part of project estimation.

What Does It Do?

In the case of very large projects, the amount of risk that even the largest contracting organizations can tolerate is exceeded. Therefore, contracting firms must develop strategies to minimize their risks. Some of these strategies involve increased cost to the project owner. In the case of risks that cannot be quantified, that cost increase can be significant. Additionally, if the contractor perceives that an owner is seeking through the contract language to shift risk to the builder, sufficient additional cost will be included in the bid to cover that added financial exposure. An off-prism review is conducted from the perspective of how contractors perceive risk and specifically considers the construction marketplace and macroeconomic factors impacting contractor risk.

When?

Because reviews are the best means for ensuring estimate accuracy and for minimizing the potential for unanticipated surprises concerning the financial condition of the project, it is good practice to perform a review each time an estimate is revised. However, in the case of off-prism evaluations, an estimate review should also occur any time there is a change in macroeconomic conditions or the construction marketplace. When the underlying economic assumptions for the estimate change, the estimate will need to be revisited.

Examples

The FHWA document *Major Project Program Cost Estimating Guidance,* June 4, 2004, specifically calls attention to the following factors that affect project cost:

- **Contracting method:** Innovative contracting techniques such as design-build, cost-plus-time bidding, and lane rental should be taken into consideration when preparing the estimate. Design-build contracts and contracts with performance-based specifications or warranties impose a higher risk on the contractor and may increase a contractor's bid. Any stipend costs should be included in the estimate.
- **Acquisition strategy analysis:** A separate value analysis on the project should be considered to determine the most economical and advantageous way of packaging the contracts for advertisement. A value analysis is a systematic approach by a multidisciplined team to identify functions of a project, establish a worth for each function, and generate alternatives that satisfy each function at the lowest life cycle cost.
- **Surety issues:** Obtaining bid and performance bonds for major projects is difficult, especially for smaller contractors. If bonding requirements are not reduced, then an increased amount for obtaining bonds should be included in the cost estimate.
- **Bidding climate impact:** Estimators should consider the economic impact of the project on the local economy. For example, material manufacturers that would normally compete with one another may need to combine resources in order to meet the demand of the major project. Extremely large construction packages also have the potential to reduce the number of contractors that have the capacity to do the work, and the project may need to be split into smaller contracts to attract additional competition. In addition, the timing of the bid solicitations can also have an affect on the cost because contractors may be more competitive during the winter months when trying to build some inventory. Cost estimates should also consider controls on the use of labor.
- **Industry capacity:** The number of potential qualified contractors that are able to bid on major projects are limited to those that have the capacity to construct the project. Contractors that bid on major projects often bid on projects throughout the country. If other major projects are being advertised concurrently, this may have a limiting effect of competition and would result in higher bids.
- **Highly specialized designs and technology:** Cost estimates should consider the impact of any requirement to use first-of-a-kind technology, new materials, or innovative construction methods.
- **Construction time:** The impacts of construction activities (e.g., sequencing, traffic control, haul routes, accessibility, and geographic locations) should be considered when developing cost estimates. Also, costs associated with work time restrictions and night work must be considered.
- **Construction incentives:** The cost for the contractor to meet material and performance incentives must be included in the cost estimate.

Tips

Bid options (i.e., 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.

Some questions that are often decided by contractors but not normally part of a state highway agency's estimation methodology include the following:

- Is this a labor-intensive project?
- Does the project depend heavily on certain pieces of equipment?
- Is there a danger of material price increases?
- What is the cash flow of the project?

Resources

Arizona DOT (1989). *Estimating Guidelines.*

Schexnayder, Cliff (2001). "Construction Forum," *Practice Periodical on Structural Design and Construction,* ASCE, Vol. 6, No. 1.

E3.3 In-House/Peer

An objective estimate review can be accomplished by a group of experienced third-party state highway agency individuals who did not participate in development of the estimate. For large or complex projects, the review is usually conducted with the project team and estimator so that the reviewers can better understand the execution plan, estimate basis, and project challenges in regards to scope and pricing.

What Is It?

A peer review typically involves an estimate validation by state highway agency estimator who has not worked on the estimate being reviewed. The state highway agency reviewer must have the experience and knowledge to carefully appraise the materials presented. In the case of larger projects, this peer validation may involve a peer team.

Why?

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 and general estimation procedure and technique inadequacies. It is easy for members of the state highway agency to conduct an estimate review because they are familiar with the formats, procedures, and processes that the agency has in place and therefore can easily spot deficiencies.

What Does It Do?

A peer review checks the estimate for completeness and correctness, including, but not limited to, the following:

- Check mathematical extensions and correctness.
- Check takeoff for omissions or oversights.
- Check for conformity between amounts of work (item quantities) with the schedule durations to determine correctness.
- Check the calculations of the indirect costs.
- Examine the estimate for buried contingency.

Compare the estimate with any similar project for an order-of-magnitude check.

When?

Each time a revised estimated is generated, there should be a review. An estimate review is the best means for ensuring accuracy and minimizing the potential for unanticipated surprises concerning the financial condition of the project.

Examples

North Carolina DOT uses a formal internal estimate review process. The process coincides with the project development process milestones.

Following is the approach used by Missouri DOT regarding timing of estimate reviews:

> **1-02.12 (4) REVIEW OF ESTIMATES.** Project cost estimates should be reviewed and updated periodically. At a minimum, project cost estimates should be reviewed on an annual basis. A new or revised project estimate should be prepared at the following major milestones or stages of project development: project initialization, conceptual plan/environmental document completion, preliminary plan completion, right of way plan completion, and contract plans completion (PS&E). The estimated project costs should be submitted to GHQ [General Headquarters] Transportation Planning at least annually, at the above noted project development milestones/stages, or when significant project scope changes are identified using a PATS [Project Amendment Tracking System] form (see Figure 1-02.7).
>
> If an annual review of the previous estimate is conducted and it is determined that no change is necessary, the project estimate file should include documentation to indicate that the previous estimate has been reviewed and remains valid.
>
> Revised cost estimates submitted for projects that are scheduled for expenditure of funds within the current fiscal year of the STIP [statewide transportation improvement plan] will not be reflected in the STIP or the approved PATS database. For example, if the project is to be awarded during the current fiscal year, the construction cost reflected in the STIP will not be revised to account for project estimates prepared after the beginning of the fiscal year. Similarly, if a project has right of way funds included in the current fiscal year of the STIP, the right of way amount will not be revised based on a revised estimate submitted in the same fiscal year. Even though these costs will not be reflected in the STIP, the revised project estimates should still be prepared in accordance with the recommended schedule. However, the submission of a

PATS form to GHQ Transportation Planning will not be required in this situation. This is the only exception that exists for not submitting a PATS form to GHQ Transportation Planning each time a revised estimate is prepared.

All estimated costs should be submitted in current dollars. GHQ Transportation Planning will make any necessary inflation adjustments. Estimate revisions will impact a district's funding balance and be used to calculate the current cost of the program, but not be used to determine any changes in the district funding distribution.

Tips

The peer review should consider the following:

- What is the basis for the assumptions made in developing the estimate?
- Are the assumptions made in the estimate consistent with the technical scope and schedule of the project?
- Are the activity durations in the schedule consistent with the estimated cost?
- Are indirect rates, escalation factors, and other factors used appropriately?
- Have the findings and recommendations of the peer review been documented in a peer review document?
- Is the peer review document included with the cost estimate documentation?
- Have the findings and recommendations of the peer review been addressed in revisions to the cost estimate?
- Are activities included in the schedule consistent with those included in the technical scope documentation and estimate?

Resources

Opfer, Neil D. (Fall 1997). "Construction Peer Review: A Technique for Improving Construction Practice," *Journal of Construction Education*, Vol. 2, No. 3, pp. 211–221. While this article discusses a peer review of contractor organizations, it includes several important peer review fundamentals. One of these is the point that the technique's success depends on significant resource commitments, including time.

Missouri DOT (2004). "Chapter 1, General Information: Needs Identification Project Scoping and STIP Commitments," Section 1-02, *Project Development Manual.* www.modot.org/business/manuals/projectdevelopment.htm.

E3.4 Round Table

Reviews can have a round-table structure, in which the estimators sit down with the reviews. As with other estimate reviews, the round-table review involves examining the estimate and the basis, but unlike other estimate reviews, the round-table review has the advantage of bringing a greater body of knowledge and experience to the review to engage in a dialogue.

What Is It?

A round-table estimate review is like the process used by contractors to validate their cost estimates before a bid letting. The project team assembles and has a detailed discussion of the schedule, conditions, and expected construction methods for the major cost items, as well as all known site conditions. Only after that discussion does the actual review of total cost and item cost begin. The cost review is top down by broad classes: direct cost total and major items, state highway agency field support cost, state highway agency administrative support cost, and included contingency.

Why?

All project estimates are very complex in terms of the factors that can determine work item costs, and estimators must make numerous judgments based on perceptions of work conditions and the physical conditions at the project site as the estimate is developed. Therefore, it is good practice to capture a different perspective from agency experts in order to validate the estimator's assessment.

What Does It Do?

Using a committee to review an estimate brings knowledge from agency experts with a broad base of experience. The reviewers who compose the committee should represent diverse sections of the agency having specific knowledge of cost-impacting factors—for example, personnel from the agency's right-of-way section for reviews during planning and design development and personnel from the construction office for a review of PS&E.

When?

Periodic reviews of estimates are important because conditions and underlying assumptions for the original and subsequent estimates often change; thus, estimates need to be revised to account for these changes. When estimates are revised, there should be a review because reviews are the best means for ensuring accuracy and minimizing the potential for unanticipated surprises concerning the financial condition of the project.

Examples

North Carolina DOT uses a formal internal estimate review process. The process coincides with the project development process milestones.

Round-table reviews often consider the following:

- **Project schedule:** Are there project duration constraints with associated cost impacts because of late delivery or because there was no compensating incentive to deliver the project on time or ahead of schedule?
- **Constructability:** Is a unique design creating some unknown factors that could impact the cost of the project? Are specialized or large machines needed to construct the project?
- **Government oversight:** Do the various government entities involved and the political sensitivity raise concerns as to who is ultimately accountable and empowered to make quick decisions? (Delays in decision making by an owner causes a contractor to incur uncompensated additional costs.)
- **Other major projects:** Are there other projects that may interfere with the contractor's ability to estimate this project? (Even major contractors have limited estimation capability; to estimate more than one large project during the same time frame is often impossible.)

Tips

An estimate review does not dig into every detail of the estimate, but it should always test the vital few items and assumptions. The Italian economist Vilfredo Pareto observed that 20% of something is always responsible for 80% of the results. That observation is recognized today as a universal principle called the 80/20 rule, or Pareto principle. The Pareto principle should guide the estimate review. Applying the rule allows the reviewers to set priorities. After a general overview analysis of the estimate, the reviewers should concentrate on the items that are the project's primary cost drivers.

The reviewers should carefully examine the selected items based on a list of important issues:

- Correctness of quantities
- Appropriateness of unit cost
- Validity of assumed construction method, considering site conditions and project phasing
- Consideration of external market factors that could affect cost (this is critically important in the cast of large, complex projects)
- Unforeseen engineering complexities
- Changes in economic and market conditions
- Changes in regulatory requirements
- Pressures by local government or other stakeholders
- Transformation of community expectations
- Market availability of materials and/or equipment
- Concise explanation of how contingency amounts were developed
- Construction schedule

There should be comparisons of costs to benchmark ratios and factors for similar projects.

Resources

U.S. Department of Energy (1997), "Check Estimates and Independent Cost Estimates." www.directives.doe.gov/pdfs/doe/doetext/neword/430/g4301-1chp13.pdf.

FHWA (2004). *Major Project Program Cost Estimating Guidance.* While this document is aimed at the estimation for major projects, this document contains many ideas that can be incorporated into a review process and stresses the need for review teams to have diverse membership composition.

E3.5 Year-of-Construction Costs (Also See C1.7)

A final step in the internal estimate review process is a check to ensure that the estimate is accurately communicated in the year-of-construction costs. Communication of these costs is discussed in Section C1.7. Estimators typically construct the estimate based on current dollars. It typically is more accurate for estimators to make judgments in current market prices during the estimate development. Additionally, net present value is more appropriate when comparing design alternatives or performing value engineering. However, estimates should be communicated to project stakeholders in year-of-construction costs because that is what the project will actually cost when it is complete and that is the number that many stakeholders will use to measure success. Therefore, an estimate review should be performed to ensure that the estimate is properly communicated in year-of-construction costs.

What Is It?

Year-of-construction cost is the estimated cost adjusted for the difference in time between when the estimate is created and when the project is to be constructed. Year-of-construction cost estimates take the "time value of money" into account. Project costs should be adjusted for inflation or deflation with respect to time due to factors such as labor rates, material cost, and interest rates. Estimated cost is most commonly inflated to the expected midpoint of construction date. This tool involves a step in the internal estimate review process to ensure that the estimate is accurately converted to year-of-construction costs for communication purposes.

Why?

Using year-of-construction cost will more accurately reflect future project costs. Funds available for projects often do not increase with inflation, but actual project costs always do. Inflation continually reduces the agency's capacity to preserve, maintain, and modernize the transportation system. While it is common to communicate a net present value for estimates when comparing projects or design alternatives, it is not a good idea to communicate the estimate to external parties in anything except year-of-construction costs.

What Does It Do?

This tool provides an internal estimate review milestone for the estimation team. It is one of the final steps before the estimate is communicated to the project team members and to external stakeholders. This tool improves estimate accuracy by identifying the effect of inflation on project cost. It defines an estimated project cost, which is developed in current dollars, in terms of the expected cost at the time of construction.

When?

Year-of-construction cost recognizes the cost escalation affect of inflation across the time period between when the estimate is made and when the project is constructed. Estimates should be communicated in year-of-construction costs from the earliest points in the project development process. This is very important for projects having long development and/or construction periods.

Examples

Florida, Minnesota, and Washington State DOTs have developed tools for calculating year-of-construction costs. Refer to Section C1.7 for specific examples. Most other state highway agencies have developed tools similar to those used in Florida, Minnesota, and Washington State.

Tips

Include a formal step in the estimate review process to ensure that the estimate is being communicated in year-of-construction costs. Use discipline in communicating year-of-construction costs at each phase of the project development.

Resources

Florida DOT's "Long Term Construction Cost Inflation Forecast" can be found at www.dot.state.fl.us/planning/policy/costs/inflation.pdf.

Minnesota DOT's "Ten Year Highway Work Plan: 2004–2013" can be fount at www.oim.dot.state.mn.us/pdpa/2004-13_10-YrHwyWorkPl.pdf.

Washington State DOT's Strategic Planning and Programming website is http://www.wsdot.wa.gov/planning.

G1 Gated Process

A gated process creates a formal mechanism to stop the project development process if a project's cost escalates beyond an acceptable limit during the project development process. Checklists and cost containment tables are two tools that can be used in support of the gated process method of cost estimation management.

G1.1 Checklist

A checklist is a tool commonly used by estimators to begin an estimate or ensure that an estimate adequately addresses project scope. Checklists are valuable tools when creating conceptual project estimates when little or no engineering information is available. Checklists are also valuable quality control tools when completing estimates at any phase of project development. Checklists can be used in conjunction with gated processes to ensure that all relevant items of scope are estimated before a project moves onto the next phase of project development.

What Is It?

A checklist is a form that indicates the completion or incompletion of specified project milestones. Checklists are typically developed through experience with many estimates. Checklists often address items that are commonly overlooked or have high cost value. Checklists can be used in a gated process to ensure that a project will not move to the next stage of project development without the completion of critical estimation milestones.

Why?

In order for a project to progress smoothly, critical cost estimation items must be completed or accounted for before another phase may begin. The checklist is a simple tool for identifying the level of progress that has or has not been made on the project. Checklists help to ensure that major scope items are not forgotten as a project moves through the development process.

What Does It Do?

A checklist can assist estimators in ensuring that an estimate is complete. A checklist can serve as a simple "Go" or "No-Go" signal for moving a project to the next phase of development. After each phase or activity is completed, the item will be "checked off" of the checklist, and the next set of responsibilities will be addressed. Checklists can also be used to help set reasonable contingencies because they can give some indication about the unknowns in a project.

When?

Checklists can be used on every project. The checklist can be developed during the programming and planning phases. The checklist can be used from the planning phase through the completion of the project. It is often valuable to develop checklists that correspond to major milestones in project development (see Cost Containment Table tools).

Examples

Mississippi DOT uses a comprehensive checklist to aid with project development. Although this example does not contain specific estimation milestones, it serves as a good basic example of a checklist. A few select portions of this checklist are seen in Figure G1.1, and a full version can be found in the resources section.

Tips

Checklists are simple tools for managing a current project, as well as reviewing completed projects. Add extra notes and lessons learned to the checklist as the project progresses to be used for referencing in the future.

Checklists are generally set up to allow a logical progression of activities. However, it is often possible to overlap phases and activities for increased budgeting and scheduling efficiency.

Resources

FHWA's "Construction Program Management and Inspection Guide, Checklist for review of estimate" is available at www.fhwa.dot.gov/construction/cpmi04ge.htm.

FHWA's "Plan, Specifications, and Estimates Checklist" is available at www.fhwa.dot.gov/construction/cpmi04gi.htm.

Illinois DOT's "Checklist for Engineer's Final Payment Estimate" is available at www.dot.state.il.us/Forms/bc111.dot.

Michigan DOT's "Memo for Final Estimates" is available at www.michigan.gov/documents/IM00-20_40872_7.pdf.

Mississippi DOT's "Project Development Checklist" is available at www.mdot.state.ms.us/localgov/planning/pdm/checklist.pdf.

G1.2 Cost Containment Table (Also See C6.1, I1.1)

Cost containment tables were previously described as communication tools in Section C6.1. In addition to being used for estimate communication, cost containment tables can be used to create gated processes. A project can be stopped if it escalates past an acceptable limit as it transitions from one project development phase to the next, thereby creating a gated process.

What Is It?

A cost containment table is an estimate reporting system that requires project team members to document summary-level estimates at critical points in the project development process. It assists in creating gated processes by documenting project costs and alerting team members when corrective action must be taken because of changes impacting project scope, cost, and schedule.

Why?

Under a gated process method, a cost containment table can be used as a checkpoint at the completion of each milestone to ensure that sufficient budget, schedule, or project goals have been met. The project can proceed toward the next milestone given a satisfactory completion of the prerequisite activities per the cost containment table.

What Does It Do?

The cost containment table is a tool for cost estimation management that is used to ensure that the project is within budget. It can also be used to verify that the scope of work is in alignment with what was defined during programming and planning.

When?

Develop a cost containment table, along with feasibility studies, early in the project development process. Use the cost containment table throughout all phases of the project.

Examples

Please refer to the example of a cost containment table from Pennsylvania DOT in Section C6.1 and Figure C6.1. This table can be used as a tracking and communication mechanism in a gated process. Because management must approve the cost containment table before the project moves to the next phase of project development in the Pennsylvania DOT example, the DOT has essentially created a gated process. The strength of the gated process will depend on the policies, procedures, and management discipline involved.

Tips

Begin to use the cost containment table early in the project development process. Update the table at all project milestones. Be proactive in the use of cost containment tables for establishing gated processes.

Resources

Pennsylvania DOT's *Estimating Manual* is available at ftp://ftp.dot.state.pa.us/public/Bureaus/design/PUB352/inside_cover_page.pdf.

The FHWA uses lessons learned from past projects to comment on the importance of cost containment. The following link references the Boston Central Artery/Tunnel: www.fhwa.dot.gov/programadmin/mega/lessons.htm.

2. Project Submittal and Activation (Chapter 2)	Date/Initials
a. Submittal of Project for STIP Approval (If Applicable)	
The ***MDOT*** Planning Division includes all ICIP, Transportation Enhancement, ITS and other earmarked projects in the STIP with no ***LPA*** action required. ***LPA*** action is required for STP roadway projects only. For STP roadway projects, the ***LPA*** must submit a request to place the project in the STIP. The request must include a brief description of the project and an accurate cost estimate for the project which must be within available ***LPA*** Federal and local funds. ☐ 1. Urbanized Areas – If the project is within an urbanized area, the ***LPA*** must submit their request to their MPO for consideration in the development of their TIP which is incorporated directly into the STIP. OR ☐ 2. Non-Urbanized Areas – If the project is not within an urbanized area, the ***LPA*** must submit their request to the ***MDOT*** Planning Division for incorporation into the STIP.	
b. Preparation of the Project Activation Request (PAR)	
☐ The ***LPA*** must prepare the PAR in accordance with the instructions within the form and submit the completed PAR to the ***MDOT*** Planning Division. All items must be complete. The ***Chief Official*** of the ***LPA*** must sign in the Applicant Approval and his/her title should be shown.	
c. Special Match Credit Program	
☐ If the ***LPA*** plans to request Special Match Credit for eligible preliminary engineering and right-of-way costs, that intent must be noted in the appropriate section of the PAR.	
d. Determination of Functional Classification (Roadway projects only)	
☐ The ***LPA*** must determine Functional Classification of a roadway to establish appropriate design criteria and standards. Functional Classification can be determined from the functional classification maps maintained by the ***MDOT*** Planning Division. Functional classification maps are included in the PDM links.	
3. Environmental Documentation (Chapter 3)	**Date/Initials**
a. Project Assessment	
☐ The ***LPA professional*** certifying the project should perform a project assessment including an Environmental Screening to identify any significant effects to the human and natural environment. If there are questions about possible effects, the ***LPA*** should contact the ***MDOT*** Environmental Division Engineer.	
b. Determination of the Environmental Action	
☐ Based upon the amount of impact a project is expected to have on the human and natural environment, the ***LPA*** must make a determination of the Class of Environmental Action and prepare the necessary environmental documentation as outlined in 23 CFR Part 771. There are three Classes of Environmental Action: Class I, II, and III (See S.O.P. ENV-02-01-00-000).	
4. Right-of-Way Procedures (Chapter 4)	**Date/Initials**
a. Right-of-Way Purchase (If Applicable)	
☐ The ***LPA professional*** certifying the project may contact the ROW Manager - Property Acquisition of the ***MDOT*** Right-of-Way Division for advice in preparing to acquire Right-of-Way. All Right-of-Way must be acquired in accordance with 49 CFR Part 24 and the ***MDOT's*** Standard Operating Procedures for Right-of-Way.	
5. Preparation of the Plans, Specifications and Estimate (PS&E) Assembly (Chapter 5)	**Date/Initials**
a. Preparation of the PS&E Assembly	
☐ The PS&E Assembly for a project must be prepared by the ***LPA professional*** in conformance with ***MDOT*** approved design criteria and standards, ADA guidelines and/or appropriate architectural criteria and standards.	
b. Submittal of the PS&E Assembly	
☐ Three (3) sets of the PS&E Assembly must be submitted, each with the required transmittal letter, to the ***MDOT*** District representative, who in turn will send one (1) set to the ***MDOT*** Contract Administration Division and one (1) set to the ***MDOT*** Construction Division. Each of the following required documentation/certifications must bear the signature of the ***Chief LPA Official*** or signature and seal of the ***LPA professional*** as indicated. ➡ *DOCUMENTATION/CERTIFICATIONS REQUIRED.* ☐ ***One (1) copy of the letter of transmittal signed by the Chief Official of the LPA (Mayor, President Board of Supervisors or Agency Head) including: a request for authorization and authority to advertise for bids; the name of the full-time LPA employee who will be the Project Manager; the name of the Project engineer/architect, if known; the name of the safety officer, if known, with proof of certification; and either a statement that construction activities will not encroach on MDOT ROW or an approved MDOT permit if activities will encroach.***	

Figure G1.1. Mississippi DOT checklist.

6. Project Authorization and Selection of a Contractor (Chapter 6)	Date/Initials
a. Authority to Advertise for Bids and DBE Requirements	
☐ The ***MDOT*** Contract Administration Division notifies the ***LPA*** of the DBE requirements and issues the ***LPA*** Authority to Advertise for Bids. The notification letter includes instructions for the ***LPA***.	
b. Advertisement for Bids	
☐ The ***LPA*** advertises for bids in accordance with instructions provided in the ***MDOT*** Contract Administration Division's letter. Example of an advertisement	
c. Opening and Approval of Bids	
☐ The ***LPA*** receives, opens and approves bids in accordance with instructions provided in the ***MDOT*** Contract Administration Division's letter.	
d. Request for Authorization to Award the Contract	
The ***LPA*** requests ***MDOT*** authorization to award the contract through the ***MDOT*** District representative. Urbanized Areas - If the project is within an urbanized area and the bid is greater than the MPO approved funds, the MPO must concur with the new amount. The following must be submitted directly to the ***MDOT*** Contract Administration Engineer: ☐ The ***LPA*** must submit either the full amount or one-third (1/3) of their share of the project	
7. Construction Administration (Chapter 7)	**Date/Initials**
a. Construction Administration Responsibilities	
☐ The ***project engineer/architect*** shall provide for sufficient inspection of the work to ensure that the project is completed in accordance with the plans and specifications. Responsibilities include, but are not limited to: 1. The supervision and inspection of the contractor doing the work, 2. The selection and processing of all material samples for testing, 3. The measuring of work for compliance with designs and standards, 4. The measurement and documentation of pay-item quantities for contractor payment, 5. The preparation, submission, and approval of all construction payment requests, and, 6. The keeping of daily project diaries.	
b. First Construction Report (*MDOT* Form CSD 201)	
☐ On the first day the contractor performs work anywhere on the project site, a First Construction Report (***MDOT*** Form CSD 201) must be prepared by the ***project engineer/architect*** with copies forwarded to the ***MDOT*** District representative, the ***MDOT*** Contract Administration Division and the ***MDOT*** Construction Division.	
c. *Project Engineer/Architect's* Project Daily Diary	
☐ The ***project engineer/architect*** must maintain an official Project Daily Diary as a historical record of job progress. At a minimum, the Project Daily Diary should include a daily record of the contractor's activity, ***project engineer/architect*** activity, all DBE activities, weather and soil conditions and how they affect the contractor's operation, and daily contract time charges. Also, any important or unusual communication between the ***project engineer/architect*** and the contractor should be noted in the Project Daily Diary. The Project Daily Diary must be signed daily by the ***project engineer/architect*** and must clearly show the date contract time began, the date contract time ended, the date work started, the date work was completed, and the date of final inspection upon completing the project with a list of primary members of the final inspection team and the agency that each represents.	

Figure G1.1. (Continued).

I1 Identification of Changes

The identification method is normally positioned in the final stages of engineering to intercept inputs impacting scope and cost. The four tools used in this method—I1.1, "Cost Containment Table"; I1.2, "Estimation Scorecard"; I1.3, "Project Baseline"; and I1.4, "Scope Change"—will have been established much earlier in the project development process, but will be used late in the engineering process to identify any deviations from the project baseline estimate. The scope and cost baseline of every project should be the reference to which all changes are compared. Throughout project development and construction, the baselines are used to evaluate performance. Most agencies that practice baselining of their projects report doing so usually at the point when an identified need becomes a "real" project and is budgeted.

I1.1 Cost Containment Table (Also See C6.1, G1.2)

The development of the cost containment table early in the project development process was described in Section C6.1.

The cost containment tool is used in the identification method to quickly call attention to any deviations in budget. Managing to a baseline cost estimate is one of the most common measures of estimation management success. As a project moves forward through its development stages, cost containment tables provide a benchmark against the project baseline. They create a standard tool that can be used by team members to track cost growth and provide immediate feedback for executive management.

What Is It?

A cost containment table is an estimate reporting system that requires project team members to document summary-level estimates at critical points in the project development process. It provides executive management with estimate totals as the project moves through critical milestones during its development. These milestones will vary from state highway agency to state highway agency, but they can include scoping, programmed amount, preliminary engineering, final engineering, award, and closeout. They can also include estimate subtotals for items like engineering, right-of-way, and construction.

Why?

Cost containment tables provide a simple and concise tool for managers and project team members to monitor and react to cost escalation as projects transition through critical phases during their development. In the context of the identification method, cost containment tools identify changes to the budget and provide information for helping the designers and estimator get the project back on budget.

What Does It Do?

Cost containment tables create transparency and accountability in the management of a cost baseline. The use of cost containment tables permits quick identification of cost escalation as it occurs. When standardized in a state highway agency, cost containment tables allow for comparison of cost escalation by the variables captured in the tables. The use of the cost containment table establishes minimal milestones that are consistent throughout the state highway agency and creates accountability for the project team for changes in the estimates from one milestone to the next.

When?

The effort to manage project costs continues from the programming and preliminary design stage through final design, and until construction closeout. In the identification method, the tool will be used during the final design and letting to ensure that cost escalation has been captured. For instance, if the price of a commodity such as steel or cement escalates rapidly during final design, the engineer's estimate will reflect the escalation and the cost containment table tool will alert the project team to the fact that the project scope may need to be adjusted to fit within a constrained budget. The table acts as a gated process to stop the project from progressing until it is estimated to be on budget. The cost containment table should only be used when a project baseline estimate is established.

Example

An excellent example of a cost containment table from the Pennsylvania DOT is described in Section C6.1 and shown in Figure C6.1.

Tips

A cost containment table requires updating at each predetermined project milestone. At each project milestone when the table is used, the estimate must be broken down into specified items. If substantial changes are present, they can then be easily identified, thereby indicating a need for further review.

Cost containment tables should be only one tool in managing cost escalation. A drawback of the cost containment table is that it only provides a "rearview mirror" look at cost escalation. While knowing that there is a problem at critical project milestones is essential, project teams should strive to anticipate cost escalation whenever possible and mitigate their effects before they occur.

Resources

Pennsylvania DOT's *Estimating Manual* is available at ftp://ftp.dot.state.pa.us/public/Bureaus/design/PUB352/inside_cover_page.pdf.

I1.2 Estimation Scorecard (Also See C6.2)

In the final stages of project engineering and letting, an estimation scorecard can be used to measure the performance of the estimation process. As described in Section C6.2, the tool should be created by the entire team early in the project development process and aligned with the project objectives that will ultimately drive the perceived project success. While the use of estimation scorecards is not prevalent with state highway agencies, scorecards are good tools for evaluating cost estimation management throughout the project development process. An estimation scorecard is an objective measure of estimate accuracy or project scope growth.

What Is It?

An estimation scorecard is an evaluation tool to measure the success of cost estimation practice and cost estimation management during the project development processes. The format of the scorecards can vary depending upon individual agency objectives, but the goal is to create an objective score for performance in cost estimation practice and/or cost estimation management.

Why?

Measurement of estimate performance is critical to improve future estimation practices. Early identification and measurement of the project success criteria helps to ensure that there is no miscommunication regarding functionality and physical structure of the completed project.

What Does It Do?

Estimation scorecards provide objective measures of estimate success. Estimation scorecards are commonly used when consultants are preparing the project design and estimate, but they can also be used internally for agency evaluations. Estimation scorecards indicate the measures that will be used at project completion to evaluate success. Once the project is complete, performance measure can be derived from comparison of target values designated during project development and the achieved values measured after project completion.

When?

The evaluation criteria of estimate success and the physical scorecard itself should be developed early in the project development process. It is then used in the identification method in the later stages of project development to determine estimate success and to help collect lessons learned for future estimates.

Examples

Section C6.2 provides examples from a scorecard developed by the Coors brewing company for construction of their capital facilities.

Tips

The use of the scorecards can ensure that all team members are clear about the expectations for a successful project. The tool will help to facilitate a structured discussion about what will define success on each project, and it will provide an objective measurement for this success.

Develop the scorecard as a team. Consider developing an overall project scorecard as well as discipline-specific scorecards.

Resources

U.S. Department of the Interior's "The Quarterly Scorecard and Corrective Actions Reports for Constructed Asset Investments" is available at www.doi.gov/pam/QuarterlyReport Guidance61605.pdf.

I1.3 Project Baseline

A project baseline is essential if a state highway agency wants to effectively manage scope, cost, and time as the project design is developed. The timing of when a baseline is set depends on state highway agency programming requirements. The level of project definition required to set the baseline depends on the complexity of the project, as well as the time allowed to prepare the scope, cost, and time baseline.

What Is It?

A project baseline refers to the cost estimate that sets the basis for controlling costs during project development. This cost is the budget included in the authorized program. When project requirements have been analyzed and documented and the project baseline has been established for scope, cost, and schedule, preliminary design and project control activities can begin. This involves the application of conventional system control techniques to the project effort.

Why?

The cost estimation management process cannot be performed effectively without a baseline cost. The project baseline cost provides the standard from which the impact of change is evaluated in terms of cost. The impact of change could result in increases or decreases in cost. For a project to be under control, it needs to be organized as a closed system. This is accomplished by establishing baselines for scope, cost, and schedule and then placing them under a change management process. Once the project has been contained in these three dimensions, it can be measured, monitored, and controlled.

What Does It Do?

The project baseline provides project management with a tool for making decisions regarding the impact resulting from changes in scope, design development, site conditions, and market conditions so that the budgeted cost for a project can be controlled. Establishing the baseline is the formal end of programming and the beginning of preliminary engineering. Controlling the project baseline is absolutely essential for project success. Other than misunderstood requirements, poor cost and schedule estimates, and technical difficulties, the issues that will most likely imperil a project are unexpected *changes.*

When?

The project baseline tool is used when the project is authorized for inclusion into the state highway agency program for design and construction letting. This occurs at the end of programming. However, the extent of the design effort to support the creation of a project baseline may vary depending on project size and complexity. Some preservation projects, such as an overlay, can be defined with only as much as 10% design completion. This may be adequate to set the baseline cost. Other larger and more complex projects may require as much as 25% design completion before setting the baseline cost.

Examples

The Washington State DOT (WSDOT) has a scoping phase that starts its project development process. The scoping phase is described as follows in WSDOT's 2006 *Design Manual:*

Scoping phase

The first phase of project development for a specific project. It follows identification of the need for a project and precedes detailed project design. It is the process of identifying the work to be done and developing a cost estimate for completing the design and construction. The Project Summary, engineering and construction estimates, and several technical reports (geotechnical, surfacing, bridge condition, etc.) are developed during this phase.

This scoping phase provides sufficient project design to prepare a baseline scope, cost, and schedule. This baseline supports the biennial programming of projects. The scoping phase has specific documentation that is required to support the project. This documentation, referred to as a Project Summary, contains three main components, as described in WSDOT's *Design Manual:*

Design Decisions Summary

An electronic document that records major design decisions regarding roadway geometrics, roadway and roadside features, and other issues that influence the project scope and budget.

Environmental Review Summary

An electronic document that records the environmental requirements and considerations for a specific project.

Project Definition

An electronic document that records the purpose and need of the project, along with program level and design constraints.

The Project Definition component includes the cost estimate for preliminary engineering, right-of-way (if part of the project scope) and construction. The Project Summary document is reviewed and approved by WSDOT region management and headquarters prior to including the project in the biennial program.

Tips

The project baseline cost estimate has to be at a certain level of detail to be meaningful for controlling costs. That is, cost elements must be defined sufficiently, with the estimate basis, assumptions, and calculations clearly documented (see the "Project Estimation File" tool). The project baseline should be established as early as possible in the project development process, but not before sufficient level of detail is available to allow for tracking changes to project scope and cost.

Resources

Washington State DOT (2005). "Design Manual," Section 330, Design Documentation, Approval, and Process Review.

Chapman, James (2005). "Principle Based Project Management," Rule Number 6, Establish Baseline Controls. www.hyperthot.com/project.htm.

I1.4 Scope Change Form (Also See C6.3)

While managing a project to the baseline estimate is the goal of every project manager, scope changes are sometimes unavoidable. Changes in scope should be documented and justified. A scope change form is critical in the identification method because it creates a standard procedure for reporting scope changes. It creates transparency and accountability. It also allows agencies to view trends in scope changes that may allow for better scope definition on future projects and in future estimates.

What Is It?

A scope change form is a document that provides a permanent record of the scope changes that occur during the project development. To create accountability, it also records who authorized the changes.

Why?

Changes to project scope almost always cause cost increases. Therefore, the requirement for formal management approval of any scope change serves to limit change, as all such proposals must be carefully reviewed. Controlling scope change serves to control cost growth. An additional reason for tracking changes to the project is to ensure that no changes take place without the full knowledge of the project team, including designers, managers, and estimators.

What Does It Do?

Scope change forms make possible easy comparison of the current project scope, schedule, and cost with the established baseline of the project. The form should require that the documented change, as well as any impacts of the change to project scope, schedule, and cost, be specifically acknowledged. An explanation is required with each change. Appropriate approvals should be required depending on the size and nature of changes.

When?

The scope change form should be used for all changes after the project baseline is established and may even be used before the baseline is established. It should continue to be used in the identification method during the latter stages of project development. As projects progress toward final design, management approval of scope changes is more critical and the scope change form provides an excellent tool to ensure that the approval is obtained and tracked.

Examples

An excellent example of a scope change form is discussed in Section C6.3 and shown in Figure C6.3. A form used by Missouri DOT is provided with instructions on how to complete it. Additional examples from the California DOT and the New York State DOT can be found through the web links in the resources part of this tool description.

Tips

Scope change forms should explicitly require all the information needed to track project changes, including scope, schedule, and cost impacts, as well as explanations and approvals. Forms should be standard; however, there should be the ability to deviate from the form for special project circumstances.

Resources

California DOT's *Project Development Procedures Manual* (PDPM) Chapter 6 addresses project cost, scope, and schedule changes: dot.ca.gov/hq/oppd/pdpm/chap_htm/chapt06/chapt06.htm.

Chapters 2 and 3 in the New York State DOT's *Project Development Manual* (PDM) discusses changes in project cost, scope, and schedule: www.dot.state.ny.us/cmb/consult/dpm1/pdm_01_30_04.html.

I2 Identification of Risk (Also See R3)

Risk identification involves the discovery of potential project risks and the documentation of their characteristics. In the context of cost estimation, an understanding of project risk will assist estimators in setting appropriate project contingencies. It will also assist managers in estimation management as the project progresses through the project development process. In the broader context of project risk management, risk identification is the first step in the following detailed process:

- Risk identification
- Risk analysis (qualitative and/or quantitative)
- Risk mitigation planning
- Risk monitoring and control

Red flag items and risk charters are two tools that assist estimators in both identifying and monitoring risks throughout the project development process. These tools support risk identification early in the project development process to assist in setting appropriate project contingencies. The tools also support the risk monitoring and control process to assist in contingency resolution as the project scope, design, and project delivery methods become fully defined.

I2.1 Red Flag Items

A red flag item list is created at the earliest stages of project development and maintained as a checklist during project development. It is perhaps the simplest form of risk identification and risk management. The list helps estimators to better understand the required contingency and helps managers to more effectively control scope growth throughout the project development process. Not all projects will require a comprehensive and quantitative risk management process. A red flag item list can be used in a streamlined qualitative risk management process.

What Is It?

A red flag item list is a technique to identify risks and focus attention on critical items with respect to critical cost and schedule impacts to the estimate. Issues and items that can potentially impact project cost or schedule in a significant way are identified in a list—or "red flagged"—and the list is kept current as the project progresses through development.

Why?

By listing items that can potentially impact a project's cost or schedule, and by keeping the list current, the project team has a better perspective for setting proper contingencies and controlling cost escalation. Occasionally, items that are considered a risk are mentioned in planning but soon forgotten. The red flag item list facilitates communication between estimators and designers concerning these impacting items. By maintaining a running list, these items will not disappear from consideration and then later cause problems.

What Does It Do?

At the earliest stages of project development, an agency develops a list of impacting items, based primarily on engineering judgment or historical records of problems. The red flagging of these items may not involve any formal qualitative or quantitative risk analysis of the factors, but it keeps the team mindful of their existence. The list also helps the team to remove contingency from the project cost estimate as the design progresses and risk issues are resolved.

When?

The composition of a red flag item list is done in the earliest stages of project development. The list should then be updated at each major milestone or as new items are identified. The list will be most useful if it is maintained and updated throughout the project development process.

Examples

California DOT has developed a sample list of risk in its *Project Risk Management Handbook.* The list is provided in Tables I2.1-1 through I2.1-4. This sample list of risks can be used as the basis for creating a list of red flag items for an individual project. The Caltrans list is quite comprehensive, and any single project's list of red flag items should not include all of these elements.

Washington State DOT also uses a "Sample Risk Elements" checklist for its cost risk assessment process. Sections I2.2 and R3.5 provide tools to help filter (qualitatively or quantitatively) the risks for each project to ensure that only the most critical risks in terms of cost impacts are being considered.

Tips

The list of red flag items should be developed in an interdisciplinary team environment. This activity works well during the scoping process. Consider brainstorming sessions with representatives from multiple discipline areas for creation of a list of red flag items. In addition to scoping documents or lists of standard items like that in Tables I2.1-1 through I2.1-4, individuals should use their own knowledge of the project and consult with others who have significant knowledge of the project or its environment.

Resources

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook.*

Curran, Michael W. (1998). *Professional Practice Guide #2: Risk.* Association for the Advancement of Cost Engineering International.

FHWA (2004). *Major Project Program Cost Estimating Guidance.*

Grey, S. (1995). *Practical Risk Assessment for Project Managers.* John Wiley and Sons, Chichester, England.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3.

NCHRP (2005). NCHRP Project 20-7/172 Final Report, Recommended AASHTO Design-Build Procurement Guide, Washington, D.C.

Table I2.1-1. Caltrans sample technical risks list.

Risk Category	Individual Risks
Technical Risks	❒ Design incomplete
	❒ Right of Way analysis in error
	❒ Environmental analysis incomplete or in error
	❒ Unexpected geotechnical issues
	❒ Change requests because of errors
	❒ Inaccurate assumptions on technical issues in planning stage
	❒ Surveys late and/or surveys in error
	❒ Materials/geotechnical/foundation in error
	❒ Structural designs incomplete or in error
	❒ Hazardous waste site analysis incomplete or in error
	❒ Need for design exceptions
	❒ Consultant design not up to Department standards
	❒ Context sensitive solutions
	❒ Fact sheet requirements (exceptions to standards)

Table I2.1-2. Caltrans sample external and environmental risk list.

Risk Category	Individual Risks
External Risks	❒ Landowners unwilling to sell ❒ Priorities change on existing program ❒ Inconsistent cost, time, scope, and quality objectives ❒ Local communities pose objections ❒ Funding changes for fiscal year ❒ Political factors change ❒ Stakeholders request late changes ❒ New stakeholders emerge and demand new work ❒ Influential stakeholders request additional needs to serve their own commercial purposes ❒ Threat of lawsuits ❒ Stakeholders choose time and/or cost over quality
Environmental Risks	❒ Permits or agency actions delayed or take longer than expected ❒ New information required for permits ❒ Environmental regulations change ❒ Water quality regulation changes ❒ Reviewing agency requires higher-level review than assumed ❒ Lack of specialized staff (biology, anthropology, archeology, etc.) ❒ Historic site, endangered species, wetlands present ❒ EIS required ❒ Controversy on environmental grounds expected ❒ Environmental analysis on new alignments is required ❒ Formal NEPA/404 consultation is required ❒ Formal Section 7 consultation is required ❒ Section 106 issues expected ❒ Project in an area of high sensitivity for paleontology ❒ Section 4(f) resources affected ❒ Project in the Coastal Zone ❒ Project on a Scenic Highway ❒ Project near a Wild and Scenic River ❒ Project in a floodplain or a regulatory floodway ❒ Project does not conform to the state implementation plan for air quality at the program and plan level ❒ Water quality issues ❒ Negative community impacts expected ❒ Hazardous waste preliminary site investigation required ❒ Growth inducement issues ❒ Cumulative impact issues ❒ Pressure to compress the environmental schedule

Project Management Institute (2004). *A Guide to Project Management Body of Knowledge* (PMBOK Guide).

Washington State DOT (2006). Cost Estimating Validation Process (CEVP) website: www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

I2.2 Risk Charter

The creation of a risk charter is a more formal identification of risks than the listing of red flag items described in Section I2.1. This tool is typically completed as part of a formal and rigorous risk management plan. The risk charter helps to set estimate contingencies and monitor potential cost escalation. It provides estimators with a list of significant risks and includes information about the cost impacts and schedule impacts that these risks might have. It also supports the contingency resolution process by tracking changes to the magnitude of potential cost and schedule risk impacts as the project progresses through the development process and the risks are resolved.

What Is It?

A risk charter is a document containing the results of a qualitative or quantitative risk analysis. It is similar to a list of red flag items (see Section I2.1), but typically contains more detailed information concerning the potential impact of the risks and the mitigation planning. The risk charter contains a list of identified risks, including description, category, and cause. It may contain measurements of magnitude such as the probability and impact of occurrence. It may also contain proposed mitigation responses, "owners" of the risk, and current status. This method may be more effective than simply listing the potential problem areas, as with the red flagging, since it is

Table I2.1-3. Caltrans sample organizational and project management risk list.

Risk Category	Individual Risks
Organizational Risks	❒ Inexperienced staff assigned ❒ Losing critical staff at crucial point of the project ❒ Insufficient time to plan ❒ Unanticipated project manger workload ❒ Internal "red tape" causes delay getting approvals, decisions ❒ Functional units not available, overloaded ❒ Lack of understanding of complex internal funding procedures ❒ Not enough time to plan ❒ Priorities change on existing program ❒ New priority project inserted into program ❒ Inconsistent cost, time, scope and quality objectives
Project Management Risks	❒ Project purpose and need is poorly defined ❒ Project scope definition is poor or incomplete ❒ Project scope, schedule, objectives, cost, and deliverables are not clearly defined or understood ❒ No control over staff priorities ❒ Too many projects ❒ Consultant or contractor delays ❒ Estimating and/or scheduling errors ❒ Unplanned work that must be accommodated ❒ Communication breakdown with project team ❒ Pressure to deliver project on an accelerated schedule ❒ Lack of coordination/communication ❒ Lack of upper management support ❒ Change in key staffing throughout the project ❒ Inexperienced workforce/inadequate staff/resource availability ❒ Local agency issues ❒ Public awareness/support ❒ Agreements

Table I2.1-4. Caltrans sample right of way, construction, and regulatory risk list.

Risk Category	Individual Risks
Right of Way Risks	❒ Utility relocation may not happen in time ❒ Freeway agreements ❒ Railroad involvement ❒ Objections to Right of Way appraisal take more time and/or money
Construction Risks	❒ Inaccurate contract time estimates ❒ Permit work windows ❒ Utility ❒ Surveys ❒ Buried man-made objects/unidentified hazardous waste
Regulatory Risks	❒ Water quality regulations change ❒ New permits or new information required ❒ Reviewing agency requires higher-level review than assumed

integrated into the risk monitoring and control processes. The terms "risk charter" and "risk register" are synonymous in the industry.

Why?

A risk charter is used to identify, communicate, monitor, and control risks. It provides assistance in setting appropriate contingencies and managing the cost estimation process. As part of a comprehensive risk management plan, the risk charter can help to control cost escalation. It is appropriate for large or complex projects that have significant uncertainty.

What Does It Do?

The charter organizes risks that can impact project cost and project delivery. A risk charter is typically based on either a qualitative or quantitative assessment of risk, rather than simple engineering judgment. The identified risks are listed with relevant information for quantifying, controlling, and monitoring. The risk charter may include relevant information, such as the following:

- Risk description
- Status
- Date identified
- Project phase
- Functional assignment
- Risk trigger
- Probability of occurrence (%)
- Impact ($ or days)
- Response actions
- Responsibility (task manager)

When?

This technique can be used throughout project development. At the earliest stages of project development, the risk charter will be helpful in a risk identification capacity. As the project progresses, more rigorous and quantitative risk management can be done and the charter will become an even more valuable tool for cost estimation management and risk monitoring and control.

Examples

Washington State DOT has built a Cost Estimating Validation Process (CEVP). The CEVP uses a risk charter (or risk register) as a fundamental tool in its comprehensive validation process. The CEVP is explained in more detail in Sections C1.2 and R3.5. Figures I2.2-1 and I2.2-2 show two aspects of the CEVP that are relevant to describing a risk charter. Figure I2.2-1 provides a summary example from a risk identification exercise that is part of the CEVP. Figure I2.2-2 provides a summary of risk descriptions in the risk charter for the CEVP analyses. For more information on these first nine projects, see K. R. Molenaar's 2005 article, "Programmatic Cost Risk Analysis for Highway Mega-Projects," in *ASCE Journal of Construction Engineering and Management,* Vol. 131, No. 3, pp. 343–353.

For more information on the current CEVP, see the Washington State DOT's 2006 CEVP website at www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

Tips

The risk charter should be developed in conjunction with a comprehensive risk management plan. It should be developed in an interdisciplinary team environment and may require external facilitation.

Resources

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook.*

Risk Issue: Commercial Property Value

Issue: Project ROW costs were developed by applying a percentage increase to the assessed valuations for each parcel. During the CEVP review the estimated cost of commercial properties carried in the ROW estimate for the project have been updated, and the multiplier increased to 75% of the assessed value, to better reflect current market conditions. There is a low level of confidence in the updated values and it is estimated that actual market conditions may be as high as 100% of the assessed valuations.

Impacts: The actual market conditions will increase the cost of acquiring commercial properties by an average of $25M. There are no significant schedule impacts.

Probability: 85%.

Mitigation: Monitor the commercial real estate market and track the actual cost of recent transactions. Keep the project ROW estimate up to date and reflective of the current commercial property real estate market. Buy early if appropriate.

Figure I2.2-1. Summary example of risk event identification exercise that is part of WSDOT's CEVP.

Market Conditions

Implementing several mega-projects at the same time may create a shortage in management, contractors, financing/funding, labor, and material.

Labor Disruptions

Labor shutdowns are likely.

Storm Water Treatment and/or Quantities

Stricter requirements in the future would require additional cost to provide additional detention ponds, the collecting and treatment of all runoff, which may have a base amount in the estimate but there may be higher amounts of treatment required or higher then expected volumes.

Changes in Permitting

Permit requirements may change over the long duration of some projects.

Off and On Site Wetlands

There is a chance that conditions actually encountered in the field may be different than assumed when the base estimate was compiled and the measures used my also change requiring additional mitigation.

Environmental Impact Statement

Disagreement between WSDOT and resource agencies and/or among agencies and the public on project impacts and associated disagreement on mitigation approaches may prompt impacts.

NEPA/404 Merger Process

Failure to reach concurrence on the range of alternatives and a preferred alternative could delay the environmental process.

Utility Issues

Routine investigations and coordination with utility companies can identify and relocate conflicting utilities throughout the project. However, unforeseen discovery of previously unknown utilities, and the need to relocate these utilities after the job is awarded and construction has started can be a significant cost and schedule liability to the project. Utilities, adjacent landowners, and other affected parties may demand "betterment" or excessive mitigation.

Rail Lines (Regular and Light)

Regional and national offices may need to approve new railroad alignments and ROW or the encroachment of new highway alignment on existing rail ROW.

Figure I2.2-2. Summary risk charter risk descriptions from the WSDOT CEVP analyses.

Curran, Michael W. (1998). *Professional Practice Guide #2: Risk.* Association for the Advancement of Cost Engineering International.

FHWA (2004). *Major Project Program Cost Estimating Guidance.*

Grey, S. (1995). *Practical Risk Assessment for Project Managers.* John Wiley and Sons, Chichester, England.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3.

NCHRP (2005). NCHRP Project 20-7/172 Final Report: Recommended AASHTO Design-Build Procurement Guide.

Project Management Institute (2004). *A Guide to Project Management Body of Knowledge* (PMBOK Guide).

Washington State DOT (2006). Cost Estimating Validation Process (CEVP) website: www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

I3 Identifying Off-Prism Issues

The macroenvironment can affect project cost in two ways: (1) by being unknown or unrecognized by project managers and estimators and (2) by changes in the environment that are completely external to the project. Unlike other aspects of project planning and estimation, understanding the macroenvironment—that is, the *off-prism* issues—has never been standardized as part of project estimation. It is therefore important to develop planning processes that focus on community concerns, externally imposed requirements, and external market conditions.

I3.1 Environmental Assessment

Environmental assessments are an integral component of the project delivery process. Mitigation of environmental issues is a cost to the project. Environmental assessments iden-

Right of Way Acquisition Problems

Changing property values, revolving funds, etc. may cause problems along with property owners who may hold out and cause economic problems and/or delays.

Right of Way Value and Impact

Several risks may be encountered such as property owner relocation, sudden growth, and area development, which may cause monetary and time impacts.

Program Management

The organizational make-up of WSDOT is being revised to accommodate mega-projects. This management structure will need constant care and feeding to ensure that decisions and information are growing in a responsible way.

Geotechnical Conditions

Inadequate geotechnical investigations during the conceptual and alignment selection phases can cause unforeseen conditions during excavation and construction of tunnels, bridges, walls, etc. This could be compounded by inadequate characterization of groundwater conditions.

Design Change in Seismic Criteria

The American Association of State Highway Transportation Officials (AASHTO) is developing new seismic design criteria for bridges. The timing of the release of this criteria and WSDOT's adoption of the criteria is uncertain.

Bridge Foundations

The foundation type for bridges in the project may need to be adapted to new information that becomes available as the project progresses.

Local Arterial Improvements and Access

Local agencies may demand additional improvements to local arterials as a condition for support of the project.

Inadequate Design/Design Uncertainty for Interchanges

Interchanges may be planned but there may be some uncertainty from the design (i.e. unit cost, inadequate design, deviation approval, municipality involvement, etc.)

Traffic Demand

Traffic demands may not be accurate in some areas (i.e. inconsistent growth patterns, age of traffic projections).

Contaminated Soil

It is possible that even after thorough due diligence and the identification of contaminated sources during design of the project, new contaminated soils or groundwater may result in discovery of new or unknown conditions that need to be taken care of during construction.

Natural Hazards

Storms, floods, earthquakes, etc. can cause damage to work under construction and may result in shut down during construction. Such conditions damage the temporary water pollution controls, temporary structures, and earthwork, which must then be repaired.

Work Window

There may be restrictions in conducting some activities (i.e. earthwork) during some parts of the year (i.e. winter).

Auxiliary Lanes

There may be uncertainty regarding if auxiliary lanes are going to be used/constructed temporarily during construction and/or permanently.

Staging Areas

Due to limitations in ROW and traffic flow staging areas may be inadequate for construction.

Figure I2.2-2. (Continued).

tify potential project scope issues related to ensuring that an appropriate cost is included in the project estimate to cover environmental mitigation.

What Is It?

An environmental assessment is a concise public document that a state agency prepares under the National Environmental Policy Act (NEPA) to provide sufficient evidence and analysis to determine whether a proposed agency action would require preparation of an environmental impact statement (EIS) or a finding of no significant impact (FONSI).

NEPA was signed into law on January 1, 1970. The act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment, and it provides a process for implementing these goals within the federal and state agencies. Many times, environmental issues driven by parties external to a project can cause additions to project scope that significantly affect project cost. This tool seeks to direct state highway agency attention to exploring these possibilities during project development in a proactive instead of reactive manner.

Why?

A study made by the U.S. General Accounting Office identified expedition of the authorizations from environmental and resource agencies as one of the most promising approaches for reducing the time it takes to plan, design, gain approval for, and build a federally funded highway project. For works in which the environmental impact is considerable, mitigation measures may pose a significant cost. Failing to consider these regulations may jeopardize not only the original budget, but also the whole project.

What Does It Do?

An environmental impact assessment (EIA) is a sound precaution and a proactive measure. Increasingly, successful project development is viewed in terms of its final result—its operational environmental performance, its acceptance by stakeholders, its contribution to sustainable development, and, critically, the scale or magnitude of environmental impact over all life cycle phases. For astute proponents, the evidence suggests that EIA followup has a valuable role to play in good project development practice.

When?

Environmental considerations are evaluated from the inception of a project and are constantly reviewed during all phases of project development. However, the impact of environmental regulations on a project is most critical during the programming and early in the preliminary engineering. The NEPA process must be completed, and all potential impacts considered, prior to full design of the project. This may require that several alternatives be investigated and related costs compared in terms of potential mitigation solutions to address environmental issues.

Examples

The FHWA document, *Major Project Program Cost Estimating Guidance,* June 4, 2004, specifically calls attention to environmental work that affects project cost:

> **Environmental Work:** Although the intent of a project may be to avoid environmentally sensitive resources, some degree of environmental consideration and analysis is required for all major projects. If work associated with the alternative in the NEPA document is not included as part of the cost estimate, the NEPA document should note where the cost for the outstanding cost element could be found. For example, this could be short-term improvements that are already included in the Statewide Transportation Improvement Program (STIP). Any additional environmental avoidance, minimization, mitigation, remediation, and enhancement costs must also be included in the cost estimate. Costs to mitigate impacts to natural resources, cultural resources, neighborhoods, and so on, must either be individually estimated or included in a contingency amount. Although large contingencies may be appropriate if no resource surveys have been conducted, resource surveys conducted as part of the NEPA process provide valuable information for refining cost estimates. Additionally, some major projects may have enhancement work that is not directly related to the project. This may include other transportation modes and non-transportation related work. These costs must be captured and included in the cost estimate. A major project that has a potentially significant effect or impacts on environmental resources or has opposition from environmental or community groups or regulatory agencies, tends to include more environmental mitigation which results in higher costs than those projects with relatively little impact or oppositions. Moreover, contingencies should be included for projects that include Intelligent Transportation System attributes, as well as in those States that are implementing Context Sensitive Strategies/Context Sensitive Design since very little historical data exists or is included in previous cost figures.

Tips

Federal, state, tribal, or local agencies having special expertise with respect to an environmental issue or jurisdiction by law may be a cooperating agency in the NEPA process. A cooperating agency has the responsibility to assist the lead agency by participating in the NEPA process at the earliest possible time; by participating in the scoping process; by developing information and preparing environmental analyses that include portions of the environmental impact statement wherein the cooperating agency has special expertise; and by making available staff support at the lead agency's request to enhance the lead agency's interdisciplinary capabilities.

Basic information about the NEPA process is available online: www.epa.gov/compliance/basics/nepa.html#requirement.

Resources

U.S. General Accounting Office (2003). *Perceptions of Stakeholders on Approaches to Reduce Highway Project Completion Time,* report GAO-03-398. http://www.gao.gov/new.items/d03398.pdf.

Marshall, Ross (September 2005). "Environmental Impact Assessment Follow-Up and Its Benefits for Industry," *Impact Assessment and Project Appraisal,* Vol. 23, No. 3.

NEPA website: www.epa.gov/compliance/basics/nepa.html.

I3.2 Percentage of Total Project Cost (Also See E3.2)

In the case of most conventional projects, engineers focus on technical solutions and pay little attention to community interest or the macroeconomic environment. However, market forces and third-party interventions can have a major impact on project cost and must be accounted for in the estimation process.

What Is It?

Frequently, in early estimation, the scope of a particular item or items cannot be quantitatively determined. However, the estimator knows from history that there will be a need to include costs for scope that is not adequately defined. Off-prism issues are issues that are often difficult to define in programming and early in preliminary engineering. These issues are often project specific and based on factors such as geographical locations, political climate, interests of the community, and economic environment, among others. One tool to account for the cost related to potential off-prism issues is to include a percentage allowance for scope that the estimator knows is required but cannot adequately define at the time of the estimate. The percentage used should be based on history and judgment of the estimator in consultation with the project team and based on the specific project location and conditions. Thus, a case-by-case evaluation of the cost impact of off-prism issues is necessary to properly implement this tool.

Why?

Every project is executed in the context of a particular political, economic, and cultural environment. The potential impact on cost of off-prism issues must be considered. Costs to mitigate impacts to natural resources, cultural resources, neighborhoods, and so on must be either individually estimated or included in the estimate as an allowance amount. It is advisable to account for any such occurrences, and an acceptable quantification of these impacts is often recognized in the form of a percentage of total project costs.

What Does It Do?

This tool acts as a safeguard to reduce the chance of any cost overruns due to known but unquantified circumstances related to off-prism issues.

When?

It is beneficial to include an allowance for off-prism issues early in programming and preliminary design and assess if the assumed percentage is reasonable based on project scope development and the location of the project. Inclusion of the allowance is especially critical when setting a project baseline cost that is programmed.

Examples

Using historical cost data, Caltrans has sometimes estimated capital outlay support cost in the environmental process as a percentage of the estimated project construction cost. In the case of one particular project, this was a straight 1% of the estimated construction cost estimate. Caltrans also spreads this total amount across the project schedule and applies an annual escalation rate (i.e., inflation rate) to the outlay timed amounts.

Tips

An alternative to handling the potential cost of off-prism issues is to identify these items as risks to the project and cover them in contingency.

Resources

More information is available from the FHWA's publication, "Major Project Program Cost Estimating Guidance," June 8, 2004, http://www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

I3.3 Market Conditions

The price for a commodity or service is dependent upon the market conditions and the situations of the contractor and agency, as well as the cost to actually secure the necessary materials and perform the work. Existing and projected market forces have a substantial impact on the cost of a project. The actual impact of such forces can vary significantly depending on the specific date on which a contract is advertised and bid and depending on the type of materials that are required to construct the work. Many market condition circumstances are beyond the control of a state highway agency and will affect all purchasers of construction services, but not always in the same way because of the different risk-shifting contract clauses.

What Is It?

This is a tool that establishes a formal process to analyze market capability to respond to the project as designed and packaged for bid. The process seeks to provide management with assurance that cost impacts driven by market conditions, both global pressures on material prices and the local construction situation, have been considered in developing the project's design, contract packaging, and estimated cost.

Why?

In developing a cost estimate, it is necessary to consider changes in the contracting situation and in general economic conditions. This is particularly true whenever historical prices are being used. Contractors usually enter into contracts with state highway agencies, which fix the price over the term of a project, but for some materials the contractor cannot secure fixed prices from the suppliers; therefore, project bidders must account for the risk of fluctuating material prices in their bids.

What Does It Do?

Contracting firms must develop strategies to minimize their risks. A primary strategy involves increased cost to the project owner. In the case of risks that cannot be quantified, such as volatility of material prices or even the availability of materials, that cost increase can be significant. Additionally, if the contractor perceives that an owner is seeking through the contract language to shift risk to the builder, sufficient additional cost will be included in the bid to cover that added financial exposure. This tool is the establishment of a structured process to continually analyze market forces—cost of materials and availability of competition—and the impact of market changes on project cost.

When?

Market conditions are volatile and will most likely change after a project is initiated but before issuance of bid documents; therefore, the process of evaluating market conditions and their affect on the estimate must be continuous through all phases of project development. When a change in market conditions is identified, the estimate must be adjusted to reflect the new conditions.

Examples

The FHWA document *Major Project Program Cost Estimating Guidance,* June 4, 2004, specifically calls attention to the following market condition factors that affect project cost:

- **Acquisition strategy analysis:** A separate analysis should consider the most economical and advantageous way of packaging the contracts for advertisement.
- **Bidding climate impact:** Estimators should consider the economic impact of the project on the local economy. For example, material manufacturers that would normally compete with one another may need to combine resources in order 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 capacity to do the work, and the project may need to be split into smaller contracts to attract additional competition. In addition, the timing of the bid solicitations can affect the cost. Cost estimates should consider availability of labor.
- **Industry capacity:** The number of potential qualified contractors that are able to bid on a project is limited as project size increases. Contractors that bid on major projects often bid on projects throughout the country. If other major projects are being advertised concurrently, this may have a limiting effect of competition and can result in higher bids.
- **Highly specialized designs and technology:** Cost estimates should consider the impact of any requirement to use first-of-a-kind technology, new materials, or innovative construction methods.

Tips

A market survey should be carried out on sizable projects to determine where the bidders will come from—is the local market sufficiently large to accommodate the project, or will the major subcontractors be at capacity and therefore likely to bid high, if at all?

Also, a reading of the market prior to finalizing the PS&E is useful for validating the estimate and can be included in a risk assessment to determine a range of expected bids.

Three circumstances are worthy of special consideration:

- Changes in the level of competition
- Limited competition
- Differing economic conditions

Continuously update the estimate to reflect current market conditions.

Resources

FHWA (2004). *Major Project Program Cost Estimating Guidance.* www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Caltrans Division of Engineering Services (November 15, 2001). "Impact of Competition on Final Bid Results for Transportation Related Construction Project (Draft)."

Merrow, Edward W., Kenneth E. Phillips, and Christopher W. Myers (1981). *Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants,* Rand Corporation. http://www.rand.org/pubs/reports/R2569.

Merrow, Edward W. (1988). *Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects,* Rand Corporation. http://www.rand.org/pubs/reports/R3560.

Sawyer, John E. (1951–1952). "Entrepreneurial Error and Economic Growth," *Explorations in Entrepreneurial History,* Vol. 4, No. 4, pp. 199–204, 1951–52.

Merrow, Edward W. (1986). *A Quantitative Assessment of R&D Requirements for Solids Processing Technology Process Plants,* Rand Corporation. http://www.rand.org/pubs/reports/R3216.

Maryland DOT (March 1, 2002). "Summary of Independent Review Committee Findings Regarding the Woodrow Wilson Bridge Superstructure Contract." The full report is available from the MDOT.

Woodrow Wilson Bridge Project Bridge Superstructure Contract (BR-3): Review of the Engineer's Estimate vs. the Single Bid, February 28, 2002. This report is available from Maryland DOT.

P1 Plans, Specifications, and Estimates (PS&E)

The PS&E is based upon very definitive contract documents that reflect the project's final design. It is used to finalize project funding prior to bid solicitation and as a baseline for evaluating the bids.

There are three basic approaches used by state highway agencies for PS&E:

1. **Historical data:** The use of historical data from recently awarded contracts is the most common state highway agency estimation approach. Under this approach, bid data are summarized and adjusted for project conditions (project location, size, quantities, etc.) and the general market conditions. This approach requires the least amount of time and personnel to develop the estimate and produces a good estimate, as long as noncompetitive bid prices are excluded from the database and appropriately adjusted data are used to build the estimate.
2. **Bottom up:** The detailed bottom-up estimate approach based on specific crews, equipment, production rates, and material costs 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.
3. **Combined:** Most projects contain a small number of items that together account for a significant portion of the project's total cost. These significant 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 bottom-up approach. The remaining items are estimated based on historical prices and adjusted as appropriate for the specific project.

P1.1 Agency Estimation Software (Also See C2.1, C3.1, D2.2)

Estimation software provides the ability to manage large data sets that support estimate development for all project types and across the range of project complexity. Estimation software can support all three costing approaches—historical data, bottom up, and combined. The use of estimation software eases the task of tracking project estimates through all phases of development and can assist in estimate and schedule reviews. Some state highway agencies have taken the initiative to develop their own estimation software. A survey in 2002 found that 18 state highway agencies are using software programs that were developed within the agency. These agency-developed estimation programs are usually subprograms of project management software that serves multiple needs beyond cost estimation and therefore are often not tailored to the specific needs of cost estimators. This is true of the Basic Engineering Estimating System discussed in the example section.

What Is It?

Agency estimation software is specifically designed to serve the estimation practice of a specific state highway agency. This usually means that the program has been designed around the agency's existing historical data files on project components, items, and costs. The software is designed to address very explicit agency approaches and satisfy discrete agency objectives.

Why?

Because of the computer's ability to handle large data sets and the flexibility it provides in specifying calculation processes, estimation software provides the estimator with a tool that rapidly handles the repetitive calculations needed to produce an estimate. The software usually has search routines that allow the user to speedily search for specific information in the supporting historical databases. The information search ability of a computer is an important asset in developing estimates for projects having a large number of cost (i.e., work) items.

What Does It Do?

Agency software, besides providing a calculation framework, allows the estimator to effectively employ the agency's historical databases in a selective yet rapid manner. The software should also be capable of performing "what-if" analyses. Typically, the software, be it agency or commercial, provides a sequential record of the data used to generate the estimate and all assumptions.

When?

To address very specific PS&E requirements, custom agency software may be the only solution. Agency software can be very good in addressing distinctive requirements imposed on any individual state highway agency; however, software development is tedious and costly, and continuing support is a critical issue. Agencies must therefore recognize the size and complexity of the software development undertaking and must balance such a commitment against the performance of commercially developed and supported software, such as AASHTO's Trns•port, which has been developed specifically to meet the needs of state highway agency estimation.

Examples

One state highway agency that approaches project estimation by building estimated cost from the bottom up currently uses a slightly modified commercial estimation program. The commercial program is used by many contractors and was originally developed to facilitate detailed estimation by a large contracting organization. This program and similar ones of this type enable state highway agencies to develop estimates from the bottom up based on crew productivity, construction methods, and selected equipment.

California DOT (Caltrans) has its Basic Engineering Estimating System (BEES). General information about BEES can be found in the Caltrans Plans, Specifications and Estimates Guide. BEES has the capability of segregating estimates by structure, alternative designs, and so forth. The BEES software is a subsystem of the Caltrans Project Information System and Analysis (PISA) and uses the information contained in the Caltrans Project Management Control System (PMCS) and their Standard Item List. The estimate data are available for bid opening purposes and for contract progress payments.

Tips

It is important that agency-developed software be user friendly and structured so that it is easy to input the required data. To be usable and reliable, estimation software must:

- Provide a precise, unambiguous definition of every element or group of elements used in the design of the software
- Perform diagnostics to the extent that the completion status of every bid item is known at any given time during estimate preparation
- Be mathematically consistent and automatically make adjustments everywhere when a revision is made
- Be devoid of instructions using program file names or other programming language
- Have databases designed so they are accessible within an extremely short time without scrolling through a myriad of items
- Allow the use of arbitrary unit prices not drawn from the database
- Allow the estimator to have cost templates for standard items
- Identify the source (database or plug) of all prices
- Be able to sort and print the data generated by the estimate in several different formats
- Automatically identify prices that are outside of specified ranges

Resources

Washington State DOT, Barlist bridge software download site, www.wsdot.wa.gov/eesc/bridge/software/index.cfm?fuseaction=download&software_id=45.

Caltrans, "Chapter 20: Project Development Cost Estimates," *Project Development Procedures Manual* (PDPM). www.dot.ca.gov/hq/oppd/pdpm/chap_htm/chapt20/chapt20.htm.

A list of Basic Engineering Estimating System (BEES) standard contract items and the weighted averages of the low bidder's prices for those items can be found at www.dot.ca.gov/hq/esc/oe/awards.

P1.2 Commercial Estimation Software (Also See C2.2, C3.2)

Because writing good software is extremely time intensive and requires a qualified staff of professional programmers who are knowledgeable about the task the software is to perform, many agencies use commercial estimation software that has already been validated and documented before release. In the case of state highway agencies, the most widely used commercial estimation software is Estimator by InfoTech. Estimator is a module of Trns•port. Trns•port is owned by InfoTech, Inc., and fully licensed by AASHTO under that name. Using this software, state highway agencies can prepare item-level estimates derived from bid histories or from cost-based estimation. A Construction Financial Management Association survey in 2004 identified HeavyBid, Hard Dollar, Bid2Win, and Timberline as the major estimation software used by the heavy construction industry. It is also interesting to note that the same survey found that about 26% of the market uses Microsoft Excel.

What Is It?

Estimation software is any computer program that assists the state highway agency in developing project cost estimates. Estimation software has preloaded templates that help the estimator and project team define the project scope, cost, and schedule. The software provides a means to track project development and can assist in project reviews. Several very good commercial programs are available and being used by a large number of state highway agencies.

Why?

Because development and maintenance of specialized agency software can be expensive and requires special talents, it is often more economical to use commercially available software, which spreads the program's development and maintenance cost over a larger user base. Software providers can also help state highway agencies structure their databases to better support the estimation process. Additionally, because the software provider works with many agencies and estimators, it has a broad knowledge of estimation and software issues.

What Does It Do?

Computers and estimation software enhance the ability of engineers to manage large data sets that are needed in developing estimates for all types of projects. Computers and estimation software can:

- Develop an unlimited number of estimates matched to project complexity and level of design, whether from scratch, other current estimates, or historical backups
- Easily change, back up, and store estimates
- Draw from unlimited amounts of historical cost information and/or labor and equipment rate tables
- Quickly copy entire estimates, individual or multiple work (i.e., bid) items, and/or activities from previous estimates
- Provide a record of what changes were made to the estimate and who made the changes

When?

Commercial estimation software offers the most effective way to prepare and manage estimates for medium to large projects involving multiple cost items. For very large, complex projects, software may be the only effective and efficient method. Most software can be used in the earliest stages of project development to create an estimate that can then be expanded at the PS&E stage when design is complete and quantities fully quantified.

Examples

The Cost Estimation System (CES) is the primary AASHTO Trns•port module for construction cost estimation. It provides a variety of estimation methods and full integration with the other Trns•port components. Available on the client/server platform and fully integrated with PES and BAMS/DSS (other Trns•port modules), CES provides an environment in which parametric, cost-based, and bid-based job cost estimates can be prepared. 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 state highway agencies is Bid Tabs by OMAN systems.

As of August 7, 2002:

- Trns•port is used by 22 state highway agencies.
- Bid Tabs is used either as a stand-alone or in conjunction with Trns•port by seven state highway agencies.
- Two other state highway agencies are in the process of testing Bid Tabs.
- One state highway agency uses HCSS HeavyBid, which is used by many contractors and was originally developed to facilitate detailed estimation by a large contracting organization. (See www.hcss.com/HBstdFeatures.asp.)
- One state highway agency uses AutoCAD to perform quantity takeoff for project estimates by combining plan views of the project area with elevation information to get a three-dimensional view of the project.

Tips

The estimator is the key to any estimation process and must know the capabilities and limitations of the software being used. Therefore, the effectiveness of any software is directly related to product support and training. When selecting software, always ensure that product support will be available and that training and training material will be provided.

Resources

For more information about Trns•port Estimator, contact the AASHTOWare contractor: Info Tech, 5700 SW 34th Street, Suite 1235, Gainesville, FL 32608. Phone (352) 381-4400; Fax (352) 381-4444; E-mail info@infotechfl.com; Internet www.infotechfl.com.

Oman Systems, Inc., P.O. Box 50820, Nashville, TN 37205. Phone (800) 541-0803; Fax 615-385-2507; Internet www.omanco.com.

Heavy Construction Systems Specialists, Inc. (HCSS), 6200 Savoy, Suite 1100, Houston, TX 77036. Phone (800) 683-3196 or (713) 270-4000; Fax (713) 270-0185; Internet www.hcss.com; E-mail info@hcss.com.

Hard Dollar BID*BUILD estimation and job control software built on a Microsoft's platform. http://www.harddollar.com/Solutions/project_driven/scheduling.asp.

BID2WIN software is a Windows-based cost estimation and bidding program built on Microsoft.NET and SQL Server technology, www.bid2win.com.

Timberline estimation software operates several different Microsoft platforms: www.sagetimberlineoffice.com/software/estimating/default.aspx.

P1.3 Cost Based

At the PS&E phase of project development, there exists adequate scope definition to generate detailed estimates from final plans and specifications. These estimates are based on a schedule of line items and calculated quantities for each line item. Cost-based estimation is one tool used to develop costs for detailed estimates. Cost-based estimation is similar to what contractors use to prepare estimates to support their bids. Nineteen state highway agencies perform detailed bottom-up estimates for major work items using historic databases to track costs based on crews, equipment, and production. Although state highway agencies do not use this tool as frequently as historical bid-based estimation (see Section P1.4), this tool is applied when the history related to the scope of the line item or items is not available. The difficulty in using cost-based estimation is obtaining accurate crew sizes and mixes and associated production rates.

What Is It?

Cost-based estimation is a tool to compute the unit cost for items of work by estimating the cost of each component to complete the work and then adding a reasonable amount for a contractor's overhead and profit. The concept requires the estimator to identify distinct work items in a project, which have complete definition so that quantities can be determined for these work items. These quantities can then be used to estimate costs for such construction components as labor, materials, and equipment to arrive at a realistic unit cost for an item.

Why?

The unique character of projects, geographical influences, market factors, and the volatility of material prices often makes historical pricing an unreliable method of estimating project costs. Cost-based estimation may provide more accurate and defendable costs to support the decision for contract award/rejection and any future price negotiations with the contractor. At the PS&E phase, work items are well defined so that the construction operations involved with a work item can be visualized to support the development of cost-based estimates.

What Does It Do?

Cost-based estimates contain six basic elements: time, equipment, labor, material, overhead, and profit. Generally, a work statement and set of drawings or specifications are used to "take off" material quantities required for each distinct task performed in accomplishing a given construction operation. From these quantities, direct labor, materials, and equipment are derived. Contractor overhead and profit are then added. The total cost divided by the quantity gives the unit price for the work item. This unit cost can then be input into the engineer's estimate to provide for a unit cost for the work item. This is necessary for the state highway agency to compare the engineer's estimate with the contractor's unit price bid for the same item.

When?

This tool is used most often when detailed plans and specifications are complete but there is a lack of historical bid data to estimate costs for a specific item of work. Typically, this work item is unusual in nature and not commonly encountered by the estimator. The estimator must still convert the cost-based estimate for an item to an equivalent unit price for incorporation into the engineer's estimate.

Examples

The AASHTO Subcommittee on Design Technical Committee on Cost Estimating is developing a guidance paper on cost-based estimation. The type of content covered in this paper is outlined below:

- Introduction
- Definitions
- Elements of a Cost-Based Estimate
- Building a Task
- Material
  - Quantity Breakdowns
  - Obtaining Prices
  - Quote Maintenance
- Equipment
  - Needs Identification
  - Ownership Rates
  - Operation Costs
  - Resources
- Labor
  - Needs Identification
  - Required Wage Rates
- Time
  - Production Rates

Effect on the Estimate
Resources
Overhead & Profit
Administration
Labor
Lump Sum Items
Software Applications
Examples
References

While still in draft form, this guidance provides quantitative examples of cost-based estimation for such items as material, equipment, labor, and time, as well as the application of these components in preparing the PS&E using this tool.

Tips

The estimator should have construction experience in order to be able to visualize a line item in terms of the operations needed to construct the work. The estimator also needs to locate sources of information related to production rates and crews, which includes calling suppliers of materials to obtain unit costs for materials and similar resources for determining equipment production and rental rates. This may require using a resource such as the *RSMeans Heavy Construction Cost Data.*

Resources

AASHTO Subcommittee on Design, Technical Committee on Cost Estimating, is developing guidance on historical bid-based estimation and cost-based estimation. Draft papers are prepared but not approved for release. To learn more, contact the Chair of this technical committee. See this website for key contact persons: http://design.transportation.org/?siteid=59&pageid=756.

Church, Horace K. (1981). *Excavation Handbook,* McGraw-Hill Book Company.

Associated General Contractors of America (1999). *Construction Estimating & Bidding Theory Principles Process.* Publication No. 3505.

R. S. Means (2006). “Heavy Construction Cost Data,” www.rsmeans.com.

Oberlender, Garold D., and Steven M. Trost (2001). “Predicting Accuracy of Early Cost Estimates Based on Estimate Quality,” *Journal of Construction Engineering and Management,* American Society of Civil Engineers, Vol. 127, No. 3, May/June.

Parker, Albert D., Donald S. Barrie, and Robert M. Snyder (1984). *Planning & Estimating Heavy Construction,* McGraw-Hill.

Rignwald, Richard C. (1993). *Means Heavy Construction Handbook,* R. S. Means Company.

R. S. Means Company (published annually). *RSMeans Building Construction Cost Data.* www.rsmeans.com.

R. S. Means Company (published annually). *RSMeans Heavy Construction Cost Data.* www.rsmeans.com.

Smith, Francis E. (1976). “Earthwork Volumes by Contour Method,” *Journal of the Construction Division,* American Society of Civil Engineers, Vol. 102, No. 1.

Frank R. Walker Company (published periodically). *Walker’s Building Estimator’s Reference Book.*

P1.4 Historical Bid Based (Also See D2.4)

Historical bid-based estimation is the most common approach used by state highway agencies. This approach relies heavily on line items with both quantities and good historical data for line-item cost. The historical data normally are based on bids from recent projects. The estimator adjusts the historical data to fit the current project characteristics and location.

What Is It?

Three basic approaches for developing an engineer’s estimates are typically used in practice. They are the historic bid-based and cost-based approaches and a combination of these two approaches. The most common approach used by state highway agencies in developing estimates for transportation projects is historical, or bid-based, estimation. There are many factors that need to be considered to develop an accurate engineer’s estimate using historical bid prices. These factors pose a certain level of risk in preparing estimates using this method. However, this method is the most common because it is very efficient and provides reasonable estimates on typical projects when using final plans and specifications.

Why?

Historical bid-based estimation is typically the most efficient method for developing an estimate for line items when adequate historical pricing data are available. Implementing a bid-history-based estimation process enables an agency to estimate the cost of proposed work using a minimum of resources. Similar projects with similar line items, quantities, and locations can be compared to quickly develop an estimate for the new project.

A bid history is essential for analysis of contract bids. Maintaining a strong bid history can discourage undesirable bidding practices. A bid history is also valuable for use in evaluating contractor-proposed changes, such as value engineering and analysis proposals. The information necessary for bid-based estimates can be useful when preparing preliminary estimates or comparing design alternatives.

What Does It Do?

This method uses data from recently bid contracts as a basis for the unit prices on the project being estimated. Data from previous projects is typically stored in a database for 3 to 5 years to provide the historical data to the estimator. The more data that are available and organized by project type, size, and location, the better resource the estimator has to produce an estimate that reflects the known scope and site conditions of the new project. Unit prices are adjusted for the specific project conditions in comparison to the previous projects. Adjustments are generally made based on the project location, size of the project, project risks, quantities, general market conditions, and other factors. The estimator has to rely on engineering judgment and experience to make these adjustments.

When?

This technique can be used as early as the programming phase but is validated to a greater extent in the PS&E stage, when project quantities are better known.

Examples

Collection, sorting, and retrieval of data are the key to success with this method. The usage of computer software provides an efficient way to handle the data.

To organize the data, it is helpful to collect data by category, such as general project information, bid data, and project-specific information. Using a data entry form, such as the one in Figure P1.4-1, to input general project information and project-specific information is an effective way to collect project information.

Using a spreadsheet is another effective way to import bid data. Figure P1.4-2 shows an example of bid data placed into a spreadsheet to be exported to a database.

Further, provisions are often made in the software to include project-specific or unique items, such as new line items, force account work, bidding climate, time of year, expected competition, other contracts, and specialty work. These types of provisions can aid in the estimation and improve estimate accuracy.

Tips

Several historical databases are available that provide current values for estimating costs of the various units of work for a project. The databases are compiled from records of actual project costs and ongoing price quotations from suppliers. The databases are published annually in the form of books, CDs, and computer-based extranets. There is, however, a danger of applying any historical database pricing without first adjusting the data for the particular aspects of the project under consideration. In construction, every project is unique, with a distinct set of local factors (such as size of project, desirability, level of competition, flexibility of specifications, work site, and hour restrictions) that come into play in bidding. When an estimation system that is attached to a price database is used, the estimator should still review each line item price to determine if it is applicable to the project being estimated. Blindly applying database prices can lead to inaccurate estimates.

Location factors should also be applied only after first considering the project size and particular nature to determine where the bidders will come from. If a large project is in a small town, the location factor for that town likely will not apply, as the bidders will be coming from elsewhere. The bids may, as a result, be much higher than the factor would indicate because the wages will be based on another location and the bidders may have to pay accommodation and travel costs for some of their workers.

Resources

The AASHTO Subcommittee on Design, Technical Committee on Cost Estimating, is developing guidance on historical bid-based estimation and cost-based estimation. Draft papers are prepared but not approved for release. To learn more, contact the chair of this technical committee. See this website for key contact persons: http://design.transportation.org/?siteid=59&pageid=756.

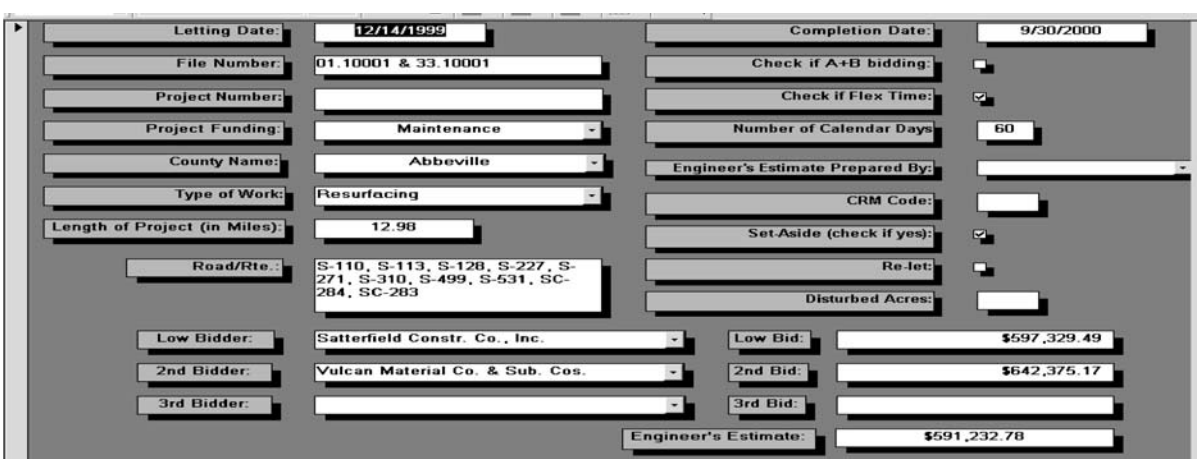


Figure P1.4-1. Data entry form example.

	A	B	C	D	E	F	G	H	I	J	K	L
1	File Number	County Number	District Number	Pay Item Number	Description	Units	Quantity	Engineer's Unit Price	Engineer's Amount	Low Bid Unit Price	2nd Low Bid Unit Price	3rd Low Bid Unit Price
2	01.7305.99	2	2	1031000	MOBILIZATION	LS	1	14246.04	14246.04	8000		
3	01.7305.99	2	2	1071000	TRAFFIC CONTROL	LS	1	45000	45000	26000		
4	01.7305.99	2	2	4011004	LIQUID ASPHALT BINDER PG64-22	TON	535.647	235	125877.05	240		
5	01.7305.99	2	2	4023000	H/M ASPH.CON.BINDER CR.-TYPE 2	TON	6612.905	48.88	323238.8	62		
6	01.7305.99	2	2	4033000	H/M ASPH.CONC.SURF.CR.- TYPE 3	TON	3306.455	56.37	186384.87	53.66		
7	01.7305.99	2	2	6020005	PERMANENT CONSTRUCTION SIGNS	SF	1270	10.97	13931.9	13		
8	01.7305.99	2	2	6040010	4"WH.SLD.LINE-PVT.EDGE-F.D.PNT	LF	148912	0.12	17869.44	0.12		
9	01.24051	1	2	1031000	MOBILIZATION	LS	1	4428.68	4428.68	10000	26500	8900
10	01.24051	1	2	1071000	TRAFFIC CONTROL	LS	1	7500	7500	7500	39750	85000
11	01.24051	1	2	2023000	REM. & DISP.OF EXIST. PAVEMENT	SY	4046	18	72828	12	23.5	15
12	01.24051	1	2	7203110	CONCRETE CURB & GUTTER(1'-6")	LF	1093	30	32790	34.5	31.25	45
13	01.24051	1	2	7204100	CONCRETE SIDEWALK(4" UNIFORM)	SY	2895	20.92	60563.4	32	44.85	45
14	01.24051	1	2	7204200	HANDICAP RAMP(CONCRETE)	EA	35	608.46	21296.1	695	1375	1250
15	01.24051	1	2	7205000	CONCRETE DRIVEWAY(6" UNIFORM)	SY	1042	25.39	26456.38	42	56.35	75
16	02.158B	2	1	1031000	MOBILIZATION	LS	1	50848.51	50848.51	55000	99850	40000
17	02.158B	2	1	1071000	TRAFFIC CONTROL	LS	1	35528.23	35528.23	56000	177050	270000
18	02.158B	2	1	2024100	REM. & DISP. OF EXISTING CURB	LF	20	13.29	265.8	10.5	154.5	150
19	02.158B	2	1	2027000	REM.& DISP.OF EXISTING CONC.	CY	29	16.95	491.55	95	154.5	150
20	02.158B	2	1	2033000	BORROW EXCAVATION	CY	2004	18.62	37314.48	21	33.75	32.75
21	02.158B	2	1	3069900	MAINTENANCE STONE	TON	940.25	15.32	14404.63	13.5	16	25
22	02.158B	2	1	4011004	LIQUID ASPHALT BINDER PG64-22	TON	2640.941	216	570443.26	245	291	285
23	02.158B	2	1	4012060	F.DEP.ASPH.PAV.PATCH-6" UNIF.	SY	3761	25.88	97334.68	35	34	33.5
24	02.158B	2	1	4013200	MILL. EXIST. ASPH. PVMT. 2.0"	SY	2440	7.85	19154	4.7	3.9	4
25	02.158B	2	1	4013400	MILL. EXIST. ASPH. PVMT. 4.0"	SY	266	14.17	3769.22	15	36.05	13
26	02.158B	2	1	4013990	MILL.EXIST.ASPH.PVMT.-VARIABLE	SY	27356	2.29	62645.24	2.2	2.8	2.25
27	02.158B	2	1	4031100	H/M ASPH.CONC.SURF. CR. TYPE 1	TON	3001	47.09	141317.09	45.75	72	70
28	02.158B	2	1	4031400	H/M AC SURF. CR. TYPE 1C	TON	46318.332	38	1760096.6	43.75	42	45
29	02.158B	2	1	5021011	F.D.CONC.PAVT.PATCH-8"	SY	392	60	23520	90	139.05	150
30	02.158B	2	1	5041300	CLEAN & SEAL TRANS. JTS.	LF	648	3.76	2436.48	7.3	5.15	50
31	02.158B	2	1	6020005	PERMANENT CONSTRUCTION SIGNS	SF	2642	8.68	22932.56	8.5	9.8	8
32	02.158B	2	1	6040005	4"WH.BRKN.LINE-GAP EX-F.D.PNT.	LF	8147	0.11	896.17	0.09	0.08	0.09
33	02.158B	2	1	6040010	4"WH.SLD.LINE-PVT.EDGE-F.D.PNT	LF	293454	0.09	26410.86	0.09	0.08	0.09
34	02.158B	2	1	6040012	6"WH.SLD.LINE-PVT.EDGE-F.D.PNT	LF	200	0.12	24	0.15	0.12	0.13
35	02.158B	2	1	6040025	24"WH.SLD.LNE-STOP/DIA-F.D.PNT	LF	1642	1.85	3037.7	2.8	2.6	2.6
36	02.158B	2	1	6040030	WH.SING.ARRW-LT,STR,RT-F.D.PNT	EA	21	30.78	646.38	28.2	25.75	28
37	02.158B	2	1	6040035	WH.WORD MESSAGE-"ONLY"-F.D.PNT	EA	1	40.97	40.97	45	41.2	42
38	02.158B	2	1	6040045	RAILROAD CROSS.SYMBOLS-F.D.PNT	EA	2	105.53	211.06	110	103	105
39	02.158B	2	1	6040105	4"YEL.BRKN.LNE-GAP EXC-F.D.PNT	LF	16421	0.1	1642.1	0.09	0.08	0.09
40	02.158B	2	1	6040110	4"YEL.SLD.LNE-PVT EDGE-F.D.PNT	LF	227589.8	0.09	20483.08	0.09	0.08	0.09
41	02.158B	2	1	6040115	24"YELLOW DIAG.LINE-F.D.PNT.	LF	150	2.04	306	3.35	3.1	3.05

April (Special) / May / June / July / July (Special) / August / August (Special) / September / October / N

Figure P1.4-2. Example of bid data placed into a spreadsheet.

P1.5 Trns•port (Also See C3.5, D2.9)

Trns•port is the AASHTO-sponsored transportation agency management software. It is a robust transportation program management system. It uses the most current information systems technology and is based on the experience and needs of AASHTO's member agencies.

Trns•port capabilities encompass the full functionality of a construction contract management system. Trns•port is an integrated system consisting of 14 modular components, and AASHTOWare is continually updating the software with new modules. Figure P1.5 shows a generic estimation workflow and functional areas where Trns•port models can assist. Each module addresses the needs of the highway agency at a particular milestone in the construction contracting life cycle, representing three functional areas: preconstruction, construction, and decision support.

What Is It?

The Trns•port Proposal and Estimates System (PES) addresses the needs of the highway agency during the pre-

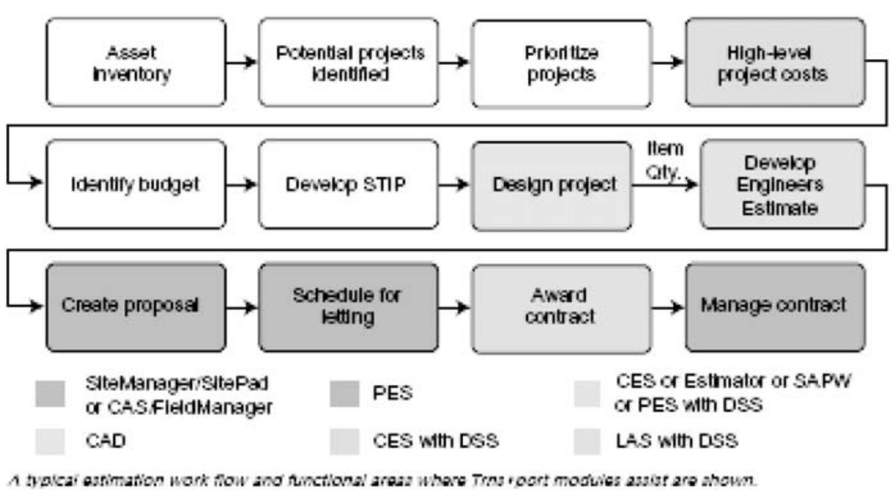


Figure P1.5. Estimation workflow and functional areas where Trns•port models assist.

letting phase of project development. PES supports preparation of the PS&E for state and federal aid highway construction projects. PES provides design, project construction administration, and estimation sections with tools to assist in project definition, funding specification, project cost estimation, contract proposal creation, and bid letting packaging.

Why?

The Trns•port PES module is designed for flexibility in project definition and in associated funding requirements (such as proposal creation using multiple funding units, differing construction engineering and contingency percentages, identification of special provisions and supplemental specifications, addendum processing, and alternative specifications at both category and line-item levels) to track and manage project scope and cost information.

What Does It Do?

The Trns•port PES module is an interactive, online system that enables management of project information during the pre-letting phase of a highway construction project development. PES permits the flexible definition of a project and its associated funding requirements to track and manage project cost information and set up a bidding proposal prior to the bid letting activity. It allows for data to be entered at the project, category, and item level. Grouping of multiple projects to track all related costs and funding sources is also possible. PES has import capabilities for receiving item and quantity data from design systems and can exchange data with the CES and estimating modules of Trns•port (see Sections D3.5 and D2.9).

When?

The PES module of Trns•port is most frequently used to support the PS&E phase and the development of an engineer's estimate.

Examples

In years past, the New York State DOT (NYSDOT) used the mainframe versions of Trns•port PES, LAS, and DSS, but as agencies moved from the mainframe to the client/server versions, AASHTO decided to drop support of the mainframe version. NYSDOT then migrated to the client/server version.

Tips

The estimator can use different reports generated by the PES module:

- Detailed cost estimate and funding summary
- Proposal schedule
- Special provisions listing
- Proposal schedule with estimated prices

The estimator must check all input and output to ensure that the estimated costs for major line items are within expected agency tolerances for the project type being estimated. This check can follow the Puerto principle, in that 80% of the estimated cost of construction is covered in 20% of the items. Comparing the overall estimate with estimates from recently bid or completed similar-type projects is another method of checking an estimate.

Additional information can be found on the following website: dot.state.ny.us/trns-port/about.html.

Resources

The Technology Implementation Company, Gainesville, Florida: www.infotechfl.com or www.cloverleaf.net.

AASHTOWare, Transportation Software Solutions, American Association of State Highway and Transportation Officials, www.aashtoware.org.

P2 Project Scoping

Scoping ensures that the development team is concentrating on the best opportunity for improvement. Projects have a greater success rate if the scoping sets clear parameters and determines what is in scope or out of scope for a particular project, what resources and skills will be required, and a time frame for completion.

To ensure that the project is based on valid analysis rather than assumption, it is important to invest sufficient time up front to define the primary objectives. Without this process, a project may be too nebulous or unwieldy for the team to manage and, therefore, will not produce the desired results—it will continually experience scope changes and scope creep, and a valid estimate cannot be developed.

P2.1 Estimation Checklist (Also See C4.2, V3.1)

Thoroughness in examining drawings and specifications usually eliminates estimate errors of omission. Checklists can be used to confirm that all cost items have been included in the estimate. Checklists are not, however, a substitute for the exercise of sound engineering judgment by the estimator or the reviewers. The estimation professionals must independently evaluate the significant data upon which the estimates are based, but the checklists help to ensure estimate completeness.

What Is It?

Checklists serve as guides in preparing, checking, and reviewing cost estimates. These templates ensure that estimators and reviewers develop a complete estimate. They guide the estimator through suggested items and consideration of factors that impact project cost.

Why?

While estimators and project managers are generally very familiar with assembling cost data and developing an estimate, the estimation process requires consideration of many work items and the factors that impact the cost of individual items, as well as factors that impact the cost of the project in general. Checklists serve to delineate the many factors that must be considered during estimate preparation. Therefore, checklists are an excellent means of (1) ensuring that the estimate completely addresses the stated scope of the project, (2) avoiding omissions, and (3) calling attention to the interaction between factors that can impact cost.

What Does It Do?

Checklists guide the estimator through suggested items and serve to ensure that all cost categories are accounted for in an estimate. The answers to the checklist questions will provide an overview of the estimate's completeness and focus the estimator's attention on critical questions. The checklists can be divided into major work areas, such as roadway and structural, to support specific parts of project estimate development. There can also be checklists that help the estimator identify background concerns that impact project cost.

When?

Checklists can support estimate creation at all stages of project development. The purpose of a checklist is to assist the estimator in planning, formatting, and developing a complete estimate. Checklists should be as inclusive as possible, with questions that specifically probe the estimate at the different stages in project development.

Example

The North Carolina DOT has an estimate checklist for functional and preliminary estimates. It includes the various items included in a project estimate, as well as the units of measurement to be used in estimating the items:

- Clearing and grubbing (acre or hectare)
- Earthwork (cy or m3)—unclassified, borrow, undercut, etc.
- Fine grading (sy or m2)
- Drainage (per mile or kilometer)
- Paving (ton or mtn, w/pavement design, or sy/m2 without)
- Stabilization (sy or m2)
- Shoulder drains (lf or meter)
- Curb and gutter (lf or meter)
- Guardrail (lf or meter)
- Anchor units (each type)
- Fencing (mile or kilometer)
- Interchange signing (type and location)
- Traffic control plan (TCP) (per mile or kilometer)
- Thermo and markers (per mile or kilometer)
- Utilities (lf or meters)
- Erosion control (acres or hectares)
- Traffic signals (each and location)
- Retaining walls or noise walls (sf or m2, with avg. height)
- Bridges (individual location)
- Reinforced concrete (RC) box culverts (individual location)
- Railroad crossing (each—with or without gates)

Tips

There can be many individual checklists to support different phases of estimate preparation and specific cost areas—for example, a plan review checklist; a site checklist; a checklist for developing quantities; and a checklist to consider construction noise, dust, and other construction nuisance issues.

Resources

Checklists for reviewing a prepared estimate are used by the FHWA and state highway agencies. The following is FHWA's "Engineer's Estimate Checklist for Full Oversight Projects":

- Check approximately 15–20% (more if possible) of the bid items against the plan quantities for accuracy.
- Do the items checked correspond with the plans and plan quantities?
- Do the pay items correspond to the type of work proposed?
- Are the units of measure appropriate for the pay item?
- Is the quantity for the pay item reasonable for the project?
- Does the unit price seem reasonable for the type, size, and location of the project?

The FHWA also has a checklist document, "Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications," which is posted on the FHWA website. In the PS&E portion of this document is a checklist that applies to specific geotechnical features, such as pile foundations, embankments, and landslide corrections. This checklist can be found at: www.fhwa.dot.gov/bridge/checklist.htm.

The U.S. Army Corps of Engineers estimate review checklist from ER1110-1-12 requires that the reviewer verify that:

- Estimates are based on approved scope of work and latest available design data.
- Estimates are developed from Corps unit price book (UPB) or approved construction cost data (e.g., the General Construction Cost Engineering Standards published annually by Richardson Engineering Services or the price data published by R. S. Means Company).
- The basis for the estimates is provided or explained; all assumptions, quotes, crew sizes, and other cost factors are documented.
- Estimates are escalated to the expected midpoint of construction using the latest approved management control plan or OMB [Office of Management and Budget] (for Civil Works projects) index.
- Estimates are prepared in accordance with latest Corps cost engineering regulations and technical manuals.
- Estimates include risk analysis to cover unknown conditions or uncertainties on work schedules.
- Estimates are internally reviewed prior to submittal.

This checklist could serve as review guidance for any state highway agency.

Defense Logistics Agency's "In-House Cost Estimate Checklist," at www.dla.mil/j-3/a-76/IRLine02.html, is not designed for projects of the type that state highway agencies handle, but it does contain some very good questions that a state highway agency might want to include in its own checklist, including:

- Is inflation calculated correctly?
- If costs are based on historical data, are appropriate adjustments included?

Wisconsin DOT's (WisDOT's) early project scoping tools can be found at www.dot.wisconsin.gov/localgov/highways/tools.htm.

WisDOT's "Local Agency Guidelines: Appendix 14.52—Project Development Checklist" can be found at http://www.mrsc.org/Subjects/PubWorks/construct/c3-checklst.pdf.

The Port Angeles Public Works Department's "Project Development Checklist" can be found at http://www.mrsc.org/govdocs/p54pwprojdevchklst.aspx.

P2.2 Scoping Documents (Also See C6.4)

State highway agencies throughout the country have created scoping documents to support the scoping process. These documents are used at project initiation to define project scope. They provide an excellent tool for project estimators to define the basis of an estimate. While scoping documents are frequently used by state highway agency planning personnel to begin the project development process, state highway agency engineers and estimators often overlook this tool in the estimation process during the latter stages of project development. The scoping documents can be used as a guide to ensure that all critical scope items are included in an estimate or to assist in communicating the estimate basis.

What Is It?

Scoping documents are standardized forms that state highway agencies use to explicitly define and document the scope of a project. They are often developed in the form of a checklist. They represent past project experience and list key scope items and lessons learned from past projects.

Why?

A scoping document is a tool to aid in project scope definition and documentation. It is a key tool in the scoping method of estimation. Scoping documents can be used before any major engineering efforts take place. They can also be used later in the cost estimation process to define the estimate basis and to aid in establishing an appropriate level of contingency.

What Does It Do?

The development of a standard scoping document provides consistency in project scope definition early in the project development process. Completion of the scoping document for each project clearly identifies the original project scope, which can be used in the documentation of the estimate basis or in the establishment of the estimate baseline. The scoping document can help document subsequent changes. This document will aid in identification of the purpose of the project and serve as a reminder of project intentions throughout project development. The document aids in identifying elements to be included in estimate and schedule considerations.

When?

The scoping document should be completed early in project development to establish a baseline scope of the project and a basis for the early project estimates. It can be reviewed at each project milestone to ensure that all critical scope items are included in the estimate and that the extraneous items of scope are not included. The document should be reviewed throughout the development of the project to check for changes in scope.

Examples

Numerous examples of scoping documents are provided in Section C6.4. Many state highway agencies use some sort of scoping document. Scoping documents vary in complexity and specificity. Some state highway agencies use a simple memo as their scoping document, while other agencies have longer, more detailed forms. Figure C6.4-1 provides an example of a scoping document from Virginia DOT, and Figures C6.4-2 provides an example of a draft project scoping memoranda from Missouri DOT.

Tips

A scoping document is an excellent tool to define an estimate basis. Use the project scoping document in a team environment with all of the appropriate disciplines represented whenever possible to minimize the chance of any oversights. Scoping documents should permit some flexibility for special-case projects, both the very straightforward projects and the more complex projects. Revisit the project scoping document at critical cost estimation practice and cost estimation management milestones throughout the project development process.

Resources

The Vermont Agency of Transportation Project Development Process Manual is online at http://www.aot.state.vt.us/progdev/Sections/PDManual/01mantabl.htm.

The New York State DOT Design Quality Assurance Bureau scoping process can be found in the first three chapters of the Project Development Manual, http://www.dot.state.ny.us/cmb/consult/dpm1/pdm_01_30_04.html.

The Missouri State DOT's report, "Implementation of Recommendations for Project Scoping," is online at www.modot.org/design/scopingreport_0403.pdf.

A series of scoping resources is available from the Virginia DOT online at www.virginiadot.org. A particularly helpful Virginia DOT guidance document for a scoping meeting is listed at www.virginiadot.org/projects/Resources/CE-1-Scoping.pdf.

Project initiation documents mark the transition from planning and programming to advanced planning. Such documents are described in Chapter 9 of the California DOT Project Development Procedures Manual (PDPM), on the Internet at http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm.

P2.3 Work Breakdown Structure

Several state highway agencies use work breakdown structures (WBSs). These are lists of all the known elements of the project scope. They are in greater detail than the list of key scope items (described in Section B1.4). They are generally assembled into groups of like or related items to form a hierarchical structure, where each descending level of the hierarchy represents an increasingly detailed definition of the project scope. A WBS is a deliverable-oriented grouping of project components that organizes and defines the total scope of the project. Work not in the WBS is outside the scope of the project. As with the scope statement, the WBS is often used to develop or confirm a common understanding of project scope. Each descending level represents an increasingly detailed description of the project.

What Is It?

A basic WBS is illustrated in Figure P2.3-1.

Why?

The WBS is an excellent tool for documenting the project scope, scope changes, and scope creep. Each change to the WBS is a change in the project team's understanding of the project scope. Small incremental changes (i.e., scope creep) can be documented by comparing the current WBS with earlier versions. A WBS can be a basis for developing a WBS for future projects that have similar project characteristics.

What Does It Do?

A good WBS fully documents the team's current understanding of the project scope. It can be amended in three ways:

- Deleting WBS elements, indicating a decrease in expected scope.
- Adding WBS elements horizontally, indicating an increase in expected scope.
- Adding WBS elements below an existing element, indicating an increased understanding of the existing scope.

When?

The initial WBS should be developed immediately after the scoping document is completed (see Section P2.2). It may be part of, or an attachment to, the scoping document.

Examples

Washington State DOT has initiated a project management process as an executive order. A major component of the project management process is to "plan the work." One activity under "plan the work" is the preparation of a work breakdown structure. A description of this activity is shown in Figure P2.3-2.

Tips

Build the WBS to the level at which you plan to manage the work. Specialty groups are a part of the project team, but they

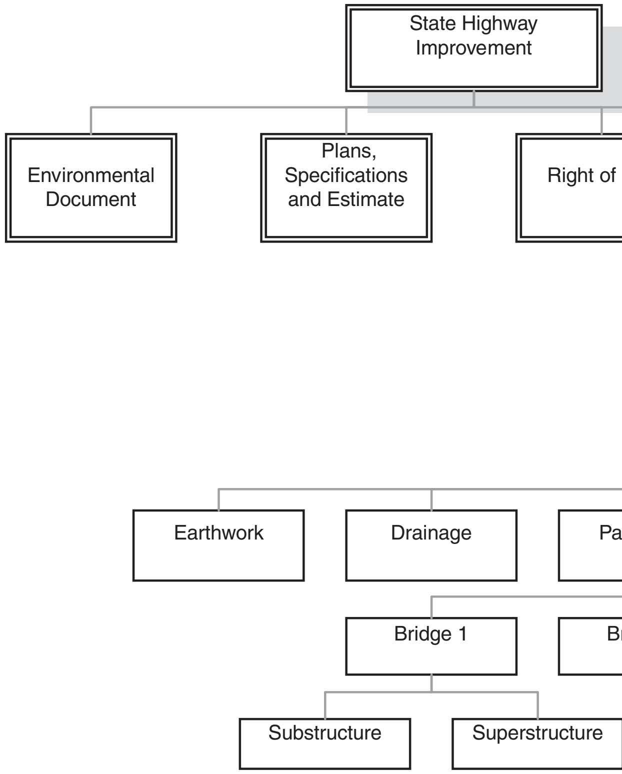


Figure P2.3-1. Graphic representation of a work breakdown structure.

should identify their deliverables and be responsible for managing their tasks and reporting progress. Remember, a good WBS is not a detailed "to do" list.

Resources

A Guide to the Project Management Body of Knowledge (3rd ed., 2004) and *Practice Standard for Work Breakdown Structures* (2002), both published by the Project Management Institute.

Washington State DOT (undated), *Project Management On-Line Guide,* see website http://www.wsdot.wa.gov/Projects/ProjectMgmt/Process.htm.

Project Management Institute (2004). *A Guide to Project Management Body of Knowledge* (PMBOK Guide).

P3 Public Involvement

People want to have a voice in transportation project decision making. State highway agencies must solicit public involvement to accommodate the public's voice in order to create a successful project. However, the public often finds both metropolitan and statewide transportation programs incomprehensible. Extra effort may be needed to obtain involvement by people unaccustomed to participating in the project development process and who, if left out of this process, could prove to be obstructive.

P3.1 Meetings

Getting started in public involvement need not be difficult. Clearly define the goals and objectives of the public involvement program, and then make them specific to the project. Offer people ways to participate that match their level of interest and commitment. Invite those who are highly involved to address specific tasks or issues on a regular basis. Scope issues may be raised through the people most closely impacted by the project.

What Is It?

Public meetings and other outreach efforts provide an opportunity for the public to participate in a general review of a specific project. These meetings also give the state highway agency a forum for providing details about the project, including the purpose of, and need for, the project. The purpose and need information informs the public that the project will correct a problem or deficiency, such as relieving congestion and improving safety. Further, the state highway agency can inform the public how the project will correct the deficiency (i.e., the scope of the project), such as adding lanes to improve traffic

Washington State Department of Transportation	Pre-Construction	On-Line Guide
	Plan the Work	Process
Activity:	**Develop the Work Breakdown Structure using the Master Deliverables List (MDL)**	Revision July 1, 2005
Description:	Tailoring and completing the project-specific Work Breakdown Structure based on the Master Deliverables List.	
Inputs:	• **Completed Initiate and Align Worksheet**	
Tools:	• **"What you need to know about the Master Deliverables List (MDL)"** • **Master Deliverables List (MDL)**	
Steps:	1. Refer to "What you need to know about the Master Deliverables List (MDL)" for a general briefing on the MDL and its role in the Project Delivery Information System (PDIS).	
	2. Review the MDL and delete the elements that are not applicable for this project and phase.	
	3. Identify your Project Phase and Sub-Phase (Levels 1 & 2), and eliminate the rest. The majority of the time in project development (design), we are in the Preliminary Engineering (PE) Phase (Level 1). Within PE, we are either in the Scoping or Design/PS&E Sub-Phase (Level 2).	
	4. Identify the categories of work or processes (Level 3) that will be a part of your project, and eliminate the rest. The processes in the MDL include subjects such as: Hydraulics, Right of Way, Traffic, Utilities, and Environmental Documentation. Consult with specialty groups to identify the specific processes required for the project.	
	5. Identify the deliverables to be produced (Level 4) for each category of work or process, and eliminate the rest. The deliverables in the MDL includes subjects such as: Type A Project, Right of Entry, Preliminary Traffic Analysis Report, and NEPA/SEPA Compliance. 6. Consult with specialty groups to identify project-specific deliverables, logical constraints, durations, and costs.	
Products:	• **Completed Work Breakdown Structure**	
Guidelines:	Build the WBS to the level at which you plan to manage the work. Specialty groups are a part of the project team, but they should identify their deliverables and be responsible for managing their tasks and reporting progress.	

Figure P2.3-2. Work breakdown structure activity description.

flow. In addition to presenting the scope, the project cost and schedule can be presented to the public.

Why?

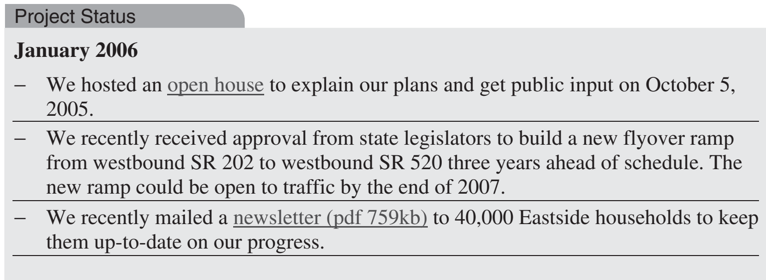
Public meetings initiate active public involvement in the project. Obtaining public response to a project is critical to the state highway agency to avoid opposition to the project, which may delay project development. Further, the public may request changes to the project that would impact the project's scope. Delays and/or changes in scope have cost and schedule ramifications.

What Does It Do?

Meetings create public awareness of the project and hopefully public buy-in with respect to the approach for addressing the need that is driving the project scope. Through meetings, the public becomes part of the project. Meetings provide an opportunity for the state highway agency to gain public trust that the project is using their tax dollars wisely.

When?

Public involvement should occur early in project development, beginning at systems planning, continuing in program-



Project Status

January 2006

– We hosted an open house to explain our plans and get public input on October 5, 2005.

– We recently received approval from state legislators to build a new flyover ramp from westbound SR 202 to westbound SR 520 three years ahead of schedule. The new ramp could be open to traffic by the end of 2007.

– We recently mailed a newsletter (pdf 759kb) to 40,000 Eastside households to keep them up-to-date on our progress.

Figure P3.1-1. Website clip of announcement for a Washington State DOT open house.

ming, then continuing through preliminary design and beyond. The timing of meetings to engage the public in the project should coincide with the availability of preliminary design information. The project team must have sufficient knowledge and understanding of the project to convey the project's purpose, need, and scope to the public in an effective manner.

Examples

An open house for a project informs the public about the details of the project and allows the public to ask questions. An illustration of this approach is shown in Figures P3.1-1 and P3.1-2.

Tips

The state highway agency should use public meetings and open house events to encourage public comments on the project. The information provided to the public should be simple and easy to understand. Graphics should be used to the fullest extent because "a picture is worth a thousand words." State highway agency staff should actively engage the public during the meeting, so techniques should be used to encourage the public to ask questions. Costs and schedule information should be provided in a manner that helps the public understand the project costs and why it takes so long to design and construct the project. The state highway agency should have key project team personnel participate in these meetings so that the public gains confidence that the project will be successful. Finally, the state highway agency should respond to any public comments and try to accommodate requests.

Resources

Howard/Stein-Hudson Associates, Inc., and Parsons Brinckerhoff Quade and Douglas (1996), *Public Involvement Techniques for Transportation Decision-Making,* Publication No. FHWA-PD-96-031 for the FHWA and the FTA. www.fhwa.dot.gov/reports/pittd/cover.htm.

FHWA (1997), *Public Involvement at Oregon Department of Transportation,* Publication No. FHWA-PD-94-021. This report describes how Oregon DOT uses a variety of public involvement techniques in both project development and statewide planning.

Washington State DOT, Project SR520, Information can be found at: www.wsdot.wa.gov/Projects/SR520/WLakeSamPk_SR202 and at www.wsdot.wa.gov/Projects/SR520/WLakeSamPk_SR202/ProjectPhotos.htm.

R1 Recognition of Project Complexity

Providing a standard definition of project complexity ensures that projects of similar complexity are subject to similar reviews and attention. This creates a common communication language among state highway agency employees regarding projects.

R1.1 Complexity Definitions

The influence of project complexity on cost estimation practice and cost estimation management is discussed throughout this guidebook. Project complexity can be a driver of cost escalation. Project complexity will significantly influence the meth-

Figure P3.1-2. Members of the public reviewed project plans and asked Washington State DOT engineers questions about the plans at an open house.

ods and tools that an estimator uses to prepare and manage project cost estimates. Some agencies have found it useful to create a formal and standard definition for project complexity in order to communicate the issue to project team members and stakeholders.

What Is It?

A complexity definition is a formal classification of project complexity that can be applied to all projects. The complexity definition can also include a definition of project type (such as new or reconstruction, size, project setting, and rural or urban), project location, available level of design detail, and other extraordinary factors. The goal is to explicitly define project complexity through the use of this classification system.

Why?

Providing a standard definition of project complexity promotes transparent communication of a project's characteristics. It can be used to assist in selecting an appropriate estimation method and tools or to invoke specific cost estimation management procedures. It helps to ensure that projects of varying complexity levels are subject to the appropriate reviews and attention. This allows for a common language between state highway agency employees for communication regarding project complexity.

What Does It Do?

This tool defines a project classification based on a specific set of complexity criteria. The classification in turn helps to identify the appropriate strategies, methods, and tools for approaching cost estimation practice and cost estimation management on the project.

When?

In terms of estimation, this tool is used to define the approach for preparing estimates during all phases of project development. It should be employed early in the project development process and revisited as design develops or if any major changes in scope are realized.

Examples

Several state highway agencies have created classifications to define the level of project complexity. Tables were created with the use of information from similar projects that have been fully evaluated to generate complexity factors for long-range planning estimates.

Pennsylvania DOT (PennDOT) has developed several tables that provide information regarding the PennDOT classification system of non-complex (i.e., minor), moderately complex, and the most complex (i.e., major) projects. These tables are shown in Figure R1.1.

Tips

Use the complexity definitions early in the project development process to select or invoke appropriate strategies, methods, and tools for project cost estimation practice and cost estimation management.

Use the complexity definitions when developing estimation policies, guidelines, and training materials.

In order to keep the tables accurately related to complexity, reassess project complexity at critical cost estimation management milestones. If the project becomes more or less complex as the design develops and more information becomes available, the definitions can be used to ensure that appropriate methods and tools are being applied.

Resources

PennDOT has established a system to define the level of complexity. See PennDOT's *Design Manual: Part 1A: Transportation Engineering Procedures,* Publication 10A, available from PennDOT.

Christine Fiori and Molly Kovaka identified five key project characteristics common to construction megaprojects: cost, complexity, risk, ideals, and visibility. Fiori and Kovaka developed a descriptive and comparative tool for megaproject evaluation for future researchers. The tool consists of a 132-element questionnaire. Each element is numerically rated (0 to 4), and a five-element composite project score is generated in the form "CCRIV." For more information, see Fiori and Kovaka's 2005 publication, "Defining Megaprojects: Learning from Construction at the Edge of Experience," presented at the Construction Research Congress 2005: www.pubs.asce.org/WWWdisplay.cgi?0520069.

R2 Right-of-Way

Right-of-way administrators have reported a number of challenges routinely encountered in right-of-way cost estimation: (1) early estimates are typically based on planning-level maps, so the extent of takings must be anticipated based on limited information; (2) often there is limited time to prepare early estimates, thereby restricting the amount of research that can be undertaken for complex parcels; and (3) right-of-way estimates are usually prepared years in advance of actual right-of-way acquisition, and significant inflation in between estimation and acquisition results in property and damage appreciation.

NON-COMPLEX (MINOR) PROJECTS	
Roadway	▪ Maintenance betterment projects. ▪ Overlay projects, simple widening without right-of-way (or very minimum right-of-way take), little or no utility coordination. ▪ Non-complex enhancement projects without new bridges (e.g., bike trails).
Traffic Control	▪ Single traffic control/management projects. ▪ Non-ITS but minor safety improvements.
Structures	▪ Bridge resurfacing or repairs which do not require re-analysis of bridge capacity. ▪ Pipes, box culverts or minor culvert replacements where design can be picked directly from design manual or standards or using simple software where detailed interpretation is not necessary. ▪ Sign structures for which the design can be picked up directly either from the standards or using design computer software. ▪ Noise walls or retaining walls for which the design can be picked up directly either from the standards or using design computer software.
Right-of-Way	▪ Involve minor right-of-way acquisitions with no displacements, maintain existing access control.
Utilities	▪ Minimal, if any.
Environmental	▪ Categorical Exclusion (level 1A or 1B) ▪ Minimum interaction with environmental and permitting agencies. ▪ Minor environmental impacts as appropriate have a Statewide Wetland Finding. ▪ Do not involve cultural resources, hazardous waste, Section 4(f) evaluations or substantial flood plain encroachments.
Stakeholders	▪ No public controversy.

MODERATELY COMPLEX PROJECTS	
Roadway	▪ 3R and 4R projects which do not add capacity. ▪ Minor roadway relocations. ▪ Certain complex (non-trail enhancements) projects. ▪ Slides, subsidence.
Traffic Control	▪ Non-ITS but major safety improvements. ▪ Interconnected traffic control/management projects.
Structures	▪ Non-complex (straight geometry with minimal skew; designs using AASHTO description factors; minimal seismic analysis; footings on rock or conventional piles and abutments) bridge replacements with minor (< 610 m [2,000 ft]) roadway approach work. ▪ Bridge rehabilitation which requires re-analysis of bridge capacity. ▪ Bridge mounted signs. ▪ Tie back walls. ▪ Noise walls. ▪ Proprietary/non-proprietary walls.
Right-of-Way	▪ Right-of-way plans needed with less than 20 moderate to significant claims and very few relocations or displacements.
Utilities	▪ Some utility relocations, most of it prior to construction, but no major utility relocations.
Environmental	▪ Categorical Exclusion level 2 or mitigated Environmental Assessment projects. ▪ Cultural resources (historical, archeological, etc.). Coordination with Museum Commission, FHWA, and/or Advisory Council. ▪ Wetland mitigation. ▪ Parkland involvement. ▪ Water and air pollution mitigation. ▪ Major coordination with Game or Fish and Boat commissions. ▪ Endangered species.
Stakeholders	▪ Involvement of public and public officials is moderate due to non-controversial project type. ▪ General communication about project progress is required.

Figure R1.1. Complexity definition tables from PennDOT Publication 10A.

MOST COMPLEX (MAJOR) PROJECTS	
Roadway	▪ New highways; major relocations. ▪ New interchanges ▪ Capacity adding/major widening. ▪ Major reconstruction (4R; 3R with multi-phase traffic control). ▪ Congestion Management Studies are required.
Traffic Control	▪ Multi-phased traffic control for highway or bridge construction that would mandate CPM during construction. ▪ Major ITS (Electronic surveillance, linkages) corridor project.
Structures	▪ Replacement, new or rehabilitation of: ▪ Unusual (non-conventional like segmental, cable stayed, major arches or trusses, steel box girders, movable bridges, etc.) ▪ Complex (sharp skewed [less than 70 degree] superstructure, non-conventional piers or abutments, horizontally curved girders, three dimensional structural analysis, non-conventional piles or caisson foundations, complex seismic analysis, etc.) ▪ Major (bridge cost of $5 million or more—Federal definition). ▪ Unusual formations (caissons, uncommon piles, mines, Karst situation).
Right-of-Way	▪ Right-of-way plans are needed and numerous relocations of residences or displacement of commercial and/or industrial properties are required. A few to over 20 property owners are involved. Major involvement of environmental clean-up. Before and after analysis.
Utilities	▪ Major utility (transmission lines, substations) relocations or heavy multi-utility coordination is involved.
Environmental	▪ Environmental Impact Studies are required or complex Environmental Assessment without mitigated finding of no significant impact. ▪ Studies of multiple alternatives. ▪ Continued public and elected officials involvement in analyzing and selecting alternates. ▪ Other agencies (such as FHWA, COE, PHMC, Game Commission, Fish & Boat Commission, DEP, DCNR, EPA, Agricultural Board, etc.) are heavily involved to protect air; water; games; fish, threatened and endangered species; cultural resources (historical, archaeological, parks, wetlands, etc), etc.
Stakeholders	▪ Controversial (lack of consensus) and high-profile projects. (Fast track design/construction, high public impact, high interaction of elected officials, etc.) ▪ Major coordination among numerous stakeholders is required.

Figure R1.1. (Continued).

R2.1 Acres for Interchange

A chronic problem in estimating the right-of-way cost, for either new interchanges or reconstructed interchanges, is establishing the land requirements, including the requirements needed for construction operations. This problem is most acute during the preparation of planning phase estimates.

What Is It?

This tool encourages early consultation between the agency's design, construction, and right-of-way sections in order to better define interchange land requirements and the cost of acquiring that land. During the planning phase of project development, the estimators and designers must understand that average interchange acreage requirements are frequently not an appropriate methodology for estimating the cost of the necessary takings. When estimating an interchange acreage requirement, consideration must be given to effects on utilities (water, sewer, gas lines, electric, cable, and fiber-optic lines), the need for space to accommodate utility relocations, and, often times, space for noise walls.

The concepts developed for each interchange should be evaluated to identify engineering issues, environmental concerns, construction requirements, and maintenance requirements. The concepts developed should be evaluated for:

- Acquisition of developed properties
- Reconstruction of other facilities
- Traffic operation issues on or into private property

- Significant acquisition of right-of-way from the protected areas (i.e., environmentally sensitive areas)
- Impacts (economic, traffic, and environmental) to existing facilities

Why?

Many state highway agencies have design guidelines that describe the elements of a typical highway interchange and required land area. Right-of-way estimates (including those for interchanges) that are prepared based on both typical acreage requirements and an average per-acre price are often inaccurate because they fail to consider impacting cost drivers and the fact that interchanges, while following standard designs, must almost always be fitted into the unique physical setting of their locations.

What Does It Do?

This is a tool to help project managers and estimators appreciate the fact that as projects become more complex, there is a greater need for coordination and communication between the disciplines participating in the development of the project's design and estimate. This is particularly important in the case of initial right-of-way estimates for interchanges. In such a case, many more supporting groups—multiple utility companies, agencies that grant environmental permits, construction, and maintenance—must be consulted before the area required for the interchange can be determined and the right-of-way cost estimated.

When?

This tool supports the estimate process for projects (new alignment or reconstruction) involving interchanges, either interchange-only projects or projects where interchanges are part of a large total scope. This tool should even be applied to projects where, during early planning, it is believed that no additional right-of-way will be required, because consultation with supporting sections (utilities relocation, environmental, and construction) may lead to a different conclusion.

Examples

The Mid-Ohio Regional Planning Commission issued a report, *Historical and Projected Transportation Funding in Central Ohio,* in 2004 (available online at http://transportation.morpc.org/tplan/finalTPlan04Funding.pdf). Section 5 of the report, "Right-of-Way Costs," provides the following guidance for that region of the country. While the cost data are most likely not appropriate to state highway agencies, the format could be used to establish interchange *reality check figures* for both acreage and land cost.

> If an ROW [right-of-way] acreage estimate is provided, that number is used. Otherwise, estimate ROW [is] needed according to type of project.
>
> For the regional Transportation Plan, two methods have been used in the past to estimate the ROW costs. The simplified method generally assumes a project is in a high (A), medium (B) or low (C-default) cost per acre area. A more complex method based on actual county auditor valuations for the adjacent parcels has also been used. For this study the simplified approach will be used. The three cost-per-acre categories are $620,000/ac, $235,000/ac and $75,000/ac. Other costs like utility relocation vary depending upon the individual project and are not included.
>
> The following ROW acreage assumptions are made based on the improvement type.
>
> . . .

Intersection Improvement:

a) Turn lane 2 approaches	
• Major Intersection:	0.5 acre
• Minor Intersection:	0.25 acre
b) Turn lane 4 approaches	
• Major Intersection:	1 acre
• Minor Intersection:	0.5 acre

Interchange Upgrade:

a) Basic Diamond/Partial Clover	5 acre
b) Complex with directional Ramp	10 acre

New Interchange:

a) Basic Diamond or Partial Clover	30 acre
b) Complex with directional Ramp	70 acre

> For the right-of-way cost, project specific estimates are made. First, for each project the parcel(s) are identified through which ROW is needed. Second, using the county auditor's data set, the cost per acre for each parcel is determined. The total ROW cost is calculated by multiplying the estimated ROW acreage and the cost per acre of the parcel. The minimum cost per acre is fixed at $75,000.

Tips

Based on a project description detailing the limits of all alternatives, a primary impact area should be established. This primary impact area identification should include work done during concept development, scoping, public involvement, and interagency coordination. Secondary impact areas, where applicable, should also be identified and discussed. A graphic detailing the primary and secondary impact corridor and proposed ROW limits should be developed. Another graphic should be developed mapping the existing land use and zoning within the primary impact area of each alternative. The graphics should delineate industrial, commercial, single-family residential, multifamily residential, public and quasi-public uses, and vacant land.

Pursuant to the Farmland Protection Policy Act of 1984 (FPPA) (Public Law 97–98—Subtitle I of Title XV, Section 1539–1549), all agricultural lands, defined as agricultural soils considered prime farmland soils, soils of statewide or local importance and unique soils, affected by the proposed action must be identified and quantified. The acreage of agricultural soils acquired by the proposed right-of-way must be determined. Additionally, it should be noted if this total exceeds 3 acres per mile of roadway improvements or 10 acres per interchange or intersection. The results of these calculations will be forwarded to the State Soil Conservation Service.

Do not show proposed right-of-way during early project development. Look at the typical section width under the worst-case scenario with maximum right-of-way needed. In the conceptual plans, look at the existing constraints so that alternatives that limit right-of-way requirements (e.g., retaining walls or steeper side slopes) can be explored.

Resources

Florida DOT right-of-way estimation guidance can be found at www.dot.state.fl.us/rightofway/documents/ROWmanual/Acrobat%20files/ch06s03.pdf.

Computer-aided design and drafting (CADD) systems use computer graphic technologies to design and map projects and to quickly consolidate many different design aspects, such as right-of-way maps, into a common database or base map. A 1999 U.S. General Accounting Office study found that 43 state highway agencies use CADD systems on more than half their projects. CADD-generated project right-of-way maps present an opportunity to enhance knowledge concerning required right-of-way requirements and to improve right-of-way estimation.

Global positing systems (GPS) are used for mapping purposes. A 1999 U.S. General Accounting Office study found that 15 state highway agencies use these systems on more than half their projects. GPS-generated project right-of-way maps present an opportunity to enhance knowledge concerning required right-of-way requirements and to improve right-of-way estimation.

The FHWA's Office of Real Estate Services has a *Project Development Guide* that contains a practical approach to project right-of-way. This document presents best practices of state and local agencies and others in the right-of-way field. The guide can be found on the Internet at www.fhwa.dot.gov/realestate/pdg.htm.

Wisconsin DOT's document "Design, Real Estate and Construction Delivery Estimates" identifies the portion of dollars that should be set aside for design, real estate, and construction delivery. The document can be found at www.dot.wisconsin.gov/localgov/highways/docs/delivery.pdf. Estimates are derived by taking a certain percentage of actual real estate acquisition costs for real estate delivery or an actual percentage of total construction costs for design and construction delivery.

R2.2 Advanced Purchase (Right-of-Way Preservation)

In order to facilitate the construction of a public improvement, it is imperative that the necessary real property interests be acquired expeditiously and in compliance with governing rules and regulations. Proactive access management and corridor preservation strategies may reduce right-of-way cost. However, transportation agencies must be very careful to avoid preemptive takings (i.e., takings in which land use rights are prematurely restricted) in long-term anticipation of projects involving right-of-way acquisition.

What Is It?

This tool educates project managers and estimators about advance purchasing of real estate and the impact of such actions on project cost estimates. For years, corridor preservation for highway projects has been a goal of the FHWA and other governmental agencies. Various activities have been undertaken in support of this goal, and legislative support was provided in ISTEA.

Protective buying may be approved only after (a) the acquiring agency has given official notice to the public that it has selected a particular location for the project alignment or (b) a public hearing has been held or an opportunity for such hearing has been afforded.

Why?

The goal of the tool is to eliminate one of the major uncertainties from the project cost estimate by purchasing right-of-way in a future corridor to protect the corridor from further development that could substantially increase the cost of real estate.

What Does It Do?

In the case of estimates prepared during early project development, it may be necessary to predict real estate values as much as a decade in advance, which is a very difficult task. Advance purchase of right-of-way can eliminate or at least moderate this volatile component of early project cost estimates and therefore improves the accuracy of the estimate.

When?

This tool should be used in the earliest stages of project development in order to avoid inflation and escalating property values caused by development within the alignment of a corridor or project. It is a good tool for a limited number of parcels. However, in the case of a long corridor, its application is limited.

Examples

The Texas legislature has given the Texas DOT (TxDOT) the authority to acquire right-of-way to preserve a corridor. Both TxDOT and the FHWA understand that such an acquisition would not negate the requirement to complete NEPA. The I-69/Trans-Texas Corridor Project in Texas will be evaluated using a tiered approach. At Tier 1, corridor-level decisions will be made. After the Tier 1 right-of-way acquisition, TxDOT can acquire right-of-way at its own risk, knowing that when the Tier 2 NEPA evaluations are initiated, the ownership of the previously acquired right-of-way cannot and will not influence the Tier 2 alternative location decision. Since the I-69/TTC corridor will be approximately 1,000 miles long, common sense would lead one to believe that only the parcels in eminent danger of being developed would be acquired. See the FHWA's March 2004 *Environmental Streamlining Newsletter* for more information on the I-69 project.

Minnesota DOT (Mn/DOT) policy requires environmental documentation prior to purchase. Additional information can be found in Appendix J of Mn/DOT's *Interregional Corridors: A Guide for Plan Development and Corridor Management* (available online at http://www.oim.dot.state.mn.us/IRC-Guide.html). Also included is information on the environmental review and documentation process as it relates to right-of-way preservation.

Mn/DOT also conducted a research project to identify circumstances under which it is optional to purchase right-of-way in advance and those in which it is not. The final report of this research project, titled *The Final Benefits of Early Acquisition of Transportation Right of Way,* is available at http://www.research.dot.state.mn.us/detail.cfm?productID=1998.

Improvements to Florida's Strategic Intermodal System (SIS), a statewide network of high-priority transportation facilities, envisions:

- Acquisition of right-of-way for the future widening of I-595
- Acquisition of right-of-way for the widening of I-4
- Acquisition of right-of-way for future improvements to SR 79
- Acquisition of right-of-way for future US 331 reconstruction to a four-lane facility

Florida DOT's *Right of Way Manual* (effective April 15, 1999; acquisition revised December 11, 2000), "Section 8.1 Advance Acquisition," can be found at www.dot.state.fl.us/rightofway/documents/ROWmanual/Acrobat%20files/ch08s01.pdf.

Tips

Brief summary of the process. To use the protective purchase option (advance purchase), there must be at least a draft environmental document (which means that the initial public hearings must have been held). An individual categorical exclusion (CE) document will be required for the protective purchase. The state highway agency will ask the FHWA division office to review and approve a protective purchase package. The package will include (but may not be limited to) a CE document, copies of property valuation appraisals, preliminary design maps, and written justification for the protective purchase.

If the FHWA division office concurs with the protective purchase, the approval will indicate that the state highway agency may incur costs that will be eligible for reimbursement at such time as a final environmental document is approved. The state highway agency may use its own funds to make the purchase and request reimbursement from the FHWA after the final environmental document is approved.

There is the potential for a decrease in the value of abutting parcels (e.g., who would want to purchase a home in an area knowing that there is a major highway project planned?). Adjacent property owners could also demand compensation at this time, and there really is no appropriate way to compensate properties not within the corridor for a property value stigma associated with a nearby project.

However, limited studies at Illinois DOT (IDOT) looking at the effect of highway improvements on adjacent property did not show evidence of property value decreases. IDOT often got comments from property owners who were not directly affected by right-of-way acquisition that the highway would damage them even though no right-of-way was taken from them. When sales prices of properties next to and away from a major highway were examined, it did not appear that the highway was a negative impact on property values. When using this tool, the agency may want to look at some examples in its area to see if properties next to major roadways sell for less than comparable properties a block or two away.

A study conducted by a national realtors organization that surveyed 2000 homebuyers nationwide on what issues were most important in choosing a home location found that access to transportation infrastructure was cited most often (43%).

Transfer of development rights. Some agencies have negotiated with property owners to transfer right-of-way dedication for future roadways for increased development densities on remaining portions of the parcel. This enables the developer to get the same number of lots or units and also enables the agency to obtain the needed right-of-way.

Resources

The FHWA's Office of Real Estate Services has a *Project Development Guide* that contains a practical approach to project right of way. This document presents best practices of state and local agencies and others in the right-of-way field. The guide can be found on the Internet at www.fhwa.dot.gov/realestate/pdg.htm. The chapter covering advance purchases, "14 Specialized Acquisition Functions," is located at www.fhwa.dot.gov/realestate/specacq.pdf.

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Global positing systems (GPS) are used for mapping purposes. A 1999 U.S. General Accounting Office study found that 15 state highway agencies use these systems on more than half their projects. GPS-generated project right-of-way maps present another opportunity to enhance knowledge concerning right-of-way requirements and to improve right-of-way estimation.

Also see the hardship/protective purchasing sections of the 23 Code of Federal Regulations. Specifically, refer to Sections 23 CFR 630.106(c)(3), 23 CFR 710.503, and 23 CFR 771.117(d)(12).

See Texas DOT's *Project Development Process Manual,* "4410: Perform Advance Acquisition for Qualified Parcels," at http://manuals.dot.state.tx.us/dynaweb/coldesig/pdp/@Generic_ BookTextView/18357;cs=default;ts=default.

R2.3 Condemnation

Typically, right-of-way acquisition, especially in urbanized areas, includes other costs besides land purchase, such as costs related to takings, condemnations, relocations, damages, and courts. As a result, it is necessary to estimate these additional costs associated with actual acquisition of land needed for projects. From FY 91/92 to FY 94/95, Florida DOT had to initiate condemnation proceedings in 42.9% of its right-of-way parcel acquisition actions.

What Is It?

This is a tool to educate project managers and estimators as to the schedule impacts, which can affect the overall project estimate, and the direct right-of-way cost impacts of using condemnation to acquire right-of-way. When right-of-way must be secured by condemnation through eminent domain procedures, it typically involves the transition of control of the settlement from the agency's right-of-way department to its legal department. At that point, issues of time, cost, and jury process are relevant to establishing the estimated cost of the right-of-way parcel.

Why?

Because of the high costs and the potential for project delays, most right-of-way offices make it a high priority to resolve and settle right-of-way parcel disputes before resorting to litigation, and a majority of the cases where condemnation proceedings have been initiated are settled before actually going to court. However, estimators must have an understanding of the potential necessity of resorting to condemnation proceeding to acquire right-of-way and of the cost consequences of such procedures.

What Does It Do?

This tool educates estimators about the direct and indirect cost of right-of-way acquisition, particularly the cost associated with condemnation proceedings, and the effect that condemnation proceedings can have on a project's time line. If a state highway agency is unable to agree with the owner on a price for a parcel of property, the agency files a condemnation suit and the court determines the property's value. Other costs in many cases can include the landowner's attorney fees, appraiser fees, technical expert fees, and relocation expenses if necessary. If the state takes a portion of a business property, it may also have to pay business damages for permanently lost profits and the reduced profit-making capacity of the business. Estimators need to understand these ramifications of right-of-way cost in order to prepare accurate project estimates.

When?

This tool should be a continuous estimator education process for all estimators who are involved in estimating the cost of right-of-way. The tool particularly supports early estimates developed when the exact project alignment is imprecise and right-of-way issues lack focus.

Examples

Oregon DOT (ODOT) holds statewide right-of-way meetings every 18 months, where all right-of-way staff meet for training sessions and to share best practices with each other. In addition to formal training programs, individual training plans are prepared at the regional level and approved by central office as part of its business plan. Portions of the right-of-way manual are available online on a shared directory, and policy memos, clarifications, and relocation meeting minutes called "Andy-grams" are frequently circulated and stored electronically. Something like this could be expanded to include training for right-of-way estimators.

The AASHTO Right-of-Way and Utilities Subcommittee sponsors conferences addressing many of the subjects that right-of-way estimators need knowledge about.

Tips

Most areas of dispute involve severance damages to the remainder of the property, and business damages. Therefore, these issues must be fully understood when estimating right-of-way cost.

Consider the effect that relocation has on a business. Does the business have specific requirements that may hinder relocation?

When the right-of-way land requirement does not require all of an owner's business property, other facts should be considered:

- Will the proximity of the proposed facility affect the operations of any businesses, in terms of access disruption, or parking loss, which could result in loss of business?
- Will the proposed action disrupt current accessibility to businesses, thereby having a potential for loss of clientele?

Resources

The FHWA report, "Evaluation of State Condemnation Process," summarizes the legal and procedural framework for acquiring real property for right-of-way, focusing on five specific states. It provides information on the statutory authority and case law that is relevant to the acquisition of real property in each of those five states. It reviews each state's approach to negotiations and valuation, the use of alternative dispute resolution or other administrative procedures used to establish value, and the payment of the property owner's attorney fees and related expenses. This FHWA report can be found at www.fhwa.dot.gov/realestate/cndmst.htm.

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The FHWA's Office of Real Estate Services has a *Project Development Guide* that contains a practical approach to project right-of-way. This document presents best practices of state and local agencies and others in the right-of-way field. The guide can be found on the Internet at www.fhwa.dot.gov/realestate/pdg.htm.

Also read "Costs of Right-of-Way Acquisition: Methods and Models for Estimation," by Jared D. Heiner and Kara M. Kockelman, *Journal Transportation Engineering,* American Society of Civil Engineers, Vol. 131, No. 3, pp. 193–204 (March 2005).

Also see the American Association of Sate Highway and Transportation Officials, Standing Committee on Highways, Strategic Plan 4-4, Right-of-Way and Utilities Guidelines and Best Practices, Jan. 2004, http://cms.transportation.org/sites/rightofway/docs/aabp%20report%20final.pdf.

R2.4 Relocation Costs

In 1999, $100 million in federal and state funds were paid to displaced business and property owners for reestablishment and relocation assistance. The Uniform Relocation Act (Uniform Act) and FHWA regulations address the benefits and protections for persons displaced by highway projects that are funded, at least in part, with federal money.

In 1987, as part of the Surface Transportation and Uniform Relocation Assistance Act (STURAA), Congress amended the Uniform Act to increase payment levels, to add benefits for small businesses, and to designate the U.S. DOT as the lead agency for the Uniform Act for all federal and federally funded programs and projects. The FHWA has the responsibility to act for the U.S. DOT. The Uniform Act was once again amended on November 21, 1997, to incorporate Public Law 105-117 by prohibiting an alien who is not lawfully present in the United States from receiving assistance under the Uniform Act.

What Is It?

This tool ensures that those estimating the cost of project right-of-way fully understand the legal requirements of parcel acquisition to include relocation costs. The Uniform Act provides relocation payments for residential occupants and for businesses, farms, and nonprofit organizations. These payments include moving expense payments and certain supplementary payments for replacement housing for residential occupants. In addition, the Uniform Act requires the availability of replacement housing for displaced persons, sets minimum standards for such housing, and requires notices and information to be provided to all property occupants. The law also requires that advisory services be provided to occupants so as to help them relocate successfully.

Why?

It is important to understand that the project schedule can be impacted by relocation actions and that there are indirect costs associated with securing right-of-way. Without the relocation of those occupying the project site, the project cannot proceed to actual construction and the schedule will be extended, thereby adding cost to the project. Estimators must understand the timing effects of relocation actions, particularly in relation to construction timing (midpoint of construction for estimation purposes), and the cost of relocation actions must be included in a project right-of-way cost estimate.

What Does It Do?

This tool seeks to educate estimators and project managers about the legal requirements that impact the right-of-way cost and the impact that relocation actions have on project schedule so that estimators and project managers can estimate project cost based on realistic schedules and can include all subsidiary (i.e., indirect) right-of-way costs in the estimate.

When?

This tool should be used when projects involve the relocation of individuals in residential properties or nonresidential relocations, businesses, farms, and nonprofit organizations. One of the main purposes of the Uniform Act is to prevent affected persons from bearing an unfair share of the burden of public projects. The act provides relocation assistance payments in addition to relocation assistance advisory services. Relocation assistance payments are designed to compensate displaced persons for costs that result from acquisition of the property on which they reside.

Examples

Residential relocation payments are intended for persons who move (or move personal property) from a dwelling as a result of a highway project receiving federal financial assistance. These payments may be subdivided into three types:

- **Moving expense payments** are designed to compensate for the moving and related costs that a person incurs as a result of having to move from his or her dwelling or to move personal property for a project.
- **Replacement housing payments** are designed to help eligible displaced persons occupy housing that is decent, safe, sanitary, adequate for their needs, and comparable to what they had before the project required their move. There are three categories of replacement housing payments: purchase supplements, rental assistance, and down payment assistance.
- **Housing-of-last-resort payments** are payments in excess of statutory maximums or payments involving other, unusual methods of providing comparable housing.

See the Caltrans brochure, "Your Rights and Benefits as a Displaced Business, Farm or Nonprofit Organization Under the Uniform Relocation Assistance Program," on the Internet at www.dot.ca.gov/hq/row/pubs/business_farm.pdf.

Tips

Consider the effect that relocation has on a business and answer the question, Does the business have specific requirements that may hinder relocation?

Resources

See the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (Public Law 91-646), as amended (42 U.S.C. 4601 et seq.).

Also see the Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally Assisted Programs (49 CFR 24).

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The FHWA's Office of Real Estate Services has a *Project Development Guide* that contains a practical approach to project right-of-way. This document presents best practices of state and local agencies and others in the right-of-way field. The guide can be found on the Internet at www.fhwa.dot.gov/realestate/pdg.htm. The section on relocation is found at www.fhwa.dot.gov/realestate/relasst.pdf.

R2.5 Right-of-Way Estimator Training

A "Highway Construction Cost Comparison Survey" conducted by the Washington State DOT in 2002 found that right-of-way costs typically vary. State highway agencies reported that variability rates for right-of-way ranged from 10% or less to over 30% of project cost. Such variability makes the use of historical cost averages for estimating right-of-way cost very unreliable. Estimators need to be trained to recognize the factors that impact right-of-way cost.

Why?

It is important that right-of-way acquisition be handled expeditiously and that project managers and estimators have a solid understanding of right-of-way acquisition processes and costs, both direct and indirect.

What Does It Do?

This tool seeks to specifically train estimators concerning the factors that influence right-of-way cost and to provide the estimators with the skills necessary to handle the challenges associated with developing right-of-way estimates. Right-of-way estimators must be trained to:

- Develop early estimates based on planning-level maps with limited information on the extent of takings.
- Adjust right-of-way estimates for the significant inflation and speculation that can occur between the time when the estimate is initially prepared (typically several years in advance of actual right-of-way acquisition) and when the parcels are purchased. Right-of-way estimates are prepared based on year of parcel purchase, not midpoint of construction.
- Account for the uncertainties associated with damages and court costs that result from condemnation proceedings.

When?

Because all state highway agencies are continually involved with projects requiring right-of-way, the right-of-way estimator training tool should be standard practice to every state highway agency. However, it has been found that court costs are highly variable and are particularly high for projects in highly developed commercial corridors, where condemnation proceedings are common. Thus, the tool may be of greater benefit to state highway agencies that regularly engage in urban commercial corridor projects.

Examples

An example of right-of-way estimation guidance can be found at www.dot.state.fl.us/rightofway/documents/ROWmanual/Acrobat%20files/ch06s03.pdf.

The FHWA's Office of Real Estate Services has a Right-of-Way Outreach and Program Research website (www.fhwa.dot.gov/realestate/research.htm), which lists available professional training and technical assistance.

Tips

Train estimators to red flag areas in proposed corridors (major streams, Federal Emergency Management Agency (FEMA) flood zones, residential and commercial structures, cemeteries, wetlands, historic properties, hazardous waste sites, parks, etc.) that can impact right-of-way cost.

Also train estimators to recognize removal items that will impact right-of-way cost (trees, buildings, abandoned slabs, etc.).

Revisit the right-of-way estimate as design proceeds and the construction limits are refined. Each time, identify total takes, relocations, and noise wall locations, and then check the cost estimate.

Understand whether the acquisition process for compensating renters differs from the process for compensating property owners.

Real estate sales prices along a corridor of several individual projects are affected by the order in which projects are accomplished. A study of residential property prices from 1979 to 1997 along an urban corridor in Texas revealed significant price effects of the corridor improvement phases. During the pre-planning phase, housing prices in the immediate vicinity of the freeway were negatively affected, while those farther away were positively affected. During the planning phase, houses in the corridor appreciated at twice the rate of other Dallas properties. Prices declined more rapidly in the corridor than elsewhere in Dallas during the early construction phases. However, prices again improved during the final construction phase, as sections of the freeway began to reopen and access improved.

During the early phase of a project development, the right-of-way needs may not be defined clearly enough to differentiate between what will be a whole take and what will be a partial take. If it is helpful, cost estimates may be limited to whole parcel acquisition. Costs of partial acquisitions, including damages to the remaining properties and project overhead, can be factored into an estimate.

Resources

The Florida DOT right-of-way estimation guidance can be found at www.dot.state.fl.us/rightofway/documents/ROWmanual/Acrobat%20files/ch06s03.pdf.

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Executive Order (EO) No. 12898 (1994), "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," requires that federal agencies be responsible for reviewing their programs and other activities to determine and prohibit any disproportionately high adverse effects on the human environments in low-income or minority communities. In the case of transportation projects, EO 12898 is implemented through the U.S. DOT and the FHWA. The U.S. DOT strategy ensures that the provisions of EO 12898 are integrated into the relevant existing guidelines used in the project planning and public participation processes. The FHWA's order requires that specific research and related data collection be conducted to provide information on environmental justice concerns.

The FHWA's Office of Real Estate Services has a *Project Development Guide* that contains a practical approach to project right-of-way. This document presents best practices of state and local agencies and others in the right-of-way field. The guide can be found on the Internet at www.fhwa.dot.gov/realestate/pdg.htm.

"The Costs of Right of Way Acquisition: Methods and Models for Estimation" is a paper presented at the 83rd Annual Meeting of the Transportation Research Board, January 2004. The paper reviews the literature related to right-of-way acquisition and property valuation. It describes the appraisal process and the influence of federal law on acquisition practices. It provides price models for estimation of costs associated with taking property using recent acquisition data from several Texas corridors and full-parcel commercial sales transactions in Texas's largest regions. Results indicate that damages depend heavily on parking, access, and location. The size of the taking is not as important as the value of improvements, and utility costs are highly variable. This paper can be found at www.ce.utexas.edu/prof/kockelman/public_html/TRB04ROW.pdf.

See the following federal laws governing acquisition:

- The Uniform Relocation and Real Property Acquisition Policies Act of 1970 (42 U.S.C. 4801 et seq.)
- Section I of the Civil Rights Act of 1866 (42 U.S.C. 1982, et seq.)
- Title VI of the Civil Rights Act of 1966 (42 U.S.C. 2000d et seq.)
- Title VIII of the Civil Rights Act of 1968 (42 U.S.C. 3601 et seq.) as amended
- The National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.)
- The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund) as amended by the Superfund Amendments and Reauthorization
- The Superfund Amendments and Reauthorization Act of 1986 (SARA) (42 U.S.C. Section 9601 et seq.)
- Section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 790 et seq.)
- The Flood Disaster Protection Act of 1973 (Public Law. 93-234)
- The Age Discrimination Act of 1975 (42 U.S.C. 6101 et seq.)
- Executive Order 11063: Equal Opportunity and Housing, as amended by Executive Order 12259
- Executive Order 11246: Equal Employment Opportunity
- Executive Order 11625: Minority Business Enterprise
- Executive Order 11988: Floodplain Management
- Executive Order 11990: Protection of Wetlands
- Executive Order 12250: Leadership and Coordination of Non-Discrimination Laws
- Executive Order 12259: Leadership and Coordination of Fair Housing in Federal Programs
- Executive Order 12630: Governmental Actions and Interference with Constitutionally Protected Property Rights

R2.6 Separate Right-of-Way Estimators

State highway agency right-of-way sections have a mission to deliver real estate services essential for public transportation projects that support the economic, environmental, and social vitality of the state. Understanding all of the costs associated with obtaining parcels and the details of acquisition law has led some agencies to establish a separate group of right-of-way estimators.

What Is It?

This tool is a group of individuals within the state highway agency who are specifically trained in techniques for estimating right-of-way cost, who construct and maintain right-of-way cost models, and who have sole responsibility for estimating the right-of-way cost portion of a project estimate. This group of right-of-way estimators could be located in the agency's right-of-way, design, or estimation sections. Location in the agency structure is not as important as developing a group having the unique skills needed to accurately estimate right-of-way costs and who can mentor and support one another in this important task.

Why?

It is extremely important that individuals attempting to estimate the cost of right-of-way acquisition be intimately familiar with the applicable state laws and implementation regulations. Over the years, states have enacted eminent domain laws governing public acquisitions under their jurisdiction. Since the enactment of the Federal Uniform Relocation Assistance and Real Property Policies Act of 1970 (Uniform Act) and passage of the various state consent laws, basic public acquisition policy has become more uniform. However, a number of states have enacted laws and regulations that go beyond federal law and provide property owners with entitlements not considered generally compensatable under federal law. Therefore, those responsible for estimating the cost of right-of-way must possess knowledge concerning a unique set of rules and regulations and understand the lead time requirements that accompany the rules and regulations.

Aside from property acquisition costs, estimators must also estimate the cost of utility relocations. These costs can run very high and may even exceed property acquisition costs. The current cost estimates for utility relocations required in the expansion of Interstate 10 in Houston, Texas, exceed $200 million. This represents a unit cost of $10 million per mile for this 20-mile project, or 30% of the right-of-way budget.

What Does It Do?

This tool ensures that the agency has individuals who are knowledgeable and specifically trained to prepare right-of-way cost estimates. Additionally, the tool provides the agency with the staff personnel having the competencies to evaluate right-of-way cost estimates prepared by outside consultants.

When?

The establishment of separate right-of-way estimators could be of great benefit to state highway agencies that regularly engage in urban commercial corridor projects. It has been found that court costs associated with acquiring right-of-way vary greatly and are particularly high for projects in highly developed commercial corridors.

Examples

Virginia DOT is currently doing right-of-way estimates through the right-of-way department, but is looking into making this task part of the in-house computer program. However, there has been some resistance because the right-of-way people feel that the computer cannot match the expert judgment that is required.

Caltrans has realized that right-of-way funds to acquire parcels needed to construct the project are typically expended during the design phase. For this reason, it is the agency's policy to have close coordination with the right-of-way branch during the design phase of project development.

Florida DOT has recommended the use of right-of-way cost estimation teams for certain projects. "Guidance Document 2: Right of Way Cost Estimates" (revised April 2004) states: "It is suggested that the district consider appointment of a team to participate in the preparation of the estimate on large or complex projects." The document is available online at www.dot.state.fl.us/rightofway/documents/ROWmanual/Acrobat%20files/guide2.pdf.

Tips

Real estate sales prices along a corridor of several individual projects are affected by the order in which projects are accomplished. A study of residential property prices from 1979 to 1997 along an urban corridor in Texas revealed significant price effects of the corridor improvement phases. During the pre-planning phase, housing prices in the immediate vicinity of the freeway were negatively affected, while those farther away were positively affected. During the planning phase, houses in the corridor appreciated at twice the rate of other Dallas properties. Prices declined in the corridor more rapidly than elsewhere in Dallas during the early construction phases. However, prices again improved during the final construction phase, as sections of the freeway began to reopen and access improved. Right-of-way estimators need to be engaged in construction data based on such information to use as aids in preparing estimates.

Resources

Computer-aided design and drafting (CADD) systems use computer graphic technologies to design and map projects. They provide an expedient way to consolidate many different design aspects, such as right-of-way maps, into a common database or base map. A 1999 U.S. General Accounting Office study found that 43 state highway agencies use CADD systems on more than half their projects. CADD-generated project right-of-way maps present an opportunity to enhance knowledge concerning right-of-way requirements and to improve right-of-way estimation.

Global positing systems (GPS) are used for mapping purposes. A 1999 U.S. General Accounting Office study found that 15 state highway agencies use these systems on more than half their projects. GPS-generated project right-of-way maps also present an opportunity to enhance knowledge concerning right-of-way requirements and to improve right-of-way estimation.

Executive Order (EO) No. 12898 of 1994, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," requires that federal agencies be responsible for reviewing their programs and other activities to determine and prohibit any disproportionately high adverse effects on the human environments in low-income or minority communities. In the case of transportation projects, EO 12898 is implemented through the U.S. DOT and the FHWA. The U.S. DOT strategy ensures that the provisions of EO 12898 are integrated into the relevant existing guidelines used in the project planning and public participation processes. The FHWA's order requires that specific research and related data collection be conducted to provide information on environmental justice concerns.

The FHWA's Office of Real Estate Services has a *Project Development Guide* that contains a practical approach to project right-of-way. This document presents best practices of state and local agencies and others in the right-of-way field. The guide can be found on the Internet at www.fhwa.dot.gov/realestate/pdg.htm.

"The Costs of Right of Way Acquisition: Methods and Models for Estimation" is a paper presented at the 83rd Annual Meeting of the Transportation Research Board, January 2004. The paper reviews the literature related to right-of-way acquisition and property valuation. It describes the appraisal process and the influence of federal law on acquisition practices. It provides price models for estimation of costs associated with taking property using recent acquisition data from several Texas corridors and full-parcel commercial sales transactions in Texas' largest regions. Results indicate that damages depend heavily on parking, access, and location. The size of the taking is not as important as the value of improvements, and utility costs are highly variable.

See also the following research:

- Buffington, J. L., M. K. Chui, J. L. Memmott, and F. Saad (1995). "Characteristics of Remainders of Partial Takings Significantly Affecting Right-of-Way Costs." TXDOT Research Report. FHWA/TX-95/1390-2F.
- Carey, J. (2001). "Impact of Highways on Property Values: Case Study of the Superstition Freeway Corridor." FHWA Report No. FHWA-AZ-01-516.
- Gallego, A. V. (1996). "Interrelation of Land Use and Traffic Demand in the Estimation of the Value of Property Access Rights." Thesis for Masters of Science in Civil Engineering, the University of Texas at Austin.

See also the following federal laws governing acquisition:

- The Uniform Relocation and Real Property Acquisition Policies Act of 1970 (42 U.S.C. 4801 et seq.)
- Section I of the Civil Rights Act of 1866 (42 U.S.C. 1982, et seq.)
- Title VI of the Civil Rights Act of 1966 (42 U.S.C. 2000d et seq.)
- Title VIII of the Civil Rights Act of 1968 (42 U.S.C. 3601 et seq.) as amended
- The National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.)
- The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund) as amended by the Superfund Amendments and Reauthorization
- The Superfunds Amendment and Reauthorization Act of 1986 (SARA) (42 U.S.C. Section 9601 et seq.)
- Section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 790 et seq.)
- The Flood Disaster Protection Act of 1973 (Public Law. 93-234)
- The Age Discrimination Act of 1975 (42 U.S.C. 6101 et seq.)
- Executive Order 11063: Equal Opportunity and Housing, as amended by Executive Order 12259
- Executive Order 11246: Equal Employment Opportunity
- Executive Order 11625: Minority Business Enterprise
- Executive Order 11988: Floodplain Management
- Executive Order 11990: Protection of Wetlands
- Executive Order 12250: Leadership and Coordination of Non-Discrimination Laws

- Executive Order 12259: Leadership and Coordination of Fair Housing in Federal Programs
- Executive Order 12630: Governmental Actions and Interference with Constitutionally Protected Property Rights

R3 Risk Analysis (Also See I2)

Risk management is concerned with future events, whose outcome is unknown, and how to deal with uncertainties by identifying and examining a range of possible outcomes. The objective is to (a) understand risks and (b) mitigate or control risks. Understanding the risks inherent with each potential project alternative is important to controlling cost and developing estimates that reflect the cost of accepted risks and risks transferred to the contractor.

Risk management and an understanding of project uncertainty will assist estimators in setting appropriate contingencies for each individual project. This understanding is also important to managers of estimation processes. Cost estimation is one tool in a comprehensive risk management process. In the broader context of project risk management, risk analysis is the second step in a comprehensive risk management process that includes:

- Risk identification
- Risk analysis (qualitative and/or quantitative)
- Risk mitigation planning
- Risk monitoring and control

Risk identification and risk mitigation planning are discussed in the Tools I2.1 and I2.2. Risk analysis and risk monitoring and control are discussed in Tools R3.1, R3.2, R3.3, R3.4, and R3.5. Additionally, communication of risk analysis results is discussed in Tool C1.2. When used together, these eight tools support a comprehensive risk management process. The tools presented in this section provide a better understanding of project uncertainty and application of contingency. The process can also assist in the contingency resolution process as the project scope, design, and delivery methods become fully defined.

R3.1 Analysis of Risk and Uncertainty (Also See C1.2 and I2)

Analysis of risk and uncertainty involves the quantification of identified risks. In a comprehensive risk management process, risk analysis is used to prioritize the identified risks for mitigation, monitoring, and control purposes. In the context of cost estimation, risk analysis can be extremely helpful for understanding project uncertainty and setting appropriate contingencies. Risk analysis can be done through qualitative or quantitative methods.

What Is It?

In the context of cost estimation, this tool quantifies project risk and uncertainty to provide a better understanding of contingency and the ultimate project cost. It involves evaluation of risks in terms of their likelihood of occurrence and their probable consequences. Likelihood of occurrence and the associated consequences can be expressed qualitatively or quantitatively. If risks can be quantified, they can provide for a better understanding of project uncertainty and assist in the cost estimation management process.

Risk analysis can be done through qualitative or quantitative procedures. In a qualitative analysis process, the project team assesses each identified risk (see also Tools I2.1 and I2.2) for its probability of occurrence and its relative magnitude of impact on project objectives. Quite often, experts or functional unit staff assess the risks in their respective fields and share these assessments with the project team. The risks are then sorted into high, moderate, and low risk categories (in terms of time, cost, and scope). The objective is to rank each risk by degree of probability and impact. The rationale for the decision should be documented for future updates, monitoring, and control.

Quantitative risk analysis procedures employ numeric estimates of the probability that a project will meet its cost and time objectives. It is common to simplify a risk analysis by calculating the expected value or average of a risk. The expected value provides a single quantity for each risk that is easier to use for comparisons. While this is helpful for comparisons and ranking of risks, estimators must take care when using the expected value to calculate project costs or contingencies. For example, if there is a 20% chance that a project will need a $1 million storm water upgrade, the estimator will include $200,000 in contingency using the expected value. If the storm water upgrade is required, this value will not be enough. Unfortunately, a great deal of information is lost in this oversimplified contingency analysis. More comprehensive quantitative analysis is based on a simultaneous evaluation of the impact of all identified and quantified risks. The result is a probability distribution of the project's cost and completion date based on the risks in the project. Quantitative risk analysis involves statistical simulations and other techniques from the decision sciences. Tools commonly employed for these analyses include first-order second-moment (FOSM) methods, decision trees, and/or Monte Carlo simulations.

Why?

Highway project delivery is a complex task that is fraught with uncertainty. Traditional methods of cost estimation often overlook risks or deal with them in a deterministic manner. Using the analysis of uncertainty and other risk tools in the cost estimation process has many advantages. Federal Transit Administration's 2004 *Risk Assessment Methodologies and Procedures* mentioned several advantages:

- Better understanding of the project delivery process, including timelines and phasing, procedural requirements, and potential obstacles.
- More realistic estimates of individual component costs and durations, thereby allowing more reasonable expectations of total project cost and duration.
- Better understanding of what the project contingency is, whether it is sufficient, and for what it may need to be used.
- Information support to other project or agency activities, such as value engineering and strategic planning.
- Potential to improve the project budget and scheduling processes, possibly for the immediate project in development but certainly for future projects.

What Does It Do?

This tool quantifies the impact of potential risks in terms of their consequences to cost and schedule estimates. It provides a systematic evaluation of project uncertainty. It assists estimators in setting appropriate contingencies and assists project managers in controlling project cost, schedule, and scope issues that can arise from uncertain or risky events.

When?

Risk analysis can be used throughout the project development process. At the earliest stages of project development, risk analysis will be helpful in developing an understanding of project uncertainty and in developing an appropriate project contingency. As the project progresses through the development process, risk analysis can be used in a comprehensive risk management monitoring and control process to assist in managing cost escalation resulting from either scope growth or the realization of risk events.

Examples

California DOT (Caltrans) has documented a qualitative risk analysis procedure in its 2003 *Project Risk Management Handbook*. The Caltrans process is largely based on the Project Management Institute's 2004 *A Guide to Project Management Body of Knowledge* (PMBOK Guide). The Caltrans handbook calls for a quantitative assessment of project risk items representing the highest degree of exposure. This quantification is important for updating the contingency amount to be included in the project estimate. Figure R3.1 shows the Caltrans process, published as Appendix C of the handbook, as an example of a qualitative risk analysis method.

The Caltrans example demonstrates a sound process for qualitative risk analysis. The outcome of the qualitative analysis is typically a ranked list of risks that can be used as red flag items or in a risk charter. Quantitative analysis typically begins with a process that is similar to the quantitative analysis shown above, but then applies a direct and more accurate assessment of probability and impact and incorporates these assessments into a probabilistic cost-risk model.

The goal of the quantitative risk analysis is to create a probabilistic cost-risk model to represent the uncertainties affecting project cost and schedule. It ultimately identifies a likely range of costs or durations that bracket potential risk cost or schedule impacts. Examples of range estimates are provided in Tools R3.4 and R3.5.

Tips

Conduct the risk analysis early in the project development process. Involve a multidisciplinary team to conduct the risk analysis. The team may benefit from outside experts to generate the list of risks and assist in the analysis. If a project requires a quantitative risk analysis, consult expert modelers. Most state highway agencies do not have in-house capabilities for performing quantitative risk analyses.

Resources

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook.* www.dot.ca.gov/hq/projmgmt/documents/prmhb/project_risk_management_handbook.pdf.

Federal Transit Authority (2004). *Risk Assessment Methodologies and Procedures.* Project Management Oversight under Contract No. DTFT60-98-D-41013.

Federal Highway Administration (2004). *Major Project Program Cost Estimating Guidance.* http://www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Grey, S. (1995). *Practical Risk Assessment for Project Managers.* John Wiley and Sons, Chichester, England.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3.

Project Management Institute (2004). *A Guide to Project Management Body of Knowledge* (PMBOK Guide).

Washington State DOT's Cost Estimating Validation Process (CEVP) website: www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

R3.2 Contingency—Identified

The standard state highway agency method for assigning contingency has been to either follow standard percentages for

Appendix C: Risk Probability Ranking

Using established methods and tools, qualitative risk analysis assesses the probability and the consequences of each identified risk to determine its overall importance. Using these tools helps to correct biases that are often presented in a project plan. In particular, careful and objective definitions of different levels of probability and impact are the keys to the credibility of the results.

For more information about risk probability ranking, see chapter 11 of the PMBOK.

▸ To rank risks by probability and impact:

Step 1: Set up a matrix to match a percentage (probability of risk) to a ranking number. Department project managers often use the matrix shown below, but they can set up a different matrix if it would better suit the project.

Risk Probability Ranking

Ranking	Probability of Risk Event
5	80–99%
4	60–79%
3	40–59%
2	20–39%
1	1–19%

Step 2: Set up a matrix to match the objective (time, cost, and scope) to a defined impact. Department project managers often use the impact numbers shown in the matrix below, but they can choose others if it would better suit the project.

Evaluating Impact of a Risk on Major Project Objectives

	Impact	1	2	4	8	16
Objective	Time	Insignificant schedule slippage	Delivery plan milestone delay within quarter	Delivery plan milestone delay of one quarter	Delivery plan milestone delay of more than one quarter	Delivery plan milestone delay outside fiscal year
	Cost	Insignificant cost increase	<5% cost increase	5–10% cost increase	10–20% cost increase	>20% cost increase
	Scope	Scope decrease is barely noticeable	Changes in project limits or features with <5% cost increase	Changes in project limits or features with 5–10% cost increase	Sponsor does not agree that scope meets the purpose and need	Scope does not meet purpose and need

Figure R3.1. Caltrans process of risk probability ranking.

Step 3: Combine the data from the two previous steps. Each risk appears in its own probability and impact (PxI) matrix.

The PDT uses a PxI matrix to combine each risk's probability and impact. These matrices establish whether each risk is high, moderate, or low. The risks can then be displayed by high, moderate, and low groupings for each of the three objectives (time, cost, and scope). Department project managers often use the PxI matrix shown below, but they can set up a different matrix and assign different scores if it would better suit the project.

Translate Score to Risk Rank

Score	Risk
1 – 6	Low
7 – 14	Moderate
15 – ++	High

Time, Cost, and Scope Objectives

Large Aversion to High & Very High Impacts

Probability					
5	5	10	20	40	80
4	4	8	16	32	64
3	3	6	12	24	48
2	2	4	8	16	32
1	1	2	4	8	16
	1	2	4	8	16
	Impact				

Figure 3. Sample PxI matrix

Some Department project managers use a PxI matrix based on narrative probabilities and impacts (very low, low, moderate, high, very high) rather than numerical ones. For a sample of this type of matrix, see "Appendix B: Sample Risk Management Plan Spreadsheet" on page 20.

Figure R3.1. (Continued).

the varying stages of project development or to rely solely on the project estimator's experience. The enumeration and qualitative assessment of a project's contributor risks offers a more effective method for determining project contingency than does the standard state highway agency practice of broad-based percent add-on contingency amounts. Attention to technical complexities, construction execution, and the macroenvironment focuses estimator attention on project risks.

What Is It?

This tool creates a process whereby the contingency amount included in an estimate is set on the basis of identified risks and the probability of their occurrence. This tool should ideally be used in conjunction with a comprehensive risk management process. When this tool is used in conjunction with a qualitative risk assessment, the contingency is set using the cost estimator's judgment and the information generated from the risk identification and analysis process, and the contingency is in compliance with state highway agency policy. When this tool is used in conjunction with a quantitative risk analysis, the contingency is set using an acceptable confidence interval for the project (i.e., the difference between the 50% and 80% confidence intervals of a range estimate).

Cost estimation methods and tools must be understood in terms of the design definition (i.e., detail) available during the various phases of project development. More generally, at any stage in the development of a highway project, cost estimates will be composed of three components for which there are different amounts of information: "Known/Knowns" (known and quantifiable costs), "Known/Unknowns" (known but not quantified costs), and "Unknown/Unknowns" (as yet unrecognized costs); these concepts are illustrated in Figure R3.2-1. Note that in this figure the contingency cost component extends into the known/known cost percentage. Also note that in this figure, at the "Advertise & Bid" point, there still will be the potential for unrecognized costs (a very small gap) and known but not quantified costs (a small gap). Only when construction is completed are all costs known. All too often, if the cost of an item is not known, it is not included in early project cost estimates. There is also opportunity for other items (e.g., environmental or construction inspection costs) to be entirely left out of early estimates. The costs associated with the three components—known/knowns, known/unknowns, and unknown/unknowns—require different methods and tools to define and quantify their possible contribution to the estimate at any particular time in the project development process.

Figure R3.2-2 illustrates how identifying, quantifying, and managing cost and schedule uncertainty relates to refining the cost estimate (i.e., managing the final project cost). This figure illustrates two crucial points that apply to situations where the scope is unchanged and where an estimate, at some early stage in the design process, has included uncertainty. The first point is that the range of cost or schedule uncertainty should

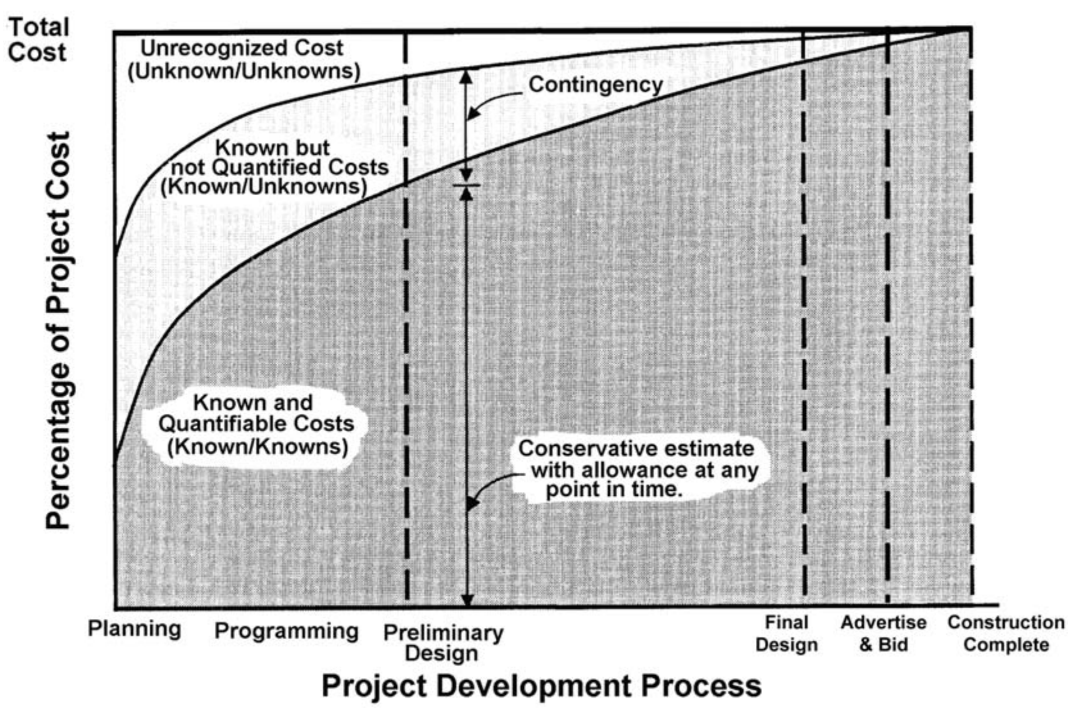


Figure R3.2-1. Components of a cost estimate.

decrease as a project proceeds from concept to final design. Estimate accuracy improves as design develops, cost variables are better defined, and uncertainty is eliminated. The second point is that if the uncertainties included in the estimate, as a contingency amount, in the early stages of project design materialize, then the estimated total will still be as expected. However, as risk management and other cost control processes are applied to the identified uncertainties, it is often possible to mitigate risks (i.e., contingency costs) and deliver the project at a lower cost.

The Association for the Advancement of Cost Engineering International (AACEI) has developed a cost estimate classification system that defines five estimate classifications. This system, shown in Table R3.2, provides an expected range of accuracy for each project development phase. A Class 5 estimate is prepared at the earliest stage of project definition, and a Class 1 estimate is prepared closest to complete project definition and final design. Table R3.2 also describes the methodological approach to the estimate as either stochastic or deterministic, depending upon the level of design and information available. A deterministic estimate contains no random variables, while a stochastic estimate contains one or more random variables. The result of a deterministic estimate is a single point of total cost, while the result of a stochastic estimate is a range of total cost. The AACEI recommends that Class 1 through 3 estimates be developed primarily as stochastic estimates, which are not commonly employed by state highway agencies, but are being described in this section on risk analysis.

Why?

The identification of project risks gives the estimator a much firmer basis for developing a reliable contingency amount than the typical top-down assignment of a percentage based on the estimated direct cost of the project.

What Does It Do?

Because risks are specifically delineated as a project is developed, specific strategies can be implemented to mitigate, transfer, or avoid significant risks. In addition, with the risks identified and quantified, control and tracking procedures can be implemented to monitor risk items on an ongoing basis. These concepts are more fully explained in Section R3.5.

When?

The tool should be employed early, and risks should be tracked throughout the project development process. Projects of an unusual or complex nature require a more in-depth evaluation of potential risks and their effect on estimated cost.

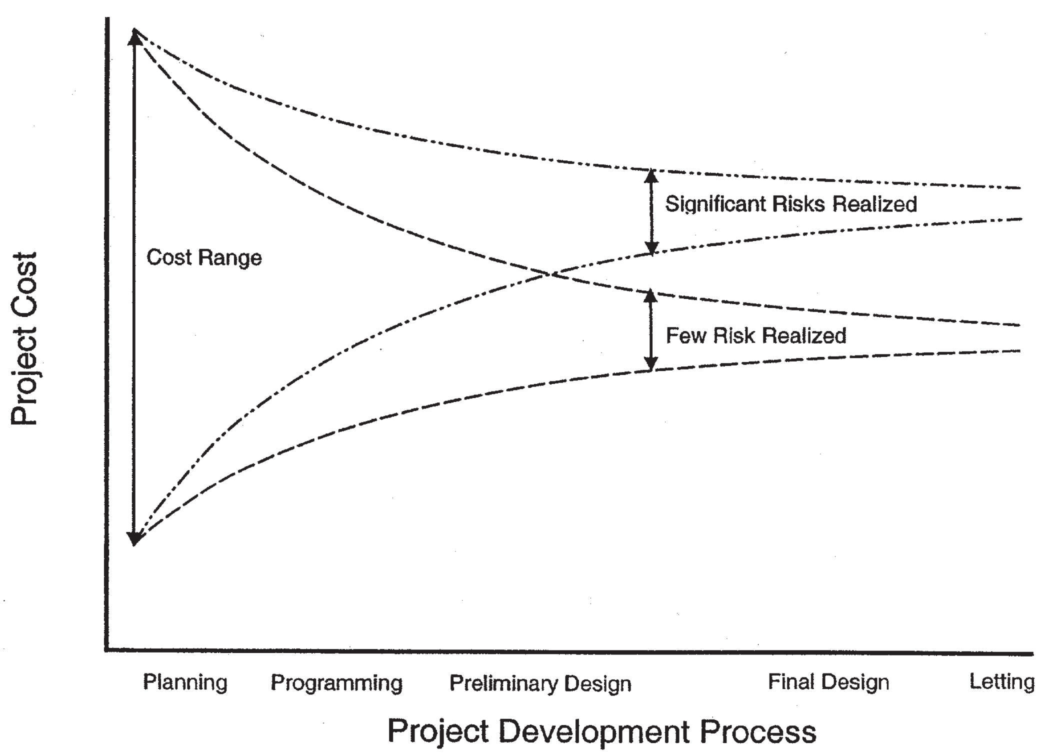


Figure R3.2-2. Refinement of a cost estimate.

Table R3.2. AACEI generic cost estimate classification matrix.

Estimate Class	Primary Characteristic	Secondary Characteristic		
	Level of Project Definition Expressed as % of complete definition	**End Usage** Typical purpose of estimate	**Methodology** Typical estimation method	**Expected Accuracy Range** Typical +/– range
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgment	+40/–20 to +200/–100
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	+30/–15 to +120/–60
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed, but Primarily Stochastic	+20/–10 to +60/–30
Class 2	30% to 70%	Control or Bid/ Tender	Primarily Deterministic	+10/–5 to +30/–15
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	+10/–5

Adapted from the Association for the Advancement of Cost Engineering International's *AACE International Recommended Practice No. 17R-97: Cost Estimate Classification System*, 1997.

The opportunities to expand the identification and quantification of risks should be pursued as design progresses and as more is known about potential exogenous risk factors.

Examples

The Cost Estimating Validation Procedure (CEVP) developed by the Washington State DOT (WSDOT) is a peer-level review on the scope, schedule, and cost estimate for transportation projects throughout the state of Washington. The objective of the CEVP is to evaluate the quality and completeness, including anticipated uncertainty and variability, of the projected cost and schedule.

The outcomes of the CEVP include:

- An estimate validation statement in the form of a CEVP project summary sheet that represents the project cost ranges and the uncertainty involved (see Section C1.2).
- Findings and recommendations that allow WSDOT project teams and senior management to better understand the basis, content, and variability of cost estimates.
- Identification and characterization of the high-risk project elements (this outcome will allow project teams to address appropriate mitigation strategies).

The CEVP is also discussed in Sections C1.2, I2.2, R3.4, and R3.5.

The Caltrans *Risk Management Handbook* calls for a quantitative assessment of project risk items representing the highest degree of exposure. This quantification is important for updating the contingency amount to be included in the project estimate. The handbook is available online at www.dot.ca.gov/hq/projmgmt/documents/prmhb/project_risk_management_handbook.pdf.

The Federal Transit Administration commissioned a report on risk assessment technologies and procedures that discusses the application of risk-based contingency. The report is titled *Risk Assessment Methodologies and Procedures.* The Regional Transportation District (RTD) in Denver, Colorado, is also employing a risk-based contingency process to its Fastracks transit program. See Denver RTD's 2006 "Risk Assessment Quantification," available online at www.rtd-denver.com/fastracks/documents/SB_208_Submittal/Risk_Analysis.doc.

Tips

To successfully attack the effects of project risk, risk analysis must take a broad view of risk; concentrating on only the technical risks can lead to oversights in other project dimensions. The analysis should consider local authority/agency impacts, industry and market risks, elements of political uncertainty, and public and/or permit approval processes that might impact timing.

Scope changes must also be considered from a broad perspective. Identification of risk goes beyond the internal project risks (such as pile driving depth) and includes exogenous factors (such as market conditions, business environment, global construction activities/demand, the macroeconomic environment, and weather). Namely, any major uncertainties that might influence the primary project outcomes of cost, schedule, or quality should be included.

Resources

Association for the Advancement of Cost Engineering International (2004). "AACE International Recommended Practice No. 10S-90: Cost Engineering Terminology." http://www.aacei.org/resources/rp.shtml.

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook.* www.dot.ca.gov/hq/projmgmt/documents/prmhb/project_risk_management_handbook.pdf.

Denver Regional Transportation District (2006). "Risk Assessment Quantification." www.rtd-denver.com/fastracks/documents/SB_208_Submittal/Risk_Analysis.doc.

Federal Transit Administration (2004). *Risk Assessment Methodologies and Procedures,* Report for Contract No. DTFT60-98-D-41013.

Federal Highway Administration (2006). "Price Trends for Federal-Aid Highway Construction." www.fhwa.dot.gov/programadmin/pricetrends.htm.

Federal Highway Administration (2004). "Major Project Program Cost Estimating Guidance." http://www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Owen, P. A., and J. K. Nabors (1983). "Quantifying Risks in Capital Estimates," *AACE Transactions*, B.5.1-B.5.7.

Stevenson, J. J. (1984). "Determining Meaningful Estimate Contingency," *Cost Engineering,* AACE International, Vol. 26, No. 1.

Washington State DOT (2006). Cost Estimating Validation Process (CEVP) website, www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

R3.3 Contingency—Percentage

As depicted in Figures R3.2-1 and R3.2-2 and Table R3.2, contingency percentages should decrease from the early stages of project development through final design. This theoretical idea of contingency has led some state highway agencies to apply fixed contingencies that decrease with project development milestones. However, it is poor policy to use fixed allowances for contingencies without good reasons. So even if the contingency amounts included in an estimate are justified based on published tables of practice, they still should be documented in writing. This requirement for documentation becomes even more important when fixed allowances or guide ranges for contingency are not followed. If extraordinary conditions exist that call for higher contingencies, the rationale and basis must be documented in the estimate.

What Is It?

Recognizing that cost estimation is inherently difficult because estimators are trying to predict the future, it is prudent to provide contingency allowances in the estimate. These contingency allowances represent the typical cost escalation experienced on similar projects as design progresses. The contingency amount can be set as a percentage of the project's direct cost with the percentage being established by analysis of historical cost experience from past projects.

Why?

At any stage in the development of a project, cost estimates will be composed of three components for which there are differing amounts of information: "Known/Knowns" (known and quantifiable costs), "Known/Unknowns" (known but not quantified costs), and "Unknown/Unknowns" (as yet unrecognized costs). These components are illustrated in Figure R3.2-1. What the contingency amount is supposed to account for is the total of the "Known/Unknowns" and "Unknown/Unknowns" of the estimate.

What Does It Do?

A contingency allowance included in an estimate is meant to provide funds for cost growth resulting from necessary but unforeseeable project scope changes, underestimation of real project costs, or errors in projecting the rate of inflation. Increases in the prices for construction services—inflation—are not to be considered covered by the contingency amount. Inflation should be handled by applying an appropriate inflation rate to the calculated project cost (see Section E3.5).

When?

Contingency amounts, added to an estimate, are a valid means of reflecting the uncertainties that remain to be defined as design progresses. A contingency amount should be included in every project estimate from the earliest planning stage of project development to the final PS&E; however, as shown in Figure R3.2-1, the magnitude of the contingency amount decreases as the scope is defined and the design progresses.

Examples

Many state highway agencies use standard percentages, such as the percentages in Table R3.3-1, to develop estimate contin-

Table R3.3-1. One state highway agency's graduated conceptual estimate contingency scale.

Project Value	Conceptual Contingency
$0 - $1,000,000	11.0%
$1,000,000 - $5,000,000	9.5%
$5,000,000 - $25,000,000	7.0%
$25,000,000 +	6.0%

gency amounts. Historical experience shows that state highway agencies can establish contingency percentages to be applied to an estimate's direct cost, but research shows that, in many cases, the applied percentages do not reflect actual conditions.

State highway agencies should only use the percentage contingency approach for projects that are similar in character to a large number of past projects for which good cost data are available.

Table R3.3-2 is a summary of guidance on contingency in Chapter 20 of the *Caltrans Project Development Procedures Manual* (available online at http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm). The table is offered as guidance for a graduated contingency. However, it should be noted that Caltrans also offers guidance on applying risk-based contingency when appropriate, as described in Sections R3.1 and R3.2.

Tips

When a state highway agency chooses to establish an estimate contingency by means of the relationship between contingency amount and project direct cost, two steps are needed to make the process work effectively:

1. The purpose of the contingency amount needs to be carefully defined. Estimators and management must understand that the contingency is intended to account for very specific unforeseen, unexpected, unidentified, or undefined costs. The project risks that cause the occurrence of these costs must be delineated in the state highway agency's estimation manual with the percentages. Examples of risk factors early in design are provided in Sections I2.1 and I2.2. Examples of possible risk factors near the final design period include:
   - **Number of bidders:** The availability of contractors willing to bid the work will affect the bid prices. Caltrans has found that, for projects in the $1 million to $10 million range, if there is only one bidder, the price will on average be 5% above the engineer's estimate, and the effect of each additional bidder is a 2% reduction in bid price compared with the state highway agency estimate.
   - **Contractor perception of project risk:** The perceptions of risk by contractors vary widely, but underground work will normally increase a contractor's bid because of geotechnical unknowns. For one-of-a-kind projects, contractors will apply more risk to their bid.
   - **Construction unknowns:** This risk factor might be addressed with a reserve to cover construction change orders due to differing site conditions and other construction issues.
   - **Quality of construction documents (plans and specifications):** Incomplete or inadequate construction documents add to project management difficulties and usually result in an increased number of change orders.
   - **Contracting method:** A range of risk management strategies affect project cost, risk transfer, risk reduction, and even financial treatments. Using lump sum or even unit price contracts to transfer risk to a contractor when project complexities exist that cannot be completely addressed until construction commences will add cost to the project. The constructor will add higher overhead and profit markup to the bid, and there will still be difficult-to-resolve change orders.
   - **Material price escalation:** Sometimes material price escalation is carried in the individual items of the estimate, and sometimes it is supposed to be part of the estimate contingency. The proper accounting should be defined in the state highway agency's estimation manual.
2. The established contingency percentages should be based on actual experience (i.e., historical data). It is important for both the state highway agency estimators and state highway agency management to know the level of accuracy achieved with the prescribed contingency percentages. Statistical analysis of past projects provides a means for measuring that accuracy and adjusting the employed percentages.

Table R3.3-2. Caltrans graduated conceptual estimate contingency scale.

Design/Estimation Milestone	Percent Contingency
Project Feasibility Cost Estimate	30% to 50%
Project Study Report Cost Estimate	25%
Draft Project Report Cost Estimate	20%
Project Report Cost Estimate	15%
Preliminary Engineer's Cost Estimate	10%
Final Engineer's Cost Estimate	5% or less

Adapted from Chapter 20 of the *Caltrans Project Development Procedures Manual* (available online at http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm).

Resources

FHWA (2004). "Contingency Fund Management for Major Projects." www.fhwa.dot.gov/programadmin/mega/contingency.htm.

FHWA (2004). "Major Project Program Cost Estimating Guidance." www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Chapter 20 of the *Caltrans Project Development Procedures Manual*, http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm.

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook*. www.dot.ca.gov/hq/projmgmt/documents/prmhb/project_risk_management_handbook.pdf.

Caltrans (1998). *State Administrative Manual*, Chapter 6000, Section 6854: CONSTRUCTION. http://sam.dgs.ca.gov/TOC/6000/6854.htm.

U.S. Army Corps of Engineers. "Military Program-Specific Information—REF8011G," http://bp.usace.army.mil/robo/projects/pmbp_manual/PMBP_Manual/REF8011G.htm.

Uppal, Kul B. (Ed.) (2005). *Professional Practice Guide #8: Contingency* (CD), Association for the Advancement of Cost Engineering (AACE) International. http://www.aacei.org/technical/ppg.shtml.

R3.4 Estimate Ranges

The outcome of a quantitative risk analysis is a probabilistic model of cost and schedule. The probabilistic model is most commonly expressed thorough an estimate range. Estimate ranges communicate the uncertainty associated with an estimate. The generation of a range can be as simple as applying an historic plus-minus factor to estimated cost (e.g., –10% to +20%). Alternatively, an estimate range may be generated through sophisticated probabilistic models and expressed in a probability density function, as shown in Figure R3.4-1, with the X-axis representing the range of cost and the Y-axis representing the probability of occurrence for a cost in that range.

What Is It?

A project cost estimate is a prediction of the quantities, cost, and/or price of resources required by the scope of an activity or project. As a prediction, an estimate must address risks and uncertainties. Consequently, engineers realize that any estimate has a potential range of final costs. When appropriate, the estimate can be expressed as a cost range. Communication of the estimate as a range is simply a statement of project cost variability.

Why?

Properly communicating the uncertainty involved in an estimate will help to ensure that decisions based upon the estimate are appropriate given the estimate's precision. A range estimate can help to convey the uncertainty of an estimate. Estimates derived from probabilistic methods (i.e., range cost estimates) better convey the uncertain nature of project costs at the conceptual phase of project development and even during later project development phases.

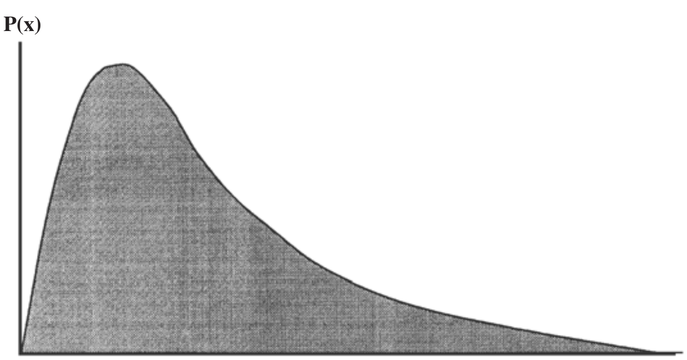


Figure R3.4-1. Probability density function for project cost.

What Does It Do?

The communication of a range of values representing the possible array of ultimate project costs creates a better understanding of estimate precision. The range does not necessarily represent the very least or the very most that the project will cost, but typically the most probable range of project costs. The size of the range will be determined by the identified uncertainties and the modeling method. The interpretation of the range depends on how aggressive the agency is with the results. For example, the agency can set the budget conservatively at a 90% confidence interval, meaning that the final project cost should be less than the budget nine out of ten times.

Currently, many agencies communicate project costs in a single-point value that includes a contingency. The use of a point estimate early in the project development process can lead to a false sense of precision and accuracy because even the best engineers cannot predict all future events that can and will impact a project's cost. The inability to provide a 100% accurate estimate can, in turn, be negatively viewed by opponents to the agency or project. Through use of an estimate range, the agency can convey the uncertainty that is inherent in the project and educate other parties about cost variability. This is also helpful within the agency to demonstrate the uncertainty about the project to other personnel who may not be intimately familiar with the project.

When?

Ranges may be considered throughout project development, but they should be used on projects in earlier stages of development to communicate the level of project knowns and unknowns about the project.

Examples

The Washington State DOT (WSDOT) has developed a risk-based approach to cost estimation in its Cost Estimating Validation Process (CEVP). The CEVP is used to convey project cost through estimate ranges. Figure R3.4-2 provides an example of how CEVP is used to convey an estimate range in the form of probability densities. The project represented has a 10% chance of being completed for \$651 million or less, while there is a 90% chance that the project will cost \$693 million or less. However, there is a chance that the project will cost as little as \$640 million and as much as \$720 million.

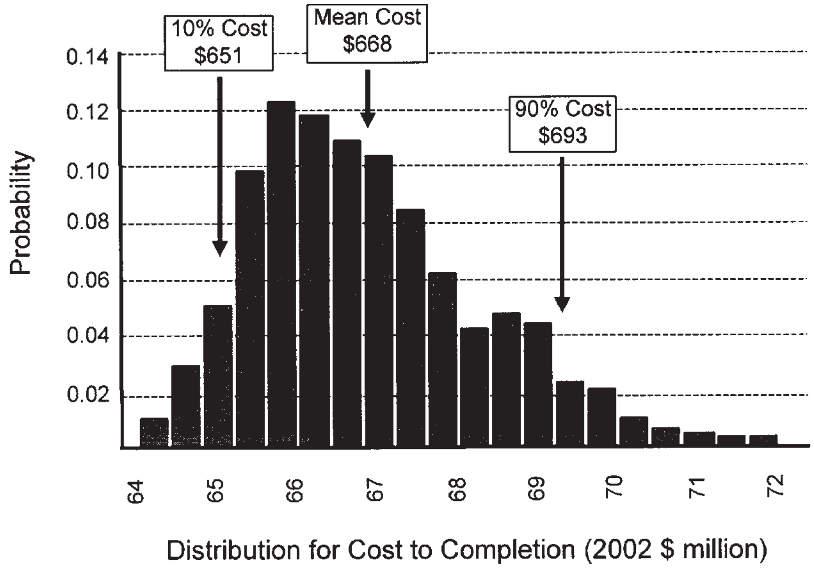


Figure R3.4-2. Estimate range (presented as a probability density function) generated through WSDOT's Cost Estimating Validation Process (CEVP).

WSDOT also uses the CEVP to present cost estimate ranges in a tabular fashion rather than a probability density function. Figure R3.4-3 is an example of how WSDOT is communicating the ranges of possible project costs for the Alaskan Way Viaduct and Seawall Replacement Project. The tabular presentation is used to present multiple ranges for multiple design options. Figure R3.4-3 also conveys how the estimates have changed during 2 years of project development.

California DOT (Caltrans) uses three-point estimates for some elements of project costs and is planning to make wider use of this technique. Figure R3.4-4 shows the type of estimate generated by this technique. Although the math may appear

ALASKAN WAY VIADUCT & SEAWALL REPLACEMENT PROJECT

Project Status: Draft Environmental Impact Statement to be completed by April 2004, with final approval expected in Spring 2005. $177 million included in the 2003 Legislative Transportation Funding package (the "Nickel Plan") provides for the EIS analysis, significant design and right of way purchases. If funding is available, construction could begin as soon as 2008.

CEVP Ranges:	2003 10% - 90%	2002 10% - 90%	Change
Rebuild – rebuilds existing viaduct and seawall	$3.2 B - $3.5 B	$3.2 B – $3.5 B	$0 B
Aerial – replaces viaduct with new, wider viaduct and rebuilds seawall	$3.2 B - $3.5 B	$5.7 B - $6.4 B	$2.5 - $2.9 B
Tunnel – Replaces viaduct and seawall with a six-lane tunnel on central waterfront	$3.8 B - $4.1 B	$10.1 B - $11.6 B	$6.3 - $7.5 B
Bypass Tunnel – Replaces viaduct and seawall with a four-lane tunnel on central waterfront and expands Alaskan Way to six lanes.	$3.1 B - $3.4 B	New Option, N/A	New Option, N/A
Surface - Replaces viaduct with a six to eight lane Alaskan Way. Rebuilds seawall.	$2.5 B - $2.8 B	New Option, N/A	New Option, N/A

Key Differences: Project limits are now primarily from Holgate Street through Battery Street Tunnel.

Figure R3.4-3. Estimate range (presented as a table) generated through WSDOT's Cost Estimating Validation Process (CEVP).

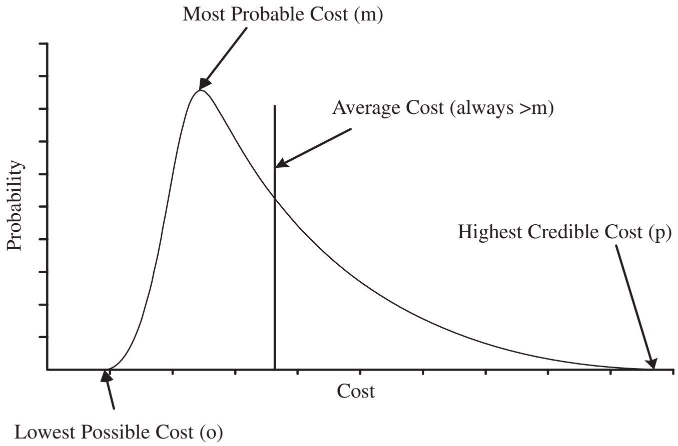


Figure R3.4-4. Caltrans three-point estimate to generate estimate range.

complex at first glance, it is easy to implement with a simple spreadsheet. The three-point estimation process uses the following steps:

1. Have subject matter experts develop three estimates for each item of work:
   a) An optimistic estimate (o): The lowest credible cost assuming that everything goes right.
   b) A most-likely estimate (m): The expert's best guess of the cost.
   c) A pessimistic estimate (p): The highest credible cost, assuming that virtually everything goes wrong.
2. The average cost of the item is $(o + 4m + p)/6$. The average is always greater than the most likely estimate. This is because there is a finite lowest-possible cost. Even in the most optimistic situation, the work package will have a cost that is greater than zero. At the other end of the scale, there is no highest possible cost. It is always possible to spend more money.
3. The standard deviation for the item, derived from the principle that 95% of events occur within two standard deviations of the mean, is:

$$\sigma_i = (p - o)/4$$

4. The standard deviation for the combination of all items in the project is:

$$\sigma_{project} = \left(\sigma_{i1}^2 + \sigma_{i2}^2 + \sigma_{i3}^2 + \ldots \sigma_{in}^2\right)^{0.5}$$

5. The cost estimate for the project is the sum of the average costs for the items. Caltrans gives the highest credible cost as the cost estimate plus three standard deviations ($3\ \sigma_{project}$). Using three standard deviations rather than two allows for the skewed nature of the probability density function.

Tips

While estimate ranges transparently convey the uncertainty involved in a project, they can be misunderstood. The range theoretically shows the highest possible cost for a project. If people focus on the high end of the range, the project can be slowed or stopped. The range should be used as part of a comprehensive risk management plan. If the risks and uncertainties that are driving the range can be understood, they can likely be mitigated and the project can be completed at a cost that is substantially less than the lower end of the range.

Resources

Federal Transit Administration (2004). *Risk Assessment Methodologies and Procedures*, Report for Contract No. DTFT60-98-D-41013.

FHWA (2004). "Major Project Program Cost Estimating Guidance." http://www.fhwa.dot.gov/programadmin/mega/cefinal.htm.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3, American Society of Civil Engineers.

Project Management Institute (2004). *A Guide to Project Management Body of Knowledge* (PMBOK Guide).

Washington State DOT (2006). "Cost Estimating Validation Process" (CEVP) website, www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

R3.5 Programmatic Cost Risk Analysis

State highway and transit agencies are beginning to realize the value of integrating cost estimation practice and cost estimation management with comprehensive risk management processes. Programmatic cost risk analysis involves all four steps of the classic risk management process—risk identification, risk analysis, risk mitigation and planning, and risk monitoring and control. The risk analysis component focuses on the quantitative risk analysis process and uses probabilistic cost models to drive the risk management process. The term "programmatic" refers to applying this process across multiple projects within the state highway agency. This form of risk management is the most comprehensive and resource-intensive manner in which to deal with project uncertainty of all the tools described in this guide.

What Is It?

A programmatic cost risk analysis is a systematic project review and risk assessment method, including probabilistic estimation, to evaluate the quality of the information at hand and to identify and describe cost and schedule uncertainties.

It involves risk identification, risk analysis, risk mitigation and planning, and risk monitoring and control. It systematically combines all of the risk identification, analysis, and communication tools described in this guide (see Sections C1.2, I2.1, I2.2, R3.1, R3.2, R3.3, and R3.4).

A successful cost risk analysis program has the following characteristics:

- Feasible, stable, and well-understood user requirements
- A close relationship with user, industry, and other appropriate participants
- A planned and structured risk management process, integral to the acquisition process
- Continual reassessment of project and associated risks
- A defined set of success criteria for all cost, schedule, and performance elements
- Metrics to monitor effectiveness of risk-handling strategies
- Formal documentation

Why?

Programmatic cost risk analysis can be used to change an agency's culture and to combat systemic cost escalation. It allows cost estimates to be transparently conveyed to management. It reveals risk and uncertainty involved with the project at each stage of the process. It provides a tool to model both the technical and nontechnical nature of the challenges in quantifying capital costs early in the project life cycle.

What Does It Do?

Programmatic cost risk analysis can help to create a culture of risk management that is forward looking, structured, informative, and continuous. Through the generation of risk-based probabilistic cost and schedule estimates, the process can assist agencies in anticipating and mitigating potential cost escalation. The process can produce prioritized lists of cost and schedule risks. It can provide estimates of these individual risk costs and their potential effects on project component schedules. Ultimately, the process can produce prioritized risk mitigation strategies, including their estimated implementation costs and cost/schedule savings, which can be incorporated into a comprehensive risk management plan.

When?

A programmatic cost risk analysis should be applied in all phases of the project development process. In the earliest phases of project development, the tool focuses on risk identification and risk analysis to produce meaning contingencies and prioritized rankings of risks. As project development progresses, the process supports risk mitigation and is managed though an active risk charter. In the final stages of project development, the tool supports the contingency resolution process though active monitoring and control.

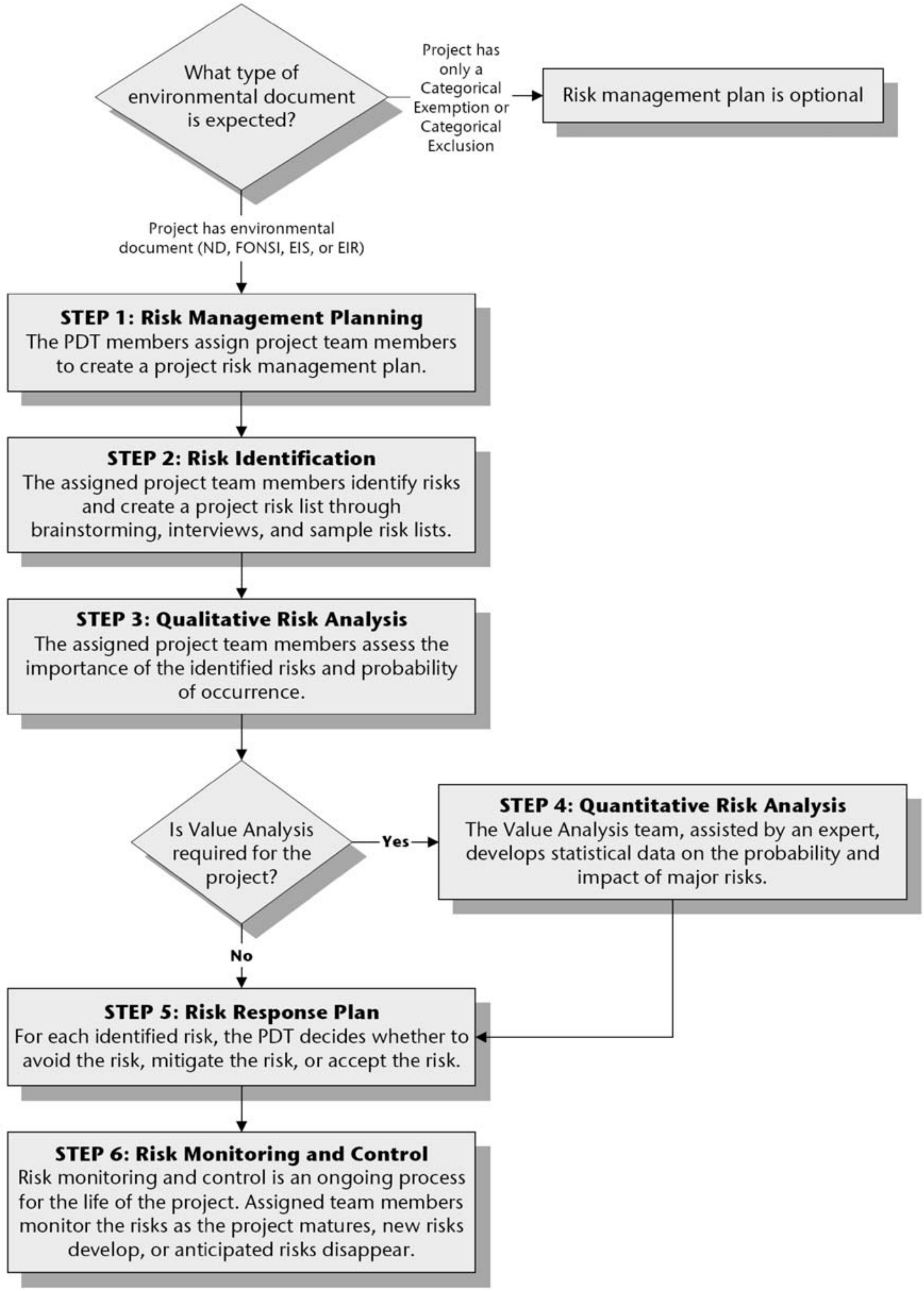
Examples

California DOT (Caltrans) has developed a comprehensive risk management process and documented it in Caltrans's 2003 *Project Management Risk Management Handbook.* The Caltrans process is largely based on the Project Management Institute's *Guide to Project Management Body of Knowledge* (PMBOK Guide). In the Caltrans process, the project team completes the risk management plan before the project initiation document (PID) component ends. The team updates the plan in each subsequent lifecycle component and continues to monitor and control risks throughout the life of the project. Figure R3.5 shows the process flowchart. Table R3.5-1 shows the two main process tasks, the four subtasks, and all of the deliverables associated with project risk management. Table R3.5-2 shows all of the process tasks and the roles associated with each task.

Caltrans has summarized its process into a risk management plan worksheet. The worksheet is available in Microsoft Excel format. It is intended to act as a risk charter for the process (see Section I2.2). The worksheet provides a tool to organize risks from the risk identification process. It provides a color-coded function for conducting qualitative risk assessments. It also provides space for inputting the results of a quantitative risk assessment. Additionally, the risk management planning worksheet provides tracking mechanisms for risk mitigation strategies as well as risk monitoring and control. An electronic version of this sample spreadsheet is available on the project management guidance website at www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm.

Washington State DOT (WSDOT) developed the Cost Estimating Validation Process (CEVP) to assist in evaluating the quality and completeness of project estimates, including the anticipated uncertainty and variability of the projected cost and schedule. The CEVP uses systematic project review and risk assessment methods, including statistics and probability theory, to evaluate the quality of the information at hand and to identify and describe cost and schedule uncertainties. The CEVP recognizes that every project cost estimate will be a mix of the very likely, the probable, and the possible. Importantly, the process examines, from the very beginning, how risks can be communicated and lowered and cost vulnerabilities managed or reduced. In other words, a dividend of the CEVP is to promote the activities that will improve end-of-project cost and schedule results. The CEVP process integrates into the entire project development process in a way similar to that of the Caltrans method previously described.

The CEVP process begins with a workshop to facilitate the risk identification and quantitative risk analysis phases of the process. A rigorous peer review and uncertainty analysis is



Source: *Project Risk Management Handbook*, Caltrans Office of Project Management Process Improvement, 2003.

PT = Project development team
EIS = Environmental impact statement
ND = Negative declaration
FONSI = Finding of no significant impact
EIR = Environmental impact report

Figure R3.5. Caltrans risk management flowchart.

Table R3.5-1. Caltrans risk management tasks and deliverables.

Process Tasks	Task Outputs (deliverables)
Risk management planning	Risk management plan
Risk identification	Project risk list
Qualitative risk analysis	Prioritized list of risks classified as high, moderate, or low.
Quantitative risk analysis (Only if the project includes Value Analysis)	An analysis of the project's likelihood of achieving its cost and time objectives
Risk response planning	Risk response plan, including one or more of the following: residual risks, secondary risks, change control, contingency reserve (amounts of time or budget needed), and inputs to a revised project plan
Risk monitoring and control	Workaround plans, corrective actions, project change requests (PCR), and updates to the risk response plan and to risk identification checklists for future projects

Source: *Project Risk Management Handbook*, Caltrans Office of Project Management Process Improvement, 2003.

the foundation of the CEVP process. A multidisciplinary team of professionals from both the public and private sectors examines the project. Table R3.5-3 presents the seven phases in the WSDOT CEVP process.

While the workshop is a key component of the CEVP process, the CEVP process involves many other components that are integrated into the cost estimation, risk management, and project management processes at WSDOT. Other elements of the CEVP process are described in Sections C1.2, I2.2, R3.1, and R3.4 in this guide. More information can be found on the WSDOT CEVP and Cost Risk Analysis website at www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

Table R3.5-2. Caltrans risk management responsibility matrix.

Process Tasks	Role					
	Sponsor	District Division Chief for Program and Project Management	Project Manager	Assistant Project Manager/ Project Management Support Unit	Functional Manager	Task Manager
Risk management planning	S	S	R	S	S	S
Risk identification	S	S	A	S	R	R
Qualitative risk analysis			R	S	S	S
Quantitative risk analysis (Performed only as part of Value Analysis)			A	S	R	R
Risk response planning	S	S	R, A	S		
Risk monitoring and control	R	R	R, A	S	R	R

Legend: R = responsible, S = support, A = approve

Source: *Project Risk Management Handbook*, Caltrans Office of Project Management Process Improvement, 2003.

Table R3.5-3. CEVP workshop format.

CEVP Process Phase	Summary Description
Phase I – Project Identification and Preparation	• Project data compilation • CEVP training and education
Phase II – Workshop Initiation	• Establishment of the workshop goals, workshop scope, and project alternatives being explored • Project team presentation of: 1) scope and assumptions for each decision alternative; 2) cost and schedule estimate; and 3) major issues and concerns • Development of project flow chart or schedule (the basis for the cost and schedule risk and uncertainty model)
Phase III – Cost Validation and Risk Identification	• Cost validation team breakout activities • Risk team breakout activities • Environmental costing team breakout activities • Modeling team breakout activities
Phase IV – Integration and Model Construction	• Breakout team reports • Reconciliation of breakout assumptions • Construction of cost and schedule risk and uncertainty model
Phase V – Presentation of Results	• Oral presentation of workshop results • Written presentation of workshop results
Phase VI – Validation of Results and Generation of Alternatives	• Project and CEVP teams validate workshop results • Alternative project scenarios are explored and evaluated
Phase VII – Implementation and Auditing	• Development of risk mitigation planning and integration into project management • Reviewing and updating of workshop results and predictions as compared with actual project results

Tips

Implementation of a programmatic cost risk analysis tool will involve significant changes to most state highway agencies' cost estimation and project management procedures. In fact, the process will likely require a cultural change within the organization. To be successful, this tool will require management's full support and commitment of resources.

Resources

Caltrans Office of Project Management Process Improvement (2003). *Project Risk Management Handbook.* www.dot.ca.gov/hq/projmgmt/documents/prmhb/project_risk_management_handbook.pdf.

Federal Transit Authority (2004). *Risk Assessment Methodologies and Procedures,* report under Contract No. DTFT60-98-D-41013.

Federal Highway Administration (2004). *Major Project Program Cost Estimating Guidance.*

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Mega-Projects," *Journal of Construction Engineering and Management,* Vol. 131, No. 3, American Society of Civil Engineers.

Project Management Institute (2004). *A Guide to Project Management Body of Knowledge* (PMBOK Guide).

Washington State DOT (2006). Cost Estimating Validation Process (CEVP) website: www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment.

V1 Validate Costs

Constant project cost evaluation is a means to better manage projects and respond to public skepticism and concern about project estimates and actual costs. Validation processes appraise the reasonableness and completeness of the assumptions, procedures, and calculations used in developing an estimate.

V1.1 Estimation Software (Also See C2, C3, D2, P1)

Computer software provides state highway agencies with the ability to manage large data sets that support estimate development for all project types and levels of complexity. Estimation programs with preloaded templates for creating cost items help project teams define the project scope, cost, and schedule. It is easy to include checks in estimation software to flag cost items that do not fall within historical price ranges.

What Is It?

Estimation software is the computer program that assists the state highway agencies in developing cost estimates. Most estimation software, be it agency developed or a commercial product, has preloaded templates that help the state highway agency 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, particularly if it includes features that flag costs that do not fall within preset historical cost ranges.

Why?

One of the advantages of using estimation software to calculate project cost is that it can provide rapid search features that detect errors or anomalies in an estimate. Estimates on large projects and even on many small urban projects are very complex, and computer software is the only efficient method of checking the many small details that support the cost calculations.

What Does It Do?

The estimation software will direct the estimator's attention to input data or costs that the software detects as not being appropriate. The software does not tell the estimator what is wrong, but it focuses attention on those areas of the estimate that should be carefully reviewed.

When?

Cost validation is an ongoing process that should be occurring during all project development stages. By using estimation software with built-in anomaly detection features, the validation checks take place as the estimate is created. This means that problem identification is continuous.

Examples

The Heavy Construction Systems Specialists, Inc. (HCSS), software, HeavyBid, has a feature that checks the estimate and takes the estimator to each questionable location so that corrections can easily be made as necessary.

The AASHTO CES and Estimator software have a feature that allows the estimator to spot unit costs that are outside the range of unit cost data included in the database. There is a statistical regression option that provides a best-fit curve with confidence intervals. This feature can be used to determine if a unit price that was input by the estimator is within the range of expected unit prices as deleted through the regression analysis.

Tips

The effectiveness of any estimation software is directly related to product support and training. When selecting software, always ensure that product support will be available and that training and training material will be provided.

Resources

For more information about Trns•port Estimator, contact the AASHTOWare contractor: Info Tech, 5700 SW 34th Street, Suite 1235, Gainesville, FL 32608. Phone (352) 381-4400; Fax (352) 381-4444; E-mail info@infotechfl.com; Internet www.infotechfl.com.

Heavy Construction Systems Specialists, Inc. (HCSS), 6200 Savoy, Suite 1100, Houston, TX 77036. Phone (800) 683-3196 or (713) 270-4000; Fax (713) 270-0185; E-mail info@hcss.com; Internet www.hcss.com.

V2 Value Engineering

Value engineering can be defined as a systematic method to improve the value of goods and services by examining function. Value is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary tenet of value engineering that quality *not be* reduced as a consequence of pursuing value improvements.

In the United States, value engineering is specifically addressed in Public Law 104-106, which states, "Each executive agency shall establish and maintain cost-effective Value Engineering procedures and processes."

Value engineering is sometimes taught within the industrial engineering body of knowledge as a technique in which the value of a system's outputs is optimized by crafting a mix of performance (i.e., function) and costs. In most cases, this practice identifies and removes unnecessary expenditures, thereby increasing the value for the manufacturer and/or their customers.

In late 1995, Congress passed the National Highway System (NHS) Designation Act, which included a provision requiring the U.S. Secretary of Transportation to establish a program that would require states to carry out a value engineering analysis for all federal-aid highway projects on the NHS with an estimated total cost of $25 million or more. On February 14, 1997, the FHWA published its value engineering regulation establishing such a program.

V2.1 Value Engineering

Value engineering is a requirement of federal-aid projects. The value engineering process is a systematic approach to improving cost-effectiveness of designs for highway projects. Value engineering can provide a mechanism for enhancing cost estimates of projects by clarifying scope and the quality of design documents.

What Is It?

Value engineering is the systematic review of a project, product, or process to improve performance, quality, and/or life cycle cost by an independent multidisciplinary team of specialists. The value engineering process, referred to as the job plan, defines a sequence of activities that are undertaken during a value engineering study before, during, and following a workshop. During the value engineering workshop, the value engineering team learns about the background issues; defines and classifies the project (or product or process) functions; identifies creative approaches to providing the functions; and then evaluates, develops, and presents the value engineering proposals to key decision makers. The focus on the functions that the project, product, or process must perform sets value engineering apart from other quality improvement or cost reduction approaches.

Why?

When value engineers talk about reducing costs, they are usually referring to either total life cycle costs or the direct costs of production. Total life cycle costs are the total expenditures over the whole life span of the highway. This measure of cost is most applicable to expensive capital equipment and includes engineering, procurement, construction, maintenance, and decommissioning costs. Individual expenditures must be discounted to reflect the time value of money, which translates to a more accurate estimate.

The main objectives that the value engineering process seeks include improving project quality, reducing project costs, fostering innovation, eliminating unnecessary and costly design elements, ensuring efficient investment in projects, and developing implementation procedures.

What Does It Do?

Value engineering uses intuitive logic (a unique "how"/ "why" questioning technique) and analysis to identify relationships that increase value. Value engineering is a quantitative method similar to the scientific method (which focuses on hypothesis and conclusion to test relationships) and operations research (which uses model building to identify predictive relationships).

The value engineering process follows a general framework commonly referred to as an eight-phase job plan, with the following phases:

1. Selection Phase: Select the right projects, timing, team, and project processes and elements.
2. Investigation Phase: Investigate the background information, technical input reports, field data, function analysis, and team focus and objectives.
3. Speculation Phase: Be creative and brainstorm alternative proposals and solutions.
4. Evaluation Phase: Analyze design alternatives, technical processes, life cycle costs, documentation of logic, and rationale.
5. Development Phase: Develop technical and economic supporting data to prove the feasibility of the desirable concepts. Develop team recommendations. Recommend long-term as well as interim solutions.
6. Presentation Phase: Present the recommendations of the value engineering team in an oral presentation and in a written report and workbook.
7. Implementation Phase: Evaluate the recommendations. Prepare an implementation plan, including response of the managers and a schedule for accomplishing the decisions based on the recommendations.
8. Audit Phase: Maintain a records system to track the results and accomplishments of the value engineering program on a statewide basis. Compile appropriate statistical analyses as requested.

The duration and assessment for these phases depend on the complexity of the project. By performing the steps in these phases, the value engineering team will evaluate several components of a project, such as designs, topographical implications, and environmental impacts, and make recommendations for several feasible options along with the cost differences and their impact on total project cost and schedule. These details are compiled into a value engineering decision document for appraisal from concerned authorities.

When?

Value engineering is most successful when it is performed early in project development. A value engineering study should be performed within the first 25–30% of the design effort prior to selecting the final design alternative. Value engineering is compulsorily performed on federal aid projects greater than $25 million and should be performed on high-cost projects. The process can provide a justified logic for alleviating cost escalations while not compromising quality.

Examples

Figure V2.1, the value analysis flowchart for Nevada DOT, shows how the value engineering process is incorporated into practice.

Tips

Often, value engineering reduces costs by eliminating wasteful practices. This can be done in several areas:

- **Material substitutions:** Unnecessarily expensive inputs can sometimes be replaced by less expensive ones that function

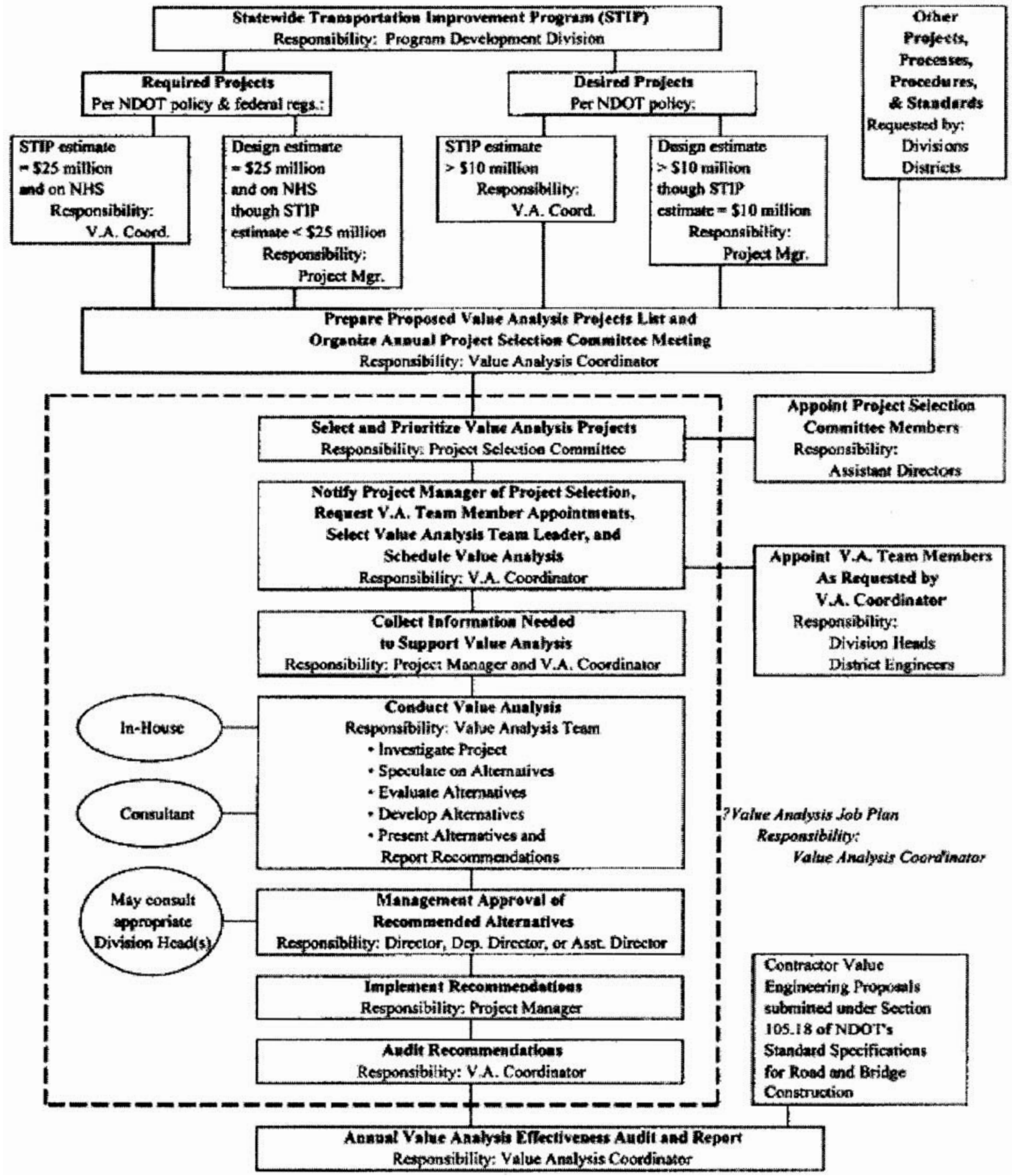


Figure V2.1. Value analysis flow chart (Nevada).

just as well. If a product has a life span of 10 years, then using a material that lasts 30 years is wasteful. In a perfectly value-engineered product, every component of a highway will function perfectly until the product is no longer useful, at which time all components will deteriorate.

- **Process efficiency and producibility:** More efficient processes can be used, and the highway can be redesigned so that it is easier to construct. Reducing unnecessary design elements, unnecessary precision, and unnecessary construction operations can lower costs and increase the speed of construction and reliability.
- **Modularity:** Many highway project design elements are identical and can be mass produced to reduce costs. Such designs are developed once and reused in many slightly dif-

ferent products, thereby reducing a project's engineering and design costs. For example, precast concrete slabs have proven to be a quick and efficient solution to time-constrained construction operations. These slabs can be factory cast for different sizes and transported and assembled at the sites by modern construction practices, such as posttensioned concrete structures. Also, these slabs can be produced to a desired quality as they are manufactured under controlled conditions.

- **Energy efficiency:** In an environmentally conscious society, value can be created by making a product or process more energy efficient for the user. For example, development and usage of customized equipment, such as slip form pavers, ensure that a single piece of equipment performs several operations that would require several resources traditionally.

Additionally, agencies must

- Ensure they have adequate training facilities or trained staff
- Identify and train value engineering team member in-house
- Share knowledge gained or results derived during value engineering studies to continuously improve the process

Resources

Wilson, David C. (2005), *NCHRP Synthesis of Highway Practice 352: Value Engineering Applications in Transportation,* Transportation Research Board. http://www.trb.org/news/blurb_detail.asp?id=5705.

Washington State DOT (1998), "Design Manual," Section 315. http://www.wsdot.wa.gov/EESC/Design/DesignManual/desEnglish/315-E.pdf.

V3 Verify Scope Completeness

Scope completeness is key to producing an accurate cost estimate. Therefore, reviewing a project's scope documents for completeness is an important task in the overall estimation process. The project that is estimated early in the development process is often not the project actually built because of scope changes that could have been avoided if more attention were given to both project requirements and community desires earlier in project development.

V3.1 Estimation Checklist (Also See C4.2, P2.1)

Many changes in scope result from an improved understanding of project need and outcome requirements. Checklists are intended to serve as guides in checking and reviewing whether there are scope omissions. The use of checklists, which cause the estimator to review the scope for completeness, will yield comprehensive and improved cost estimates.

What Is It?

This tool is the employment of checklists or templates that estimators and managers use to ensure that the project scope is complete. These checklists guide the estimator through an inventory of items and questions that address both the design elements of the project and other things that drive project cost, such as environmental permits, purchase of right-of-way, and utility interference.

Why?

Estimators are generally very familiar and proficient with assembling cost data and developing item costs, but for the estimate to be of value, it must match what will actually be built and the build environment conditions. Thus, one of the first steps to achieving estimate accuracy is verifying that the project scope is complete, in terms of both the physical structures to be built and the environment where the construction will take place.

What Does It Do?

Checklists serve to delineate the large number of factors that must be considered during scope development. Therefore, they are an excellent means of avoiding omissions and calling attention to the interaction between factors that can impact scope and cost. The answers to the checklist questions will provide an overview of scope completeness and focus the estimator and project management team's attention on critical issues that need to be considered.

When?

Scope checklists can support estimate creation at all stages of project development. The purpose of a checklist is to assist the project team in developing a complete description of project scope. Checklists should be as inclusive as possible, with questions that specifically probe the scope at the different stages in project development.

Examples

A scope checklist for bridge construction might review the following topics:

1. Maintenance of traffic
2. Removals
3. Foundation
4. Wetland mitigation

5. Garbage dump removal
6. Toxic waste removal
7. Utilities (relocation companies/owners)
8. Unusual conditions, such as power stations, sewerage plants, high-tension lines, and pumping stations
9. Railroad engineering
10. Right-of-way summary
11. Mitigation for wetland sites
12. Sidewalks on bridge
13. Maintenance operations, such as cleaning existing pipes, drainage structures, and ditches
14. Noise barriers

Tips

The project scope should clearly define each deliverable, including exactly what will be produced and what will not be produced. Get approval from all stakeholders. There can be many individual checklists to support the different phases of project development, but they should all include questions about third-party requirements.

The project scope must be monitored as the project proceeds through the development phases to ensure that any and all changes are properly managed.

Resources

Sturgis, Robert P. (1967). "For Big Savings—Control Costs while Defining Scope." AACE 11th National Meeting, AACE International, Vol. 67-C.3, pp. 49–52.

Though it is not strictly for transportation work, a scope development checklist can be found on the Construction Industry Cooperative Alliance (CICA) web page at www.ces.clemson.edu/cica/Toolbox/files/SD1_Scope%20Development%20Checklist.doc. CICA is a cooperative alliance between member firms from the construction industry in the eastern United States and Clemson University's Department of Civil Engineering.

APPENDIX B

Implementation Framework

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Implementation Framework

Please see Chapter 8 for guidance on completing this table.

Cost Management Strategy (*Strategies*)	Performance Improvement Opportunity/Action (*Methods*)	Implementation Steps (*Tools*)	Responsible Party and Performance Measurement
Management—Manage the estimation process and costs through all stages of project development.			
Scope/Schedule—Formulate definitive processes for controlling project scope and schedule changes.			
Off-Prism—Use proactive methods for engaging external participants and conditions that can influence project costs.			
Risk—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—Apply appropriate delivery methods to better manage cost, as project delivery influences both project risk and cost			
Document Quality—Promote cost estimate accuracy and consistency through improved project documents			
Estimate Quality—Use qualified personnel and uniform approaches to achieve improved estimate accuracy			
Integrity—Ensure checks and balances are in place to maintain estimate accuracy and minimize the impact of outside pressures that can cause optimistic biases in estimates			

APPENDIX C

Definitions

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Definitions

Acquisition: The act or process of acquiring fee title or some interest therein other than fee title of real prioperty (real estate).

Allowance: Additional resources included in an estimate to cover the cost of known but undefined requirements for an activity or work item. An allowance is a normal cost.

Appraisal: A written statement independently and impartially prepared by a qualified appraiser setting forth an opinion of defined value of an adequately described property as of a specific date, supported by the presentation and analysis of relevant market information.

Competitive Bidding: The process whereby construction projects are required to be advertised and awarded to the lowest responsible and responsive bidder through open bidding, unless use of an eligible force account is more cost-effective.

Conceptual Estimate (Initial Estimate): A project cost estimate prepared prior to the NEPA decision document. Usually, quantities have not been determined at this time. The estimates are prepared for the range of alternatives evaluated under NEPA. In some cases, the relative dollar amount is expressed as a range used for decision making to proceed with project development.

Condemnation: The legal process of acquiring private property for public use or purpose through the acquiring agency's power of eminent domain. Condemnation is usually not used until all attempts to reach a mutually satisfactory agreement through negotiations have failed. An acquiring agency then goes to court to acquire the needed property.

Confidence Level: The probability that a range will contain the value under consideration. For example: "there is a 90% probability that the ultimate project cost will be less than $(number)."

Confidence Range: The difference between the upper and lower values of a set of numbers or results within specific confidence levels.

Construction Administration Cost: The normal cost of administration, management, reporting, design services in construction, and community outreach required in the construction phase of a project.

Construction Allowance: An amount of additional resources included in an estimate to cover the cost of known but undefined requirements for a construction activity or work item. A construction allowance is a normal cost.

Construction Contingency: An additional markup applied to cover the cost of undefined and as-yet unknown construction requirements that are expected to be zero at completion of construction. Construction contingency is a risk cost.

Construction Phase: The project development phase that includes advertising the project, awarding the contract, and performing the actual construction.

Contingency: A markup applied to account for substantial uncertainties in quantities and unit costs and the possibility of currently unforeseen risk events related to quantities, work elements, or other project requirements. Contingency is a risk cost.

Cost Estimate Validation Process (CEVP) Schedule: The schedule assessed by the CEVP team, including consideration of all normal costs, allowances, contingency, risk, and opportunity events.

Cost Team: The CEVP team members plus project team members who reviewed all elements of normal cost (including allowances) for the particular project under consideration.

Cost Validation: A detailed examination of normal costs (including allowances) for the particular project under consideration to assess validity, reasonableness, consistency, and accuracy of these costs.

Damages: A loss in value of the remaining property caused by the acquisition, planned use, or construction. Normally, the value of the damage is based on the before-and-after appraisal or cost to cure. An owner is entitled to payment of damages and receives this payment as a part of just compensation.

Design Allowance: Additional resources included in an estimate to cover the cost of known but undefined requirements for a design element. A design allowance is a normal cost.

Design Contingency: A markup applied to cover the cost of undefined and as-yet unknown design requirements. The design contingency is expected to be zero at completion of design. Design contingency is a risk cost.

Eminent Domain: The right of a government to take private property for public use. In the United States, just compensation must be paid for private property acquired for federally funded programs or projects.

Environmental Clearance: The process whereby a project must conform to the National Environmental Policy Act (NEPA), the National Historic Preservation Act (Section 106), and Section 4(f) of the U.S. DOT Act, and other relevant federal and state environmental laws.

Estimate: The most probable cost for a project, consisting of normal costs, contingencies, and the probable cost of risk events.

Fair Market Value: The price that a willing buyer will pay a willing seller for a piece of real estate.

Federal Share: The portion of the project cost funded by the federal government. These federal funds are normally matched with state and/or local government funds to make up the total cost of the project. The federal portion, or share, is 80% for most projects; however, in states with large amounts of federal lands, a higher federal share is authorized. See Matching Funds.

Final Estimate: The estimate developed when design is approximately complete and all quantities are known.

Highest and Best Use: The legal use (or development or redevelopment) of a property that makes the property most valuable to a buyer or the market.

Just Compensation: The price an agency must pay to acquire real property. The price offered by the agency is considered to be fair and equitable to both the property owner and the public. The agency's offer to the owner is just compensation and may not be less than the amount established in the approved appraisal report as the fair market value for the property. If it becomes necessary for the acquiring agency to use the condemnation process, the amount paid through the court will be just compensation for the acquisition of the property.

Matching Funds (Local Funding Share): The percentage of nonfederal funds required for almost all TEA-21 programs on a project-by-project basis to match a federal contribution. The standard ratio is a 20% match from state and local sources, with a federal share of 80%. See Federal Share.

Monte Carlo Simulation: A technique using multiple simulations incorporating the variability of individual elements to produce a range of potential results.

National Environmental Policy Act (NEPA): The federal law that requires every federal agency, prior to approving a major federal action that could significantly affect the quality of the human environment, to prepare a detailed report evaluating both environmental impacts and alternatives to the proposed action. The environmental clearance required of federal-aid projects may take a variety of forms: environmental impact statement (EIS), environmental assessment (EA), finding of no significant impact (FONSI), and categorical exclusion (CE).

Negotiation: The process used by acquiring agencies to reach amicable agreements with property owners for the acquisition of needed property. An offer is made for the purchase of property in person or by mail, and the offer is discussed with the property owner.

Nomination: The process by which a public or private entity submits an application for a candidate project to the state DOT for consideration. In most states, the nominating entity must be a public agency with tax-bearing authority.

Normal Cost: The most probable cost for a unit or element of the project. The normal cost represents the cost that can most reasonably be expected if no significant problems occur. The normal cost typically has small uncertainty or variance.

Obligation: The second step in the funding process; the formal commitment by the FHWA of a specified amount of funding for a particular project, usually made when project or project phase is ready to begin billable work.

Overmatch: The share of state or local matching funds (or in-kind value) brought to a project that is over and above the required state/local share.

Parcel: Any plot of land. For the purposes of this report, "parcel" generally refers to the part being acquired, but it may also be used in association with original or remainder parcels.

Partial Taking: Acquisition in which the original property is severed to form two parcels, leaving a "remainder." Damages are most often associated with partial takings, which may require the removal of access, parking, buildings, or other improvements.

Plans, Specifications and Estimates (PS&E): The documentation submitted by the project sponsor that must receive state DOT approval before federal funds can be obligated to proceed with contract letting and project construction.

Preliminary Engineering Phase: The project development phase that includes preparation of environmental and construction documentation, such as plans, specifications, and cost estimates. Preliminary right-of-way work, appraisal maps, and estimates may also be reimbursed with federal-aid funding for the preliminary engineering phase.

Probability: The chance of an event occurring, measured as a percentage or fraction, where 100% or 1 represents certainty.

Programming Estimate: The estimate for the selected alternative. This estimate can be based on some quantities. This estimated project cost begins with NEPA approval and continues up to the PS&E.

Project: An undertaking to develop, implement, or construct a particular transportation enhancement at a specific location or locations.

Project Schedule: The schedule, as presented by the project team, corresponding to the project team estimate.

Project Team: The team representing the particular project under consideration.

Range: The difference between the upper and lower values of a set of numbers or results, either absolutely or related to confidence levels.

Range Cost Estimate: A cost estimate that shows a range of costs related to a specific confidence level.

Rehabilitation: The act or process of returning a property to a state of utility through repair or alteration that makes possible an efficient contemporary use while preserving those portions or features of the property that are significant to the property's historical, architectural, and cultural values.

Restoration: The act or process of accurately recovering the form and details of a property and its setting as it appeared at a particular period of time by means of the removal of later work or by the replacement of missing earlier work.

Right-of-Way (ROW): A linear corridor of land used for transportation or other facilities, such as highways, roads, streets, railroads, trails, light-rail, and utilities.

Risk: The combination of the probability of an adverse event and its consequences.

Risk Assessment: A systematic evaluation of possible risk events in order to quantify risk to the project.

Risk Events: Potential adverse events that negatively affect the defined project (resulting in impacts to cost, schedule, safety, performance, or other characteristics), but do not include the minor variance inherent in normal costs. Examples include political and/or management changes, changes in regulations and laws, earthquakes, fires, floods, and unknown archeological sites.

Risk Team: The CEVP team members plus project team members who reviewed all elements of risk (including contingency) for the particular project under consideration.

Selected Project: A project or project phase contained in an approved statewide transportation improvement program (STIP) that has been advanced for implementation by the state highway agency in cooperation with the metropolitan planning organization or public transportation operator, as appropriate.

Soft Match: The value of activities outside the project scope, but directly related to the project, that are credited toward the nonfederal share of a project.

Sponsors: Individuals, partnerships, associations, private corporations, or public authorities recommending a particular project and committed to its development, implementation, construction, maintenance, management, or financing. In most states, an enhancement project sponsor must be a public entity with tax-bearing authority.

Surface Transportation: All elements of the intermodal transportation system, exclusive of aviation but inclusive of water.

Variance (Variability): Inherent fluctuations due to random events that result in a range of potential values for a quantity.

Whole Taking: An acquisition that involves the taking of the original parcel in its entirety.

Abbreviations and acronyms used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation