American Association of State Highway and Transportation Officials

AASHTO

The Voice of Transportation

PRACTICAL GUIDE TO COST ESTIMATING

2013 • FIRST EDITION

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CHAPTER 1

Practical Guide to Cost Estimating Overview

1.1 INTRODUCTION

Project cost estimating is a major challenge for state departments of transportation (DOTs). This challenge is the result of four critical project management and development issues. First, definitive project solutions are difficult to define for many of the questions that arise early in project development. Second, it is often difficult to quantify major areas of variability and uncertainty in project scope and cost. Third, it is difficult to evaluate the completeness and quality of early project estimates. And fourth, it is difficult to track the cost impact of scope development that occurs between cost estimates. These four challenges are amplified because many factors, such as insufficient knowledge about right-of-way costs and project location characteristics, environmental mitigation requirements, traffic control requirements, or work-hour restrictions, influence project cost estimates, especially during the early stages of project development. Moreover, there are other process-related factors that make cost estimation a challenge, such as assessment of the cost impact of engineering complexities and constructability issues, changes in economic and market conditions, changes in regulatory requirements, local governmental and stakeholder interests, and community expectations.

Historically, cost escalation or increases have been problematic within the DOT environment. One significant reason behind this problem is attributed to poor estimating practices including the inconsistent application of contingency. The National Cooperative Highway Research Program (NCHRP) Project 8-49, completed in 2007, focused on the issue of cost escalation and produced a guidebook on highway project cost estimating and cost estimating management aimed at achieving greater estimating consistency and accuracy. The Project 8-49 guidebook, NCHRP Report 574, provides appropriate strategies, methods, and tools to develop, track, and document realistic cost estimates during each phase of the project development process (Anderson et al. 2007). In parallel with the NCHRP work, the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Design's Technical Committee on Cost Estimating has developed this manual, which specifically serves those charged with developing and managing estimates for DOTs.

1.1.1 Background

Estimating the cost of transportation projects is a critical function that supports the project development process. The cost estimation process not only involves the collection of relevant factors relating to the scope of a project and the expected resource costs, but it requires anticipating impacts to project costs over time caused by changes related to project scope, available resources, and national and global market conditions. A DOT's ability to successfully manage and deliver its program is largely dependent on its ability to realistically estimate project costs early in the conceptual development stage before final engineering has been completed. Cost estimates are the basis for many key financial decisions. Thus, the inability to accurately estimate project costs can result in poor financial decisions as follows:

- Overrun budgets—fewer projects in program can be developed.
- Underrun budgets—could have developed more projects.
- Cost too high—reduced benefit-to-cost ratio that may lead to rejecting a project that should be accepted.
- Cost too low—high benefit-to-cost ratio that may lead to accepting a project that should not be accepted.

Poor financial decisions ultimately lead to a lack of confidence in the DOT's ability to meet its project and program commitments.

Because of the specialized nature of many transportation projects, accurately estimating project cost requires a very specific skill set. A successful estimator will need expertise in translating early project concepts into costs and visualizing completed facilities from drawings at different levels of completion, a thorough knowledge of construction methods and equipment, and an excellent understanding of economics and how market conditions (i.e., bidding environment) impact construction costs. The application of these estimating skills requires training and experience at a localized level. Very little training or guidance is available nationally on how to develop transportation project cost estimates, and most DOT's have been forced to develop their own estimating processes based on history, experience, and available resources.

1.1.2 Purpose

With increasing transportation needs, funding limitations at both the federal and state levels, and the high cost of transportation improvement projects, it is important to have a toolbox of techniques that support accurate estimation of project costs. There is no single "right way" to prepare an estimate, and these guidelines are not intended to promote one technique over another. The purpose of this guide is to provide a nationally recognized and accepted set of cost estimation and cost management practices that each DOT can draw from and use appropriately to its situation.

1.1.3 Audience

The primary users of this guide are estimators within DOTs that prepare estimates during specific project phases or across the entire project development process. Some of these estimators may have other responsibilities, such as being project managers, lead designers, or staff involved in planning. Further, there may be others who require knowledge of the cost estimating process but do not necessarily prepare cost estimates. As such, this guide is intended to be a resource for professionals involved in the preconstruction phases of project development where key financial decisions are made based on project cost estimates.

1.2 PROJECT DEVELOPMENT PHASES

Due to slight variations in the terms used by the state department of transportation to describe their project development phases, a generic set of terminologies is presented in this guide consistent with other published documents. These project development phases are described in Table 1-1 and shown in Figure 1-1. To ensure the applicability of terms, DOTs from across the country participated in a vetting of the four phases. Typically, a DOT will prepare project cost estimates during each of the four phases of project development.

Figure 1-1 depicts the various plans and programs that each project development phase supports. Sometimes, there is overlap between phases as needs and deficiencies are converted into specific projects, alternative project solutions are assessed, and the preferred alternative is selected. When federal money is involved, DOTs are required to have fiscally constrained long-range plans and a State Transportation Improvement Program (STIP). Some agencies also have an intermediate-range plan (IRP), such as a 10-year improvement plan. When DOTs do not have an IRP, projects often move from planning directly into the STIP.

Table 1-1. Development Phases and Typical Activities

Development Phases	Typical Activities
Planning	Purpose and need; improvement or requirement studies; environmental considerations; right-of-way considerations; schematic development; project benefit/cost feasibility; public involvement/participation; interagency conditions.
Scoping	Environmental analysis; alternative analysis; preferred alternative selection; public hearings; right-of-way impact; environmental clearance; design criteria and parameters; funding authorization (programming).
Design	Right-of-way development and acquisition; preliminary plans for geometric alignments; preliminary bridge layouts; surveys/utility locations/drainage.
Final Design (aka PS&E)	Plans, specifications, and estimate (PS&E) development—final right-of-way acquisition; final pavement and bridge design; traffic control plans; utility drawings; hydraulics studies/final drainage design; final cost estimates.

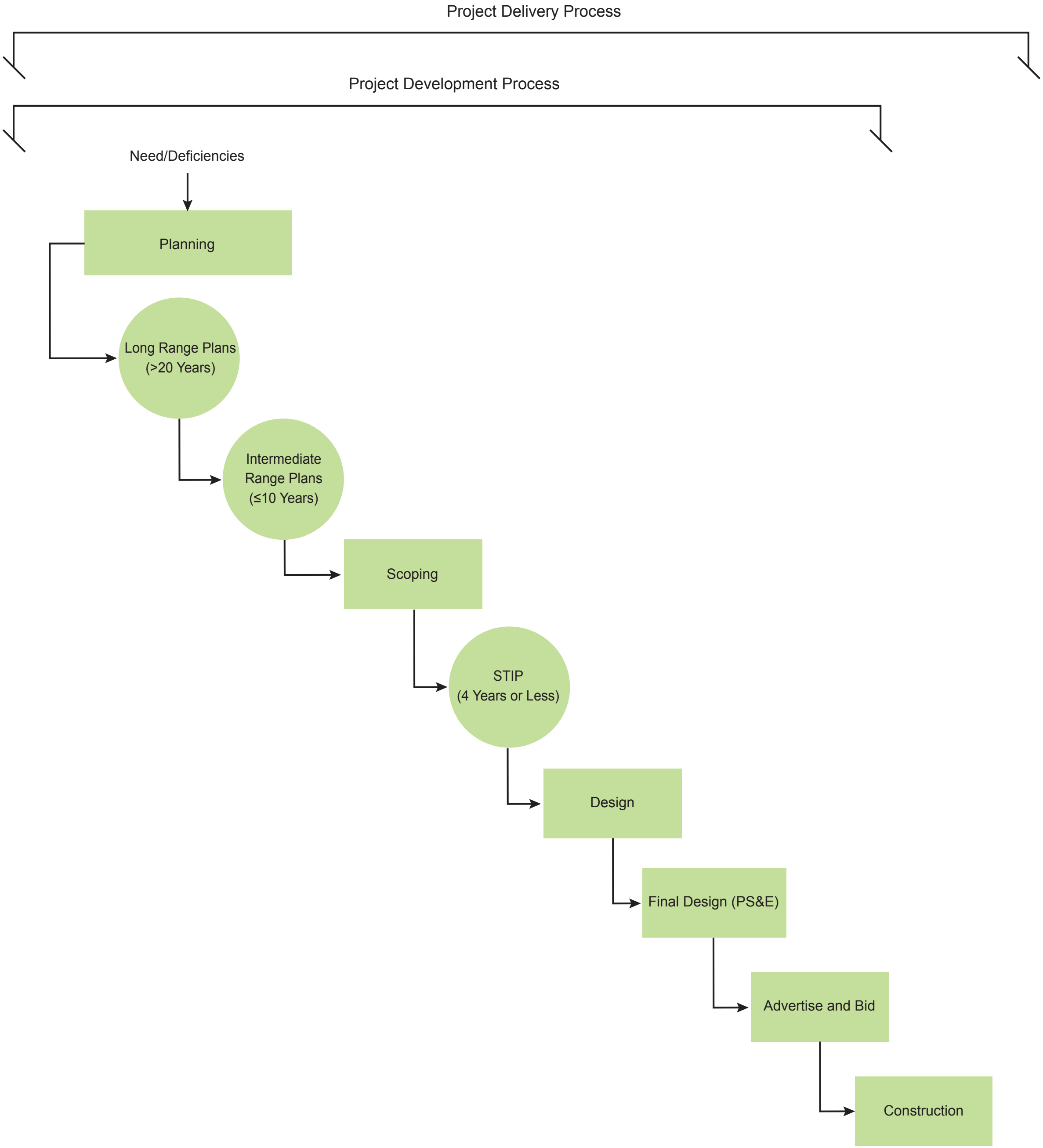


Figure 1-1. Project Development Phases (NCHRP 8-49)

As projects progress through the project development process, cost estimates are required. The types of estimates and their purpose will vary according to project phase and the level of project maturity. Table 1-2 captures the various estimate types, their purposes, and the agency plans/programs the estimates support during project development. Further, Table 1-3 shows level of project maturity (definition) and implies uncertainty through the use of methods and possible ranges related to estimate types.

Table 1-2. Estimate Types and Purposes

Project Development Phase	Estimate Type, Purpose, and Plan/Program Supported
Planning	**Conceptual Estimating—** Estimate Potential Funds Needed (20-Plus-Year Long-Range Plan)
	Prioritize Needs for Long-Range Plans (Intermediate-Range Plan—10 years)
Scoping	**Scope Estimating—** Establish a Baseline Cost for Project and Program Projects (IRP and STIP)
Design	**Design Estimating—** Manage Project Budgets against Baseline (STIP)
Final Design	**Plans, Specifications, and Estimate Estimating—** Compare with Bid and Obligate Funds for Construction

The information shown in Tables 1-2 and 1-3 emphasizes that cost estimates have different purposes in support of project development, different methods are used during project development, and estimate ranges start off very wide on the early stages of a project and become very tight at full definition (i.e., completed plans and specifications). Thus, appropriate estimate techniques and tools vary based upon the project development stage.

Table 1-3. Cost Estimating Classification

Project Development Phase	Project Maturity (% project definition completed)	Purpose of the Estimate	Estimating Methodology	Estimate Range
Planning	0 to 2%	Conceptual Estimating—Estimate Potential Funds Needed (20-year plan)	Parametric (Stochastic or Judgment)	–50% to +200%
	1% to 15%	Conceptual Estimating—Prioritize Needs for Long-Range Plans (IRP—10-year plan)	Parametric or Historical Bid-Based (Primarily Stochastic)	–40% to +100%
Scoping	10% to 30%	Design Estimating—Establish a Baseline Cost for Project and Program Projects (IRP and STIP)	Historical Bid-Based or Cost-Based (Mixed, but Primarily Stochastic)	–30% to +50%
Design	30% to 90%	Design Estimating—Manage Project Budgets against Baseline (STIP, Contingency)	Historical Bid-Based or Cost-Based (Primarily Deterministic)	–10% to +25%
Final Design	90% to 100%	PS&E Estimating—Compare with Bid and Obligate Funds for Construction	Cost-Based or Historical Bid-Based Using Cost Estimate System (Deterministic)	–5% to +10%

1.2.1 Cost Estimating Process

As identified in NCHRP Report 574, cost estimating is a process comprised of a series of steps, as shown in Figure 1-2 (Anderson et al. 2007). Each step is critical to developing consistent and accurate estimates during each phase of project development. The steps in the process are supported by key inputs such as historical data, market and macro-environment conditions, cost estimating techniques and tools, and third-party requirements. The cost estimating process is initiated with input from the project development phases including project definition requirements (aka scope), project characteristics, and functional group inputs/requirements. The output of the process is approved estimate packages that support the various plans/programs shown in Figure 1-2 and described in Table 1-1.

In the early phases of project development, DOTs must prepare estimates that characterize total project cost (TPC). The main components of TPC are engineering/design, right-of-way, and construction. Included in these general components would be costs related to environmental mitigation and utility relocation requirements. The estimating tools and techniques differ depending on the component of TPC being estimated. This guide covers key techniques and tools used to estimate these component costs.

At a point in the project development process, the estimated project cost must be used to set a baseline cost for management purposes. This baseline cost is tied to a baseline project definition and construction letting date. The baseline project definition, cost, and schedule should be set prior to programming a project into the IRP or no later than before a project is included in the STIP. DOTs have different policies on which total project cost components are included in the STIP and how these components are included in this document. In any case, the baseline cost should incorporate all project costs or total project costs regardless of how individual components are programmed. Cost management will not be effective if there is no confirmed baseline cost.

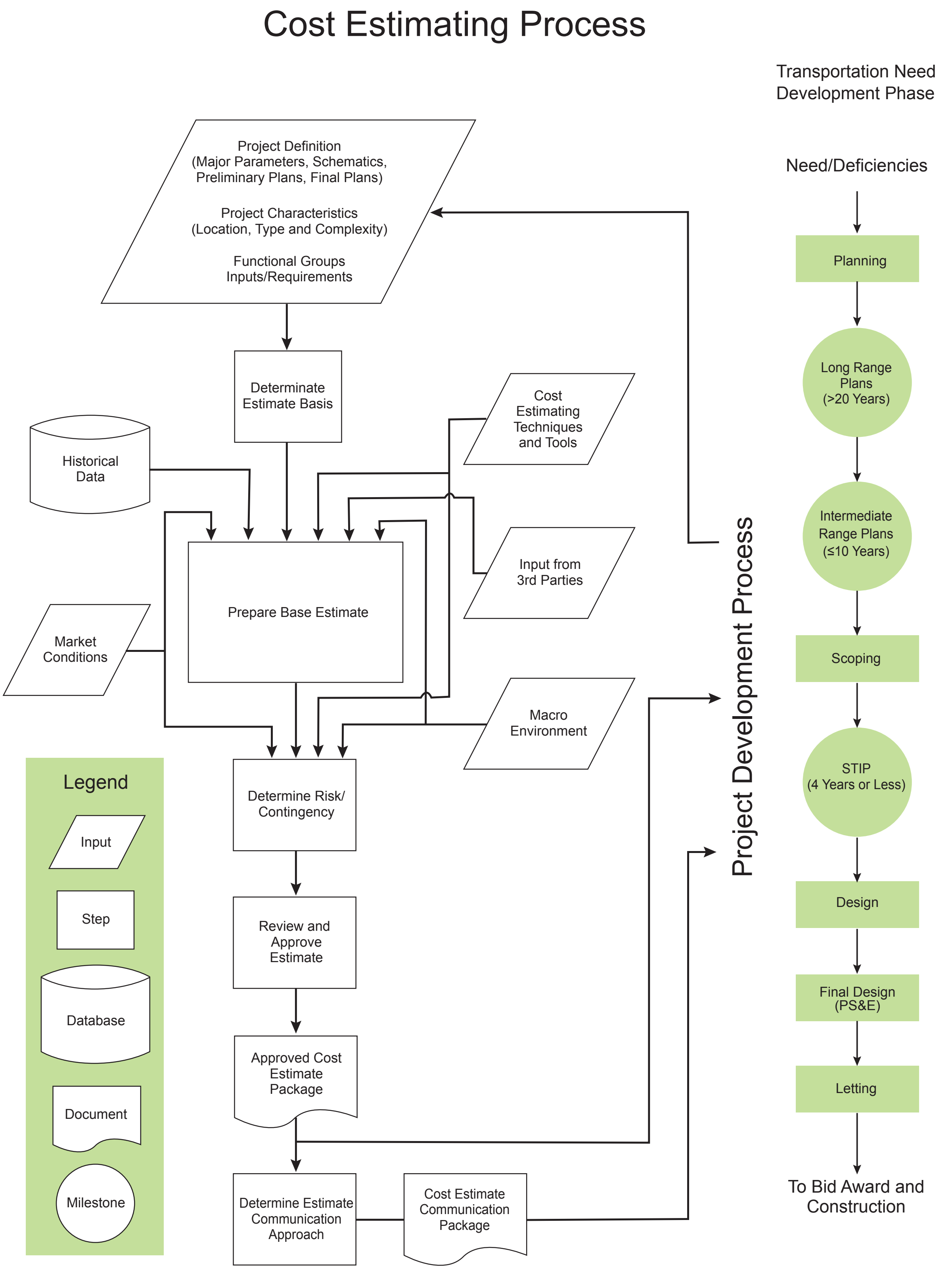


Figure 1-2. General Cost Estimating Process

1.2.2 Estimating Focus

This guide focuses on two of the cost estimating process steps shown in Figure 1-2: (1) prepare base estimate; and (2) determine risk and set contingency. These critical steps are supported by estimating techniques and tools that are used throughout the transportation industry. The steps demand that a project cost estimate be composed of a base estimate and a contingency. The base estimate is defined as the most likely project cost estimate in any phase, which normally includes all estimated known project costs. Project contingency is defined as an estimate of costs associated with identified risks, the summation of which is added to the base estimate. The sum of the base estimate and contingency reflects the total project cost estimate (also adjusted for inflation).

As shown in Figure 1-3, the relative magnitude of the base and contingency costs changes over time. During planning, there are numerous unknowns, and quite often the base estimate is less than the contingency dollar estimate. Over the duration of the project development process, the base estimate increases while the contingency amount decreases. The shift between the base and contingency relates to the level of project maturity; that is, as project definition advances, the level of unknowns or risks should decrease. Some of the risk dollars are shifted into the base estimate work items as quantities are defined, while other risk dollars may be mitigated.

In this guide, the techniques and tools described include those used to prepare conceptual estimates and those used to prepare construction estimates, such as bid-based and cost-based estimating. The relationships between the estimate technique and historical data are discussed. These techniques and tools are presented in the context of the Prepare Base Estimate step. The Determine Risk and Set Contingency step is described in the context of risk-based estimating. Different types of risk/contingency techniques and tools, including top-down percentage and bottom-up risk-based estimating, are presented.

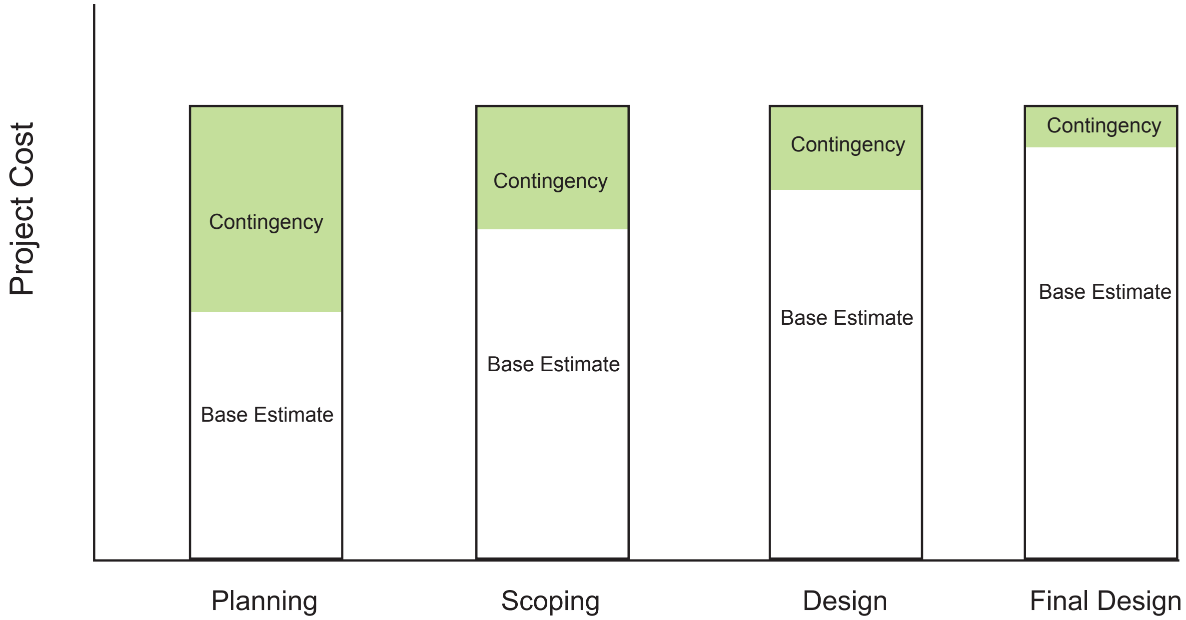


Figure 1-3. Application of Contingency

The cost estimating process shown in Figure 1-2 has other steps that are critical to preparing accurate and consistent total project cost estimates. These steps are:

- Determine estimate basis
- Review and approve estimate
- Communicate estimate

Determining the estimate basis includes collection of information about the project definition, project characteristics, and input/requirements of different functional disciplines involved in the project. Specific information might include drawings, design parameters, project complexity, and project location (i.e., rural or urban, or both). The cost estimator uses this information to prepare the base estimate.

Reviewing and approving the estimate involves completing an unbiased analysis of estimate basis and assumptions to include the estimate methods used and completeness of the estimate in terms of covering the project's definition, verifying cost data, quantities, and calculations; and understanding differences between the current estimate and previous estimates. The approval component of this step ensures management accountability for the final cost estimate, noting any changes from previous estimates.

Determining the estimate communication approach is the final estimating process step. This step involves communication of key information to both internal and external project stakeholders. This communication is critical to achieving estimate transparency and credibility. The communicated information should explain the estimate basis, estimated costs including key assumptions, and estimate uncertainty. The communication document should be very concise with only key information provided to the reader.

1.3 OVERALL GUIDEBOOK STRUCTURE

This guidebook has two parts. Part I focuses on key cost-estimate techniques. Part II focuses on cost management activities.

1.3.1 Part I—Key Estimate Techniques

Part I of this guide covers in separate chapters the following cost estimating techniques:

- Conceptual Estimating
- Bid-based Estimates
- Cost-based Estimates
- Risk-based Estimates

Conceptual or parametric estimating techniques are primarily used to support development of planning or early scoping phase estimates when minimal project definition is available. Statistical relationships or non-statistical ratios, or both, between historical data and other project parameters are used to calculate the cost of various items of work (i.e., center lane miles or square foot of bridge deck area).

Historical bid-based estimating is an approach that relies heavily on elements or bid item, or both, with quantities and good historical bid data for determining item cost. The historical data normally is based on bids from recent projects. The estimator must adjust the historical data to fit the current project characteristics and location. The historical data must also be adjusted to reflect current dollars. With the use of historical bid data, estimators can easily prepare cost estimates. This approach is the most commonly used method for DOTs in developing cost estimates for their transportation projects.

Cost-based estimating considers seven basic elements: time, equipment, labor, subcontractor, material, overhead, and profit. Generally, a work statement and set of drawings or specifications are used to "take off" material quantities required for each discrete task necessary to accomplish the project bid items. From these quantities, direct labor, materials, and equipment costs are calculated based on assumed production rates. Contractor overhead and profit are then added to this direct cost. The total cost divided by the quantity gives the estimated unit price for the work item.

Risk-based estimating combines (1) traditional estimating methods for known items and quantities with (2) risk analysis techniques to estimate uncertain items, uncertain quantities, and risk events. The risk-based portion of the estimate typically focuses on a few key elements of uncertainty and combines Monte Carlo sampling and heuristics (rules of thumb) to rank critical risk elements. This approach is used to establish the range of total project cost and to define how contingency should be allocated among the critical project elements.

Each of these four techniques is discussed in detail in Chapters 2, 3, 4, and 5, respectively.

1.3.2 Part II—Cost Management

Cost estimating is closely tied to cost management. Part II of this guide covers the following topic areas:

- Inflationary considerations
- Letting strategies for cost control
- Analysis of contractor bids
- Performance measures for cost estimating

Inflation is critical to estimating costs in the future. Inflation covers changes in cost over time. Adjustments for inflation include converting historical data to current dollars. Adjustments for inflation also include converting current dollars to future dollars based on a rate of inflation and the midpoint of construction expenditures. Indexing uses several tools such as cost indexes, statistical analysis, and other modeling techniques. Experts in economics should be consulted when establishing future inflation rates.

Letting strategies are an important component of the estimating process. The use of both short- and long-term strategies will improve project bids and the validity of cost estimates. Long-term strategies are fundamental changes in the bid letting process and include timing of lettings, balancing of lettings, and packaging of projects for letting. Short-term strategies include such actions as contractor-selected packaging of projects, contractor self-imposed award limits, flexible notice to proceed, and contractor use of construction alternatives.

Analysis of contractor bids by a state department of transportation is a significant component of the competitive bidding process. To ensure a competitive contracting environment, agencies must have effective and consistent bid review and award recommendation procedures. The procedures must be transparent in a manner that is publicly understandable, economically efficient, legally defensible, and socio-politically acceptable.

Performance measures are tools to better understand and control outcomes of cost estimating. More generally, performance measures are broad classifications of DOT organizational outcomes for the efficiency of services and programs. Performance measures must align with the strategic goals and performance objectives of the DOT. Cost estimating performance measures track the attainment of cost estimating and project delivery functions. Tracking and evaluating cost estimating data allow efficient allocation of estimating resources while assisting in the development and justification of budgets and project proposals.

1.4 ROADMAP FOR GUIDE USE

This guide can be used by different agencies and consulting professionals in a number of ways. The primary user would likely be the agency estimator who is involved in preparing cost estimates across the project development process. Such an estimator would use Chapters 2, 3, 4, and 5. If the estimator is involved in only one phase, such as final design (PS&E), the use of the bid-based or cost-based, or both, estimating techniques would likely be the estimator's focus chapters. Alternatively, estimators involved in planning would use conceptual estimating techniques such as parametric estimating found in Chapter 2. Other professionals such as project managers and lead design engineers would likely want to refer to Chapters 3, 4, and 5 depending on how much direct estimating they must perform. These professionals should read Chapter 1 to gain a basic understanding of the cost estimating process and what aspects of the process are covered in the guide. Managers involved in project development should review Chapter 1 to gain an overall perspective of project cost estimating.

In addition to the cost estimating chapters, the estimator should refer to Chapter 6 if adjusting historical data and cost estimates to reflect either current dollars or future dollars. Agency management and project managers should read Chapter 7 to determine letting strategies that will aid in controlling costs. Chapter 8 should be of interest to construction engineers and estimators, as evaluation of bids can aid in cost control as well as provide valuable information for estimating future projects. Finally, agency management would be interested in Chapter 9, which provides insights into program and project management by providing concepts around performance measures for cost estimating.

All users of this guide are encouraged to refer to the references listed at the end of each chapter. These references provide more specific information concerning the various techniques and tools discussed in each chapter.

1.5 CHAPTER 1 REFERENCES

Anderson, S., K. Molenaar, and C. Schexnayder. *NCHRP 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*, Transportation Research Board of the National Academies, Washington, DC, 2007. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_574.pdf (Mar. 29, 2011).

CHAPTER 2

Conceptual Estimating

2.1 OVERVIEW

The use of conceptual estimating techniques is primarily for supporting the preparation of planning and early scoping estimates when very little project definition is available. These techniques assist in estimating total project cost by major components:

- Right-of-way (ROW)
- Construction (CN)
- Engineering/Design (often termed preliminary engineering [PE])
- Construction engineering (CE)

A number of estimating techniques are conceptual by classification. The basis of these techniques is either statistical relationships or ratios between project definition information/data and historic costs. For a particular facility type, the development of a gross estimate of a project using statistically derived relationships between key dimensional information and historical costs is often referred to as parametric conceptual estimating. One approach is to use the relationship between facility type and dimensions and costs as reflected in statistically derived equations from historical data. The other common approach is to use ratios between historical data and key project parameters to calculate the cost of work elements.

Because these are estimates prepared early in project development when specific work items are undefined or unquantifiable, it becomes very difficult to estimate costs in detail. Therefore, both approaches use major project features that reflect a specific type of facility (i.e., centerline miles for pavements and square feet of deck area for bridges) to develop the cost relationships. Further, estimators use historical percentages to estimate construction elements that are difficult to quantify early in a project. Historical percentages are also used for total project cost components such as engineering/design, construction engineering, and right-of-way.

2.1.1 What Is It?

Conceptual cost estimation is a methodology used to estimate total project cost when a project is in its earliest stages of development. The techniques described here are straight forward, but a DOT should have its own historical cost database to support development of these estimates based on minimal definition of project parameters or facility components. DOTs consider these techniques sophisticated if statistical relationships are used, but when using ratios or percentages, the techniques are relatively simple.

Early in project development, a project's definition is usually very ambiguous. However, newly developed projects are often similar to previous projects that are under design, under construction, or recently completed by the agency. Historical cost data from these past projects can serve as a basis for developing a uniform, repeatable, conceptual estimating approach. Conceptual estimating approaches provide reasonably accurate estimates in a timely manner. Statistical relationships or non-statistical, ratios, or both between historical data and other parameters form the basis for conceptual estimating.

2.1.2 Why Use It?

The purpose of conceptual estimating is to develop early projections of project cost when limiting information to only gross dimensions reflecting key facility features. The time and effort required to prepare a conceptual estimate should be minimal. The techniques provide simplified, reliable, early estimates based on historical data and adjusted to current costs. Because of these attributes, decision-makers use conceptual estimates to develop long-range plans, assess benefit-to-cost ratios for prioritizing projects, and compare the cost of different project alternatives.

2.1.3 When to Use It?

Estimators use conceptual estimating in the planning phase of project development to support long-range plans (i.e., >20 years) and early in the scoping phase of project development to support intermediate-range plans (i.e., 10 years). The best instance to use conceptual estimating is on less complex projects that tend to be standard in terms of project components, such as preservation projects (overlays) or bridge rehabilitation projects. Complex projects can also utilize conceptual estimating; however, using conceptual estimating for highly complex projects often requires greater project definition and therefore a more detailed assessment of quantities and unit prices even in the earliest phases of project development.

2.2 KEY INPUTS

The two key pieces of data needed to develop a conceptual cost estimate are (1) good historical cost data; and (2) project-related information matched to cost data. To analyze historical price data effectively, it is critical that projects and work items be properly classified. Further, it is vital to normalize cost data to a specific point in time (i.e., 2011 dollars) and location (i.e., statewide average costs). The historical cost data must be qualified in relation to what the data covers from a project definition perspective. This section covers these issues.

2.2.1 Project Definition

The exactitude and work description detail during early project definition can vary greatly. At a high level, project definition reflects the general components of a facility, such as construction, engineering/design, construction engineering, and right-of-way. Simply stated, specific project details are frequently in terms of project boundaries, such as between milepost A and milepost B. Some descriptive information usually included is whether the project is a preservation (i.e., overlay), rehabilitation (remove and replace), reconstruction (add capacity) project, or new construction (new roadway/bridge). Estimators then use general descriptions of the project elements such as pavement width or lane widths, bridge deck dimensions, and possible drainage requirements. In addition, some assumptions are made regarding the pavement or bridge type.

Estimators at the conceptual stage regularly develop the project definition using sketches or schematic drawings with approximate dimensional information. In addition, there should be some idea of whether or not right-of-way is required, as well as a statement about potential environmental impacts. However, in most instances, there is a lack of specificity around details. In general, the level of project definition varies depending on when in the project development process the conceptual estimate is being prepared; that is, early in the planning phase or early in the scoping phase or at some point between. Project complexity also affects the level of project definition. To prepare a credible conceptual estimate for more complex projects, there needs to be an increased level of definition details.

2.2.2 Project Characteristics

Since project definition is incomplete, estimators most likely cannot define specific work characteristics. Thus, the estimate focus must be on the "larger picture" characteristics such as project location, potential environmental issues and utility impacts, and the extent of right-of-way required. Depending on project complexity, consideration should be given to traffic management and major drainage issues. Thus, the project's level of complexity would be the principle driver that defines specific project characteristics. It is highly recommended that the estimator visit the project site to comprehend the project's definition in relation to existing site characteristics and in consideration of major constructability issues that might be relevant to the project (i.e., significant potential material logistic and traffic management issues). If a physical visit is not possible, utilizing technology such as Google Street View or Google Earth in many cases aids the estimator in gaining an understanding of site conditions.

2.2.3 Historical Database Requirements

The DOT historical database to support conceptual estimating should have data corresponding to construction and non-construction components of total project cost. In the construction area, cost factors are required for pavements and bridges and in some cases a combination of both categories. Often, it is advisable to use percentages to estimate elements of work not covered by construction cost factors for pavements and bridges. Computer software is typically used to store and access historical data. Historical percentages are necessary cost factors for non-construction elements such as right-of-way, preliminary engineering, and construction engineering.

Database requirements to support conceptual estimating can take different forms. Unlike bid-based estimating where capturing historical bid data comes directly from the letting process, the DOT must assemble a database for conceptual estimating by using multiple pieces of information. The use of actual bid data or project cost data matched to physical project data allows for the development of different types of conceptual estimating cost factors, such as dollars per centerline mile or dollars per square foot of bridge deck area, under specified conditions. Similar projects can also be a source of cost data for conceptual estimating. A similar project can form the basis for calculating average lane-mile or bridge deck costs. Project type and the elements that define the project such as ROW, environmental requirements, utility adjustments, and urban or rural location influence the development of a historical database. Separate datasets are usually required and developed for a variety of project types. Because such databases will improve the accuracy of early estimates and save time in preparing future estimates, the DOT should commit time and money to develop accurate supporting information. Estimating software can help with creating the databases. Moreover, DOTs can use estimating software to prepare conceptual estimates.

Typically, the data required to develop the necessary historical cost factors come from the DOT's financial management system responsible for processing project expenditures. To facilitate the capturing of this project-specific data, it is necessary that unique expenditure accounts and respective activity codes (PE, ROW, and CE) be assigned to a project as soon as expenditures begin accruing during project development. Standard pay items typically capture construction costs. DOT program or project managers, or both, along with business managers, should be well versed in the structure of their DOT's coding system and should be excellent resources in the initial setup of queries for data retrieval. It is likely the project/contract award amounts will require further analysis to become useful historical data for conceptual estimating purposes.

A project that has experienced a cradle-to-grave life cycle is typically a viable candidate for analysis in deriving respective non-statistical cost relationships. These relationships can be used as a sample for generating the work-type-specific global cost relationships needed when using the conceptual cost estimating techniques. To ensure correct processing of all construction-related costs, it may be necessary to use past projects completed one to five years prior to the date of analysis. Additionally, based on the historical nature of these data, a DOT-specific or more generic means of correcting the expenditures for inflation is required to normalize the dataset to the analysis year. In terms of reliability and statistical significance, the more relevant the samples are, the better the global analytical dataset will be.

2.2.3.1 Construction Cost Factors

DOTs define basic cost elements with the activities associated with traditional project development processes. Cost data for the construction component starts with the lowest level of cost details and pay items from contractor bids. These construction costs reflect the anticipated contract award amount represented by a responsive low-bid construction contractor. Actual construction bids for a project are aggregated to reflect a fundamental parameter associated with the project type (i.e., $/mile or $/square foot) in combination with other factors for cost elements, such as but not limited to roadway approaches for bridge projects or utilities, large culverts, or bridges, or some combination thereof, within a roadway project. The sum of these construction cost elements becomes the fundamental basis for estimating the remaining project components (i.e., ROW, PE, and CE). Current conceptual cost factors developed from historical data might not include newly enacted project requirements. For example, conceptual cost factors will likely not capture any new costs imposed by a recently legislated environmental regulation. Therefore, an appropriate contingency will need to account for these new project requirements until estimators receive and analyze data associated with the actual cost of this work and can then assign it a cost element or assume these costs are captured by the conceptual cost factor.

2.2.3.1.1 Lane-Mile Cost Factors

A DOT develops lane-mile cost factors based on the concept of using typical sections representing common types of facilities and historical cost data to derive key cost factors. For example, estimators can use typical lane configurations and pavement type sections as the basis for estimating pavement construction cost for a given length of roadway, pavement thickness, and typical shoulder width. Often, cost estimators develop costs per lane mile using specific pay items from historical bid data and typical sections. Historical data may reflect weighted costs for a given time period and are not necessarily specific to any one area or district within a state. However, it is beneficial to use data from a specific district to provide a location-specific cost factor. Based on the typical section as depicted in Figure 2-1, Table 2-1 shows an example of developing a lane-mile cost factor using weighted average unit prices per pay item.

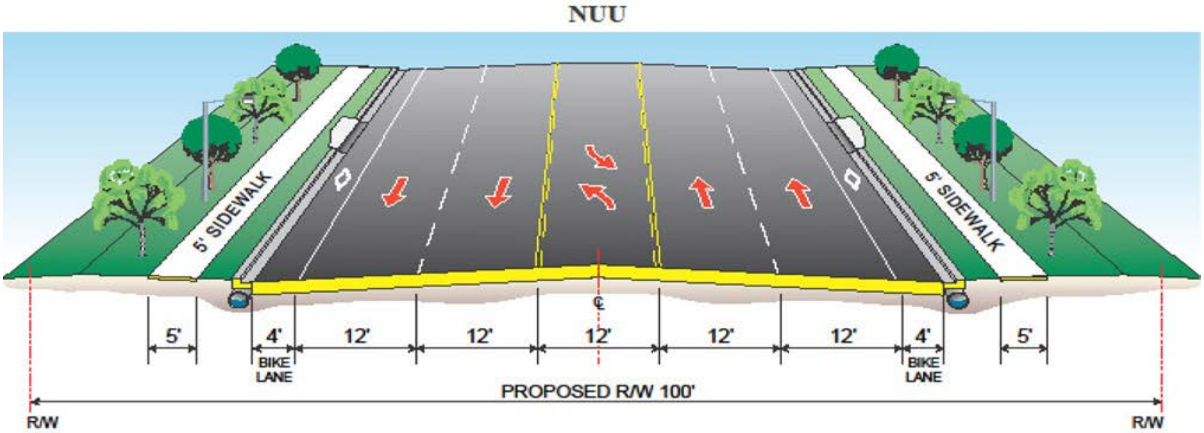


Figure 2-1. Typical Section (NUU = New Construction Undivided Urban)
Source: Florida Department of Transporation Specifications & Estimates Office http://www.dot.state.fl.us/specificationsoffice/Estimates/LRE/Default.shtm

Table 2-1. Development of Lane-Mile Cost Factor

Pay Item	Description	Total Quantity	Unit	Weighted Avg. Unit Price	Total Amount
0101 1	Mobilization	10.00	%*		$419,501.06
0102 1	Maintenance of Traffic	7.00	%*		$274,439.94
0104 10 3	Sediment Barrier	10,560.00	LF	$.84	$8,870.40
0104 11	Floating Turbidity Barrier	250.00	LF	$7.76	$1940.00
0104 12	Staked Turbidity Barrier-Nylon Reinforced PVC	250.00	LF	$3.75	$937.50
0104 15	Soil Tracking Prevention Device	1.00	EA	$2,154.40	$2,154.40
0104 18	Inlet Protection System	53.00	EA	$35.52	$1,882.56
0107 1	Litter Removal	1.20	AC	$16.66	$19.99
0107 2	Mowing	1.20	AC	$29.11	$34.93
0110 1 1	Clearing and Grubbing	20.18	AC	$4,832.63	$97,522.47
0120 1	Regular Excavation	19,360.00	CY	$3.54	$68,534.40
0120 6	Embankment	103,851.73	CY	$4.96	$515,104.58
0160 4	Type B Stabilization	42,920.53	SY	$2.35	$100,863.25
0285709	Optional Base, Base Group 09	39,893.33	SY	$10.66	$425,262.90
0334 1 24	Superpave Asph Conc, Traf D, Pg76-22	6,582.40	TN	$86.37	$568,521.89
0337 7 20	Asph Conc Fric Course, Inc Bit, Fc-12.5, Fc6, Pg76-22	3,191.47	TN	$140.75	$449,199.40
0400 2 2	Concrete Class II, Endwalls	36.00	CY	$795.54	$28,639.44
0425 1351	Inlets, Curb, Type P-5, <10”	36.00	EA	$3,061.55	$110,215.80
0425 1451	Inlets, Curb, Type J-5, <10”	10.00	EA	$4,602.64	$46,026.40
0425 1521	Inlets, DT Bot, Type C, <10”	5.00	EA	$1,899.03	$9,495.15
0425 1541	Inlets, DT Bot, Type D, <10”	1.00	EA	$2,404.23	$2,404.23
0425 2 41	Manholes, P-7,<10’	5.00	EA	$2,589.96	$12,949.80
0425 2 71	Manholes, J-7, <10’	1.00	EA	$4,477.67	$4,477.67
0430171103	Pipe Culvert Optional Material, Round-Shape, 37–48”, Storm Sewer	5,056.00	LF	$137.23	$693,834.88
0430171104	Pipe Culvert Optional Material, Round-Shape, 49–60”, Storm Sewer	200.00	LF	$195.73	$39,146.00
0430175112	Pipe Culvert, Optional Material, Round, 12”S/CD	2,328.00	LF	$43.82	$102,012.96
0430175130	Pipe Culvert, Opt Material, Round, 30”S/CD	208.00	LF	$66.39	$13,809.12
0520 1 10	Concrete Curb and Gutter, Type F	10,560.00	LF	$12.68	$133,90.80
0522 1	Sidewalk Concrete, 4” Thick	5,866.67	SY	$26.49	$155,408.09
0550 10220	Fencing, Type B, 5.1–6.0, Standard	1,180.00	LF	$8.56	$10,100.80
0550 60234	Fence Gate, Type B, Sliding/Cantilever, 18.1–20.0’ Opening	1.00	EA	$1,871.04	$1,871.04
0570 1 1	Performance Turf	31,680.00	SY	$.62	$19,641.60
0570 1 2	Performance Turf, Sod	18,197.33	SY	$1.58	$28,751.78
0700 20 11	Single Post Sign, F&I, Less Than 12 SF	20.00	AS	$239.28	$4,785.60
0700 20 12	Single Post Sign, F&I, 12-20 SF	2.00	AS	$671.53	$1,343.06
0700 21 11	Multi-Post Sign, F&I, 50 SF or Less	2.00	AS	$2,879.36	$5,758.72
0706 3	Retro-Reflective Pavement Markers	810.00	EA	$3.31	$2,681.10
0711 4	Directional Arrows-Thermoplastic	18.00	EA	$71.33	$1,283.94
0711 11111	Thermoplastic, Standard, White, Solid, 6”	4.00	NM	$2,891.87	$11,567.48
0711 11131	Thermoplastic, Standard, White, Skip, 6”	4.00	GM	$907.97	$3,631.88
0715 1 13	Lighting Conductors, F&I, Insulated, No 4 to No 2	19.284.00	LF	$1.42	$27,383.28
0715 2 11	Lighting—Conduit, F&I, Underground	5,280.00	LF	$3.49	$18,427.20
0715 2 12	Lighting—Conduit, F&I, Under Existing Pavement Sawcut	1,048.00	LF	$11.43	$11,978.64

Table 2-1. Continued

Pay Item	Description	Total Quantity	Unit	Weighted Avg. Unit Price	Total Amount
0715 14 11	Lighting—Pull Box, F&I, Roadside-Moulded	35.00	EA	$347.86	$12,175.10
0715500 1	Pole Cable Distribution System, Conventional	35.00	EA	$743.44	$26,020.40
0715511140	Light Pole Complete—Special Design, F&I, Single Arm Shoulder Mount, Aluminum, 40'	35.00	EA	$4,000.00	$140,000.00
0999 25	Initial Contingency Amount (Do not bid)	1.00	LS	$50,000.00	$50,000.00
	TOTAL				**$4,664,511.63**

Description: Configuration—New Construction 5-Lane Undivided Urban Arterial with Center Turn Lane and 4 ft Bike Lanes
Basis—Typical Roadway Configuration and Section for 1 mi and Bid Pricing. **Cost per Mile Factor—$4,700,000**

*For Mobilization and Maintenance of Traffic, a percent of total construction cost. Source: Florida DOT Specifications & Estimates website—http://www2.dot.state.fl.us/SpecificationsEstimates/costpermile.aspx

An alternative approach is to develop lane-mile cost factors based on the concept of using the actual cost of completed or ongoing projects. The data should represent typical DOT projects. These completed or ongoing projects have known costs and definitions. The completed project cost becomes dollars per centerline mile by dividing the cost of the completed project by the total centerline miles for the project. The cost per centerline miles reflects a specific location and time period. The compiler of these gross cost numbers should note the location and time information. This cost per centerline mile factor allows estimators to estimate a similar project that has the same types of construction categories. Table 2-2 illustrates this approach.

Table 2-2. Illustration of Construction Cost per Centerline Mile Based on Similar Project

ITEM DESCRIPTION CATEGORY	TOTAL COST $ × 1000 (early 2007 Cost)
Preparation	882
Excavation/Grading	5,560
Drainage/Storm Sewer	1,229
Structures	4,574
Pavement (bituminous)	12,926
Erosion Control and Planting	2,716
Traffic	5,937
Other Items	1,249
Mobilization	2,454
Total Construction	**37,527**
Cost per Lane Mile Calculation: **Cost per Mile—Construction = $37,527,000/(59.72 – 54.75) = $7,550,000 per centerline mile in 1st Quarter 2007 Dollars**	

Source: Minnesota DOT Training Course

Descriptor:
- City 1 on Trunk Line X to Interstate-Z Interchange

Location:
- County T
- Milepost 54.75 to Milepost 59.72

Existing:
- Two-lane undivided highway

Definition:
- Add two lanes between Trunk Line Y and Interstate I-Z to create a four-lane divided highway
- Replace one bridge over creek
- Remove and replace bridge at Trunk Line X and Trunk Line Y
- Build two new bridges at Road 3 and the Trunk Line X and Interstate I-Z interchange
- Implement full, partial, and modified limited access along the project limits
- Add turn lanes and acceleration lanes at various locations
- Resurface existing lanes

Current Estimate:
- The construction cost-estimate summary above was prepared when letting Project B for construction. Costs reflect early 2007 dollars.

2.2.3.1.2 Bridge Cost Factors

DOTs derive bridge costs based on deck area (usually in $/SF) in a manner similar to the lane-mile approach for roadways. They build this cost factor using bid data for typical bridge types and span lengths together with location characteristics (over land or water). Since cost per square foot of deck area varies, it is important to provide a range for the deck cost factor. Again, one must specify the time period and project location to create the cost factors. It is also important to state the dimensional data (width and length) used to calculate the deck area (“Recording...” 1995). Table 2-3 provides an example of bridge cost factors including a reference to deck area calculations and other qualifications regarding the cost data.

Table 2-3. $/SF of Bridge Deck—Statewide Average Historical Ranges in 2011 Dollars

Type of Bridge	Measure (SF Bridge Deck)	Low ($/unit)	Average ($/unit)	High ($/unit)
Prestressed Concrete Girders—Span 50-175 ft				
Water Crossing w/Piling	SF	150	175	200
Water Crossing w/Spread Footings	SF	140	165	190
Dry Crossing w/Piling	SF	120	155	180
Dry Crossing w/Spread Footings	SF	110	145	160
Reinforced Concrete and Post-Tensioned Concrete Box Girder—Span 50-200 ft				
Water Crossing w/Piling	SF	200	250	300
Water Crossing w/Spread Footings	SF	175	225	275
Dry Crossing w/Piling	SF	160	200	250
Dry Crossing w/Spread Footings	SF	150	190	230
Concrete Bridge Removal	SF	20	35	50
Widening Existing Concrete Bridges (including Removal)	SF	175	200	300
SE Wall Precast Concrete Panels	SF	30	40	50
SE Wall Welded Wire	SF	20	30	40

Source: Washington State Department of Transportation (Design Manual 2011).

NOTES: Bridge areas are computed as follows:

Typical Bridges: Width × Length
Length:
- Distance between back of pavement seats, or for a bridge having wingwalls, 3'-0 behind the top of the embankment slope; typically end of wingwall to end of wingwall.

Special Cases:
- Widening—actual area of new construction

Figure 2-2 illustrates incorporating an increased level of detail into a database of bridge cost factors. As noted in Figure 2-2, comparative bridge costs provide guidance on where in the cost factor range the estimator may want to select from based on general bridge dimensional information and typical location characteristics. An approach defined by the Federal Highway Administration (FHWA) helps in calculating the cost factors ("Recording..." 1995).

2.2.3.1.3 Historical Percentage Cost Factors

Historical percentages are often used to estimate costs for construction elements that are not typically defined at the planning phase and are not covered in historical data sources (i.e., lane-mile cost factors). A percent is developed based on historical cost information from past projects to cover very specific construction elements such as drainage and environmental mitigation. This percentage is based on a relationship between the selected construction elements and the total construction cost category.

The projects from which historical percentages are developed should be very similar in definition and complexity to the project being estimated. The elements that are represented by the percentage should be based on a similar set of standard pay item numbers. Several projects should be used to develop the percentages so that a range of percentages can be reviewed prior to selecting the specific percentage that is applied by the estimator. As the dollar size of the project increases, historical percentages for elements normally decrease.

Developing a historical percentage starts with identifying construction elements that can be estimated using a percentage. Then, several different projects are identified that are similar to the project being estimated. From those projects, the estimator determines the standard item numbers for the elements of interest and the actual cost for those item numbers. The sum of the cost of these item numbers is calculated. The percent of this sum to the total construction cost for each project is calculated (i.e., percent of project construction cost without the elements). The estimator selects the percent that best fits the project being estimated.

2.2.3.1.4 Computer-Generated Cost Factors

Computer software is often used to aid in storing and sorting historical cost data and other pertinent project details. In its most elementary form, one can use a spreadsheet to store historical lane-mile information based on different types of projects. Table 2-2 provides an example of the calculated lane-mile cost based on a completed project. Figure 2-3 shows a typical spreadsheet of lane-mile costs. The estimator preparing a conceptual estimate can retrieve the lane-mile data from a spreadsheet. Alternatively, computer software, such as the AASHTOWare Project BAMS/DSS, and ExeVision's integrated Project Delivery (*i*PD) allow users to store bid data. These systems provide structured classification of bid items used by a DOT, and they allow for classification of contracts based on work type.

Historical data from the DOT database, such as AASHTOWare Project BAMS/DSS data, used with other programs helps to develop lane-mile costs, as illustrated in Table 2-1. To refresh the lane-mile cost, estimating personnel update the calculations based on current bid data. Finally, historical cost data can be stored within an estimating program along with other project type elements and dimensional information. An example of such a program is the AASHTOWare Project TRACER. AASHTOWare Project Cost Estimation also helps to develop conceptual estimates. Rather than developing templates for typical sections in order to establish cost factors for lane miles, using these same templates helps with developing cost groups in AASHTOWare Project Cost Estimation to represent elements of work. These cost groups could then be included within the estimate when one needs the work elements. The resulting estimate would more closely resemble that of a detailed estimate, but it would include higher contingencies due to the greater uncertainties in the earlier stages of the project.

COMPARATIVE BRIDGE COSTS

JANUARY 2011

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 Projects, 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 25%-150%	
Structures with More than 2 Construction Stages	
Unique Substructure Construction	
Widenings Less Than 15 ft.	

Structural Section	**(Str. Depth/Max Span)**		**Common Span Range (feet)**	****Cost Range ($/FT^2)**	**Remarks**
	Simple	**Continuous**			
RC SLAB	0.06	0.045	16–44	100–300	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	100–200	
RC BOX	0.06	0.055	50–120	110–180	
CIP/PS SLAB	0.03	0.03	40–65	90–200	
CIP/PS BOX	0.045	0.04	100–150	90–170	
PC/PS SLAB	0.03 (+3" AC)	0.03 (+3" AC)	20–50	100–250	No falsework required
PC/PS	0.06 (+3" AC)	0.055 (+3" AC)	30–120	120–230	
BULB T GIRDER	0.05	0.045	90–145	120–200	
PC/PS I	0.055	0.05	50–120	110–190	
PC/PS BOX	0.06	0.045	120–200	140–250	
STRUCT STEEL I-GIRDER	0.045	0.04	60–300	170–425	

Figure 2-2. Bridge Cost Factors

Source: Caltrans Bridge Cost Estimating

NOTE: Removal of a box girder structure costs from $8–$15 per square foot.
**Cost Range/SQFT is calculated using "Bridge Costs Only" as defined by the FHWA.

Reconstruction						
T.H. #	Length in miles	Location	Contract Amount $	$ per Mile	Type of Repair/Costs/Other	Year
2	4.5	Bemidji-Grace Lake	3,734,756.99	829,946.00	Grade and pave to four lanes	1995-1996
32	1.69	In Thief River Falls 5703-33	3,275,825.00	1,938,357.99	Reconstruct	1992
32	3.135	In Red Lake Falls	3,315,468.00	1,057,565.55	Reconstruct	1992
75, 175	1.56	Hallock	3,476,319.00	2,228,409.62	58-34 Oil	2002
1	1.214	In Thief River Falls	1,664,879.00	1,371,399.51	58-34 Oil	2002
2	0.765	In East Grand Forks	4,014,751.67	5,248,041.40		2002
2		Jct. 222 to 3.6 miles E.	3,131,000.00	869,722.00	Unbonded; overlay Str Conc 98.65/sq.m, Lane Pavement 250mm 9.35/sq.m, Lane Pavement 20mm 5.85/sq.m	
11		Roseau 1.12 miles	3,493,950.00		S.P. 12.5; 3.F; 14,079 ton, - $42/ton, (3,F), Common ex. $5.30/yd.	2005
64	3.9	Akeley to Co Rd 33	3,026,749.00	776,089.00	3,C $24/ton; 44,961 ton, Subgrade Ex $1.50/cubic yd, 51,000 cubic yds, Common Ex $1.50/cubic yd; 240,452 cubic yds, Much Ex $1.70/cubic yd, 112,379 cubic yds	2005
64	5.986	Jct. 87 to Co. Rd 33	2,851,304.00	476,169.00	SP 12.5; 26,426 ton @ 30.21 Select Gran. 96,230 @ 1 cent/yd cubed	
2	0.5	In Crookston 6002-54 Main to Robert	2,046,183.00	4,092,366.00	Reconstruct	1997
2	0.786	Crookston 6002-56 Groveland to Broadway	3,256,000.00	4,142,493.64	Reconstruct	1998
2	0.75	Crookston 6002-59 E. end Bridge to 1.2 Km E.	1,998,000.00	2,664,000.00	Reconstruct	1999

Figure 2-3. Lane-Mile Costs Based on Completed Projects
Source: Cost Estimation… 2008

2.2.3.2 Cost Factors for Non-Construction Components of Total Project Cost

When focusing on total project cost, a common conceptual estimating technique is to estimate non-construction cost components as percentages of the calculated construction cost. Estimators typically relate these percentages to construction costs where the percentage comes from historical expenditures using activity codes (ROW, PE, and CE).

2.2.3.2.1 Preliminary Engineering

The scope of PE includes all data acquisition and design activities from the time the project is programmed at the scoping phase through the time the project is awarded. PE covers all resource identification and environmental permitting activities. All activities undertaken by contract administration necessary to process the project for award are included in PE costs. Finally, the PE covers all activities that involve the resolution of utility conflicts, relocation, or access management.

Table 2-4 is an example of percentages for various activities under the PE component. These percentages come from the historical relationships between the activity and construction costs.

PE percentage considerations are as follows:

Table 2-4. Preliminary Engineering Costs' Average Percentage Ranges (% of Construction)

Activity	Low	Average	High
Survey/Data Collection	2%	3%	6%
Design	2%	4%	6%
Environmental	2%	3%	6%
Utilities	2%	3%	5%
Contract Admin	2%	2%	2%
Totals	**10%**	**15%**	**25%**

Source: AASHTO Subcommittee on Design—Technical Committee on Cost Estimating

- **Level of data acquisition**: surveys—digital and field enhancements; type of topography (mountainous, rolling, or flat); coastal or other waterways; rural, suburban, or city (central business district). The more field enhancement or specialized surveys required, the higher the PE percentage.
- **Level of design engineering**: new location, widening of roadway corridors, interchanges or urban/city locations. Minimal constraints would generally have a lower percentage; increased design effort because of city location complexities may require higher percentages due to more conflicts or constraints and specifications.
- **Length, size of project**: every project requires the basic effort to ensure all aspects are completed. Longer or larger projects usually mean repeated or prolonged tasks, but the effort becomes more cost effective and can lower the PE percentage of construction costs.
- **Level of environmental documentation (CE, EA, or EIS)**: level of public involvement. An Environmental Assessment (EA) or Environmental Impact Statement (EIS) with an above-average level of public involvement requires a higher PE percentage.

2.2.3.2.2 Right-of-Way

Right-of-way includes all activities associated with the assessment and acquisition of property for a project. The ROW components cover all costs associated with the acquisition of all easements and property parcels necessary to construct a project. ROW percentages, as depicted in Table 2-5, consider the local real estate market—such as rural, suburban, or central city—and the type of acquisition, such as minimal frontage take (strip); partial take, rendering the parcel uneconomical; or total take. Uneconomical or total takes may then require relocation or other compensation as a part of acquisition.

For non-complex or minor projects with minimal ROW requirements, the use of percentages of construction costs to estimate ROW is usually acceptable. However, moderately complex and major projects need at least a limited definition of scope to identify real estate requirements before preparing an accurate ROW conceptual estimate. Chapter 4 of NCHRP Report 625, *Procedures Guide for Right-of-Way Cost Estimation and Cost Management*, describes procedures for completing conceptual ROW cost estimates (Anderson et al. 2009).

Table 2-5. Average Percentage Ranges for Right-of-Way Costs (% of Construction)

Factor	Low	Average	High
Location	15%	40%	75%
Type of Take	15%	35%	75%
Totals	**30%**	**75%**	**150%**

Source: AASHTO Subcommittee on Design—Technical Committee on Cost Estimating

2.2.3.2.3 Construction Engineering

Construction engineering covers the cost of all activities associated with administering a project from the date of award until final acceptance or the time the construction engineering expenditure account is closed. This cost includes, but may not be limited to, payroll and expenses accrued by DOT or consultant inspection forces, or both; material testing and evaluation by the DOT or consultant forces, or both; central office administrative and business-related efforts; and field reviews by the DOT or design staff, or both.

In the case of conceptual estimates, the estimator should calculate CE costs as a percentage of total construction costs. The percentage will vary with the type and complexity and net dollar size of the project. According to the Washington State DOT, the percent could be as low as 8 percent for large ($10,000,000 or greater) roadway or structure preservation projects and as high as 20 percent for small ($250,000 or less) preservation projects ("Contract Estimate," 2011). Alternatively, for small highway improvement projects in an urban environment, CE could be as high as 26 percent and as low as 10 percent for large improvement projects. The WSDOT average for CE across all improvement and preservation program projects is 15 percent.

2.2.4 Macro-Environment and Market Conditions

Planning estimates are too many years from letting dates to consider adjustments to the base estimate for macro-environmental and market conditions.

2.3 PREPARE BASE ESTIMATE

Preparing a base estimate for conceptual estimating requires that estimators determine the basis from which the estimate will be prepared (see Figure 1-2). The basis of the estimate mainly comes from the project definition and project characteristics (see Section 2.2). The challenge when preparing a conceptual estimate is to ensure that the estimate covers all categories of each major project component, that is, construction, right-of-way, preliminary engineering, and construction engineering. At this level of estimating, defining the construction effort is often very difficult due to lack of project information. The estimator should visit the project site to confirm the completeness of project definition requirements and assess potential constructability (i.e., material storage locations, haul routes, and construction staging issues). Further, a site visit can help detect potential environmental mitigation, utility relocation, and right-of-way issues that might influence cost. After establishing the estimate basis, the estimator can prepare the base estimate (see Figure 1-2). There are six general steps for preparing a base estimate (Anderson et al. 2008):

1. Select appropriate estimating approach.
2. Determine estimate components and quantify.
3. Develop estimate data.
4. Calculate cost estimate.
5. Document estimate assumptions and other estimate information.
6. Prepare estimate package.

2.3.1 Select Appropriate Estimating Approach

There are a number of approaches to conceptual estimating based on the project's definition and the type of past data available. For example, if the project does not have structures and only represents pavement activities, the estimator should utilize the lane-mile estimate. If the project is a bridge rehabilitation project, the estimator should use the bridge-cost-per-square-foot-of-deck-area approach. If the project has pavement and bridge construction work, then the estimator should use both sources of historical data. Alternatively, if there are similar past projects in terms of both project definition and project characteristics, then using a lane-mile approach based on the similar project might be the best approach. If using a computer-based conceptual estimating tool (i.e., TRACER), then the project definition must define key project parameters that serve as inputs to the estimating software. Then, the estimator should use percentages for the other components of total project cost including right-of-way, preliminary engineering, and construction administration. Estimators should estimate right-of-way by using the techniques described in NCHRP Report 625, *Procedures Guide for Right-of-Way Cost Estimation and Cost Management*. Chapter 4 of that guide is dedicated to conceptual ROW cost estimation (Anderson et al. 2009). The estimator must select the approach that best reflects the project definition and historic cost database developed by the DOT. If the appropriate historic cost database is not available, the estimator must develop the requisite historic cost data.

If using a conceptual estimating software tool, it will guide the process for steps 2, 3, and 4. For example, TRACER's output includes quantities for various items of work, unit prices, and calculations to derive a construction base cost estimate. This tool uses a parametric approach for conceptual estimating. The database that supports this tool is the *RS Means Heavy Construction Cost Data* manual. TRACER uses statistical relationships between major highway project systems, termed modules, and the details that describe the 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 for inputs into TRACER—bridge size (length and width), separation type (over highway and height), and definition (superstructure and substructure type). TRACER then generates all direct construction costs. Next, the user should add the contractor overhead and profit based on project location and insert these values with the provided template. TRACER is an estimating tool that incorporates historical cost data and statistical relationships and can adjust costs for different locations. Figures 2-4 to 2-6 show an illustration of how this tool works to estimate all the construction costs for a component of a project, such as bridges (Anderson et al. 2007). Figures 2-4 and 2-5 show the types of project definitional input needed, while Figure 2-6 illustrates typical cost-estimate output.

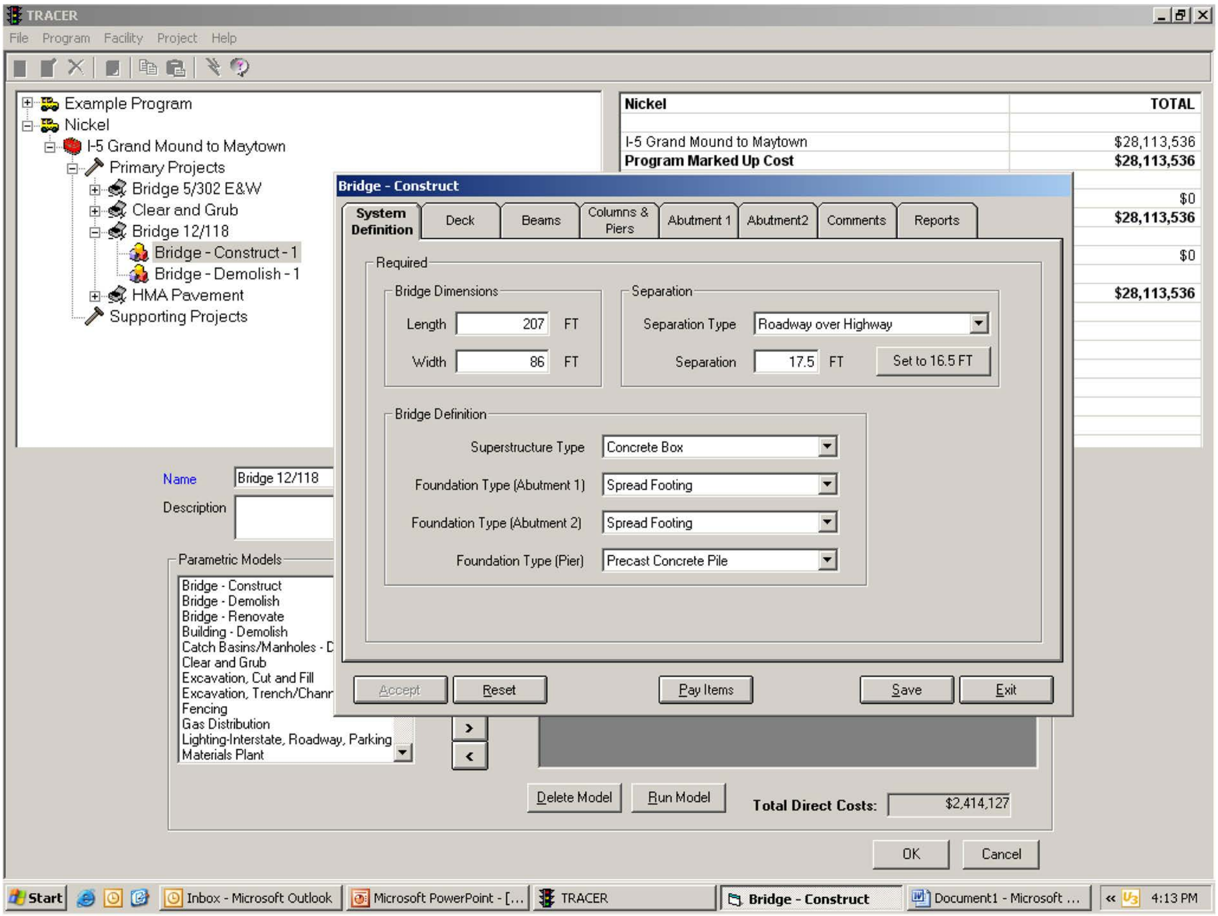


Figure 2-4. Typical TRACER System Input for a Bridge

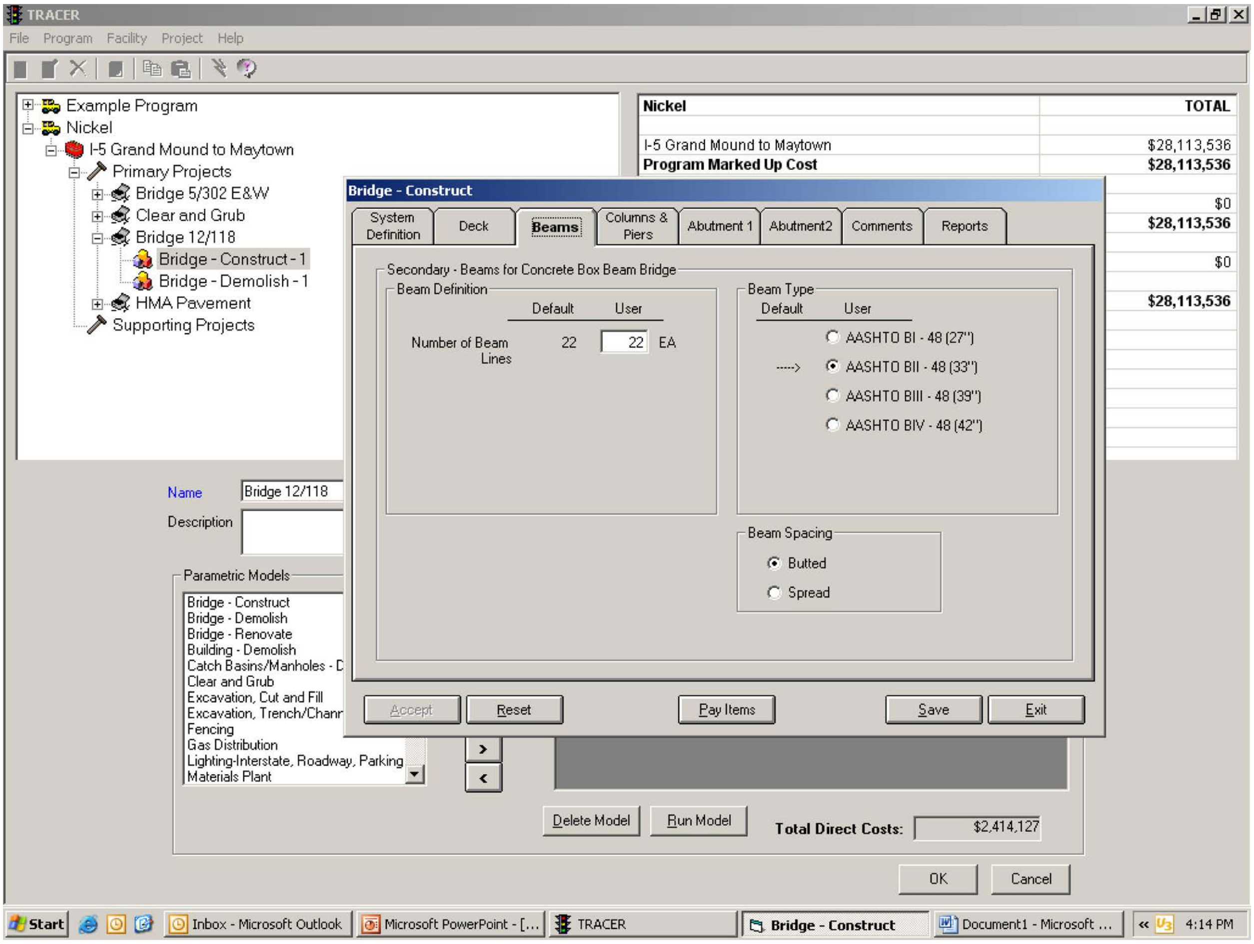


Figure 2-5. Typical TRACER Beam Input for a Bridge

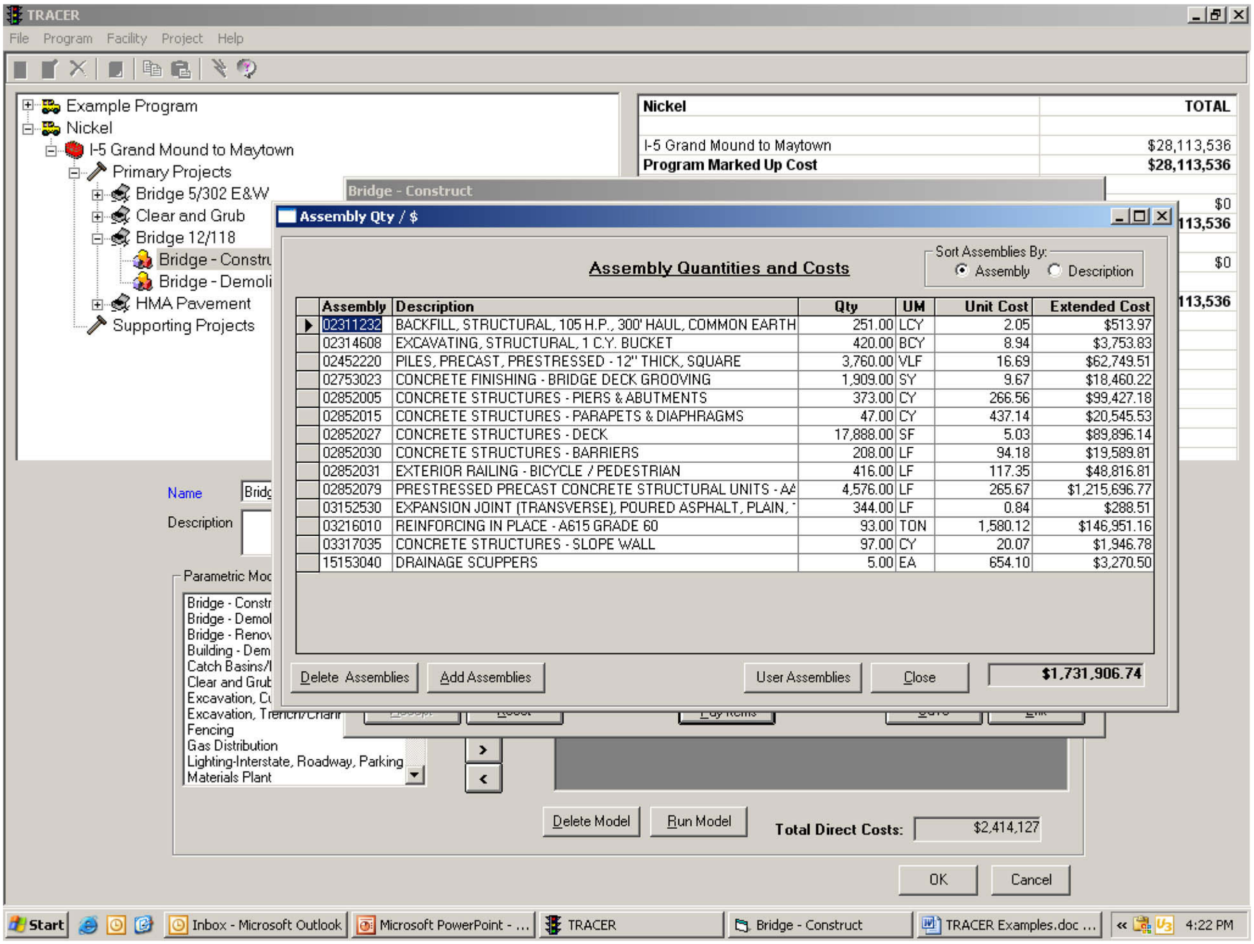


Figure 2-6. Typical TRACER Output for a Bridge

If such a software program is not used, then the estimator has to perform steps 2, 3, and 4 as discussed in the following sections.

2.3.2 Determine Estimate Components and Quantify

Conceptual estimating requires the estimator to determine what components are required to estimate total project cost. This effort is straightforward for most non-complex projects where ROW is not required. The more difficult requirement is determining the work categories needed for the construction component. For example, if the project requires both structures and pavement construction, estimators will then derive quantities for the major parameters such as lane miles and square foot of bridge deck area or retaining wall area. The estimator must define the lane mile as centerline or project lanes for estimating purposes only. If using centerline, then estimators should identify mileposts at the project boundaries. The difference between the mileposts represents the centerline distance. If project lane miles are used, the estimator needs to know how many lanes are involved in construction. This may include existing lanes plus new lanes added if the project is a capacity expansion. Next, the estimator should calculate the total project lane miles. If the project involves bridges or other major structures, then the basic dimensions of the replacement or new bridges must be determined (i.e., deck width, length, height above water or land).

If estimators choose to use true parameter estimating software, such as TRACER, then the inputs are element types plus dimensional information. More design assumptions are necessary to adequately describe the pavement structure or bridge type and configuration (see Figures 2-4 and 2-5 for examples). The program calculates quantities based on statistical models (see Figure 2-6).

2.3.3 Develop Estimate Data

In this step, the estimator has to match the types of quantities developed in the previous step with the construction cost data available in the DOTs historical cost database. Then, the estimator has to ensure proper adjustments of historical data to fit the current estimate. Adjusting historical data depends upon the type of project, its definition, and specific site characteristics, as these attributes relate to the current estimate. In addition, the estimator must decide on the percentage to use in calculating ROW, PE, and CE costs, again from the data in the DOT's historical cost database. It might be necessary to develop the appropriate cost data if the DOT database does not cover the items needed to complete the project estimate.

2.3.3.1 Selecting Historical Cost Data

Selecting the appropriate historical data for estimating a project is vital. The estimator must ensure that the data selected represents the type of project for which an estimate is being prepared. As an example, if the project relates to pavement work only, then a lane-mile approach is appropriate. In this case, the estimator can select the appropriate project type and the corresponding cost factor (i.e., dollars per lane mile). Bridge estimating takes a similar approach. The bridge type selected from DOT charts must be similar to the current bridge estimate. The estimator then selects the corresponding cost factor. If the project has both pavement and bridge categories, the estimator may select cost factors developed from similar past projects.

In selecting the cost factor, the estimator should be clear about the project definition or scope covered by the cost factor (i.e., does the factor include substantial environmental mitigation costs or costs for relocating utilities?). This is critical information to know when adjusting historical cost factors to fit the project for which an estimate is being prepared. Other adjustments will also likely be necessary.

2.3.3.2 Adjustments to Cost Data

There are several areas where the estimator should consider adjusting the historical cost factors selected when developing the cost data for estimating a new project. These factors include:

- Time—age of historical data impacts its validity.
- Location of project versus location basis for cost factors.
- Unique project location characteristics (geography).
- Scope—evaluating the extent to which the cost factors cover the specific project.
- Unique project definition requirements.

2.3.3.2.1 Time

The estimator must note the time basis related to the cost factor selected. For example, in Table 2-3, the cost factors represent 2007 dollars. If an estimator uses these data to estimate bridge costs for a project, then he/she must adjust the cost factor selected to current dollars using the DOT's highway cost index.

2.3.3.2.2 Location

Cost factors are often developed based on statewide averages. In some states, construction costs are different by district or region depending on location. Cost differentials may be due to labor wage changes. Typically, an urban area has higher wage rates than a rural area. Other differentials in costs resulting from location could affect both materials and construction equipment (e.g., typical haul distances). In all cases, the estimator has to evaluate cost differentials between statewide averages and costs for the actual project location. Thus, estimators must make appropriate increase or decrease adjustments as necessary.

2.3.3.2.3 Unique Project Location Characteristics

Estimators should take into consideration the location of the project in relation to such issues as terrain, batch plants, and haul distances. Flat terrain normally improves contractor productivity, so costs should be lower compared to terrain characterized by hills or mountains. If distance influences the transportation of materials, then costs are likely higher than the average. The estimator must use judgment to adjust cost factors so they reflect these types of location characteristics. The estimator may need input from construction engineers in developing adjustments for such factors.

2.3.3.2.4 Scope

The estimator has to develop percentages to cover work elements not covered by the basic cost factor. For example, if the cost factor for a bridge (i.e., dollars per bridge deck area) does not cover the approach slabs, then the estimator has to add this cost. Developing percentages should help estimate these types of additional costs. The database of cost factors should clearly identify what is included in the standard cost factor so estimators can make any appropriate adjustments when applying the cost factor on a current project estimate.

2.3.3.2.5 Unique Project Definition

In some instances, a project has unique project scoping issues. For instance, if a project adds lanes using an existing grass center median, the amount of drainage required will increase substantially in terms of catch basins, pipe, and retention ponds. If the pavement cost factor assumes a grass center median, but with the new lanes located on the outside of the existing pavement structure, then the estimator has to make an adjustment for the cost of additional drainage work. The estimator could develop a percentage of other construction costs to apply to the lane-mile factor to capture added drainage requirements. Alternatively, the estimator could make some assumptions about the likely scope of the drainage and ponds and then calculate costs by developing quantities and using bid prices. Cost adjustments are sometimes required for wetlands and other environmental impacts not clearly identified in cost factors.

2.3.3.3 Summary

There is an argument for including various adjustments to cost factors for contingencies, especially cost factors related to location characteristics, project definition, and project complexity. This approach is certainly acceptable as long as the contingency estimate can clearly identify costs related to these types of adjustments. The cost-estimate documentation should describe all adjustments and how the estimator calculated the costs for any adjustments. If data reflect historical cost factors as a range, the estimator may use a cost factor on the higher end of the range to incorporate the impact of the adjustments discussed.

2.3.4 Compile Cost Estimate

Once the quantity information is calculated for major construction categories (i.e., centerline miles or bridge deck area) and a unit cost is derived for those components (i.e., dollars per centerline mile or dollars per bridge deck area), estimators can use spreadsheets to calculate the costs for each category. In addition to construction cost, the estimator has to select the appropriate percentage for ROW, PE, and CE to reflect the level of effort for each of these components. These percentages are used to calculate the ROW, PE, and CE costs. If the estimator uses a computer software program, then the program makes the calculations and generates cost details and a cost summary for the project (see Figure 2-5).

2.3.5 Document Estimate Assumptions and Other Estimate Information

Support documentation includes project work narratives and schedule, backup data, and sketches. This documentation must be in a form that is understandable, checkable, verifiable, and easily correctable. Estimators must make sure to document the reasons for all cost adjustments and clearly detail any computations of the adjustments made.

2.3.5.1 Estimate Basis

References to sketches, basic descriptions of the project's definition, and any assumptions used to develop a project's definition should be included in the documentation. In addition, the project location and any unique project conditions that affect the estimate should also be included in the documentation, as discussed in Section 2.2.3.

2.3.5.2 Estimate Supporting Data

Estimators draw data from multiple sources when creating a conceptual estimate, so estimators need to document these sources together with notes supporting any adjustments made based on engineering judgment or experience. Estimators should back up data by documenting the following estimate-related information:

- Quantity computations: The quantities for major parameters should reference sketches or information provided by the planning staff. Estimators must show dimensional information clearly in the documentation, using sketches as necessary to support quantity calculations.

- Estimated cost factor: The source of historical cost factors used to develop major categories of work should be explained and documented (i.e., source and rationale for selecting the cost factor). So, estimators will document the rationale for adjusting a base cost factor, such as for geographical location, quantity considerations, scope differences, impact of unique project definition requirements, and difficult site conditions or constraints, or some combination thereof. Finally, they must remember to document all adjustments made to estimated cost factors for current market conditions and any macro-environmental conditions.

2.3.6 Prepare Estimate Package

All estimate-related information should be included in a project estimate file that organizes estimate information for use in preparing a risk analysis to set contingency options, for estimate reviews, and for estimate approval by planning or program delivery management. For an outline format for such a suggested project estimate file, see Figure 2-7. The estimate basis details are oriented toward the types of information available in planning. The cost-estimate section should reflect typical types of conceptual estimating detail.

2.4 DETERMINE RISK AND SET CONTINGENCY

Estimators need to separately develop a contingency amount for the project based on the risk analysis process discussed in Chapter 5. They should expect to have larger contingency percentages for conceptual estimates based on both the lack of detailed project definition and the types of conceptual estimating techniques used to prepare conceptual estimates. Also, conceptual estimates are often prepared quickly, so the estimator may not have time to carefully analyze and make all the necessary adjustments to the base estimate; therefore, a larger contingency percentage becomes appropriate. For more information on specific risk analysis techniques, refer to Chapter 5.

2.4.1 Contingency

Conceptual cost estimates have substantial uncertainty associated with the completeness of the project's definition as well as the techniques used to prepare these estimates. They require considerable estimator judgment to ensure complete project definition and to determine the most appropriate historical cost data to use for estimating purposes. A risk analysis, as discussed in Chapter 5, covers estimate variability associated with the level of definition and cost factors used in preparing the conceptual estimate.

The estimator is probably in the best position to assess the uncertainty associated with cost factors, while planners/designers can assess the completeness of the project definition.

PROJECT ESTIMATE FILE

TYPICAL OUTLINE

Conceptual Estimate

TOTAL PROJECT COST ESTIMATE SUMMARY

- Total Project Cost Estimate Summary One Page (component level of total project cost)
- Key Project Requirements
- Key Estimate Assumptions
- Major Risks

TOTAL PROJECT COST ESTIMATE DETAILS

- Estimate Basis
  - Project Description (brief narrative description of project requirements)
  - Schematic or Sketches
  - Key Dimensional Information
- Cost Estimate
  - Cost Estimate Summary (components: construction [could include separate costs for pavement structure and bridge components], PE, ROW, CE)
  - General Estimate Basis (type of conceptual estimating approach [i.e., lane mile, past similar project, percentage], historic data used, adjustments to historic data)
  - Assumptions (as required for different component estimates)
  - Backup Calculations (for different component estimates)
  - Review notes and recommended changes
- Risk Analysis
  - Risks (red-flag items, risk register, etc.)
  - Contingency (contingency basis and calculation)

Notes:

Figure 2-7. Project Estimate File Outline
Source: Adapted from: Cost Estimation... 2008

2.5 QUALITY ASSURANCE AND QUALITY CONTROL

Completing a quality assurance and quality control review assists in validating all conceptual estimates. A key issue of quality is to ensure the project's definition is fully covered and the estimated costs are representative of the level of project definition associated with project planning.

The review of a conceptual estimate, at a minimum, should examine the sources of cost factor data, the fit with the project type, and all adjustments to costs made to account for project-specific definition and condition requirements. The detail and depth of a review will vary depending on the type of project, its size and complexity, and the time available for the review. For large projects or corridors in urban areas that are extremely complex, qualified professionals should subject the estimate to an external review. There may be certain critical cost factors in these estimates that require a unique expertise to verify estimated costs. The estimate review should take place only after quantifying project risk and adding in appropriate contingency amounts, as these costs need a detailed check and review.

2.5.1 What to Check?

Conceptual estimates typically have little detail to check. One review approach for these types of estimates is to compare estimated costs with other similar projects. Estimators compare conceptual cost estimates for current projects to projects currently under construction, recently bid, or in the letting phase. For proper comparison purposes, estimators will need to convert these past projects to the appropriate cost factor. To illustrate, estimators should divide the construction cost by the appropriate quantity such as the centerline miles. Next, they must compare the resultant dollar per centerline mile of the similar project to the same number for the current conceptual estimate. If there are substantial differences between the two cost factors, the estimator has to explain the differences. Then, the estimator makes a decision as to whether or not to change the current estimate based on this check.

2.6 SUMMARY

The goal of estimating is to determine a reasonable cost to deliver a project. It is best to base conceptual estimates on the most current project definition information available. Highway estimators develop conceptual estimated costs based on historical cost factors. They adjust the historical data, based on key parameters, for geographical location, project definition differences, and major site conditions or constraints that possibly influence costs, or some combination thereof.

To create a conceptual base estimate plus a reasonable contingency, it is necessary to prepare a comprehensive total-project cost estimate based on major project parameters. When using historical cost factors, the estimator must ensure that these cost factors reflect the scope of the current project estimate as best determined by planners and designers.

2.7 PROJECT EXAMPLES

In this section, three different planning phase project scenarios illustrate the application of conceptual cost estimating. The three projects are (1) a bridge project; (2) a pavement project; and (3) a project that has both structures and pavements. The cost estimates reflect total project cost for a base estimate, that is, without contingency. Refer to Chapter 5 for additional information on risk and contingency.

2.7.1 Bridge Project

The fundamental parameter associated with this type of project is the bridge deck area. For consistency, estimators should calculate the deck area using guidelines associated with the annual FHWA Bridge Construction Unit Cost update ("Recording..." 1995). From the construction unit cost update, the estimator must calculate the deck area using the designed bridge length multiplied by the bridge width determined from the out-to-out deck dimension. Estimators can use this same procedure for determining deck area for new and rehabilitated structures.

Other assumptions required for establishing the bridge deck area are as follows:

- Estimators need to establish the assumed width for the bridges based on the functional classification of the existing highway. The proposed widths provided below are examples for discussion purposes, and estimators will need to modify these examples as necessary to make them DOT-specific.
  - Freeways—typical width of 4 ft-12 ft-12 ft-10 ft plus 3 ft for curbs 41 ft
  - Principal Arterials—typical width of 6 ft-12 ft-12 ft-6 ft plus 3 ft for curbs 39 ft
  - Major/Minor Collectors–typical width of 4 ft-11 ft-11 ft-4 ft plus 3 ft for curbs 33 ft
  - Local Roads—typical width 2 ft-10 ft-10 ft-2 ft plus 3 ft for curbs 27 ft

  Note: For bridges with anticipated lengths of less than 50 ft, it may be appropriate to eliminate the 3 ft additional width for curbs if assuming the bridge rail will be fascia mounted.
- In generating cost estimates at this stage, the required length for a new bridge is usually unknown. Therefore, the estimator has to assume that length. The recommendation for that assumption is to use the existing bridge length plus 20 ft. For bridges on a new alignment, estimators should use the length from the top-of-bank to top-of-bank plus 20 ft. For lack of any more definitive information, estimators can derive the top-of-bank to top-of-bank from existing topographic maps when available.
- For bridge rehabilitation projects, estimators should use the existing width unless one objective of the project will be to attain additional width. In those cases, estimators must use a practically attained width based on the current superstructure configuration (i.e., existing beam spacing or substructure width).

The sample calculations provided in Table 2-6 are for a bridge reconstruction/replacement project on a straight existing alignment over a waterway where, based on the site conditions, there will be minimal roadway approach work. The highway classification is a minor collector in a rural setting with an existing bridge length of 110 ft.

Table 2-6. Bridge Replacement Conceptual Estimate Example

Bridge No. 123 Replacement Project on State Route 456		
Highway Functional Classification:	Minor Collector	min. design width = 30'
Site Terrain Features:	Flat	
Surrounding Population Density:	Rural	

Project Site Parameters	Existing	Proposed	Comments
Bridge Type	Prestressed Concrete Girder	Prestressed Concrete Girder	Prestressed Concrete Girder
Horizontal Alignment	Tangent	Same	Replacement on existing
Vertical Alignment	+2% tangent	Same	Replacement on existing
Bridge Length	110 ft	130 ft	Assume 20 ft increase in length for new structure
Bridge Width	27 ft	33 ft	30 ft deck width plus 3 ft for curbs
Roadway Approach Width	28 ft	30 ft	Will require minimal approach work
Right-of-Way	75 ft	Same	Will require only temporary construction easements

Total Project Cost Estimate

Step	Cost Element		Cost Factor (CF)	Cost	Instructions and Comments
A	Bridge Costs	Area = 130 ft×33 ft = 4290 sq ft	$155/sq ft	$665,000	Cost = Area × $CF_{step\ a}$ mid-range cost factor used based on site conditions (see Table 2-3)
B	All other Construction Costs (approaches and other incidentals)		35%	$232,700	Cost = $Cost_{step\ a} \times CF_{step\ b}$ minimal roadway approach construction
C	**Construction Cost Total**		**n/a**	**$897,700**	Cost = $Cost_{step\ a} + Cost_{step\ b}$
D	PE Costs		15%	$134,700	Cost = $Cost_{step\ c} \times CF_{step\ d}$ average for rural projects
E	ROW Costs		5%	$44,900	Cost = $Cost_{step\ c} \times CF_{step\ e}$ low cost factor used for rural projects requiring only temporary construction easements
F	CE Costs		15%	$134,700	Cost = $Cost_{step\ c} \times CF_{step\ f}$ average for rural projects
	Total Project Base Cost (w/out contingency) =			**$1,212,000**	Cost = $Cost_{step\ c} + Cost_{step\ d} + Cost_{step\ e} + Cost_{step\ f}$
	Reported Total Project Base Cost (w/out contingency) =			**$1,200,000**	Current-Year 2011 dollars

Note: PE, ROW, and CE costs are a percentage of the construction costs. The total project costs are the sum of all of the cost elements, except bridge costs, which are part of the construction costs.

2.7.2 Asphalt Paving Project

The fundamental parameter associated with this type of project is the length of lane-miles of highway to be treated.

The sample calculation provided in Table 2-7 is for a paving project where from the annual average daily traffic (AADT) and existing pavement conditions, a state transportation department believes in and can justify an investment in a minimal treatment of milling and resurfacing. The highway classification is a minor collector with a fairly consistent existing width of 24 ft plus 5 ft shoulders throughout the project length.

Table 2-7. Asphalt Paving Project Conceptual Estimate Example

Cost Element		Cost Factor	Amount	Comments
Construction Costs	Length = 7.550 mi rural	$830,000/mi	$6,266,500	Mill and resurface, use lane-mile cost factor
PE Costs		2%	$125,300	Low end due to rural
ROW Costs		0%	$0	Typical
CE Costs		5%	$313,300	Low end due to rural
Total Project Base Costs (w/out contingency)			$6,705,100	2011 dollars statewide average
Use			**$6,700,000**	**2011 dollars statewide average**

Here, again, the construction cost is the amount awarded for completion of the project. PE, ROW, and CE costs are a percentage of the construction costs. The total project base cost without contingency is the sum of all of the cost elements.

General considerations are as follows:

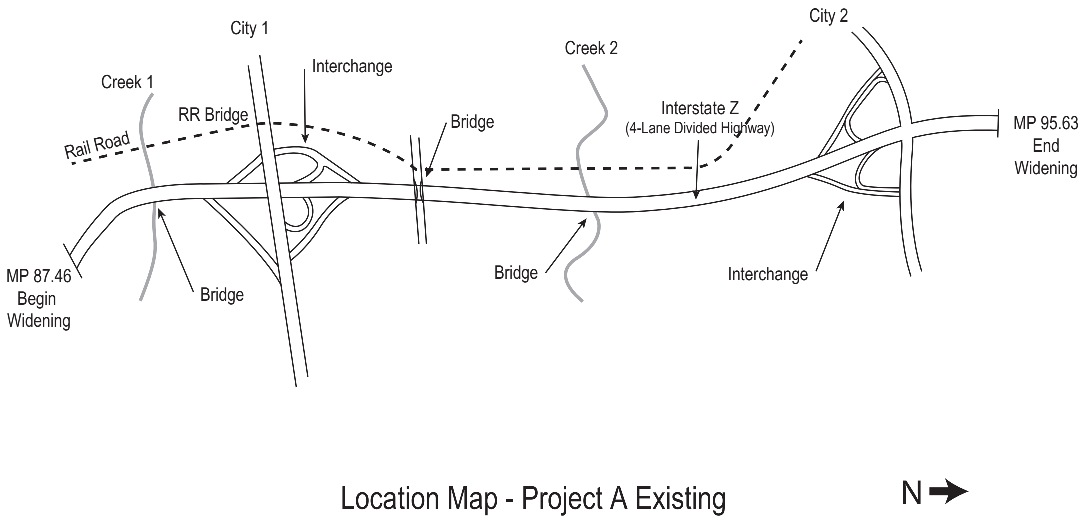
- Cost factor is developed using the approach covered in Figure 2-1 and Table 2-1—milling and resurfacing a two-lane rural road with 5 ft paved shoulders with a lane-mile cost of $831,214.
- Project site conditions (i.e., urban/rural) may have the most influence on PE and CE factors.
- Assume ROW is not required for mill and overlay projects.
- Contingency will be added (see Chapter 5).
- With construction cost factors based on historical projects, must make adjustments to account for current market fluctuations in the price of asphalt and/or fuel.

2.7.3 Paving and Bridge Project

In this example, the use of past project cost data is due to its similarity to the current project estimate. See Table 2-8 below for the basic project definition parameters, Figure 2-8 for the location map and existing cross-section, and Table 2-9 for the estimate of project costs.

Table 2-8. Conceptual Estimate of Project A Using Similar Past Project

Project A:	Capacity Addition
Descriptor	Interstate-Z City 1 to City 2 Widening
Location	County U
	Milepost 87.4 to Milepost 95.6
Existing	Four-lane interstate with 32 ft center median between the northbound and southbound lanes
	Project location map—see Figure 2-8 below
	Typical existing roadway cross section—see Figure 2-8 below
Concept Definition	Add two lanes to I-Z, one in each direction (north and south) between mile post 87.4 and mile post 95.6
	Improve curve sight distance between mile post 87.46 and Creek 1 bridge
	Remove and replace existing bridge over I-Z and City 1 and City 2 interchanges with wider bridges
	Widen bridge over railroad tracks at City 1
	Remove existing bridges and replace bridges over Creek 1 and Creek 2 with wider bridges
	Make ramp improvements at both City 1 and City 2 interchanges with Interstate Z



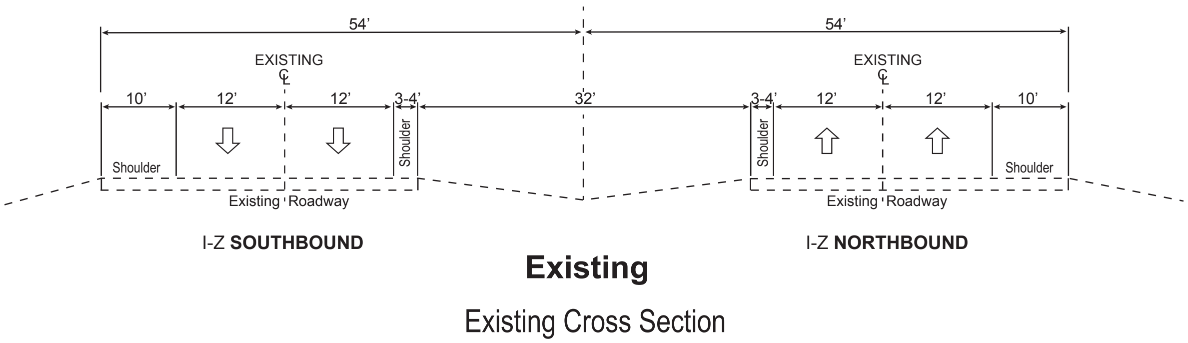


Figure 2-8. Project A Location Map and Existing Cross Section

Table 2-9. Conceptual Estimate of Project A Total Project Cost

Conceptual Cost Estimate		
Project length	95.6 – 87.4 =	8.2 miles
Cost per mile from Table 2-2 (2007 dollars)	$7,550,000/mile =	$7.55M/mi
Construction cost (2007 dollars)	8.2 mi x $7.55/mi =	$61.91M
10% adjustment for additional drainage, excavation, ponds, plus substantial grading at curve past MP 87.4	+ $61.91 x 0.10 =	+ 6.19M
2% reduction for economy of scale considerations	–$61.91 x 0.02 =	–1.24M
Adjusted construction cost (2007 dollars)	$61.91M + $6.19M – $1.24M =	$66.86M
Adjust to present value from index (4% for 4 years)	$FV = PV(1 + i)^t$ $66.86M x $(1.04)^4$ =	$78.2M
Total construction cost without contingency		**$78,200,000**
R/W costs for some acquisitions—assume 5% of total construction cost	$78.2M x 0.05 =	$3.9M
PE costs for complex project design—assume 10% of total construction cost	$78.2M x 0.10 =	$7.8M
CE costs for large project with no anticipated significant contracting issues—assume 8% of construction cost	$78.2M x 0.08 =	$6.3M
Total Project Cost (without contingency)	$78.2M + 3.9M + 7.8M + 6.3M =	$96.2M
Total Project Cost Estimate (without contingency)		**$96,200,000**

2.8 CHAPTER 2 REFERENCES

Anderson, S., K. Molenaar, and C. Schexnayder. *NCHRP 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*, Transportation Research Board of the National Academies, Washington, DC, 2007. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_574.pdf (Mar. 29, 2011).

Anderson, S., K. Molenaar, and C. Schexnayder. *NCHRP Report 625: Procedures Guide for Right-of-Way Cost Estimation and Cost Management*, Transportation Research Board of the National Academies, Washington, DC, 2009. http://onlinepubs.trb.org/onlinepubs/nchrp /nchrp_rpt_625.pdf (Mar 30, 2011).

Anderson, S., K. Molenaar, J. Shane, P. Hughes, and J. Hall. *Cost Estimation and Cost Management Technical Reference Manual*, Minnesota Department of Transportation, Minneapolis, Minnesota, 2008. http://dotapp7.dot.state.mn.us/edms/download?docId=670233 (May 1, 2011).

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Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges. U.S. Department of Transportation, Federal Highway Administration, Report No. FHWA-PD-96-001, Office of Engineering, Bridge Division, 1995.

2.9 CHAPTER 2 ADDITIONAL RESOURCES

Cost Estimating Guidance. U.S. Department of Transportation, Federal Highway Administration, 2007. http://www.fhwa.dot.gov/programadmin/mega/cefinal.cfm (May 1, 2011).

Cost Estimating Manual for WSDOT Projects. Washington State Department of Transportation, 2009. http://www.wsdot.wa.gov/publications/manuals/fulltext/M3034/EstimatingGuidelines.pdf (May 1, 2011).

Schexnayder, C. J., S. L. Weber, and C. Fiori. NCHRP Project 20-07/Task 152 report, *Project Cost Estimating a Synthesis of Highway Practice*, Transportation Research Board, National Research Council, June 2003.

CHAPTER 3

Bid-Based Estimates

3.1 OVERVIEW

Creating cost estimates from historical bid prices is a relatively straightforward process. After determining the quantities for different items from project plans, the estimator matches the items to appropriate historical unit bid prices or to average historical unit bid prices. To generate unit price data, DOTs systematically compile bid data from past project lettings. These data are broken down by bid line item. Average prices can be calculated from these data in numerous ways for the estimator's use.

3.1.1 What Is It?

The most common estimating method used by DOTs for developing transportation project cost estimates is the historical bid-based approach (Anderson et al. 2009). Historical bid-based estimating uses data from recently let contracts as the basis for determining estimated unit prices for a future project. Historical bid price data from previously let projects are typically stored in a database for 3 to 5 years. However, for price averaging and use in new estimates, the data retrieval period is often limited to 1 to 2 years, unless there is not sufficient bid data for an item, in which case dated data must be used. In such an instance, the estimator may search the bid database across a longer time period.

Historical data can be easily sorted and analyzed in a multitude of ways. The prices for the new estimate should be adjusted for specific project conditions in comparison to the previously bid projects.

3.1.2 Why Use It?

Due to the fact that this method is efficient in terms of staff resources versus other methods of estimating and has proven to provide reasonable estimates on typical projects, the historical bid-based estimating method is used to some extent by all DOTs (Anderson et al. 2009 and Schexnayder et al. 2003). However, there are many factors that need to be considered to develop an accurate construction estimate using historical bid prices. These factors can pose a certain level of risk in using this method to develop an estimate. Consequently, the estimator must ensure that the selected historical prices match the conditions of the project being estimated.

3.1.3 When to Use It?

Historical bid-based estimating can be used as early as the scoping phase and subsequently throughout the design phase of project development as long as the project's definition is described in terms of items for which quantities can be developed. While the method can be used as early as the scoping phase to develop a baseline estimate, it is easier to apply at the PS&E phase when line-item quantities are well defined. It is also often used to develop prices for minor items in support of cost-based estimating.

3.2 KEY INPUTS

The estimator should strive to prepare the most accurate estimate possible, in as much detail as is explicitly described in the project documents. The estimate should be based on the best unit price data available consistent with item-level scope and project characteristics. Key inputs are shown in Figure 1-2 and include project definition requirements, project characteristic descriptions, historical data, and macro-environmental and market conditions.

3.2.1 Project Definition

Historical bid-based estimating is frequently used in the scoping phase of project development, but more often this technique is used in the design phase and when preparing the engineer's estimate before letting the project.

At the scoping phase, there should be schematic plans and a complete design basis that can be used to develop the estimate. Because of limited design detail during this phase, it is likely that the cost estimate will only be prepared for major items. Moreover, when bid-based estimating is used, the estimator has to identify items, determine item quantities, and select an appropriate historical bid price. As the project moves through design and plans are prepared in more detail, the estimates are prepared based on quantity knowledge for a greater number of items. Prior to releasing the project for letting, the estimator works with complete plans and specifications, and the contract requirements are set. A schedule of pay items and the associated quantities is prepared by the designers. This PS&E estimate is often completed by a central office estimator.

3.2.2 Project Characteristics

When preparing a bid-based estimate, careful attention must be directed to project location, construction season, traffic control, work-hour restrictions, and coordination with multiple utility companies, railroads, or agencies granting environmental permits. By nature, complex projects are more difficult to estimate and contain more construction risk elements. FHWA advises that special attention be given to the impact of any requirement to use first-of-a-kind technology, new materials, or new methods of construction (*Cost Estimating Guidance* 2007). Furthermore, contractually required construction sequencing, haul routes, accessibility, and requirements for night work all impact productivity. Finally, the issue of small quantities of work should not be overlooked because these items can result in separate and inefficient operations that are usually more costly due to lower production rates and higher material costs. When adjusting estimate bid prices, all of these factors must be considered by the estimator.

3.2.3 Historical Database Requirements

In order to prepare a historical bid-based estimate, it is necessary to compile bid data from past project lettings. A very effective way to do this is to establish a bid line-item database. The database can be as simple or elaborate as needs dictate. Moreover, it is advisable to track as many aspects of the project's unique characteristics as practical. Many methods are available to capture the data needed to perform a historical bid-based estimate.

Two steps common in developing a historical database are acquiring bid data and storing that data (Anderson et al. 2009 and Ramesh 2009). Acquiring bid data is focused on capturing the raw data from letting tabulations as well as documenting project features that affect cost. The raw data can be acquired from bid tabulations using commercial software such as AASHTOWare Project BAMS/DSS, ExeVision's *i*PD, Oman Systems Bid Professional, or in-house methods developed by the DOT's information technology department.

When establishing a database, an important decision must be made concerning additional information that should be acquired about key aspects of a project that may affect cost and should be known when using the data to prepare a new estimate. It is generally easier to cope with too much data than not enough, and the added information could improve the accuracy of the estimate. Table 3-1 is a listing of items that could be considered when establishing a database.

Table 3-1. Typical Items Included in a Historical Bid-Based Database

• File Number	• Contractor Name
• County	• Contractor Address
• District	• Type(s) of Work
• Bid Item Number	• Funding
• Item Description	• Completion Date
• Item Quantity	• Working Days
• Item Account	• Estimate Preparer
• Unit of Work	• NPDES Acreage
• Letting Date	• Hourly Work Restrictions
• Estimated Construction Start Date	• A+B Bidding
• Number of Bidders	• Road/Route
• Low Bidder Amount	• Project Number
• Second Bidder Amount	• Warranty
• Third Bidder Amount	• Staging Area
• Estimated Unit Price	• Stage Construction/Number of Stages
	• ROW Restrictions (area available for work)
	• Urban vs. Rural
	• Special Construction Area
	• Projects Limits
	• Bridge Type (over land vs. water; over railroad)

When storing data, another important decision relates to what bid information should be included in a database; that is, how many and which bids from each past project should be stored. As listed below, there is significant variance as to how DOTs approach this issue:

- Low bid only
- Low and second bid
- Three lowest bids
- All bids (but may exclude single bids that are very high or low)
- All bids except high and low

By including those aspects of a project that have an effect on the cost of the work, it is possible to retrieve and analyze the data to estimate the reasonable cost for anticipated work. It can also be very useful to have a field where appropriate comments that may affect the determination of a future estimated unit price can be added. Figure 3-1 shows an example data entry form.

A spreadsheet is an effective way to import historical bid data into a database. Figure 3-2 is an example of bid data placed in a spreadsheet and ready to be exported into a database. For a database to be effective, it needs to be routinely updated. It is recommended that the database be refreshed and updated after each bid award, or on some other regularly recurring basis.

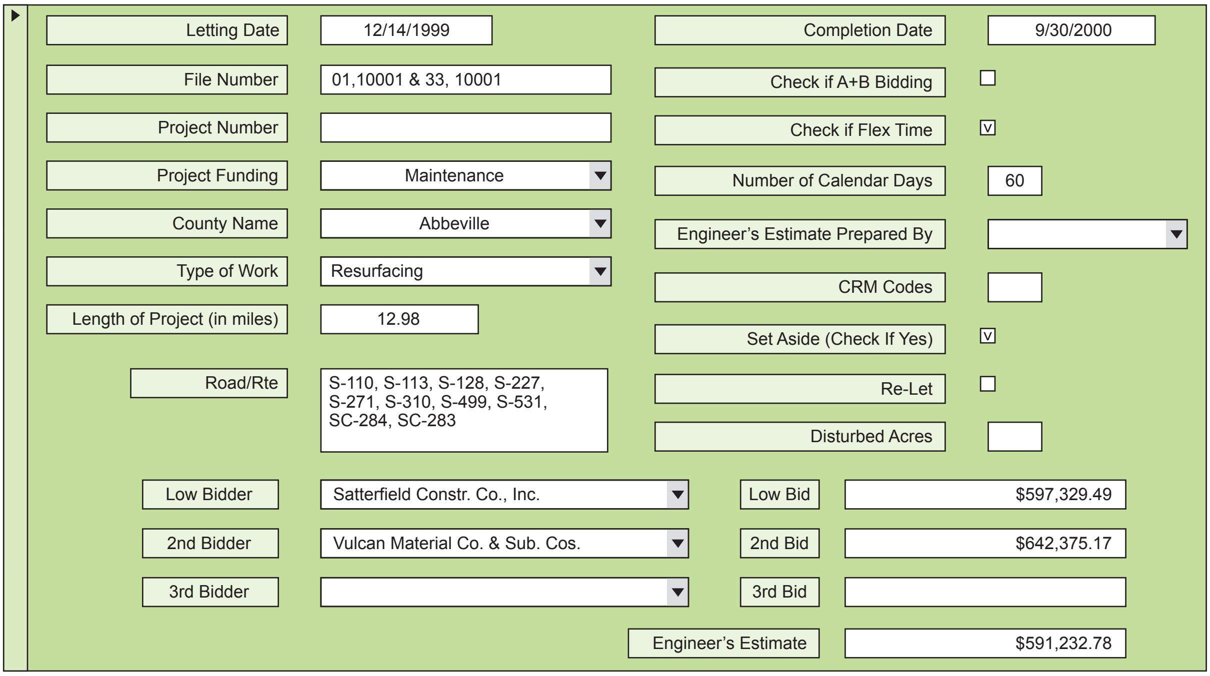

Letting Date: 12/14/1999
File Number: 01,10001 & 33, 10001
Project Number:
Project Funding: Maintenance
County Name: Abbeville
Type of Work: Resurfacing
Length of Project (in miles): 12.98
Road/Rte: S-110, S-113, S-128, S-227, S-271, S-310, S-499, S-531, SC-284, SC-283
Completion Date: 9/30/2000
Check if A+B Bidding: ☐
Check if Flex Time: ☑
Number of Calendar Days: 60
Engineer's Estimate Prepared By:
CRM Codes:
Set Aside (Check If Yes): ☑
Re-Let: ☐
Disturbed Acres:
Low Bidder: Satterfield Constr. Co., Inc. — Low Bid: $597,329.49
2nd Bidder: Vulcan Material Co. & Sub. Cos. — 2nd Bid: $642,375.17
3rd Bidder: — 3rd Bid:
Engineer's Estimate: $591,232.78

Figure 3-1. Typical Data Entry Form

Storing bid information in a database is focused on structuring and formatting the bid data in a manner so that historical prices can be accessed for future use in cost estimating. A standard line-item number system is common to all types of databases. Other key information would include the item unit of measure, item quantity, and actual bid price. As suggested, there are a number of ways bid data can be stored in the database. One method is shown in Figure 3-2, where descriptors from Table 3-1 are used to identify information related to item bid data.

The database information can be extracted to allow analysis, such as the calculation of averages for individual bid items over a given period of time. These averages can be simple means or weighted by quantities. 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. It must be remembered, however, that averaging of data will obscure seasonal pricing. Alternatively, a regression analysis can be run on subsets of the data for individual items based on project location or quantity, or both.

	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 3-2. Spreadsheet Used to Import Bid Data

In addition to 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 priced data should be considered to determine average prices used in estimates. Typical look-back periods for averages are 1 year, 18 months, or 2 years. Several DOTs retain data for as long as records exist, and estimators can examine that data for items that are not frequently encountered or items that have seasonal price swings.

The database information can be displayed as a spreadsheet, such as shown in Figure 3-2. Figure 3-2 shows data from only one project. Databases are often stored in files that can be placed on the agencies' intranet or Internet sites for use by all personnel and consultants. Alternatively, the database can be developed using commercial software such as AASHTOWare Project BAMS/DSS, ExeVision's *i*PD, or Oman Systems Bid Professional. Estimators should know where the database resides and exactly how the prices they are using were created, as there are multiple mathematical methods to arrive at an average unit price.

3.2.4 Macro-Environmental and Market Conditions

The external environment and current market conditions must be examined to ensure historical bids properly reflect current conditions where the project will be constructed (see Figure 1-2). As the estimator selects historical bid prices from the database, modifications may be necessary for time of year, expected competition, contractor availability, specialty work, and factors like contract incentives.

3.2.4.1 Work Season

The deadline of the project has a major influence on bid prices. Contractors consider the expected work season or seasons when bidding a project. This is directly correlated with the weather effects on certain activities, particularly earthwork, placement of concrete, and paving.

If a contractor or contractors have fully allocated company resources for the season, bid prices will be higher and there may be limited competition. Projects that can be constructed with an expectation of good weather usually draw lower bid prices, and the opposite is equally true. If forced to work out of season, there is an increased risk to the contractor, and the result is higher bid prices.

The estimator preparing the final engineer's estimate needs to be especially aware of the time of the advertisement and account for any expected fluctuations in bid prices due to seasonal factors, lower production during temperature extremes, and additional protections for weather-sensitive materials.

3.2.4.2 Competition/Contractor Availability

Projects that are advertised late in the season or after contractors have scheduled their work for the year can expect higher bid prices. This is due to a lack of competition caused by limited contractor capacity. Projects that are bid during a period of time when contractors are trying to acquire backlog for the season are bid more competitively.

3.2.4.3 Multiple Projects

Advertising multiple projects at the same time can influence bid prices. Contractors only have limited staff resources to develop project estimates. Many times in the case of large or complex projects, a contractor does not have the resources to develop bids for more than one project per letting. The most prudent course of action in this case is for the DOT to manage the program to ensure that this factor does not influence competition. If multiple large projects must be scheduled for bid at the same letting, then the DOT estimate needs to reflect that situation. Contractors will most often account for this in their bids as a risk and may adjust their bid prices upward by as much as 10 to 20 percent.

Other factors to consider in a multiple project letting environment are the resources required for the projects and whether multiple active projects in an area will create conflicts. For example, multiple large-scale bridge projects in a given area may create a shortage in structural steel or skilled labor. In these cases, the estimator must be aware of the price effect when the market attempts to support multiple projects.

Additionally, having multiple contracts in an area may create conflicts between the projects. These conflicts result from impacts such as construction staging and traffic control, labor issues, and coordination between contractors. Such conflicts need to be considered in the adjustment of database historical bid prices.

Alternatively, there are potential benefits of having multiple contracts in an area. This approach could increase competition. Also, a contractor already in the vicinity may have lower mobilization costs and material sources, resulting in economies of scale.

3.2.4.4 Specialty Work

Specialty items are not necessarily new items or new construction methods but are items that are somehow different than the majority of the work on a given project. On a pavement rehabilitation project, signal work may be classified as specialty work, whereas it would not be on a project that was comprised of predominately signal and lighting work. Projects that include specialty work or are totally comprised of specialty work items need to be characterized correctly when estimating. Estimating specialty work bid items requires a thorough understanding of the work involved and the resources required to accomplish the work. When estimating specialty items utilizing historical bid data, the comparisons between the work and the differences must be fully accounted for in the development of the estimate. Another factor to consider is the number of qualified contractors/subcontractors capable of performing the project or project elements of work. Other examples of specialty work include landscaping, guideposts, fencing, or mechanical rehabilitation of moveable bridge components.

3.3 PREPARE BASE ESTIMATES

Preparing a base estimate requires that the estimator determine the basis from which the estimate will be prepared (see Figure 1-2). The estimate basis is mainly derived from the project definition and project characteristics. The estimator should visit the project site to confirm the completeness of project definition requirements and assess potential constructability issues that might impact cost (i.e., material storage locations, haul routes, and construction staging issues). Once the estimate basis is established, the estimator can prepare the base estimate (see Figure 1-2). There are six general steps for preparing a base estimate (Anderson et al. 2009):

1. Select appropriate estimating approach
2. Quantify estimate components
3. Develop estimate data
4. Compile cost estimate
5. Document assumptions and other estimate information
6. Prepare estimate package

3.3.1 Select Appropriate Estimating Approach

There are a number of different estimating methods. In this chapter, the focus is on historical bid-based estimating. This method is a common approach because most DOTs collect historical bid data. Similar projects with similar items, quantities, and locations can generally be estimated quickly using historical bid data and engineering judgment. Bid-based estimating is often used in support of other estimating methods such as cost-based estimating and the use of historical percentages.

Estimates based on bid history data can serve as the basis for more detailed methods of cost estimating. By establishing the procedures for collecting, retrieving, and analyzing historical bid data, an agency has information readily available for all types of estimates, PS&E, contract modification agreements, value engineering/analysis proposals, cost reduction incentive proposals, change orders, or design alternates. The bid history information is also valuable for other reports not necessarily related to estimating.

Limitations of historical bid-based estimating include (1) the database of bid data must be maintained; and (2) consistent bid items must be used for all contracts, and the work covered by these bid items must be consistent. For example, if a trenching item that is routinely used for an excavation of 24 inch depth is used for a different depth, the bid data becomes skewed and does not reflect the actual work performed. Unique or seldom-used items are also difficult to estimate using this approach due to the lack of available historical data. This method is often considered to be the most susceptible to individual project conditions that may or may not apply to the project being estimated. Unbalanced bids can also be an issue if not recognized or handled in an appropriate manner. The submittal of unbalanced prices by the contractor has the potential to skew or contaminate the bid history database.

For a program based on historical bid-based estimating to be successful, the projects and bid items must be consistent in regard to bid items, scope, and administration. Inconsistencies in projects and non-typical projects are opportunities for inaccuracies in historical bid-based estimates. The inconsistencies and factors that make bid items or projects non-typical must be factored in and considered in the development of historical bid-based estimates.

Using historical bid-based estimating techniques is difficult for lump-sum items. Most lump-sum items are very different from one project to another. For that reason, using past bid history is often not a good indicator of the future bid price for lump-sum items. However, if the bid history information can be used as a basis and tied back to the work involved, a fair estimate can be produced from the data. For example, a project has a demolition item to remove eight typical residences on a project. The bid history could be used as a basis to establish a cost per typical residence for demolition. Information on the definition of "typical" in this instance should be noted or recorded in the database for future use.

3.3.2 Quantify Estimate Components

Historical bid-based estimating is most frequently used when preparing PS&E estimates. In that application, a schedule of pay items is developed by the design group based on final plans and contract documents. Quantities for each pay item are also computed by the design group. The estimator is then charged with developing estimated prices that reflect current costs.

Historical bid-based estimating can be used for developing a scoping phase estimate. In that application, the estimator is often responsible for identifying work items and deriving the quantities as well as selecting the best historical bid price to employ. The estimator may not necessarily have specific pay items but will consider elements that represent a composite of similar pay items. For example, estimating asphalt paving may focus on an item-level bid-based cost that reflects both the base course and wearing course (i.e., $60 per ton). The exact asphalt types may not be available when generating the scoping estimate for the asphalt. As the design is further developed, different asphalt items and quantities are defined and the historical bid-based pricing can be modified to reflect more specific information.

3.3.3 Develop Estimate Data

Developing estimate data for a project and its unique items requires two steps: (1) accessing historical unit prices from the agency database; and (2) adjusting the unit price to fit the project being estimated. Accessing unit prices may require analysis by the estimator depending on how the price data are stored in the database. Adjusting a historical unit price requires that the estimator understand the key features of the item affecting cost (i.e., location, time, and scope).

It is imperative that estimators have the most up-to-date data for establishing unit prices to use in preparing estimates. In addition, during times of rapidly fluctuating prices, it is advisable to limit the period of time from which unit bid data are analyzed. For example, looking at unit bid prices from too far back in time will skew the selection of an appropriate unit bid price for the estimate. Depending upon the bid items selected and the data in a given database, three months of data may be sufficient for establishing a unit bid price. However, there may be instances when bid data are not available for a specific item. In this case, the estimator must review bid data that are much older. The estimator will need to adjust the bid price to reflect current market conditions including past inflation impacts.

Another source of historical data comes from similar projects that were recently bid. In this case, the similar project must be truly similar in terms of items, the work content of the items, and the quantities for each item. Using bid prices from similar projects reduces the time and effort in accessing and adjusting bid prices using the historical database. Adjustments to the bid prices from similar projects should be considered, as there may be some differences related to project characteristics that may impact the historical bid price, such as changes in haul distances and bidding environment. The estimator will need to thoroughly understand the project characteristics of the similar project to adjust the project bid prices to reflect the similar project being estimated.

3.3.3.1 Accessing Unit Costs

While databases are very useful for storing and retrieving data, in order to perform computations and analysis of data, a spreadsheet works much better. It is possible to easily perform a number of mathematical operations after data are placed in a spreadsheet.

Once tables of collected data have been established, database queries are a good way to retrieve the stored information. A properly constructed query will retrieve data that are relative to the situation for which an estimate is being prepared. Figure 3-3 provides an example of query results for a specific bid item. In addition to being useful for routine estimating, a well-constructed database can be very useful in providing answers for ad hoc situations. Specialized queries can be devised as needed.

For example, a simple query can provide the total linear feet of the various sizes of reinforced concrete pipe let to contract over a certain period of time. Another query could provide the total mileage of resurfacing projects let within a given time period or pull data from within a geographic area for different grades of asphalt. These data could then be analyzed to determine the potential costs for various asphalt grades on future projects in the area. Although not directly related to estimating, this type of information is valuable to management and the construction industry.

File Number	Bams Number	Description	Unit	Quantity	Low Bid	Type of Work
43.7205.01	4011004	LIQUID ASPHALT BINDER PG64-22	TON	2.728	$250.00	Chip Seal
28.7905.01	4011004	LIQUID ASPHALT BINDER PG64-22	TON	7.626	$290.00	Full Depth Patching
32.7905.04	4011004	LIQUID ASPHALT BINDER PG64-22	TON	11.904	$280.00	Full Depth Patching
02.7905.02	4011004	LIQUID ASPHALT BINDER PG64-22	TON	19.840	$300.00	Full Depth Patching
40.100C	4011004	LIQUID ASPHALT BINDER PG64-22	TON	20.000	$300.00	Culvert Rehab.
31.104B	4011004	LIQUID ASPHALT BINDER PG64-22	TON	29.000	$225.00	Bridge Replacement
40.2003	4011004	LIQUID ASPHALT BINDER PG64-22	TON	60.000	$290.00	Intersection Improvement
32.7205.01	4011004	LIQUID ASPHALT BINDER PG64-22	TON	63.054	$250.00	Chip Seal
02.114B	4011004	LIQUID ASPHALT BINDER PG64-22	TON	64.000	$280.00	Bridge Replacement
32.189BR3	4011004	LIQUID ASPHALT BINDER PG64-22	TON	80.000	$336.00	Widen, Grading, Drainage, Paving
40.105CR1	4011004	LIQUID ASPHALT BINDER PG64-22	TON	80.000	$250.00	Intersection Improvement
02.7905.01	4011004	LIQUID ASPHALT BINDER PG64-22	TON	83.460	$250.00	Full Depth Patching
40.527A	4011004	LIQUID ASPHALT BINDER PG64-22	TON	89.000	$244.00	Intersection Improvement
32.7205.02	4011004	LIQUID ASPHALT BINDER PG64-22	TON	117.167	$250.00	Crack Seal
40.119CR1	4011004	LIQUID ASPHALT BINDER PG64-22	TON	147.605	$265.00	Resurfacing
02.7905.99	4011004	LIQUID ASPHALT BINDER PG64-22	TON	162.300	$250.00	Full Depth Patching
28.103C	4011004	LIQUID ASPHALT BINDER PG64-22	TON	169.000	$220.00	Grade, Drain, Pave
32.7905.05	4011004	LIQUID ASPHALT BINDER PG64-22	TON	181.660	$290.00	Full Depth Patching
02.2004.1	4011004	LIQUID ASPHALT BINDER PG64-22	TON	196.000	$235.00	Grade, Drain, Pave
28.110C	4011004	LIQUID ASPHALT BINDER PG64-22	TON	207.115	$225.00	Resurfacing
28.105CR1	4011004	LIQUID ASPHALT BINDER PG64-22	TON	216.000	$252.00	Intersection Improvement
36.134BR1	4011004	LIQUID ASPHALT BINDER PG64-22	TON	289.000	$275.00	Interchange Improvements
31.2004	4011004	LIQUID ASPHALT BINDER PG64-22	TON	315.038	$250.00	Resurfacing
40.2001	4011004	LIQUID ASPHALT BINDER PG64-22	TON	353.000	$291.50	Intersection Improvement
28.2004	4011004	LIQUID ASPHALT BINDER PG64-22	TON	471.077	$202.00	Resurfacing
32.33041	4011004	LIQUID ASPHALT BINDER PG64-22	TON	485.236	$210.00	Shoulder Paving
40.610A	4011004	LIQUID ASPHALT BINDER PG64-22	TON	520.000	$275.00	Interchange Improvements
02.112C	4011004	LIQUID ASPHALT BINDER PG64-22	TON	523.755	$210.00	Resurfacing
40.232B	4011004	LIQUID ASPHALT BINDER PG64-22	TON	553.517	$260.00	Resurfacing
02.2004	4011004	LIQUID ASPHALT BINDER PG64-22	TON	607.716	$205.00	Resurfacing
02.7305.98	4011004	LIQUID ASPHALT BINDER PG64-22	TON	705.681	$286.00	Shoulder Paving
02.165B	4011004	LIQUID ASPHALT BINDER PG64-22	TON	757.384	$254.00	Resurfacing

Record: 1 of 46

Datasheet View

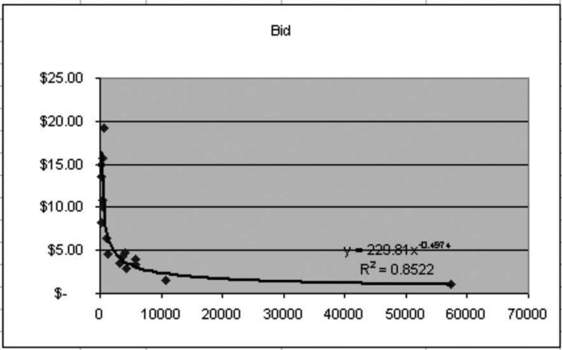
Figure 3-3. Typical Database Query

When analyzing data to determine a unit price for use in an estimate, contractor unit bid prices that are obviously unbalanced, either high or low, should not be included in any analysis. Using only the lowest unit bid prices received for each item of work on a given project to determine unit bid prices may result in an estimate that under-predicts project costs, whereas using only the average unit bid prices received for each item of work may result in a construction estimate that over-predicts costs. The most accurate method to consider is dropping outlying data from the set and then using statistical techniques such as weighted averages or regression analysis to determine the most appropriate unit bid price that represents a contractor's actual costs plus reasonable profit. Care must be exercised with average data, as they can obscure seasonal pricing.

Constraints of time and manpower at times cause estimates to be prepared quickly and with a minimum of effort. Spreadsheets can optimize resource utilization by focusing on the items in a project that account for the majority of the total cost. For most projects, the bulk of the cost can be accounted for in relatively few work items (Pareto Principle or 80–20 Rule, which asserts that generally 20 percent of the pay items represent 80 percent of a project's cost). Using normal spreadsheet functions, it is possible to compute average prices for each item of contract work. At this point, major items can be determined as a percentage of the total amount. Major items can be defined as those items that comprise a set percentage of the total project cost. Eighty percent has been used effectively in typical estimating practices. For example, on a mill and overlay project, the majority of cost may be in the cold milling, plant mix, shouldering material, mobilization, and traffic control items, with relatively minor costs associated with striping and guideposts.

Readily available software allows computation of statistical information such as averages, weighted averages, and standard deviations. Data can be sorted, filtered, plotted, and analyzed in numerous ways, as the following example shows (Figure 3-4).

	A	B	C	D	E	F	G	H	I	J	K
1	4013990	MILL.EXIST.ASPH.PVMT.-VARIABLE			POWER		$ 2.17	11817	Average Price	Weighted Average Pric	
2	**Letting Date**	**District**	**File Number**	**Type of Work**	**Length of Proje**	**Quantity**	**Low Bid**	**Project Funding**	$ 7.56	$ 2.29	
3	9/9/2003 0:00	1	02.151B	Resurfacing	9.74	200	$ 15.00	Federal			
4	3/11/2003 0:00	1	31.2003	Resurfacing	1.77	250	$ 8.22	Federal			
5	2/11/2003 0:00	1	28.132B	Resurfacing	5.51	311	$ 13.50	Federal			
6	11/11/2003 0:00	1	02.155B	Resurfacing	13.61	450	$ 15.65	Federal			
7	2/11/2003 0:00	1	02.144B	Resurfacing	9.87	500	$ 10.85	Federal			
8	11/11/2003 0:00	1	28.143B & 31.12	Resurfacing	10.23	533	$ 10.03	Federal			
9	3/9/2004 0:00	1	43.143BR1	Resurfacing	7.27	743	$ 19.22	Federal			
10	12/9/2003 0:00	1	32.202B	Resurfacing	11.69	1019	$ 6.40	Federal			
11	9/9/2003 0:00	1	28.140B, 31.122E	Resurfacing	15.5	1386	$ 4.58	Federal			
12	2/11/2003 0:00	1	43.133B	Resurfacing	11.97	3140	$ 3.53	Federal			
13	9/9/2003 0:00	1	40.205B & 40.20	Resurfacing	8.22	3752	$ 4.25	Federal			
14	4/13/2004 0:00	1	43.158B	Resurfacing	14.72	4184	$ 4.70	Federal			
15	3/9/2004 0:00	1	32.212BR1	Resurfacing	8.26	4385	$ 2.85	Federal			
16	4/13/2004 0:00	1	02.2004	Resurfacing	5.19	5736.33	$ 4.00	Federal			
17	11/11/2003 0:00	1	32.213B & 40.21	Resurfacing	12.77	5860	$ 3.30	Federal			
18	2/11/2003 0:00	1	32.190B & 32.19	Resurfacing	10.72	10803	$ 1.50	Federal			
19	2/11/2003 0:00	1	40.185B & 40.18	Resurfacing	11.36	57280	$ 1.02	Federal			



3069900 4012060 4013200 **4013990** 4022000 4031100 4031400 6020005 6040005 6040010 6040015 6040025 6040030 604

Figure 3-4. Historical Bid Analysis Using Regression

In Figure 3-4, information for variable-depth milling is presented for resurfacing projects in a specific geographical area. The data covers a 1-year period. In addition, a graph showing unit cost versus quantity with a trend line fitting the price and quantity has been plotted. The average price and the weighted average price have been computed, and a price (G:1) based on the quantity (F:3 to F:19) has been computed. The example in Figure 3-4 is for purposes of illustration. It is possible to select data and plot graphs in a similar manner to determine relationships relative to the project being estimated. Additionally, many other analysis approaches can be used to fit specific situations.

Based on experience, an estimator can use basic spreadsheet functions to select and analyze data appropriate to the situation being estimated to arrive at a reasonable cost for the anticipated work. For minor items of work on a project, using average prices or regional prices is as effective as using more detailed analysis. Data can also be sorted to refine the analysis to consider factors such as region or project type.

On occasion, items of work, for which a DOT has little or no historical data, are included in a project. In those instances, similar items may provide guidance, but additional investigative work may be necessary. If the item is thought to be of minor significance, spending extra time in determining a reasonable bid price is of little benefit. If the item is considered major or is likely to be significant to the bid, research should be conducted to establish a cost. Contacting others that may be familiar with the use of the item in question can usually help in determining a price. Suppliers, other state transportation departments, the Transportation Estimators Association's List Service, regional transportation commissions, port authorities, RS Means publications, and even contractors can be a valuable resource in establishing prices. Be wary of relying on estimates from a single source; multiple sources should be used.

If the item in question is unique in some manner, whether it is innovative, new, or experimental, or is considered a specialty item, costs may need to be adjusted to account for the contractor's unfamiliarity with the work and potential increased risk in construction. If the work is likely to be subcontracted out, the prime contractor will add markup to the subcontractor's price.

3.3.3.2 Bid Price Adjustments

The discussion contained herein is meant to identify factors that should be considered because they can have an effect on the cost of construction and more specifically on individual contract bid items and their unit prices. The degree to which any factor may affect the cost of any given bid item is indeterminate; that is, there is no one approved answer in selecting a unit price. Common sense, experience, and judgment all play a role in using historical bid prices to determine a reasonable unit bid price to use in an estimate. The factors described below are not meant to be a comprehensive list but are representative of important considerations in adjusting historical bid price data. Regional, local, and political factors, as well as materials, should also be considered by each DOT to determine if they add value to its particular situation and bid history database. In addition, other factors may need to be considered in establishing unit bid price estimates and overall contract costs.

3.3.3.2.1 Geographic Considerations

Geographic considerations can have a profound effect on the selection of unit bid prices. A project's location, whether in an urban, suburban, or rural setting, and in relation to material supply sources and available labor should be considered in establishing prices for an estimate.

A project in an urban setting generally has to contend with construction operations occurring in more confined workspaces, greater volumes of traffic, limited hours of operations, and night time work requirements. Some of these factors may be offset by availability of local contractors, materials, equipment, and personnel.

Projects located in rural settings may have less-restricted work areas, less traffic to contend with, and additional hours to complete the work—all factors that increase productivity. On the other hand, materials, equipment, and personnel may all have to be brought in from out of the area, which may increase costs related to transportation, support, wages, and per diem.

On projects that use large quantities of aggregates, whether for base, surface, or earthwork, or some combination thereof, the distance to material sources has a large impact on costs. Material sources in close proximity to the work reduce trucking and material handling costs and can increase production rates. On rural projects, the cost of erecting a concrete batch plant or hot mix asphalt plant may increase unit bid prices.

Terrain may also be a consideration in establishing an item's cost. Mountainous terrain and steep grades cause production rates to fall, whereas level terrain and straight roadways generally have the opposite effect.

Other location-related considerations that affect costs could occur due to local policies, taxes, restrictions, and air (attainment vs. not-attainment areas) and water quality. In some locations, locally specific rules and regulations governing noise, pollution, disposal of materials, working hours, and the construction season all increase the cost of construction. Another example of a location-related consideration is that of projects located on tribal lands. Tribes may impose Tribal Employment Rights Office Taxes for projects on tribal lands. These taxes generally range from 1 to 4 percent of the cost of the construction on the tribal lands but vary from tribe to tribe.

3.3.3.2.2 Quantity Considerations

The plan or expected quantity of a given work item affects the unit cost of constructing or supplying the item. This is not just a supply and demand issue, but one of production efficiency and the ratio of fixed cost to variable cost in producing an item. Generally speaking, the unit price for larger quantities of a given material will be less than smaller quantities. Suppliers offer discounts for larger quantity orders, and mobilization, overhead, and profit are all spread out over a larger quantity, thereby reducing their effect on a per-unit basis. Waste is also spread over a larger quantity, thereby having a smaller impact on unit cost. Larger quantities give rise to efficiency by allowing suppliers to gain experience and expertise in completing the work.

In some instances, projects with extremely large quantities of certain materials may actually cause an increase to the unit bid price. A project with numerous or large structures may affect both the production and delivery for specified steel, asphalt, or cement.

Generally, small quantity items are less cost effective to construct and hence lead to higher unit prices. Not only do suppliers charge more for smaller purchases, but in some instances, the lot size or the amount that has to be purchased is greater than the needed quantity. Small quantities do not generally allow for high production rates or other efficiencies, again causing a higher unit cost. Smaller-quantity items are frequently subcontracted out; this practice increases contractors' overhead, and they usually apply a markup to the items.

3.3.3.2.3 Item Availability

Materials that are readily available or ones that are commonly used are generally less expensive to purchase and install or construct. The contracting community is familiar with these types of items, and this experience reduces costs and risks. Non-standard pay items or materials that are in short supply are usually more expensive, and this should be considered in establishing the unit price.

3.3.3.2.4 Scheduling/Lead Time

To be efficient, a contractor needs to schedule its resources including labor, equipment, and supplies. When a contractor can plan for and maximize resource utilization, the contractor can be more competitive pricing the work. Transportation agencies should strive to let projects early or well before the work is scheduled to commence so as to allow contractors ample lead time for planning and scheduling resources as well as time to obtain permits and process materials. Lead time needs to be considered in the estimating process by estimating the project based upon when it will be built. For example, a project that is two seasons long and has the majority of its paving in the second year should attempt to account for this fact in the unit prices.

3.3.3.2.5 Difficult Construction/Site Constraints

Difficult construction and site constraints will increase the cost of construction for a contractor. Placing piles under water, working near active railroads or adjacent to historic buildings (possibly fragile), constructing on or near environmentally hazardous sites, and having limited room to construct an item are all examples of constraints that should be considered when deriving an estimated unit price.

3.3.3.3 Lump-Sum Items

From an estimating standpoint, use of lump-sum bid items should be avoided or minimized where possible. If the work to be performed can easily be quantified, then a payment method that includes a quantity should be used. However, lump-sum bid items are often used when an item of work can be easily defined but not all the components or details can be clearly determined. This fact can make estimating lump-sum items difficult for the estimator. The more information and breakdown of a lump-sum item that an estimator possesses, the greater the likelihood that an accurate lump-sum estimate can be developed. In any case, an estimator should try to define a lump-sum item in terms of its simplest, most basic components and should consider other factors that may not be easily estimated. By breaking out a lump-sum item into smaller items of work for which the estimator may have historical data and then applying reasonable estimated prices to those sub-units, the estimator can more accurately establish a price for the overall lump-sum item.

Since breaking out a lump-sum item into smaller components is difficult and time consuming, many DOTs apply percentages or ranges to some lump-sum items based upon historical data for similar project conditions. When determining estimates in these instances, the more consideration that can be given to an item's many components, the greater confidence in determining a reasonable estimated price there will be. Estimating methods other than historical bid-based techniques may be more applicable for lump-sum items.

Using lump-sum items typically transfers risk to a contractor. Contractors cannot necessarily rely on overruns to cover work that they, and possibly the DOT, did not foresee.

Different DOTs use the lump-sum method of payment for different items or types of work. The items of work discussed next are some representative examples of what some states use when applying the lump-sum method of payment.

3.3.3.3.1 Mobilization

Mobilization is a contract pay item used to cover a contractor's preconstruction expenses and the costs of preparatory work and operations. Since there is no clear list of what this work effort would cover, and each contractor has the ability to adjust its bid as needed to cover these expenses, there are no definite rules as to what percentage or value should be used per project. Mobilization costs are most often dependent on the amount and size of equipment and staff the contractor will need to relocate for the project. Many projects will require that the contractor mobilize the crew and equipment multiple times.

Another major factor to consider when estimating mobilization costs is the contract specifications in regards to mobilization. Do the specifications include payment restrictions or limits? When will the contractor receive partial or full payment for mobilization? How much of the mobilization cost will the contractor be required to finance? Full payment up front may result in higher mobilization prices and bid item unbalancing for other bid items. The specifications may play a significant role in determining an estimated value for mobilization.

Consideration should be given to the location of a project, the complexity of a project, work requiring specialized equipment, the type of work, and the working season. If the project will extend over more than one construction season, this should be considered when determining mobilization costs, as the contractor may demobilize for the winter and remobilize in the spring. Rural verses urban projects, projects with multiple work sites, projects with a substantial level of preparatory removal items, projects with large quantities of excavation, and projects extending over two seasons where the contractor would be expected to shut down operations and move out will typically require a higher mobilization percentage.

To adequately estimate mobilization costs on a project utilizing historical-based data, the overall project must be very comparable in size, location, and work involved. For this reason, organizations that rely on historical bid-based estimating methods often use a parametric figure to estimate mobilization costs. This figure is normally a percentage of the overall construction item total and in the range of 6 to 18 percent. Some examples of this follow:

- Typical mobilization estimates for a roadway project may be 8 percent based on past history for a state.
- Typical mobilization estimates for a structures project may be 10 percent based on past history for a state.
- Typical mobilization estimates for small projects that are not complicated may be 12 percent based on past history for a state.

3.3.3.3.2 Traffic Control and Maintenance of Traffic

No matter how much time and effort a DOT spends in evaluating how a project will likely be constructed, contractors will have different ideas on how to execute the work to their advantage. Innovation by contractors can realize cost savings for DOTs but can quickly make all their efforts in developing a usable traffic control plan obsolete. This fact is why many states now use the lump-sum method of payment, or other alternative methods, for traffic control/maintenance in lieu of developing full-scale traffic control plans. The use of a lump-sum item for traffic control can have a significant reduction in preliminary engineering effort and also a reduction in construction inspection efforts. Even so, considerable effort on the part of the DOT needs to occur to approximate the types and quantities of traffic control devices, the number of times an item has to be moved, and the duration for which the items will be needed.

If the DOT feels that certain limitations are of significant importance, then those limitations need to be identified and stated in the special provisions/specifications for the project. Items such as when lane restrictions can be imposed, duration that a detour can be in place, and maximum length of a work zone will all have a bearing on the minimum number and type of devices that are necessary to prosecute the work. Significant items that the DOT will require such as minimum amounts of portable precast concrete barrier rail and number of changeable message signs, arrow boards, and truck-mounted impact attenuators should all be identified. This informs the contractor that these items have to be used in the construction of the project and that they need to be included in the bid. The inclusion of these items may reduce risk to the contractor, which can be reflected in a lower lump-sum price. It will at least reduce the potential for claims once the project is under construction.

The establishment and identification of these significant items and consideration of the anticipated phasing/staging of the work along with imposed limitations, as well as approximate types and numbers of other anticipated traffic control devices, will all aid the estimator in establishing a reasonable lump-sum cost. By breaking out the larger portions of the cost in a lump-sum item, the estimator can rely on historical bid data for those items and the given limitations to come up with a reasonable lump-sum cost.

3.3.3.3.3 Clear and Grub

Clearing and grubbing is the removal and disposal of all vegetation, trash, and natural and manmade objects from a project's worksite in order to allow construction of the anticipated improvements. Although payment for clearing and grubbing is sometimes measured by square yard or acre, it is frequently paid for on a lump-sum basis. When payment is made on a lump-sum basis, the estimator needs to have knowledge of the area to be cleared. Knowledge of the size of the area to be cleared; the type of terrain; types of obstructions to be removed or filled in; and density of brush, trees, and rocks will aid in estimating this item. By analyzing this information and comparing to previous projects with similar characteristics, the estimator can determine a reasonable estimate.

If the breadth or scope of a project is unique, then breaking the item out into smaller components may aid in determining an estimated price to perform the work. By breaking the area to be cleared into quantifiable segments that may be similar to clearing and grubbing that has been previously performed, an estimator can add up the segments to produce the estimate. Similarly, if the area is broken out into subunits for which there may be historical data, the individual units can be estimated and summed to form a reasonable estimate.

3.3.3.3.4 Structural Steel

Some states pay for structural steel for bridges by the lump-sum payment method. The lump-sum payment will usually include the cost of all metal used in the construction of the bridge including nuts, bolts, washers, stud connectors, scuppers, plates, and anchorages and includes all costs of fabrication, delivery, and erection. In order to determine a reasonable cost estimate to use for the lump-sum item, the weight of material needs to be calculated. This, however, is time consuming to calculate and has a high potential for error. When calculating the weight of each plate, every clip has to be cut out, the weight of holes has to be deducted, and the weight of bolts must be added to obtain an accurate total weight. The main girders themselves are not too difficult to calculate, but the cross-frames, bearings, and splices are time consuming and always difficult. Because of these difficulties, an approximate weight is calculated.

Once the approximate weight is calculated, a cost per pound is applied to derive an estimate of cost. This cost is based on historical bid price data for projects with bridges or bridge projects with similar characteristics. Pricing can also be obtained through suppliers. The estimate is then adjusted for any project-specific issues.

3.3.3.3.5 Demolition

Estimating demolition lump-sum items requires that the estimator understand the work involved and the commonalities between the work proposed and the historical bid items. Many times, demolition work is similar in nature, involving an excavator and trucks with trash trailers. This type of operation is the most common, and the difference in bid item price is determined based on the number of days the operation will take to remove the necessary items. Special care should be taken when known environmental hazards exist within the demolition area. The hazardous material removal and remediation needs to be accounted for in the bid item depending on what the material is and the significance to the contractor's operations.

3.3.4 Compile Cost Estimate

Once items are defined and quantified, and a suitable unit price derived, the estimator may compile the estimate. This can be accomplished by using the DOT's in-house system, AASHTO Trns•port Proposal and Estimating System (PES) or Estimator, or both, ExeVision's iPD, Oman Systems Bid Professional, or using a spreadsheet. Under any of these methods, accuracy of the input must be checked, formulas should be verified, and the cost summaries generated must be cross checked to ensure accuracy. In the letting phase, the AASHTO Trns•port Cost Estimating System is often used, as are ExeVision's iPD and Oman Systems Bid Professional. The use of packaged software programs can ensure that calculations are consistent and accurate.

3.3.5 Document Assumptions

Support documentation includes project work narratives and schedule, supporting data, and sketches and drawings. This documentation must be in a form that can be understood, checked, verified, and easily corrected. Assumptions about what the contract documents require should be available as estimator notes. The reasons for all unit price adjustments must be documented.

3.3.5.1 Estimate Basis

References to sketches or early drawings, preliminary plans, final plans, specifications and contract requirements, project location, and unique project conditions are all information that supports the estimate. This information should be included in the documentation.

3.3.5.2 Estimate Supporting Data

Estimators draw data from multiple sources when creating a bid-based estimate. These sources must be documented together with any adjustments made based on engineering judgment or experience. The following estimate-related information should be documented:

- Quantity computations: The quantity take-off computations for items should be referenced to drawings. Dimensional information should be clearly shown in the supporting calculations. Estimators should use sketches as necessary to support quantity calculations.
- Estimated bid price: The source of historical bid prices that are used to develop item pricing should be explained (i.e., age of data, geographical location of bids, type of project, number of bids considered [low only, low, second and third bid]). The rationale for selecting an estimated unit price, such as using a weighted average or a best-fit regression curve, should be documented. Adjustments made to estimated unit prices for current market conditions and any macro-environmental conditions must be documented. Other adjustments to estimated bid prices for geographical location, quantity considerations, item availability, and difficult site conditions or constraints, or both, should be captured in written form.

3.3.6 Prepare Estimate Package

All estimate-related information should be included in a project estimate file that organizes estimate information for use in preparing a risk analysis for contingency setting, for estimate reviews, and for estimate approval by district or central office management. An outline format for such a project estimate file is suggested in Figure 2-7.

A bid-based estimate should always be delivered in a standard format, or project estimate package, that presents the cost in different levels of detail. This estimate format should include summaries of major cost categories as well as individual item-level costs. The project estimate package should include the estimate basis (i.e., project definition documents and project characteristics) and all supporting documentation used to estimate item costs. Contingency will be added to the base estimate through a risk analysis. The risk analysis and estimated contingency should be added to the project estimate package.

3.3.7 Risk Analysis and Contingency

The contingency amount should be developed separately based on a risk analysis process, as discussed in Chapter 5. However, as the design is completed and the PS&E estimate is prepared, the item bid pricing should reflect known risks. Adjustment of item bid prices for risks should be clearly documented in the project estimate file.

3.3.7.1 Contingency

Bid-based estimates prepared during the scoping and design phases should incorporate uncertainty under the contingency cost category. This means that estimated bid prices should reflect the estimator's best judgment and experience based on known conditions and current-day pricing. Variability in either the quantity or the bid price should be covered under the risk analysis and then incorporated into the contingency estimate. The estimator is probably in the best position to assess the uncertainty associated with bid pricing. If quantities are determined by the estimator, this person should also provide input on uncertainty associated with any quantity take-off.

In the PS&E engineer's estimate, the estimator is providing bid prices for a schedule of work items. In this case, the estimator should adjust his or her bid prices to reflect uncertainty associated with the particular item of work being estimated. This uncertainty should be captured in the bid price as an adjustment (i.e., contingency). This is necessary so that bid prices in the engineer's estimate can be compared to the contractor's bid prices when performing a bid analysis.

3.4 QUALITY ASSURANCE AND QUALITY CONTROL

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

All estimates must be reviewed. The review as a minimum should examine the quantities for reasonableness, the sources of cost data, and all adjustments to cost data made to account for project-specific conditions.

The detail and depth of a review will vary depending on the type of project, its size, and its complexity. For large projects or corridors in urban areas that are extremely complex, the estimate should be subjected to an external review by qualified professionals. There may be certain critical elements in these estimates that require a unique expertise to verify estimated costs. The estimate review should take place only after project risks have been quantified and an appropriate contingency amount is included, as these risk-related costs should also be checked in detail.

3.4.1 How to Check?

When reviewing a bid-based estimate, the reviewer may start with cost summaries that identify major categories of work. Using the 80–20 rule will focus the reviewer's effort on those categories that make up the majority of the project cost. The reviewer can then drill down and review specific quantities and unit costs for items that comprise the category. If unit prices seem out of line with bid history or the reviewer's experience, then the reviewer may want to develop a cost-based estimate for those items in question (see Chapter 4). When the cost-based estimate is converted to a unit price, it can then be compared to the estimated unit price derived from historical bids.

3.5 SUMMARY

The goal of estimating is to determine a reasonable cost to deliver a project. Quantities should be estimated based on the most current plans available. Estimated bid prices should be based on recent historical bid prices adjusted for current market conditions and other factors, such as geographical location, seasons, quantity differences, and difficult site conditions or constraints, or some combination thereof.

To create a base estimate plus a reasonable contingency, it is necessary to prepare a fully detailed and accurate estimate for the cost of performing many items. When using historical bid data, the estimator must ensure that this historical bid data reflects the scope of the item that is being estimated.

Estimate reviews take time and resources, and they are an easy step to skip when project estimators are busy with other tasks. However, reviews are vital to achieving consistent and accurate estimates.

3.6 PROJECT EXAMPLE

The application of bid-based estimating will be illustrated through a component of a project that is currently at the end of the scoping phase of project development. The project will be placed in the DOT's

STIP 4 years from letting. Sufficient design is completed to provide preliminary drawings. The estimator will be required to develop quantities for excavation of a slope and pavement structure. The estimate will be adjusted to current-day dollars.

As shown in Figure 1-2, the estimator must determine the estimate basis. This effort results in inputs such as those shown in Figure 3-5. This figure shows a preliminary design of the section of the highway considered in this example problem. The roadway starts at NB 10+00 and ends at NB 35+00. It is intended to have a width of 56 ft from NB 10+00 to NB 25+65. Then the roadway gradually tapers from NB 25+65 to NB 32+45 to a width of 90 ft. The width is constant at 90ft from NB 32+65 to NB 35+00. A typical cross section of the new pavement structure is shown in Figure 3-6. As noted in Figure 3-5, there is a substantial slope shown with an elevation of +265 on the east side of the new pavement to +190 on the west side of the pavement next to the existing roadway. This slope is excavated to provide for the new roadway as shown in the cross sections in Figures 3-7, 3-8, and 3-9. The estimator also notes that the project is considered in a rural location but close to a major urban population center. The project terrain is relatively flat for the most part.

The estimator must develop bid data from the historical database (see Figure 1-2) as input for estimating the cost of excavating the soil and transporting it for disposal (the soil cannot be reused for fill) and for placing the pavement structure. The DOT has statewide bid averages that can be referenced for estimating purposes. These statewide averages are described by pay item number, total quantity placed, and average unit bid price. Examples are shown in Table 3-2.

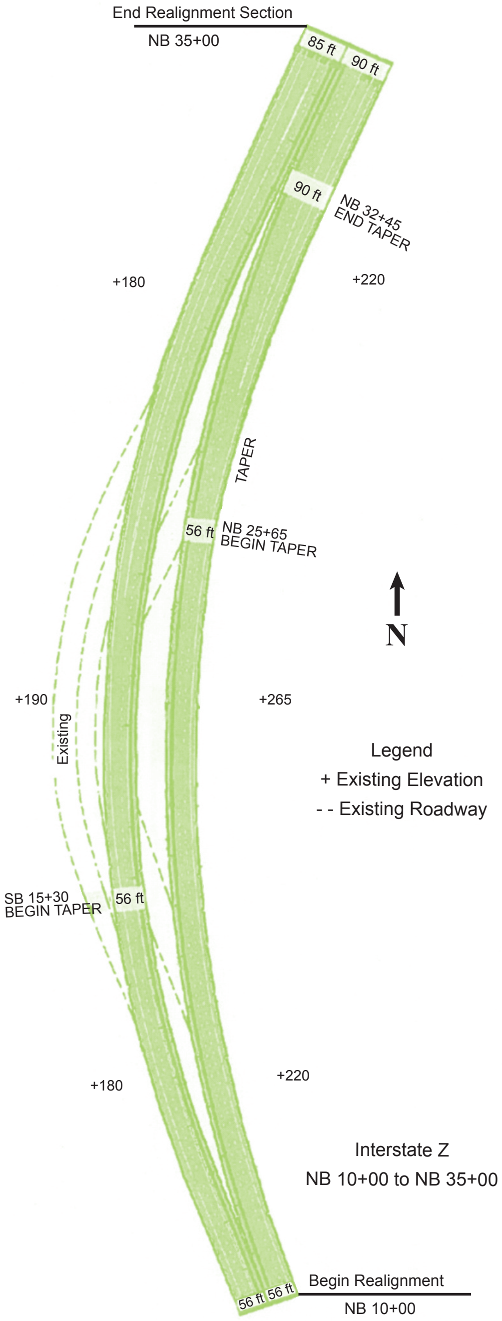


Figure 3-5. Section NB 10+00 to NB 35+00 of the Roadway Plan

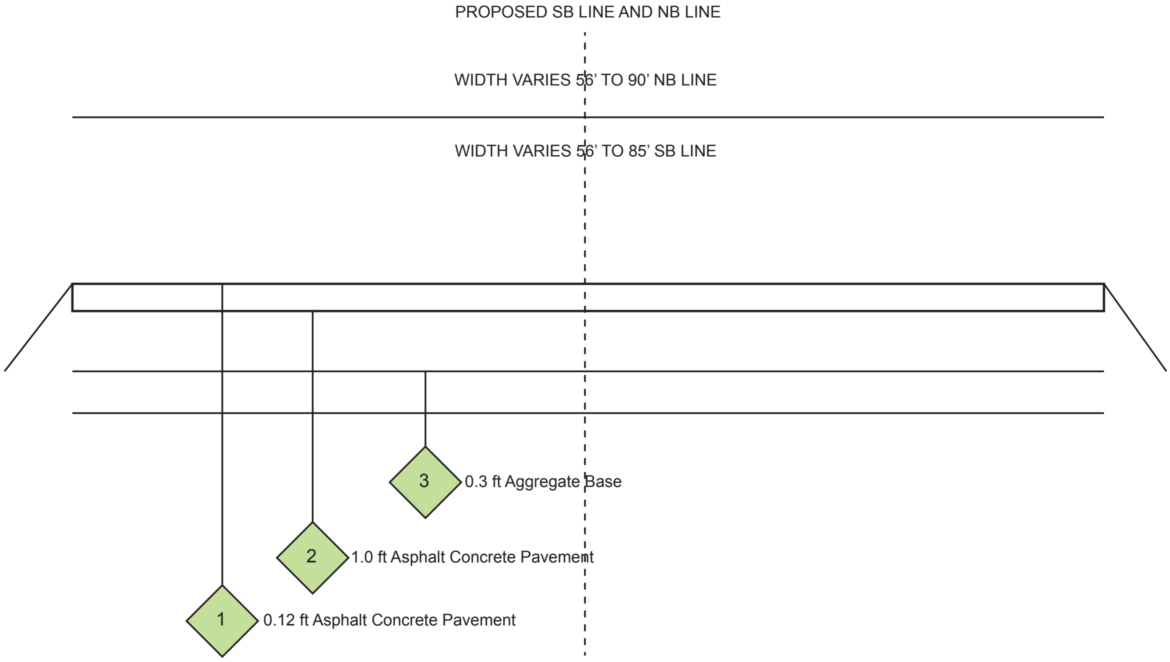


Figure 3-6. Typical Pavement Cross Section

Three cross sections from the existing site are provided to perform the excavation estimate. Figures 3-7, 3-8 and 3-9 show the three cross sections at NB 12+00 (Section A), NB 23+00 (Section B), and NB 28+00 (Section C).

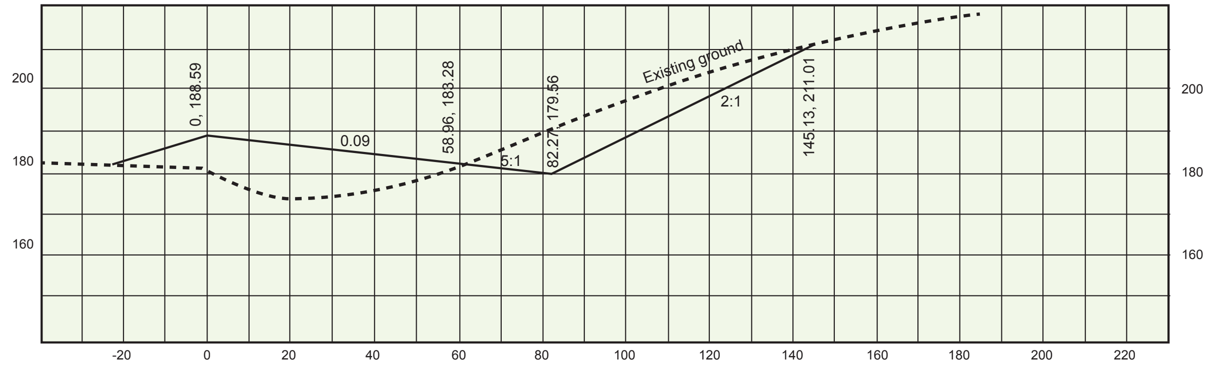


Figure 3-7. Cross Section for Earthwork Calculation at NB 28+00 (Section A)

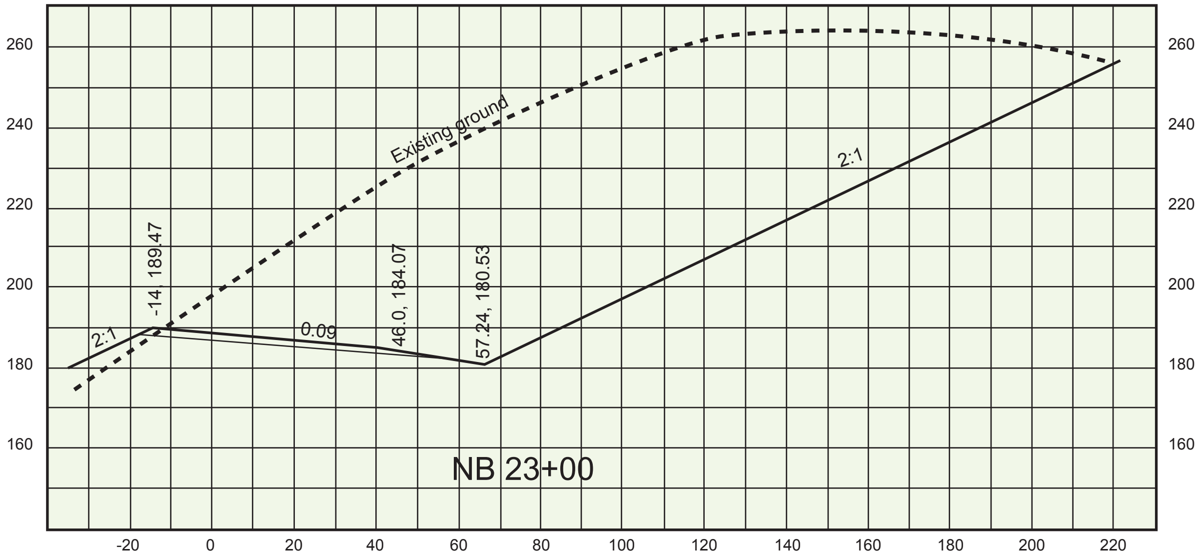


Figure 3-8. Cross Section for Earthwork Calculation at NB 23+00 (Section B)

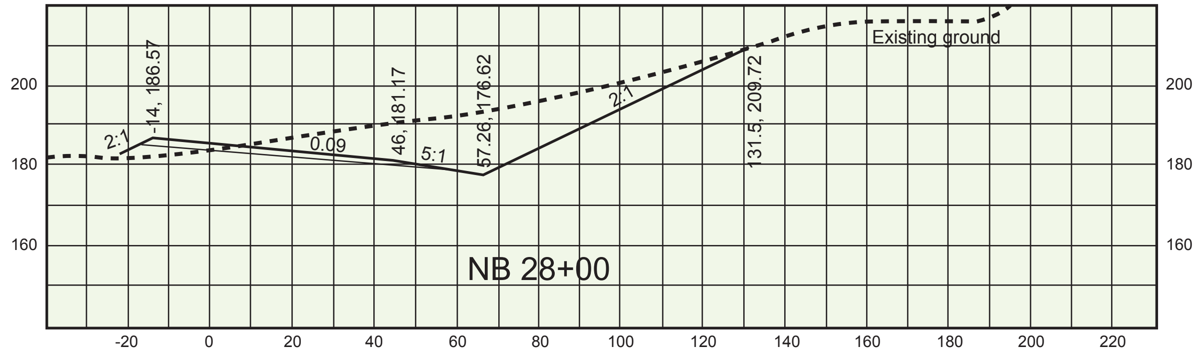


Figure 3-9. Cross Section for Earthwork Calculation at NB 28+00 (Section C)

Table 3-2. DOT Statewide Bid Averages—2010

Item Group	Item Number	Item Description	Units	Quantity	Dollars (000s)	Average Price	Contract Occurr.
2105	2105.501/00010	Common Excavation	CY	1,087,668	$6,050	$5.56	53
	2105.503/00010	Rock Excavation	CY	198,306	$2.100	$10.59	2
	2105.505/00010	Rock Excavation	CY	21,082	$105	$5.00	4
	2105.507/00010	Subgrade Excavation	CY	129.901	$754	$5.81	18
2211	2211.501/00010	Aggregate Base Class 1	Ton	8,750	$96	$10.94	1
	2211.501/00030	Aggregate Base Class 3	Ton	2,409	$19	$8.00	1
	2211.502/00050	Aggregate Base Class 5	Ton	124,770	$1,730	$13.86	18
2360	2360.501/23200	Type SP 12.5 Wearing Course Mix (3,B)	Ton	902,593	$41,041	$45.47	50
	2360.501/22200	Type SP 12.5 Wearing Course Mix (3,B) SPEC	Ton	39,298	$1,439	$36.03	1
	2360.501/23300	Type SP 12.5 Wearing Course Mix (3,C)	Ton	652,989	$29,729	$45.51	16
2360	2360.502/23200	Type SP 12.5 Non Wear Course Mix (3,B)	Ton	162,857	$7,558	$46.41	8
	2360.502/24200	Type SP 12.5 Non Wear Course Mix (4,B)	Ton	33,391	$1,683	$50.41	9
	2360.502/24300	Type SP 12.5 Non Wear Course Mix (4,C)	Ton	5,395	$277	$51,40	1

With the preliminary drawings and the historical database, the estimator must prepare the base estimate for the excavation and pavement structure items of work for this section of the roadway. The first step in the cost estimating process is to select the appropriate estimating approach. In this project situation, the estimator will develop approximate quantities from the preliminary drawings provided by design. Thus, the estimator will use the bid-based estimating technique. The next step is to quantify estimate components. Using the drawings provided by design and with the help of the design group, item numbers are selected for the work, as depicted in Table 3-3.

There are a number of item numbers to select from, as shown in Table 3-2. Thus, it is important that the estimator discuss this selection with the appropriate design group. At this stage, the actual type of asphalt mix may not be known yet. The estimator must determine the most likely price for asphalt. The estimator then develops quantities for each item number shown in Table 3-3.

Table 3-3. Selected Item Numbers for Project Estimate

Item Group	Item Number	Item Description	Units	Quantity	Estimated Bid Price	Total Item Cost
2105	2105.501/00010	Common Excavation	CY			
2211	2211.502/00050	Aggregate Base Class 5	Ton			
2360	2360.501/23300	Type SP 12.5 Wearing Course Mix (3,C)	Ton			
2360	2360.502/24300	Type SP 12.5 Non-Wear Course Mix (4,C)	Ton			

3.6.1 Excavation

The excavation quantity is calculated using the end-area method. When using this method, the end areas of an excavation are calculated and then the end areas are added together and divided by 2 (assume it is a trapezoid). This product is multiplied by the length of the excavation sections and divided by 27 to find the cubic yards. Using Figures 3-7, 3-8, and 3-9, the end areas were calculated as 500 SF, 8,600 SF, and 900 SF, respectively. Two calculations were made between NB 12+00 to 23+00 and NB 23+00 to 28+00 to derive 7,380,000 CF or 273,000 CY.

3.6.2 Pavement Structure

The pavement structure is comprised of an aggregate base, a non-wearing course, and a wearing course. The pavement is between NB 10+00 to 35+00. The pavement width varies, as shown in Figures 3-5 and 3-6. The total square yards is calculated as 17,800 SY. The square yards are converted to pounds of asphalt using 110 lb per square yard. This quantity converts to 11,800 tons of asphalt for the non-wearing course and 1,500 tons for the wearing course. The aggregate base is calculated by converting the estimated 1,780 CY of aggregate to tons at 1.8 tons/CY. Thus, the total quantity is 3,200 tons. The quantity analysis results are added to Table 3-3, as shown in Table 3-4.

Table 3-4. DOT Selected Item Numbers with Quantities for Project Estimate

Item Group	Item Number	Item Description	Units	Quantity	Estimated Bid Price	Total Item Cost
2105	2105.501/00010	Common Excavation	CY	273,000		
2211	2211.502/00050	Aggregate Base Class 5	Ton	3,200		
2360	2360.501/23300	Type SP 12.5 Wearing Course Mix (3,C)	Ton	1,500		
2360	2360.502/24300	Type SP 12.5 Non Wear Course Mix (4,C)	Ton	11,800		

Next, the estimator must develop estimate data pertinent to the items selected using historical bid data (see Table 3-2). The estimator should review the historical bid price and make appropriate adjustments to reflect quantity volume, site conditions, project location, and the current market environment. For example, the excavation quantity is very large for this project and almost 30 percent of the total quantity of common excavation in the historical database (see Table 3-2). There might be an economy-of-scale adjustment to the $5.56 per CY statewide average. This adjustment might be offset by haul distance if the location of a dump site is beyond the typical distance for most projects. Similar analysis should be conducted before finalizing the unit price for each item number. The estimated bid prices corresponding to the item numbers are added to Table 3-5, and the estimator compiles the cost estimate to derive an estimated cost.

Table 3-5. Estimate of Costs for Selected Items

Item Group	Item Number	Item Description	Units	Quantity	Estimated Bid Price	Total Item Cost
2105	2105.501/00010	Common Excavation	CY	273,000	$5.00	$1,365,000
2211	2211.502/00050	Aggregate Base Class 5	Ton	3,200	$12.00	$38,400
2360	2360.501/23300	Type SP 12.5 Wearing Course Mix (3,C)	Ton	1,500	$52.00	$78,000
2360	2360.502/24300	Type SP 12.5 Non Wear Course Mix (4,C)	Ton	11,800	$45.00	$531,000

The estimator should document assumptions and other estimate information (i.e., calculations) for review and later tracking against updated estimates.

3.7 CHAPTER 3 REFERENCES

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CHAPTER 4

Cost-Based Estimates

4.1 OVERVIEW

Contractors bidding heavy highway-type work typically use cost-based estimating methods for arriving at a contract bid price. Such estimates reflect the cost to construct the specified work in the most economical manner based on the contractor's capability and considering the time allowed by the contract. These detailed task-by-task estimates reflect the unique character of a project, geographical influences, market factors, and the volatility of material prices. In addition to the direct costs for performing the tasks, indirect costs of project overhead expense are calculated and a reserve to protect for project risk is determined. Finally, to arrive at a bid number, the contractor adds a desired profit amount to the total estimate of project expenses. Therefore, the item estimates include direct cost, overhead expense, a risk amount, and a reasonable profit amount.

4.1.1 What Is It?

Cost-based estimating requires the estimator to carefully review the construction requirements as described in the contract documents, visualize the construction process, and model the costs to complete the work. These estimates are based on many sub-estimates of work crews and equipment completing tasks at assumed rates of productivity. Bid items are broken down into detailed task-by-task work activities. The direct cost for each task is developed with separate costs for the labor, equipment, subcontractor, and material components of the work required to complete a task.

4.1.2 Why Use It?

Cost-based estimating uses the latest price data for materials, equipment, and labor, so unlike bid-based estimating which uses historical data, it provides a much more accurate projection of costs during periods when prices are escalating rapidly. Additionally, since most contractors use a cost-based estimating approach to prepare bids, this method of estimating can provide a DOT with an accurate and defensible project estimate to support the decision for contract award/rejection and any future price negotiations with the contractor after contract award. By using the same estimating method as the proposing contractors, the agency estimator must understand the nuances of the site-specific project characteristics. However, the agency estimator usually does not have the same access to historical production rates and material quotes as a contractor. Even without this company and vendor/subcontractor information, the cost-based estimating method has the potential to provide an extremely accurate estimate and is a superior tool for analysis of bids and during negotiation of project changes.

4.1.3 When to Use It?

Cost-based estimating is used primarily to prepare the engineer's or PS&E estimate. The method is also applicable for creating estimates of major items even at the design and scoping phases of project development if rough assumptions about quantities and conditions can be made. This is good practice because the process causes the estimator to focus on the specific characteristics of the project.

The cost-based estimating process can be used in a supporting role for a bid-based estimate when there are bid items for which there is no historical data and to establish a valid price for lump-sum items. In both cases, the majority of the project bid items are estimated using historical bid data, and the cost-based estimating process is only used for a limited number of items.

Properly prepared cost-based estimates require significantly more effort in terms of time, analysis of how to perform the work, and skill. Agencies that routinely utilize cost-based estimates typically do so for only those items that comprise the major portion of a project's cost. These items can be identified by applying the 80–20 rule, which states that approximately 80 percent of the project cost is contained in 20 percent of the items (the Pareto Principle, mentioned previously in Section 3.3.3.1). Because these items account for most of the project cost, they should receive prime emphasis and effort in both estimate preparation and review.

Although more time is required to prepare a cost-based estimate compared to a bid-based estimate, once the appropriate personnel are in place, the labor and equipment cost data files are created, and the production data sources are identified, the process is routine and manageable.

4.2 KEY INPUTS

The estimator should strive to create the most accurate estimate possible, in as much detail as explicitly presented by the contract documents, and based on the best cost and production data available.

4.2.1 Historical Database Requirements

Historical data are required as productivity and pricing resources for most tasks except earthwork. Much of the required productivity and pricing data can be found in various commercially available estimating books (RS Means and Walker's are two examples). Steel and structural concrete are good examples of estimate items that use historical data. In the case of structural concrete work, production depends on the ability to erect formwork and the time allowance for achieving strength. Concrete and asphalt paving production are usually controlled by either plant capability or the intricacy of layout, which controls paver maneuvers. The productivity of the paver can be determined based on factors such as the paver speed, the cycle time of the asphalt/concrete delivery trucks, and the number of trucks. Earthwork estimating relies less heavily on historical databases due to higher variability in production rates. To estimate earthwork, the critical attributes that must be determined are (1) the quantities involved, volume, or weight; (2) the haul distances; and (3) the grades for all segments of the haul roads. With that data, it is possible to predict the production rate for a group of machines (linked-system production rate) and the cost per unit of production for each type of earthwork.

Agency-specific historical databases are helpful and can be created from completed projects. Historical production and cost data from similar past work are excellent resources when adequate details have been saved and adjustments to project specifics can be defined. Portions of other estimates having similar work can be retrieved and re-priced to the current project rates.

When using the data from commercial resources and agency-specific historical databases, the estimator's experience and ability to relate the data to a specific circumstance are important. To do this, the estimator must visualize the construction process.

4.2.2 Labor Cost

Direct labor cost requirements are broken into work tasks. A labor crew, including equipment, usually performs each work task; therefore, the crew and its cost must be defined, and a production rate must be established for the task.

Crews may vary in size and mix of skills. The number and size of each crew should be based on two factors: having sufficient workers to perform a task within the construction schedule time limits and the available workspace. Once the crews are developed, the task labor costs can be determined based on the production rate of the crew and the labor wage rates.

Production rate is the relationship of work in-place and the time required to accomplish that work. It can be cubic yards per hour, tons per shift (also indicate the duration of the shift), or feet of trench per hour.

$$\text{Production rate} = \frac{\text{unit of work in-place}}{\text{unit of time}}$$

Unit of work in-place denotes the unit of production accomplished. It can be the volume or weight of the material moved, volume of concrete placed, weight of steel hung, or any similar measurement of production.

Unit of time denotes an arbitrary time unit, such as an hour, a shift, or any other convenient duration in which the unit of work in-place is accomplished.

4.2.3 Equipment Cost

Construction equipment and plant refer to the tools, instruments, machinery, and other mechanical implements needed to construct the project. Construction plant is defined as concrete batch plants, aggregate-processing plants, conveying systems, and any other processing plants that are erected in place at the job site and are essentially stationary or fixed in place. Equipment is defined as items that are portable or mobile, ranging from small hand tools to tractors, cranes, and trucks. For estimating purposes, plant and equipment are grouped together as equipment costs.

4.2.3.1 Equipment Types

The task of the estimator is to match the right machine or combination of machines to the job at hand. Considering individual tasks and their quantity, this machine selection process is measured by matching the equipment spread's production against its cost.

The estimator should carefully consider number, size, and function of equipment to arrive at optimum equipment usage. Some factors to consider during the equipment selection process are:

- Job progress schedule (production rate).
- Space availability and machine mobility and size.
- Equipment capabilities.
- Distances material must be moved.
- Grade steepness and direction.
- Weather conditions.
- Hauling restrictions.
- Mobilization and demobilization costs.

The following are examples of equipment types:

- Scrapers—Tractor-pulled scrapers are designed to load, haul, and dump loose material in controlled lifts. The greatest advantage of tractor-scraper combinations is their versatility. They are best suited for moving earth at haul distances, greater than 500 ft but less than 3,000 ft (see Figure 4-1).
- Excavators—Hydraulic front shovels are used predominantly for hard digging above track level and for loading haul units. Hydraulic hoe-type excavators are used primarily to excavate below the natural surface of the ground on which the machine rests. The loader is a versatile piece of equipment designed to excavate at or above wheel/track level. Unlike a shovel or hoe, a loader must maneuver and travel to position the bucket to load or dump.
- Trucks—Over-the-road and off-highway trucks are hauling units that provide relatively low hauling costs because of their high travel speeds. The productive capacity of a truck depends on the size of load and the number of trips it can make in an hour. However, highway load limits and truck weight capacity may limit the volume of the load that a unit can haul.
- Cranes—These are a broad class of construction equipment used to hoist and place loads. Manufacturers offer different option packages that enable configuration of the crane to a particular application, standard lift, tower unit, or duty cycle. Units in the low to middle range of lift capacity have good lifting characteristics and are capable of duty-cycle work such as handling a concrete bucket. Machines of 100-short-ton (a short ton, or U.S. ton, equals 2,000 lbs. as opposed to a metric or long ton, which equals 2,240 lbs.) capacity and above are built for lift capability and do not have the heavier components required for duty-cycle work.

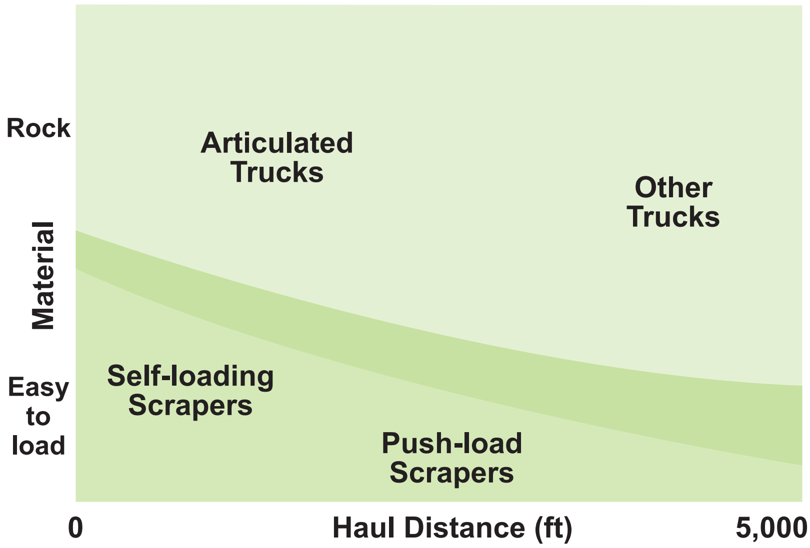

Figure 4-1. Earthwork Hauling Equipment for Ease of Material Movement vs. Haul Distance

4.2.3.2 Equipment Costs

Two readily available publications, the *Rental Rate Blue Book* (2011) and the *AED Green Book* (2011) provide detailed equipment cost data. The *Blue Book* contains cost data reflecting ownership of a machine with the intent of long-term use—a machine owned by the contractor. The *Green Book* provides monthly, weekly, and daily average rental rates for using a machine from an equipment rental firm—a machine rented for a short duration for a particular job or task. Both of these publications contain introductory sections that indicate how to use the equipment cost information.

If the equipment will be needed on the project over an extended period of time, the estimator should probably use the *Rental Rate Blue Book* (2011) data adjusted by appropriate regional factors. The estimator should use the monthly, daily, or hourly rate of the *AED Green Book* (2011) if the equipment will be limited to only one specific operation for a short period of time.

In cases of a highly specialized plant, 100 percent of the plant cost may have to be charged to the project. For a less highly specialized plant, some salvage may be anticipated, depending on storage cost, resale value, and probability of sale or reuse in the immediate future. The total amount charged to the project, including operation, maintenance, and repair, should be distributed in proportion to the time the plant is used on the various contract items or based on the produced material that is used in an item.

The costs of small power and hand tools and miscellaneous non-capitalized equipment and supplies are usually estimated as a percentage of the labor cost. The allowance must be determined by the estimator in each case, based on experience for the type of work involved. Unit prices based on historical data already include a small tools allowance. Such allowance can range as high as 12 percent of direct labor cost but is usually much lower. The cost estimator must ensure that this cost is not duplicated in the overhead rate percentages.

Mobilization costs for equipment include the cost of loading at the contractor's yard, transportation to the construction site, permits, unloading at the site, necessary assembly and testing, and standby costs during mobilization and demobilization. All labor, equipment, and supply costs required to mobilize the equipment should be included in the mobilization cost. Demobilization costs should be based on that portion of the equipment that would be expected to be returned to the contractor's yard and may be expressed as a percentage of mobilization costs.

Mobilization and demobilization costs for a plant should be based on the delivered cost of the item, plus erection, taxes, and dismantling costs at the end of the project. Maintenance and repair are operating costs and should be distributed throughout the working period.

4.2.4 Material Cost Data

Prices for materials and supplies may be acquired by obtaining quotations or from catalogs and historical data. The estimator should review the pricing and assess its reasonableness prior to use. Care should be taken to make proper allowances for quantity discounts, inflation, and other factors affecting cost.

4.2.5 Subcontract Items

Specialty items are usually more effectively performed by subcontractors. The estimator must first determine those parts of the work that will be subcontracted. Such items as striping, signing, traffic control, and electrical work are usually subcontracted. When the work to be subcontracted has been determined, those items will be identified in the estimate. These will usually be priced using historical bid averages, but if they represent major cost items, then a cost-based estimate should be created to price the item even if the work will be subcontracted.

4.2.6 Macro-Environment Market Conditions

The macro-environment market conditions 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.

Inflation will add cost to a project. The time value of money should be considered for longer-duration projects first in terms of labor rates and second for materials and supplies, particularly those that will be purchased in the later years of the work.

Market conditions or changes in the macro-environment can affect the costs of a project, particularly large projects. The size of the project affects competition and the number of bids that an agency receives for the work. Inaccurate assessment of the market conditions can lead to incorrect project cost estimation. Changing market conditions affect the available labor force and commodity prices, all of which must be accounted for in the estimate.

Macroeconomic environmental/market conditions are critical considerations for cost-based estimates. Sophisticated construction companies create a timeline breakout of major purchases (including fuel for large earthmoving jobs) and adjust the estimated cost of items that will be purchased in later years of a multiyear project. The DOT estimator should take a similar approach.

4.3 PREPARE BASE ESTIMATE

The Base Estimate is a permanent document that serves as the basis for business decisions. Estimators should follow standard practices and use documented procedures. A base estimate is the most likely estimated cost of a project without including contingencies to account for uncertainties due to variation and risk events. It will include:

- Documentation of estimate assumptions, types of cost data and adjustments to cost data, and unique aspects of the project.
- Coverage of all known project elements.
- Coverage of all known project conditions.
- Documentation that key ratios were checked to ensure that the estimate is consistent with past experience.

Documentation serves to eliminate the overlap of assumptions and provides a descriptive trail regarding what is known about the project. This allows for the project "knowns" as well as the "unknowns" to be clearly identified. Documentation must be in a standard format. Good documentation serves to permit the use of previous estimates in creating new project estimates.

4.3.1 Project Definition

The first step in preparing a base estimate is to thoroughly examine the contract documents starting with the general and supplemental conditions. Clauses in the general conditions of the specifications affect project construction methods and indirect costs. The general conditions are usually standard for all jobs; therefore, the content is easily understood. However, the estimator must carefully review the supplemental (special) conditions, as these describe the unique characteristics of the project and alter the general conditions. They often describe project-specific requirements different than the standards.

The estimator should carefully review any environmental impact and mitigation commitment statements in the contract documents. During this examination, it is appropriate to make notes of anything that can affect construction duration or productivity, or add indirect and risk costs to the work.

4.3.2 Project Characteristics

When preparing a cost-based estimate, careful attention must be directed to project location, construction season, traffic control, work-hour restrictions, and coordination with multiple utility companies, railroads, or agencies granting environmental permits. By nature, complex projects are more difficult to estimate and contain more construction risk elements. FHWA advises that special attention be given to the impact of any requirement to use first-of-a-kind technology, new materials, or methods of construction (*Cost Estimating Guidance* 2007). Furthermore, contractually required construction sequencing, haul routes, accessibility, and requirements for night work all impact productivity. Finally, the question of small quantities of work should not be overlooked because these items can result in separate and inefficient operations that are usually more costly due to lower production rates and higher material costs.

4.3.3 Labor Pricing

Labor productivity and therefore cost is subject to many diverse and unpredictable factors. Consequently, there is no substitution for the knowledge and experience of the estimator when estimating labor productivity. For labor-based crews, the task productivity of craftsmen, such as carpenters, steelworkers, and masons, may be based on the average of historical data tempered with expected job conditions. However, for some types of work, the task productivity of crew members, such as equipment operators, is determined by the productivity of the equipment spread.

The labor effort needed to perform a particular task varies with many factors, such as:

- Relative experience and capability.
- Size and complexity of the job.
- Climatic and topographic conditions.
- Degree of mechanization.
- Amount of task repetition.
- Existing labor–management agreements or trade practices, or both.

The effect of these labor efficiency factors and the work practices that exist in the project locality must be considered in selecting productivity rates.

Production rates should be selected considering the conditions of the project, such as terrain, traffic level, day or night work, possible utility conflicts, and weather. Work reports from past projects are an excellent resource along with agency field personnel who have witnessed tasks being completed on past projects. Other resources include equipment performance handbooks that log how much and how fast a piece of equipment can do certain tasks. A helpful tool for an estimator is to keep production logs for different types of work under different types of conditions. This can be as simple as how many feet of pipe per day can be installed in a low-, medium-, or high-production situation.

4.3.3.1 Craft Wage Rates

The cost of labor is sometimes the most variable and difficult piece of data to define for an estimate. The local labor market and conditions should be investigated to determine the available supply of all classes of labor and its competence. Local work practices must be studied to ascertain their effect on productivity.

Direct labor costs are defined as base wages plus labor cost fringes (additives) including payroll taxes, fringe benefits, travel, and overtime allowances paid by the contractor for personnel who perform a specific construction task. The various crafts in construction usually negotiate their own wage rates and working conditions. If a union workforce is expected, these must be individually examined and understood. In addition to the actual workers, there are generally working crew foremen who receive an hourly wage and are considered part of the direct labor costs. In some areas, there may be a prevailing wage rate that is set by a local government. If funds are coming from this local government for the project, that prevailing wage rate must be adhered to.

Indirect labor costs are wages and labor cost fringes paid to contractor personnel whose effort cannot be attributed to a specific construction task. Personnel such as superintendents, engineers, clerks, and site cleanup laborers are usually included as indirect labor costs (project overhead).

A wage rate must be determined for each labor craft. The total labor rate will include the base wage rate plus labor overtime, payroll, taxes and insurance, fringe benefits, and travel or subsistence costs. Wage rates on federally funded work are generally well defined. The Davis-Bacon Act, PL 74-403, requires a contractor performing the construction to pay not less than the prevailing rates established by the Department of Labor. A schedule of minimum rates is included in the project specifications. Where labor is in short supply for certain crafts, the work is in a remote area, or it is known that rates higher than the set rate scale will be paid, the higher wage rates should be used instead of the minimum wage since they will be required to attract the necessary craftsmen to the job. The wage rate should be adjusted to include travel time or night differential where these are a customary requirement.

4.3.4 Equipment Pricing

An important consideration in the preparation of an estimate is the selection of the proper equipment and the determination of production rates based on identified job conditions. Equipment production is influenced by the size and number of units, job size, availability of space for equipment operations, and project construction schedule for the various work tasks (Peurifoy et al. 2011).

4.3.4.1 Scrapers

The production cycle for a scraper consists of six operations: (1) load, (2) haul travel, (3) dump and spread, (4) turn, (5) return travel, and (6) turn and position to pick up another load:

$$T_s = \text{load}_t + \text{haul}_t + \text{dump}_t + \text{turn}_t + \text{return}_t + \text{turn}_t$$

Loading time is fairly consistent regardless of the scraper size. Even though large scrapers carry larger loads, they load just as fast as smaller machines. The average load time for push-loaded scrapers in common earth is 0.80 minutes. The economical load time for a self-loading elevating scraper is usually around 1 minute. Both the haul and return time depend on the distance traveled and scraper speed (*Caterpillar Performance Handbook* 2011). Hauling and returning are usually at different speed ranges. Therefore, it is necessary to determine the time for each separately. If the haul road has multiple grade or rolling resistance conditions, a speed should be calculated for each segment of the route.

4.3.4.2 Excavators

If a shovel or hoe excavator is considered as an independent machine (a one-link system), its production rate can be estimated using the following steps:

- Step 1—Obtain the heaped bucket load volume from the manufacturer's data sheet. This would be a loose volume (loose cubic yard) value.
- Step 2—Apply a bucket fill factor based on the type of machine and the class of material being excavated.

- Step 3—Estimate a peak cycle time. This is a function of machine type and job conditions to include angle of swing, depth or height of cut, and in the case of loaders, travel distance.
- Step 4—Apply an efficiency factor.
- Step 5—Conform the production units to the desired volume or weight units (lcy to bcy or tons).
- Step 6—Calculate the production rate.

The basic production formula is:

$$\text{Production} = \frac{3{,}600 \text{ sec/hr} \times Q \times F \times (AS{:}D)}{t} \times \frac{E}{60 \text{ min/hr}} \times \text{Volume correction}$$

where

Q = heaped bucket capacity (loose cubic yard)

F = bucket fill factor

$AS{:}D$ = angle of swing and depth (height) of cut correction

t = cycle time in seconds

E = efficiency (min/hr)

4.3.4.3 Loaders

While loaders (track or wheel) can be classified as excavators, they must travel to excavate and load. Therefore, they work in repetitive cycles, constantly reversing direction, loading, turning, and dumping. The production rate for a wheel loader will depend on the following factors:

- Fixed cycle time required to load the bucket, maneuver with four reversals of direction, and dump the load.
- Time required to travel from the load point to the dump position.
- Time required to return to the load point.
- Volume of material hauled each cycle.

When travel distance is more than minimal, it will be necessary to add travel time to the fixed cycle time. For travel distances of less than 100 ft, a wheel loader should be able to travel, with a loaded bucket, at about 80 percent of its maximum speed in low gear and return empty at about 60 percent of its maximum speed in second gear. In the case of distances over 100 ft, return travel should be at about 80 percent of its maximum speed in second gear.

4.3.4.4 Trucks

The productive capacity of a truck depends on the volume or weight of the load it carries and the number of trips it can make in an hour. The number of trips completed per hour is a function of cycle time. Truck cycle time has four components: (1) load time, (2) haul time, (3) dump time, and (4) return time. Load time is a function of the number of bucket cycles to fill the truck box. The haul and return times will depend on truck weight, engine horsepower, and the haul and return distances, considering the condition of the roads traversed. Dump time is a function of the type of equipment and conditions in the dump area.

Balancing the capacities of the trucks with the excavator bucket size is important. Matched capacities yield maximum loading efficiency and reduced task cost. A practical rule of thumb frequently used in selecting the size of trucks is to use trucks with a capacity of four to five times the capacity of the excavator bucket.

4.3.4.5 Cranes

In the case of cranes, it is not so much the speed of making a lift as a question of necessary lifting capacity and working range. The crane is a support machine that is idle much of the time waiting for a load to be attached or secured in position. As a result, when estimating crane expense, it is the hourly or daily cost of the machine times the duration to complete the task, be it setting concrete or steel beams or availability for handling formwork and a concrete bucket.

4.3.5 Material Pricing

Permanent materials are those items that are physically incorporated into and become part of the permanent structure. Supplies are those items that are used in construction but do not become physically incorporated into the project, such as temporary traffic control barrier, construction signs, dust control products, concrete forms, and form liner. For the purpose of estimating, both can be considered materials unless they need to be separated because of different tax rates.

The estimator should keep a log of material price quotes that are received from suppliers. It should not be necessary for every job to get new material quotes for every item. However, for large quantity materials such as aggregate, asphalt, cement, and steel, quotes should be updated on a per-job basis due to variability in supply and project characteristics.

It may be necessary to adjust current prices to reflect the cost expected at the actual purchase date. This cost adjustment, if required, should not be included as a contingency but should be clearly and separately defined in each estimate. The estimator should adjust current pricing to future pricing using specific escalation factors. Computations of adjustment should be clear and should be maintained as supporting data for the cost estimate.

4.3.5.1 Material Waste

Waste and loss considerations should be included in material unit price computations. This methodology results in a quantity take-off of work placement that is not altered to reflect material losses. Nevertheless, the alternative methodology of increasing the measured quantity by waste and loss quantity is acceptable if the excess quantity will not be used for any other purpose. The methodology used by the estimator should consider the impact of charging labor on the excess quantity. In either case, a statement is required in the estimate documentation explaining the methodology used.

4.3.5.2 Freight

The estimator should check the basis for the price quotes to determine if they include delivery. If they do not include delivery, freight costs to the project site must be determined and included. The supplier can usually furnish an approximate delivery cost. For delivery charges, free on board (FOB) refers to the point to which the seller will deliver goods without additional charge to the buyer. If the materials or supplies are FOB factory or warehouse, freight costs to the construction site should be added to the cost of the materials or supplies.

If the cost of materials or supplies includes partial delivery, FOB to the nearest rail station, the cost of unloading and transporting the materials or supplies should be included in the estimate. If the materials or supplies are a large quantity in bulk, which would require extensive equipment for unloading and hauling, it is good practice to prepare a labor and equipment estimate for the material handling and delivery.

4.3.5.3 Handling and Storage

The contractor is usually required to off-load, handle and stockpile, or warehouse materials on site. These costs should be included in the project estimate. For common items, such as construction materials or equipment needing secure storage, the cost for the security fencing, temporary building, and material handling should be considered as an indirect cost and be included in the job-site overhead cost.

4.3.5.4 Taxes

When applicable, state and local sales taxes should be added to the cost of materials or supplies. Care should be taken to apply the sales tax rate as required. The estimator should verify the tax rates and the applicability of these rates for the project location. Sales tax is considered to be a direct cost of the materials and supplies and is included in the estimate.

Some states and municipalities do not charge sales tax on material for government-funded projects, in which case tax would not be included in the calculation.

4.3.6 Subcontract Pricing

The cost of subcontracted work is the total cost to the prime contractor for the work performed. Subcontractors' costs include direct labor, materials and supplies, equipment, second-tier subcontracts, mobilization and demobilization, transportation, setup, and overhead and profit charges. The subcontract prices a contractor receives reflect direct cost with the subcontractor's overhead and profit added. These items reduce prime contractor risk but do not eliminate all risk, as a subcontractor can default and many Disadvantaged Business Enterprise (DBE) contractors cannot post a performance bond.

4.3.7 Contractor Indirect/Overhead and Profit

The actual construction work tasks cover the majority of the cost associated with a bid item, but the contractor has additional costs that are not included in the work task costs for an item.

Indirect/overhead costs are those costs that cannot be attributed to a single task of construction work. Costs that can be applied to a particular item of work should be considered a direct cost to that item and are not to be included in overhead costs. The overhead costs are customarily divided into two categories (Knutson et al. 2008):

- Job overhead, also referred to as general conditions or field office overhead.
- General home office overhead, commonly referred to as general and administrative (G&A) overhead.

Contractor overhead will vary from project to project and may even vary from month to month within any given project. Job overhead items should be estimated in detail for all projects.

Job overhead costs are those costs at the project site that occur specifically as a result of the project. Examples of job overhead costs are:

- Job supervision and office personnel.
- Engineering and shop drawings/surveys.
- Site security.
- Temporary facilities and project office.
- Temporary material storage.
- Temporary utilities, such as electricity and water.
- Preparatory work and laboratory testing.
- Telephone and communications.
- Permits and licenses.
- Insurance (project coverage).
- Quality control.
- Temporary job-site facility operation and maintenance.

The costs of mobilization and preparatory work, including the setup and removal of construction facilities and equipment, are part of overhead costs, unless there is a specific bid item. For large projects, the cost for each part of this initial work should be estimated on a labor, materials, and equipment basis.

General home office overhead expenses are those incurred by the contractor in the overall management of the business. Since they are not incurred for any one specific project, they must be apportioned to all the projects.

4.3.7.1 Duration of Overhead Items

After the overhead items have been listed, a cost must be determined for each. Each item should be evaluated separately. Some items, such as erection of the project office, may occur only once in the project. The estimator should use the developed job schedule in estimating overhead duration requirements. Costs reflective of each particular item during the scheduled period should then be applied. The product of duration and unit cost is the overhead cost for the item.

4.3.7.2 Distribution of Overhead

Overhead costs should be summed and distributed to the various bid items. A proportionate distribution is commonly made by percentage ratio of total direct costs to those direct costs in each item. Regardless of the method of distribution, the estimates should clearly demonstrate the procedures and cost principles applied to develop the overhead amount.

4.3.7.3 Contractor Profit

Profit is viewed differently by every contractor, but most have general rules of thumb for deciding on a profit amount to be added to a project bid. Profit can be hard to specifically quantify. Profit margins generally range from 3–10 percent, but this level can vary greatly depending on perceived risk and expected project duration. One approach is to use a consistent profit percentage on all jobs. Another approach is to document the project risk and use a percentage consistent with project risk.

Heavy/highway contractors having a large investment in equipment often base the profit percentage on an equipment return on investment. Another technique used by contractors to predict project risk is based on a breakdown of job cost into percentages for labor, equipment, subcontractors, and materials. A high labor percentage is an indicator of increased risk and will dictate a higher profit percentage.

The DOT estimator must be consistent in accounting for overhead and profit in estimates. Contractors vary regarding where they place their overhead and profit dollars. Most contractors attempt to add overhead and profit amounts to those bid items that they have confidence as to the quantity of work and that will not be deleted by the DOT. The prime contractor's overhead and profit on subcontractor work will not be added to subcontractor work items, as this causes administrative problems for the prime contractor. The prime contractor's overhead and profit on subcontractor work will instead be carried on prime's work items.

For the DOT estimator, it may be best to calculate and apply profit and overhead on a per-item basis, excluding expected subcontractor items. The reason for this is the fact that the DOT estimator may not have a cost-based estimate for every item on the project, so if a global profit and overhead are used, the markups may inadvertently be applied twice due to historical bids having markup in individual items. Also, to truly have a benchmark cost per item, all costs of that item should be included. Having the entire markup in one pay item, such as the mobilization pay item, is not an accurate depiction of how the cash flow for the project will actually occur.

4.3.8 Adjustments

All historical pricing data must be adjusted for project location, work methodology, work quantity, and other dissimilarities that affect prices.

4.3.8.1 Project Size

Project size can affect cost, both material and labor; therefore, in developing an estimate, costs may have to be adjusted to project size. Increased project size can reduce indirect cost when considered as a percentage of direct cost.

4.3.8.2 Unit Cost

The costs of certain items are independent of quantity, but for most items, costs are sensitive to quantity.

4.3.8.3 Waste

Material waste must be accounted for in each bid item. While the amount of waste can be assumed to be a percentage, say from 2–10 percent depending on the item, it is better to carefully consider the specific conditions of a work item. Paving and base items will result in higher waste amounts due to the nature of the work and the rigidity of the specifications.

When constructing a slab on a grade, it is necessary to carefully prepare the excavation or embankment to the proper grade. Yet, it is very difficult and expensive to cut the grade to the exact elevation. If it happens that the grade is cut with a positive variance (slightly above the required grade), the slab will not have the contract-specified thickness and, consequently, the work will be rejected. Therefore, a contractor must always anticipate working to a minus tolerance, as that will guarantee an acceptable slab thickness. In the case of thin slabs (less than 1 ft in thickness), the grade tolerance has a severe impact on the waste factor. Formwork defines volume of structural concrete almost exactly. The waste factor, therefore, is controlled by the placement amount. For a small placement, it is necessary to order some overage of material to ensure the total required quantity is available, and waste is then a high percentage of the quantity. For a large placement, this overage amount is very small on a percentage basis.

In the case of work items that use pre-manufactured products, such as pipe and signals/signing, there is little wasted material. Nevertheless, pre-manufactured products such as pipe may only be available in standard sizes, and waste will be determined from these standard sizes.

4.3.9 Compilations

In the case of earthwork, the computed volumes from the cross sections represent two different material states. The volumes from the fill cross sections represent compacted volume. If the volume is expressed in cubic yards, the notation is compacted cubic yards. In the case of cut sections, the volume is a natural in-situ volume. The term *bank volume* is used to denote this in-situ volume; if the volume is expressed in cubic yards, the notation is bank cubic yards. If the cut and fill volumes are to be combined, they must be converted into compatible volumes.

Organizations usually have their own standard formats for displaying estimated cost information in segregated and accumulated columns and rows. A typical format is presented in Table 4-1, which illustrates how to capture important cost information.

Estimating sheets similar to Table 4-1 are usually generated by special estimating programs or by using a spreadsheet program that pulls in labor and equipment data from a database setup especially for the project. The task quantity and production rates are calculated first and then entered into the program. The machine unit costs are extracted from the equipment database and then multiplied by the estimated use duration to generate total machine costs. Labor costs are generated in a similar manner; however, as labor rates often vary from job to job, it is usually necessary to establish a labor rate database for each job. To generate the Table 4-1 cost for the hoe, a machine ownership rate of $120 per hour, an operating rate of $45 per hour, and an operator labor rate of $19 per hour were used. The “Other” column is used for consumable materials. In this case, it has been assumed that it will be necessary to purchase the water that will be used for compaction moisture control. If there were permanent materials involved, the table would have a material column.

Table 4-1. Example of an Excavation Task Estimate Format

Task	16,108	bcy, haul		**stations**	9		**Unit**
Production	263	bcy per hr	**Total**	**hours**	61		**cost**
Personnel/ machine	**No.**	**Ownership**	**Operate**	**Labor**	**Other**	**Total**	**($/cy)**
Foreman w/truck	1	$610.00	$122.00	$1,830.00	$0.00	$2,562.00	$0.159
Hoe	1	$7,320.00	$2,745.00	$1,159.00	$0.00	$11,224.00	$0.697
Trucks	2	$4,270.00	$7,198.00	$1,098.00	$0.00	$12,566.00	$0.780
Dozer	1	$2,745.00	$1,403.00	$1,098.00	$0.00	$5,246.00	$0.326
Compactor	1	$1,220.00	$1,006.50	$518.50	$0.00	$2,745.00	$0.170
Water truck	1	$732.00	$366.00	$518.50	$805.40	$2,421.90	$0.150
Spotter	1	$0.00	$0.00	$427.00	$0.00	$427.00	$0.027
	Total	$16,897.00	$12,840.50	$6,649.00	$805.40	$37,191.90	$2.309
	Unit cost	$1.049	$0.797	$0.413	$0.050	$2.309	

4.3.10 Document Assumptions

Supporting documentation includes project work narratives and schedule, supporting data, and drawings and sketches. The documentation must always be in a form that can be understood, checked, verified, and easily corrected. Assumptions about what the contract documents require should be available as estimator notes.

4.3.10.1 Estimate Supporting Data

Estimators draw data from multiple sources when creating a cost-based estimate. These sources must be documented together with any adjustments made based on engineering judgment or experience. Sources include the following:

- Quantity computations—The quantity take-off computations for the tasks estimated should be organized by task for the bid items and kept as supporting documentation.
- Crew, labor, and equipment rates—The details used to prepare and express the crew composition and associated rates for labor and equipment costs must be shown. The information contained on these sheets provides the support for the task unit labor and equipment costs. Even if the estimator is only using a spreadsheet program for labor and equipment rates, all crafts and equipment should be created in files and then data from those files drawn into the estimate as needed. It then becomes very easy to update a rate file for each new project estimate.
- Production rates—The information used to develop and analyze crew production rates must be documented.

- Mobilization, preparatory work, and demobilization—These costs should be itemized and totaled separately. These costs may be combined at the summary level with overhead if they are not paid as a separate bid item.
- Overhead costs—The itemization and calculation of overhead costs, for both the job site and the home office, should be presented.

Task documentation, in terms of labor, equipment, and production, can take the form of spreadsheet tables (Table 4-2); the advantage of these is that they can be archived and easily modified for future projects.

Table 4-2. Excavation Crew Documentation

CREWS COMPOSITION			
Overburden			
PRODUCTIVITY =	**475**	**M3/HR @ 80%**	**Crew E01110**
1 HYD EXC 385BL OF	6	M3 BUCKET	1 Foreman
1 LOADER 988FX OF	0	M3 BUCKET	1 Operator Cl 1
4 CAT 773B CAPACITY	55	TONS	5 Operator
1 DOZER D8 TO HELP THE MOVE THE MATERIAL	—	—	3 Laborers
Rock			
PRODUCTIVITY =	**795**	**M3/HR @ 80%**	**Crew E01114**
1 HYD EXC 385BL OF	6	M3 BUCKET	1 Foreman
1 LOADER 988FX OF	9	M3 BUCKET	2 Operator Cl 1
8 CAT 773B CAPACITY	55	TONS	12 Operator Cl 3
3 DOZER D8 WITH SINGLE SHANK	—	—	4 Laborers
1 DOZER D8 TO HELP THE MOVE THE MATERIAL	—	—	—
Rock–Structural			
PRODUCTIVITY =	**288**	**M3/HR @ 80%**	**Crew E01121**
1 HYD EXC 345BL OF	4	M3 BUCKET	1 Foreman
1 LOADER 988FX OF	0	M3 BUCKET	1 Operator Cl 2
4 CAT 769D CAPACITY	36	TONS	6 Operator Cl 3
1 DOZER D8 WITH SINGLE SHANK	—	—	3 Laborers
1 DOZER D8 TO HELP THE MOVE THE MATERIAL	—	—	—

Note. Overburden—the soil mantel, often organic, found directly over useful construction materials, be they soil, sand, gravel, or rock.

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, which means documentation is critically important. Documented estimate assumptions should be tied to specific statements in the contract documents or the plans.

4.3.11 Risk Analysis to Set Contingency

Uncertainty and risks require a contingency amount to be added to the base estimate. A formal risk process integrated into the estimate development process will provide a better understanding of the project delivery structure, including schedule, contact packaging, procedural requirements, and potential constructability issues. Risk analyses lead to realistic expectations of cost and duration. Many agencies use percentages to cover expected risk (establish a contingency amount). This may be satisfactory for small projects where there is a good history for developing a percentage value, but for complex projects, a realistic contingency can only be determined by conducting a risk analysis.

Contractors use a variety of different approaches to protect themselves from perceived project risk. Some contractors add additional dollars to cover perceived risks directly to the price of those bid items for which there is uncertainty in either the estimated cost or quantity. Whenever a bid item has a fixed cost, a portion of its total cost amount under-runs are a risk. Another approach is to add a lump-sum cost for those risks that have a high potential to occur. A final approach is the addition of a lump sum for the overall risk on a project (i.e., using the estimator's or company owner's "gut feel" for the overall project risk). Because the agency does not know how individual contractors will distribute risk, it is suggested that the agency follow the risk-based approach described in Chapter 5.

Critical issues that most contractors consider when adding a risk contingency are:

- Percentage of labor cost to total project cost.
- Waste factor for concrete or asphalt on grade.
- Weather patterns compared to project schedule.
- Availability of materials and subcontractors.

An issue not often discussed but which underlies all contractor-included contingency is trust, and this is usually included based on who will be the transportation agency's person with budget authority over the project. Concerning the agencies they regularly work for, all contractors have a feel as to how quickly issues will be resolved and decisions handed down. Risk contingencies decrease as trust improves.

It should be noted that the amount of contingency included for risk in a cost-based estimate is relatively small compared to contingency in the case of the previously discussed design estimates. Cost-based estimating is generally not used when large amounts of uncertainty in the scope or design are present.

No matter which method is used to calculate a contingency amount, the incorporated contingency amount must be documented to properly communicate the accuracy of the estimate.

4.4 QUALITY ASSURANCE/QUALITY CONTROL

Cost-based 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.

All estimates must be subjected to review. As a minimum, the review should examine the quantities for reasonableness, the sources of cost data, and all adjustments to cost data made to account for project-specific conditions.

The details of a review will vary depending on the type of project, its size, and its complexity. For large projects or corridors in urban areas that are extremely complex, the estimate should 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. The estimate review should take place only after project risk has been quantified and an appropriate contingency amount, overhead, and profit are included, as these will also be checked in detail during the review.

4.4.1 How to Check?

Every check of an estimate should start with an evaluation of the compatibility of the estimate assumptions with the contract documents. This must include review of the geotechnical, hazardous material, and environmental documents, which often contain directions that affect how the work can be conducted and consequently influence bid prices.

If a similar project has been performed, estimators should compare the estimates to obtain an order-of-magnitude check. The next step is to review those items that make up the majority of the cost using the Pareto Principle, or 80–20 rule. Bid items can easily be compared to bid tab historical data as a preliminary check. Any items that are outside of a reasonable cost range should be probed in more detail.

When checking unit bid item cost, it is good practice to also have available the unit costs of the tasks that make up a bid item. Experienced estimators usually have a feel for what certain work tasks cost, and it is easier to spot an unreasonable task unit cost number than a bid item error.

While an estimate can be technically solid, based on tangible factors like quantities and cost for materials, there are other concerns that drive contractor bid prices, and these must also be considered by agency estimators. Questions that should be asked include:

- Is this a labor intensive project?
- Does the project depend heavily on certain pieces of equipment?
- Does a single machine control production?
- Is there a danger of material price increases?
- What is the cash flow of the project?

4.5 SUMMARY

The goal of estimating is to determine the cost to deliver a project. Earthwork computations involve the calculation of earthwork volumes, the balancing of cuts and fills, and the planning of the most economical material hauls. The quantity take-off for concrete work is completed to check work quantities in the bid schedule and to establish work quantities that are not listed in the bid schedule as pay items. Typically, on a unit price job, the agency uses only one or two bid items, such as concrete by volume and reinforcing steel by weight, to compensate the contractor for concrete work. This means that many tasks will have to be estimated and their costs accumulated to arrive at an item bid price.

To create a base estimate plus a reasonable contingency, it is necessary to prepare a fully detailed and accurate estimate for the cost of performing many tasks. Direct labor costs are the base wages plus labor cost fringes (additives) including payroll taxes, fringe benefits, travel, and overtime allowances paid by the contractor for personnel who perform a specific construction task. Estimating labor productivity is subject to many diverse and sometimes volatile factors. There is no substitution for the knowledge and experience of the estimator when estimating labor productivity. An important consideration in the preparation of the estimate is the selection of the proper equipment to perform the required tasks. The estimator should carefully consider number, size, and function of equipment to arrive at optimum equipment usage.

Estimate reviews take time and resources, and they are an easy step to skip when project estimators are busy with other tasks. However, reviews are vital to achieving consistent and accurate estimates.

4.5.1 Deliverables

A cost-based estimate should always be delivered in a standard format that presents the cost for each of the individual project bid items but that can easily be expanded to examine the task costs and makeup of each task including direct, indirect, and assigned contingency amounts. In the case of routine, repetitive-type projects, it should be possible to estimate indirect cost as a percentage of the project's direct cost. However, in the case of more complex projects, indirect cost should be estimated from the bottom up. Contractors do not arrive at a contingency amount by simply using a percentage. Contingency reflects perceived risk expressed as a monetary amount—dollars.

4.6 PROJECT EXAMPLE

This example considers completing a cost-based estimate for a concrete wall. The bid quantity for wall concrete is 123 cy. To determine the wall thickness and height, it is necessary to study the project drawing. From that study, it is found that the walls:

- Vary in height from 6 to 7 ft.
- Have a width of 8 inches.
- Have a total length of 765 ft.
- Require Number 6 reinforcing bars.

4.6.1 Concrete Estimate

A quantity take-off for concrete work is necessary to establish work quantities that are not listed in the bid schedule as pay items but are required to complete the work. The information needed to prepare a concrete estimate includes:

- Concrete volumes.
- Formwork contact surface area.
- Ground contact area.
- Cure areas.
- Reinforcing steel weights.
- Embedded items.

4.6.1.1 Formwork

Form cost is a large portion of the total cost for concrete work. The thinner or more complicated, or both, the structure, the greater the number of square feet of forms per cubic yard of concrete, and, therefore, the greater the form cost per cubic yard of concrete. The formwork take-off is concerned with square feet of concrete contact area (sfca) and should delineate the type of form to be used, i.e., field-built timber, purchased form system, or steel forms. The take-off should state the number of times a form will be reused. Form reuse is a function of shape, how many times the same shape will be formed, and the material used to create the form.

A study of the project drawing shows that the total length of the wall is 765 ft and that the wall has an average height of 6.5 ft. This yields 9,953.58 sfca of formwork [(2 sides × 765 ft × 6.5 ft) + (2 ends × 0.66 ft × 6.5 ft)].

4.6.1.2 Reinforcing Steel

Other than in the case of mass concrete, most concrete structures have reinforcing steel cast within the concrete. On many projects, reinforcing steel is paid for under a separate unit price bid item, although on some jobs there is no separate item and its cost must be included within the concrete bid price. Some estimating references recommend that, as normal practice, an allowance of between 2 and 5 percent of calculated bar weight should be added to the total to account for waste and splices.

4.6.1.3 Pricing Concrete

Estimating the cost of concrete work is normally accomplished by applying historical production rates against the work task quantities. The historical production rates are based on specific crew (to include equipment) makeup by number and skill level. This is a different approach from that used to estimate earthwork cost, where production is calculated based on specific project conditions, such as haul distance, haul road grade, haul route rolling resistance, and specific machine type. When there are no historical concrete production data available, estimating reference books (see Table 4-3) are available that present a broad range of production data for most construction tasks.

Table 4-3. Reference Book Data for Concrete Placements

Work Task	Productivity (Normal 8-hr Day)	Unit of Measure	No.	Crew and Equipment
Forms in Place				
Job-built plywood wall forms, to 8 ft high, 1 use, below grade	300	sfca*	1	Carpenter foreman
			4	Carpenter
			1	Laborer
Job-built plywood wall forms, to 8 ft high, 2 use, below grade	365	sfca	1	Carpenter foreman
			4	Carpenter
			1	Laborer
Reinforcing Steel in Place				
Walls #3 to #7 bars	3	ton	4	Ironworker
Walls #8 to #18 bars	4	ton	4	Ironworker
Placing Concrete				
Walls 8-in. thick, direct chute	90	cy	1	Labor foreman
			4	Laborer
			1	Cement mason
			2	Vibrator
Walls 8-in. thick, pumped	100	cy	1	Labor foreman
			5	Laborer
			1	Cement mason
			1	Equipment operator
			2	Vibrator
			1	Concrete pump
Walls 8-in. thick, crane and bucket	80	cy	1	Labor foreman
			5	Laborer
			1	Cement mason
			1	Equipment operator
			1	Assistant equip. operator
			2	Vibrator
			1	Concrete bucket
			1	Crane, 55 ton
Concrete Curing				
Sprayed membrane cure compound	95	csf†	2	Concrete laborers
*sfca = square foot contact area; †csf = hundred square feet.				

4.6.1.4 Crew Productivity

Typical production data for the required wall construction tasks can be found in an estimating reference book. The placement method will impact production; estimators should consider using both a concrete pump and a crane and bucket (see Table 4-4).

Table 4-4. Concrete Placement Production Using Reference Book Data

Placing rate, using a pump (8-in. walls)	Placing rate, using a crane (8-in. walls)
= 12.5 cy per hr	= 10.01 cy per hr
Placing time, using a pump	**Placing time, using a crane**
= 9.84 hr	= 12.3 hr

4.6.1.5 Labor Cost

If a concrete pump is used to place the concrete, the labor crew will, based on the reference book data, have a labor foreman, five laborers, a cement mason, and an equipment operator. If the project is covered by the Davis-Bacon Act, the contractor will, as a minimum, have to pay the wage rates and fringes as stated in the Department of Labor wage decision. If the project is not covered by Davis-Bacon Act, wage rates are set at the contractor's discretion based on market conditions at the project location. If the project will last more than 1 year, the contractor should consider wage inflation in the out years. A labor rate analysis is shown in Table 4-5.

Table 4-5. Labor Rate Analysis

Worker Classification	Davis–Bacon Rate per Hour $	Current Area Rates $	Projected Rate 1 Year Out $	Projected Rate 2 Years Out $	Estimate Rate $
Carpenter foreman	19.50	22.00	22.50	23.00	22.50
Labor foreman	17.75	20.00	20.50	21.00	20.50
Carpenter	14.50	14.00	14.50	15.50	16.00
Ironworker	15.00	13.00	13.50	14.50	15.00
Laborer	9.00	9.00	12.00	12.50	12.10
Cement mason	15.00	16.00	16.50	17.50	17.00
Equip. operator—crane	19.00	18.00	18.50	19.50	18.50
Equip. operator—pump	16.00	14.00	14.50	15.50	16.00
Equip. operator—assistant	13.00	14.00	14.50	15.50	14.00

Using the Table 4-5 labor rates, the estimator should estimate the labor and equipment cost component for placing the 123 cy of wall concrete using a concrete pump. The calculated placing time is 9.84 hr; therefore, the estimator should use 10 hr to calculate placement labor and equipment cost. The vibrators will cost $5.24 per hr, and the combined owning and operating (O&O) cost for the pump is $80 per hr. The cost estimate is shown in Table 4-6.

Table 4-6. Cost Estimate for Placing Wall Concrete

Task	123 cy*, place concrete, pump					
Production rate	12.5 cy per hour			**Total hours**	10	
	No.	**Hourly rate**	**Labor**	**Equipment**	**Total**	**Unit cost ($ per cy)**
Foreman	1	$20.50	$205.00	—	$205.00	$1.667
Laborer	5	$12.10	$605.00	—	$605.00	$4.919
Cement mason	1	$17.00	$170.00	—	$170.00	$1.382
Equip. operator	1	$16.00	$160.00	—	$160.00	$1.301
Vibrator	2	$5.24	—	$104.80	$104.80	$0.852
Concrete pump	1	$80.00	—	$800.00	$800.00	$6.504
		Total	$1,140.00	$904.80	$2,044.80	$16.624
*cy = cubic yard.						

The wall will be constructed in two equal parts, so only half of the required formwork material will be purchased (two uses of the wall forms). A complete estimate for the concrete walls, item 21, is shown in Table 4-7.

4.6.1.6 Risk

The percentage contribution of each cost category is denoted at the bottom of Table 4-7. Labor, at 52 percent, is the most significant cost component in this example. The “other” cost category at 29 percent, and the “material” category, at 17 percent, are significant cost contributors. The material category, i.e., concrete cost, has two components: (1) quantity, and (2) price. The accuracy of the quantity component is a function of the quality of the project plans and the estimator’s attention to detail in computing the volume of concrete required. With a complete set of plans, the accuracy of the quantity take-off should not be an issue. Once the contract has been executed, the contractor should be able to lock in the price of material by means of a purchase order to the concrete supplier. Therefore, the 17 percent material cost component usually does not subject the contractor to a high degree of risk.

Table 4-7. Concrete Cost Estimate

Task	123 cy*	Wall				
Forming	9,945 sfca†					
Production	45.6 sfca/hr		**Total hr**	218		
	Labor	**Equipment**	**Material**	**Other**	**Total**	**Unit cost ($/sfca)**
Forming crew	$21,494.80	—	—	—	$21,494.80	$2.161
Material	—	—	—	$12,840.66	$12,840.66	$1.291
Total	$21,494.80	$0.00	$0.00	$12,840.66	$34,335.46	$3.453
Unit cost	$2.161	$0.000	$0.000	$1.291	$3.453	—
Placing	123 cy					
Production	12.5 cy/hr		**Total hr**	10		
	Labor	**Equipment**	**Material**	**Other**	**Total**	**Unit cost ($/cy)**
Concrete crew	$1,140.00	—	—	—	$1,140.00	$9.268
Pump	—	$904.80	—	—	$904.80	$7.356
Concrete	—	—	$7,564.50	—	$7,564.50	$61.500
Total	$1,140.00	$904.80	$7,564.50	$0.00	$9,609.30	$78.124
Unit cost	$9.268	$7.356	$61.500	$0.000	$78.124	—
Cure	510 sf					
Production	1187 sf/hr		**Total hr**	1		
	Labor	**Equipment**	**Material**	**Other**	**Total**	**Unit cost ($/sf‡)**
Labor	$24.20	—	—	—	$24.20	$0.047
Curing comp.	—	—	—	$17.95	$17.95	$0.035
Total	$24.20	$0.00	$0.00	$17.95	$42.15	$0.083
Unit cost	$0.047	$0.000	$0.000	$0.035	$0.083	—
Item total	$22,659.00	$904.80	$7,564.50	$12,858.61	$43,986.91	$357.617
Unit cost	$184.220	$7.356	$61.500	$104.542	$357.617	—
% total cost	**52%**	2%	**17%**	**29%**	100%	—
*cy = cubic yard; †sfca = square foot contact area; ‡sf = square foot.						

However, the 52 percent "labor" and the 29 percent "other" (forming material) components can represent significant risk. The forming material, like the concrete, has two cost components: (1) quantity, and (2) price. It is important to realize the estimate was prepared based on the assumption that the forms can be used twice.

Labor risk is a different matter. Labor cost is very sensitive to the forming production rate used in creating the estimate. The estimate was constructed with a forming production rate of 45.6 sq ft per crew hour. If that forming production is not achieved, the cost of the work can increase significantly. When form production falls to 40 sq ft per hour, the wall cost rises by $24.73 per cy; a 12 percent reduction in the forming production rate adds 7 percent to the total wall cost. The estimator must exercise judgment in selecting production rates. Even when using historical data, it is necessary to carefully look at the proposed project and consider if the historical rates should be adjusted.

4.7 CHAPTER 4 REFERENCES

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Risk-Based Estimates

5.1 OVERVIEW

Risk-based cost estimates apply risk identification and uncertainty analysis techniques to forecast project contingency. Risks are uncertain events or conditions that could affect the project cost if they occur. Risk-based estimates produce an expected value and a range of project costs. They also provide a ranking of risks to monitor during the project development process to help manage contingency and prevent cost and schedule growth in future estimates. Estimators will typically use risk-based estimates during the planning, scoping, and early design phases. However, estimators can apply risk-based estimates at any point when there is significant uncertainty in the project definition or estimating information.

5.1.1 What Is It?

In its simplest terms, risk-based estimates use risk analysis to forecast costs of unknown, or uncertain, items. They combine traditional estimating methods with risk analysis processes to estimate the uncertain items of work, any uncertain quantities, and possible risk events (Association for the Advancement of Cost Engineering International [AACEI] Risk Committee 2000; Molenaar et al. 2010). Risk-based cost estimates strip all contingency from the line items in the base estimate and estimate contingency values explicitly. The base estimate should contain items without contingency (i.e., no conservatism or "fudge factor" should be included on individual items). Estimates for contingency are made through either a "top-down" value based on historical data or a "bottom-up" value based on the risk events. Top-down contingency estimates relate risks to ranges of contingency from historical data. Bottom-up contingency estimates use simulation to assess (a) risk events through an estimate of a risk's probability of occurrence and magnitude of impact; and (b) uncertainty in costs or quantities by applying ranges of values.

The output of risk-based estimates can be either deterministic (i.e., one number) or probabilistic (i.e., a range of values). Deterministic outputs combine the probability and impact of risk events to develop a single expected value of contingency. Probabilistic outputs combine probability and impact of risk events through simulation to produce a range of values for contingency. The simulation-based portion of the estimate typically focuses on a few key elements of uncertainty and combines Monte Carlo sampling and heuristics (rules of thumb) to rank critical risk elements.

5.1.2 Why Use It?

Risk-based estimating techniques can uncover potential cost escalation and provide useful information for the monitoring and management of uncertainty (Project Management Institute [PMI] 2004; International Organization for Standardization [ISO] 2009). Communication of ranged cost estimates can provide the design team and project stakeholders with a transparent understanding of the uncertainty in early cost estimates. Modeling of contingency can also help to provide a better understanding of the amount that a contractor will include in the bid for project risks at letting. However, developing a risk-based estimate is not a trivial task. Comprehensive risk identification requires the estimator to work with numerous team members in risk identification efforts and data-gathering exercises. The use of simulation modeling to determine contingency requires training and practice.

5.1.3 When to Use It?

Estimators apply risk-based estimates most frequently in the planning, scoping, and early design phases of complex projects. Table 1-3 presents a cost estimating classification and recommends the use of risk-based estimating in project scoping and planning. Complex projects can also benefit from risk-based estimates in early design. In special circumstances, such as design-build, large, or highly complex projects, risk-based estimates can provide great value in terms of estimating potential contingency that a contractor will include in a bid (Anderson et al. 2007 and Molenaar et al. 2010).

Figure 5-1 provides a graphical depiction of when risk-based estimates apply. Figure 5-1 is an extension of Figure 1-3 and Table 1-3. Figure 5-1 illustrates two key points relating to risk-based estimates. First, an estimate at any given point is made up of a base estimate component and a contingency component (see Chapters 1-4). As the project progresses in development, the contingency amount is expected to decrease because the project information is refined and more details become available. Typically, the base estimate increases as some of the contingency is realized and included in the base estimate. The second point that Figure 5-1 illustrates is the transition from a risk-based range estimate to a baseline estimate when moving from the planning to the programming phases. Risk-based estimates can generate the range estimates for the planning and programming phase and can also assist in determining proper contingency in the design phase.

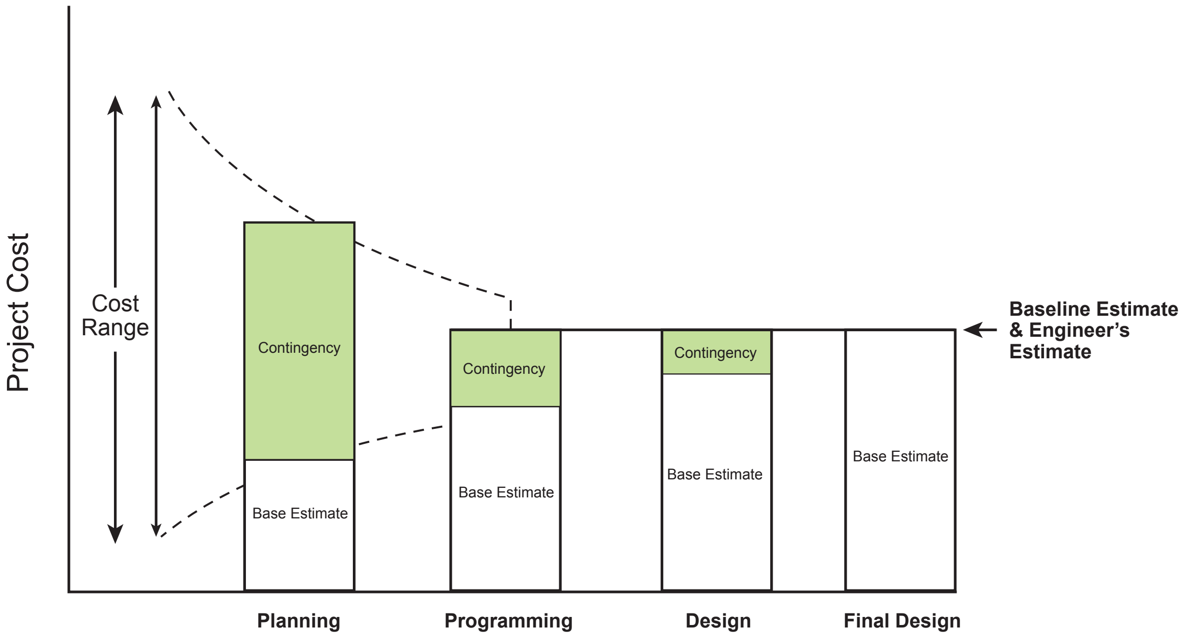


Figure 5-1. Refinement of a Cost Estimate (Molenaar et al. 2010)
(Case where baseline estimate is equal to engineer's estimate).

5.2 KEY INPUTS

The key inputs to a risk-based estimate are an identification and quantification of uncertainty surrounding the project scope (i.e., items of work, quantities of work, rates of production, etc.) and uncertainty surrounding risk events (i.e., a change in design standards, discovery of hazardous material, etc.). Risk-based estimates account for the potential impacts of uncertainty in both of these areas. Sources for these key inputs include:

- A definition of project complexity.
- A list of design and estimating assumptions and concerns.

5.2.1 Project Complexity

Project complexity is a primary input to risk-based estimating. Project complexity drives the level of effort and choice of tools for a risk-based estimate (Molenaar et al. 2010 and Anderson et al. 2008). Project complexity is described in a number of ways. Some descriptions rely on project attributes to convey the project complexity. For example, attributes related to roadways, traffic control approaches, structures, right-of-way, utilities, environmental requirements, and stakeholder involvement are often used to distinguish different levels of project complexity. Table 5-1 provides an example of complexity classification from *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*. Each agency is encouraged to develop its own definition of complexity given its specific needs and resources.

Table 5-1. Example of Complexity Classification

Most Complex (Major)	Moderately Complex	Non-Complex (Minor)
• New highways; major relocations • New interchanges • Capacity adding/major widening • Major reconstruction (4R; 3R with multi-phase traffic control) • Require congestion management studies	• 3R and 4R projects that do not add capacity • Minor roadway relocations • Certain complex (non-trail enhancement) projects • Slides, subsidence	• Maintenance betterment projects • Overlay projects, simple widening without right-of-way (or very minimum right-of-way take) and little or no utility coordination • Non-complex enhancement projects without new bridges (i.e., bike trails)

Note: 4R is rehabilitation, restoration, resurfacing, or reconstruction.

NCHRP Report 564: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs employs a three-level complexity categorization in Table 5-1 to determine the approach to estimating contingency. Projects in the highest complex category (major projects) may include new highways, major relocations, or reconstruction. Highly complex projects can require a bottom-up, probabilistic-based approach to estimating contingency (Monte Carlo simulation is discussed in detail in Section 5.3.2.3). Projects with minor complexity, such as maintenance projects, may require only a listing of red-flag risks and a top-down contingency estimate based on a percentage of the base cost estimate. Moderately complex projects, such as minor roadway relocations, will typically require a qualitative risk assessment and top-down percentage contingency estimate. However, these projects may also require a deterministic examination of individual risks to ensure that the top-down percentage contingency is adequate (Molenaar et al. 2010). The sections that follow explain all of these methods—risk-based percentage contingency estimate, risk-based deterministic contingency estimate, and risk-based probabilistic contingency estimate.

5.2.2 Design and Estimate Assumptions and Concerns

The other two primary inputs for a risk-based estimate stem from a review of the assumptions made by the designer in the project definition and the assumptions made by the estimator to create the estimate. The designers must make initial project definition assumptions during the planning or scoping phases, or both. Risk-based estimates are often made when limited resources—or no resources—have been invested in design. This is the nature of conceptual design, and it drives uncertainty in the project scope and project cost estimate. Likewise, estimators must make estimating assumptions in planning- and programming-level estimates because very little detail will be available regarding project definition. Estimating and design assumptions serve as triggers for risk identification when creating a contingency estimate.

Two other sources of risk information are risk checklists and risk analyses from similar projects. Estimators that maintain historical risk checklists will improve their chances of identifying potential risks on future projects. However, these historical checklists should not be the primary sources of information. Preferably, they should only be used after conducting an independent and thorough review of the project complexity and the estimating and design assumptions.

5.3 DETERMINE RISK AND SET CONTINGENCY

Determining risk and setting contingency requires experience, judgment, and the proper tools to quantify as much of the project cost estimate uncertainty as practical. An estimator can never completely eliminate the uncertainty or the risks from any cost estimate. Therefore, an estimator needs to include a reasonable contingency amount in a project cost estimate to account for the risk exposure. A reasonable contingency amount must provide coverage for any possible cost overruns, and the estimator must be able to explain why the specific contingency amount is included in the estimate. The risk exposure and the corresponding contingency amount typically decrease as a project advances through project development phases.

This section separates risk identification from risk-based estimating of contingency. Risk identification is common to all risk-based estimating approaches. After discussing risk identification as the approach to determining risk, this guide presents three common risk-based approaches to setting contingency:

- Type I—risk-based percentage contingency estimates.
- Type II—risk-based deterministic contingency estimates.
- Type III—risk-based probabilistic contingency estimates.

5.3.1 Determine Risk

Risk identification is the first step in all risk analysis approaches. It should involve all members of the project team, as risks events can come from any functional area or stakeholder group. Risk identification tools, such as risk checklists, can be helpful. However, brainstorming in a risk identification workshop setting is perhaps the best approach to risk identification, as it will produce a project-specific list of risks and prompt the discussion of critical project elements.

5.3.1.1 Objectives of Risk Identification

The objectives of risk identification are to (a) identify and categorize risks that could affect the project; and (b) document the identified risks. The outcome of the risk identification is a list of risks. Ideally, the list of risks should be comprehensive and non-overlapping. What is done with the list of risks at that point depends on the nature of the risks and the nature of the project. On minor, low-cost projects with little uncertainty (few risks), the risks may simply be kept as a list of red-flag items. The red-flag items can then be assigned to individual team members to monitor (or track) throughout the project development process. They can also be used for risk allocation purposes, as described in Section 5.3.2.3.2. On major, high-cost projects that by nature have greater uncertainty (many risks), the identified risks can feed a rigorous process of assessment, analysis, mitigation and planning, allocation, and monitoring and updating.

The risk identification process should stop short of assessing or analyzing risks so as not to inhibit the identification of "minor" risks. The process should promote creative thinking and leverage team experience and knowledge. In practice, however, risk identification and assessment are often completed in a single step, and this process can be called risk assessment. For example, if a risk is identified in the process of interviewing a team member or expert, it is logical to pursue information on the probability of it occurring, its consequences/impacts, the time associated with the risk (i.e., when it might occur), and possible ways of dealing with it. The latter actions are part of risk assessment, but they often begin during risk identification. For clarity, however, this document will treat the two activities of risk identification and assessment as discrete processes.

5.3.1.2 Risk Identification Process

The risk identification process begins with the team compiling a list of the project's possible risk events. Possible risks are those events or conditions that team members determine would adversely affect the project cost. The identification process will vary depending upon the nature of the project and the risk management skills of the team members, but most identification processes begin with an examination of issues and concerns raised by the project development team. These issues and concerns can be derived from an examination of the project description, work breakdown structure, cost estimate, design and construction schedule, procurement plan, and general risk checklists. Checklists and databases can be created for recurring risks, but project team experience and subjective analysis will almost always be required to identify project-specific risks.

The team should examine and identify project events by reducing them to a level of detail that permits an evaluator to understand the significance of any risk and identify its causes (or risk drivers). This is a practical way of addressing the large and diverse number of potential risks that often occur on highway design and construction projects.

Upon identification, the risks should be classified into groups of like exposures. Classification of risks helps to reduce redundancy and provides for easier management of the risks in later phases of the risk analysis process. Classifying risks aids in creating a comprehensive and non-overlapping list. Classifying risks also provides for the creation of risk checklists, risk registers, and databases for future projects. Table 5-2 provides an example categorization of risks and a risk checklist. It is a summarization of information found in the SHRP2 Report *Guide for the Process of Managing Risk on Rapid Renewal Projects* (Roberds et al. 2011).

5.3.1.3 Risk Characteristics

During the risk identification step, risks can be characterized to aid in later assessment and planning. It is often helpful to think of risk in broader terms of uncertainty. Uncertainty involves both positive and negative events. A risk is defined as an uncertain event or condition and, if it occurs, it has a positive or negative effect on a project's objectives (PMI 2004). However, it is often helpful to separate uncertain events into those that can have a negative effect (risks) and those that can have a positive effect (opportunities). Some estimators choose to use the terminology of both risk and opportunity to characterize uncertainty in their risk management programs. However, teams must be cautious not to overlook risk or focus on solving problems when using the risk/opportunity characterization during the risk identification process. Estimators and project managers may underestimate risk when thinking about uncertain items. It is often better to focus on risks during the identification stage and explore opportunities during the mitigation process.

Another characteristic of risks is that many risk events have triggers. Triggers, sometimes called risk symptoms or warning signs, are indications that a risk has occurred or is about to occur. Triggers may be discovered in the risk identification process and watched in the risk monitoring and updating process.

The identification and documentation of triggers early in the process can greatly help the risk management process.

Table 5-2. Common Transportation Risks and Risk Categories

Environmental Risks	External Risks
• Delay in review of environmental documentation • Challenge in appropriate environmental documentation • Defined and non-defined hazardous waste • Environmental regulation changes • Environmental impact statement (EIS) required • NEPA/404 Merger Process required • Environmental analysis on new alignments required	• Stakeholders request late changes • Influential stakeholders request additional needs to serve their own commercial purposes • Local communities pose objections • Community relations • Conformance with regulations/guidelines/design criteria • Intergovernmental agreements and jurisdiction
Third-Party Risks	**Geotechnical and Site Risks**
• Unforeseen delays due to utility owner and third-party • Encounter unexpected utilities during construction • Cost sharing with utilities not as planned • Utility integration with project not as planned • Third-party delays during construction • Coordination with other projects • Coordination with other government agencies	• Unexpected geotechnical issues • Surveys late or in error, or both • Hazardous waste site analysis incomplete or in error • Inadequate geotechnical investigations • Adverse groundwater conditions • Other general geotechnical risks
Right-of-Way/Real Estate Risks	**Design Risks**
• Railroad involvement • Objections to ROW appraisal take more time or money, or both • Excessive relocation or demolition • ROW Acquisition problems • Difficult or additional condemnation • Accelerating pace of development in project corridor • Additional ROW purchase due to alignment change	• Design is incomplete/design exceptions • Scope definition is poor or incomplete • Project purpose and need are poorly defined • Communication breakdown with project team • Pressure to deliver project on an accelerated schedule • Constructability of design issues • Project complexity (scope, schedule, objectives, cost, and deliverables are not clearly understood)
Organizational Risks	**Construction Risks**
• Inexperienced staff assigned • Losing critical staff at crucial point of the project • Functional units not available or overloaded • No control over staff priorities • Lack of coordination/communication • Local agency issues • Internal red tape causes delay getting approvals, decisions • Too many projects/new priority project inserted into program	• Pressure to deliver project on an accelerated schedule • Inaccurate contract time estimates • Construction QC/QA issues • Unclear contract documents • Problem with construction sequencing/staging/phasing • Maintenance of traffic/work zone traffic control

The risk identification process identifies and categorizes risks that could affect the project. It documents these risks and, at a minimum, produces a list of risks that can be assigned to a team member and tracked throughout the project development and delivery process. Risk identification is continuous, and there should be a continual search for new risks that should be included in the process. The tools and techniques outlined in this section should support the risk identification process, but it will be the people involved in the exercises who are most critical to the success of the process.

5.3.2 Set Contingency

While this chapter focuses on risk-based approaches to estimating contingency, it does not recommend that Monte Carlo simulation is the proper tool for every project contingency estimate. Rather, it suggests a three-tier approach to risk analysis and contingency estimation. The three-tier approach stems directly from project complexity. A determination of the project complexity is made based on the three categories in Table 5-1. This leads to the selection of a risk analysis and contingency estimating approach as shown in Figure 5-2.

Figure 5-2. Three-Tier Approach to Contingency Estimation

Based on an evaluation of where the project falls in the three different levels of complexity, a different type of risk analysis is defined for the project. The three types of risk analysis and contingency estimation correlate directly to the three levels of complexity:

- Type I—non-complex (minor) projects.
- Type II—moderately complex projects.
- Type III—most complex (major) projects.

The three risk analysis types can be briefly described as follows:

- Type I—risk-based percentage contingency estimates: A Type I risk-based approach is the simplest form of risk analysis and should be used for non-complex (minor) projects. A Type I risk analysis involves the development of a list of risks and the use of a top-down percentage of project cost to estimate the contingency.
- Type II—risk-based deterministic contingency estimates: The Type II risk-based approach correlates to moderately complex projects and involves more rigorous risk identification tools. It involves a top-down percentage contingency estimate that is supplemented with a bottom-up estimation of specific contingency items.
- Type III—risk-based probabilistic contingency estimates: A Type III risk-based approach applies to the most complex (major) projects. It will need to be facilitated by individuals trained in quantitative risk management practices. Using a comprehensive and non-overlapping set of risks, the estimator generates a probabilistic estimate of cost and schedule to determine an appropriate contingency.

The type of risk analysis will determine the selection of appropriate risk-related tools for risk identification, risk analysis, and estimation of contingency. All projects, regardless of project size and project complexity, require some form of risk analysis and risk management planning. The basic risk analysis steps remain the same, but the tools and level of effort vary with the risk analysis level.

5.3.2.1 Risk-Based Percentage Contingency Estimates

In the case of minor and some moderately complex projects, transportation estimators commonly determine contingency estimates from a percentage of the base cost. Many states apply a predetermined contingency on their projects (Molenaar et al. 2010). However, this predetermined contingency varies greatly from state to state. The definition of what contingency covers also varies from state to state, and even within agencies across regions or functional units. In an attempt to better account for the unique effects of project complexity and phase in project development, this guide presents a sliding-scale contingency approach that is based on a Delphi study of 23 professional estimators from DOTs around the country (Olumide et al. 2010). This guide recommends the use of the sliding-scale contingency amounts shown in Tables 5-3 and 5-4 and Figures 5-3 to 5-5. However, this general guidance should be adjusted for each DOT given its historical experience and current market conditions.

Table 5-3 provides some typical risks that are representative of each of the three levels of project complexity. Table 5-4 correlates to Figures 5-3 to 5-5 and provides a description of the project complexity, phase of project development, phase description, level of definition, estimate type, and historical data that were used to develop the sliding-scale contingencies.

Table 5-3. Examples of Representative Risks for Project Complexities

Project Type	Most Complex	Moderately Complex	Non-Complex
Representative Risks	• Unresolved constructability issues • Design complexity • Political factors • Complex environmental requirements	• Geotechnical issues • Changes in materials/foundation • Delays in permitting process • Bridge redesign/analysis	• Contractor delays • Changes in program priorities • Errors in cost estimating • Inaccurate technical assumptions

Figures 5-3 to 5-5 present the sliding-scale contingencies based on the results of the Delphi study (Olumide et al. 2010). Design 1, Design 2, and Design 3 correspond to different levels of design completion and project definition (see Table 5-4). For instance for non-complex projects, Design 1 is 15-40 percent level of definition, Design 2 is 40-70 percent, and Design 3 is 70-100 percent level of definition. These three stages of design are 4 years or less from letting using bid-based or cost-based, or both, estimating techniques and historical data.

Table 5-4. Description of Project Characteristics Relating to Sliding-Scale Contingency Values

Project Type / Complexity	No. of Phases	Phase of Project Development	Phase Description	Level of Definition	Estimate Type	Historical Data
Non-Complex (Minor)	5	Planning	10 to 20 yrs from letting	1–5%	Parametric with historical percentages	Cost per lane-mile, past projects
		Programming/ Preliminary Design	5 to 10 yrs from letting	5–15%	Bid-based (80/20 rule) with other	Recent bids, past projects
		Design 1	4 yrs or less from letting	15–40%	Bid-based with 75% line items identified	Recent bids
		Design 2	less than 4 yrs from letting	40–70%	Bid-based with 90% line items identified	Recent bids
		Design 3	less than 4 yrs from letting	70–100%	Bid-based, cost-based. All items (Pay)	Recent bids or labor, material, equipment costs
Moderately Complex	5	Planning	10 to 20 yrs from letting	1–15%	Parametric with historical percentages	Cost per lane-mile, past projects
		Programming/ Preliminary Design	5 to 10 yrs from letting	15–25%	Bid-based (80/20 rule) with other	Recent bids, past project
		Design 1	4 yrs or less from letting	25–35%	Bid-based with 75% line items identified	Recent bids
		Design 2	less than 4 yrs from letting	35–70%	Bid-based with 90% line items identified	Recent bids
		Design 3	less than 4 yrs from letting	70–100%	Bid-based, cost-based. All items (Pay)	Recent bids or labor, material, equipment costs
Most Complex (Major)	4	Planning	10 to 20 yrs from letting	1–15%	Parametric with historical percentages	Cost per lane-mile, past projects
		Programming/ Preliminary Design	5 to 10 yrs from letting	15–35%	Bid-based (80/20 rule) with other	Recent bids, past projects
		Design 1	less than 4 yrs from letting	35–75%	Bid-based with 80% line items identified	Recent bids
		Design 2	less than 4 yrs from letting	75–100%	Bid-based, cost-based. All items (Pay)	Recent bids or labor, material, equipment costs

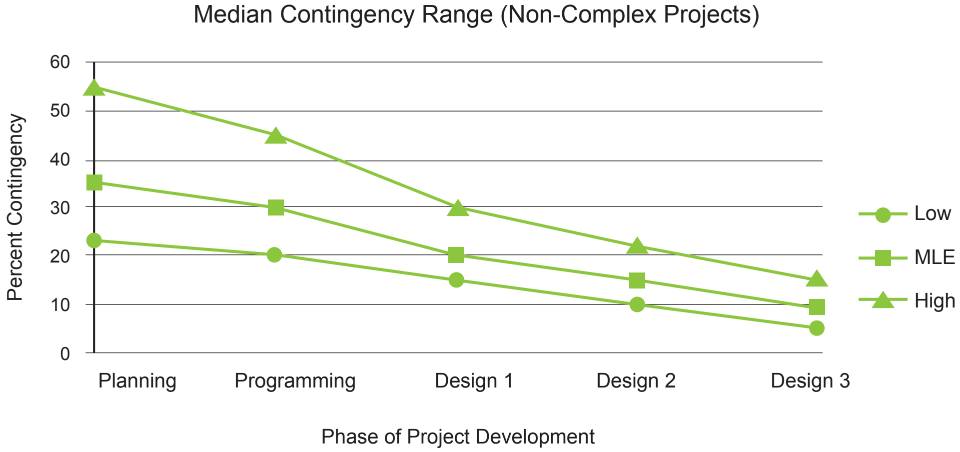


Figure 5-3. Sliding Scale for Non-Complex (Minor) Projects

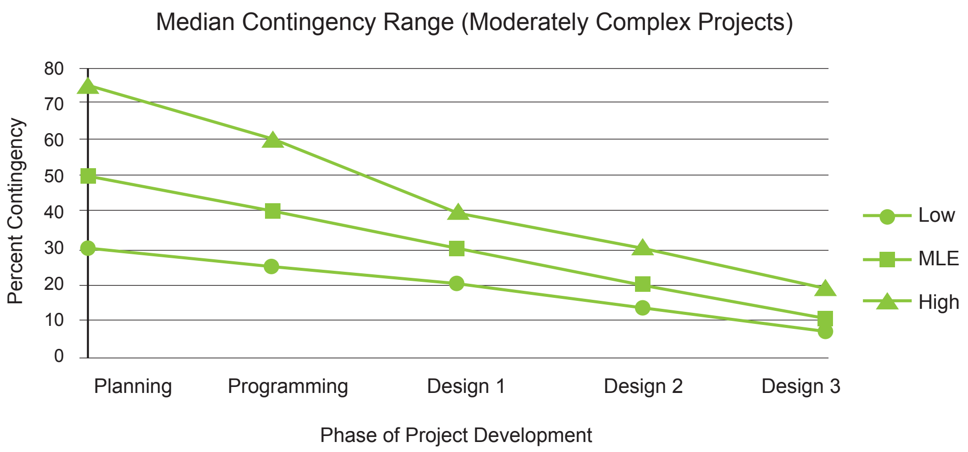


Figure 5-4. Sliding Scale for Moderately Complex Projects

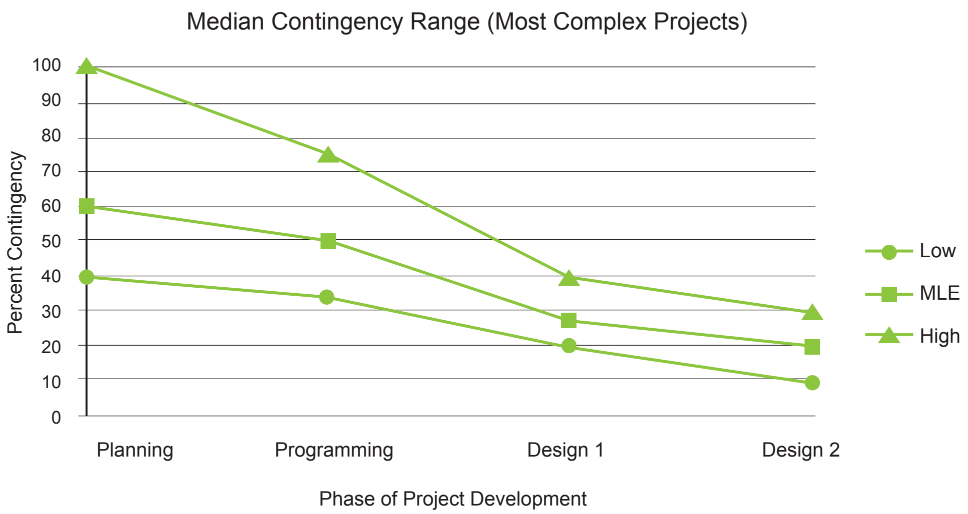


Figure 5-5. Sliding Scale for Most Complex (Major) Projects

To properly apply these scales, estimators must separate the base estimate from the contingency estimate, choose the appropriate category of project complexity, and know the phase of project development at the time of the estimate. Application consists of six steps:

1. Remove all contingencies and conservative biases from the base estimate.
2. Classify the project by complexity as most complex (major), moderately complex, or non-complex (minor) (see Table 5-1).
3. Determine current phase of project development (see Table 5-4).
4. Perform a risk identification to determine potential risks that could impact the project.
5. Add the appropriate contingency to the base estimate using the appropriate sliding scales (see Figures 5-3 to 5-5).
   a) Use the low and high estimates to create a range estimate.
   b) Use the Most Likely Estimate (MLE) for deterministic estimates.

c) Choose two unique values between the low and high estimates to create a unique contingency range (when preparing a planning estimate).
d) Choose a value between the upper or lower ends of the range when an estimator can identify risks (Step 4) that would justify the use of a value that is higher or lower than the most likely estimate (when setting a baseline cost for budgeting).

6. Repeat the process at each major phase of project development.

The application of the contingency charts is straightforward. However, the contingency values are not insignificant, as seen in the Figures 5-3, 5-4, and 5-5. Most likely values for contingency at the planning stage are 40 percent, 60 percent, and 80 percent on non-complex, moderately complex, and complex projects, respectively. These values were created with an understanding that the base estimate will contain no line-item contingencies or conservative estimates. If estimators include contingencies within the base estimate, these base estimate contingencies will be burdened again with the sliding-scale contingency factors, thus creating an excessively high estimate. Estimators must be diligent in removing all conservatism from the base estimate at all phases when applying this approach.

The risk-based percentage contingency approach allows estimators to quickly create a range estimate by applying the high and low ends of the contingency scale to the base estimate. The use of range estimates is encouraged for planning and early programming estimates (see Section 5.1). Planning estimates are rarely used for setting a project baseline estimate due to the incomplete nature of the scope in this early phase, and a range estimate communicates the uncertain nature of the project's definition during this phase. As the project moves into programming and preliminary engineering, a baseline estimate is required for project controls and a range estimate is typically not appropriate. For baseline estimates, estimators should examine project risks and uncertainties and choose an appropriate contingency value from the range provided.

The implied retirement of contingency is a benefit of applying this approach. For example, the most likely value for contingency will change from 40 percent to 10 percent as project development proceeds from planning to letting on a non-complex project. This reduction in contingency values implies that the base estimate accuracy will increase by these same percentages if the planning estimate is correct. Although the risk-based percentage contingency approach does not directly correlate risks to contingency amounts, estimators can keep a list of risks and key design and estimating assumptions throughout the process. These risks and assumptions should be resolved as the design progresses and the contingency decreases. If risks are not resolved, the estimator can choose to maintain a contingency at the higher end of the suggested range.

5.3.2.2 Deterministic Risk-Based Contingency Estimates

The risk-based deterministic approach correlates to moderately complex projects and involves more rigorous risk identification tools. It involves a top-down percentage contingency estimate that is supplemented with a bottom-up estimation of specific contingency items. The percentage contingency is completed in the same fashion as described in Section 5.3.2.1. The top-down percentage contingency approach is then supplemented with an estimate of the probability and impact of specific risks to ensure that the contingency percentage is adequate.

Risk-based deterministic approaches assign a risk factor to various project elements based on historical knowledge of the relative risk of various project elements. For example, pavement material cost may exhibit a low degree of cost risk, whereas acquisition of rights-of-way may display a high degree of cost risk. Project contingency is determined by multiplying the estimated cost for each risk by its respective probability of occurrence. Table 5-5 provides an example of a deterministic risk-based analysis for the calculation of contingency through the expected value for each identified risk. This method profits from its simplicity and the fact that it produces an estimate of cost contingency. However, the project team's knowledge of risk is only implicitly incorporated in the various risk factors.

Table 5-5. Simplified Deterministic Risk-Based Analysis Method Example

Project Cost Element	Estimated Impact	Probability of Occurrence	Cost Contingency
Initial Purchase of Right-of-Way	$1,200,000	20%	$240,000
Known Hazardous Substance	$125,000	10%	$12,500
Coordination with Railroad Agencies	$50,000	10%	$5,000
Treatment of Water Discharged from Site	$400,000	3%	$12,000
Total			**$269,500**

The simplified deterministic example provided in Table 5-5 should not be the sole determinant of project contingency, but rather it should be used as a "back-check" for the sliding-scale contingency approach described in Section 5.3.2.1. If the two analyses result in different contingencies, the higher of the two values should be used.

A primary benefit of using the deterministic contingency approach is a quantification of the potential risk impact through its expected value (probability x impact). By quantifying the probability and impact of potential risks, the project team can better understand the potential risk effects. The analysis allows the team to better manage its resources when mitigating or managing the risks. From the example in Table 5-5, it is apparent that the team should focus on mitigating the risks stemming from the initial right-of-way purchase. The analysis also shows that impact of water discharged from the site ($400k) is larger than the impact of the treatment of a known hazardous substance ($125k). However, factoring the probability of occurrence into the analysis shows that the contingency required for each item is essentially equal ($12.5k and $12k). Using a probability x impact analysis (i.e., expected value) for contingency shows that the team should treat these items equally in its efforts to mitigate and manage them.

Two primary errors can occur when using the deterministic risk-based contingency approach. These errors occur if the list of risks is not (1) comprehensive, and (2) non-overlapping. If the list of risks is not comprehensive, the resulting contingency estimate will be low. This error is easily mitigated by using the sliding-scale contingencies from Section 5.3.2.1 when the deterministic value is lower than the sliding-scale value. If the list of risks is overlapping, there is a chance that the deterministic approach may "double-up" the contingency for these overlapping items and result in a contingency value that is too high. To mitigate this potential error, estimators should strive to make the risks independent.

While deterministic methods are quite simple, they do not reflect the complexity of many highway projects. The most complex projects usually require a probabilistic risk-based contingency estimate.

5.3.2.3 Probabilistic Risk-Based Contingency Estimates

Estimators develop probabilistic risk-based contingency estimates using a range of tools. The most common probabilistic estimating tool is the Monte Carlo simulation. In fact, the term *risk-based estimate* is often used synonymously with Monte Carlo simulation techniques. Monte Carlo methods are computerized probabilistic calculations that use random number generators to draw samples from probability distributions. The objective of the simulation is to find the effect of multiple uncertainties on a quantity of interest (such as the total project cost or project duration). There are many advantages of Monte Carlo methods. They can determine risk effects for cost and schedule models that are too complex for common analytical methods. They can explicitly incorporate project team knowledge of possible risk events and uncertainty in known values for both cost and schedule risk events. They have the ability to reveal, through sensitivity analysis, the impact of specific risk events on the project cost and schedule. The discussion of probabilistic estimates in this section will focus on Monte Carlo simulations of uncertainty in the base estimate and identified risk events.

5.3.2.3.1 Developing a Probabilistic Risk-Based Estimate

Probabilistic risk-based information can provide estimators with confidence in their estimates and communicate uncertainty to all project stakeholders. However, the level of effort, time, and resources devoted to risk-based estimating can be significant and needs to be appropriate to the project magnitude. For major projects, a common approach is to develop an independent team of subject matter experts to review an existing project estimate. These reviews often take on the form of a workshop similar in nature to those used for value engineering studies. The risk-based estimating workshops provide the input for the Monte Carlo models. The workshops have an additional benefit of enhancing team understanding and alignment concerning risk. However, developing a probabilistic risk-based estimate does not necessarily require a workshop approach if the size of the project does not warrant this level of effort. A well-experienced estimator can develop a reasonable risk-based estimate with input from the project team members individually. The benefit to having an independent team is that it reduces the potential bias of the project team.

Several software packages are available to conduct risk-based estimates. The software is typically add-on packages to spreadsheets such as Microsoft Excel or to scheduling software such as Primavera. Many packages will require some modification to account for the issues associated with transportation projects. For transportation project cost estimates, the simulation objective is to find the effect of multiple uncertainties on the total project cost or project duration. Monte Carlo simulations provide an estimate of the cost for all identified risks based on the probability that they will occur and the interactions between the risks.

The most stringent methods are those that require as inputs a probability distribution for the various performance, schedule, and costs risks. Risk variables are differentiated based on whether they can take on any value in a range (continuous variables) or whether they can assume only certain distinct values (discrete variables). Whether a risk variable is discrete or continuous, two other considerations are important in defining an input probability: its central tendency and its range or dispersion. An input variable's mean and mode are two alternative measures of central tendency; the mode is the most likely value across the variable's range. The mean is the value where the variable has a 50 percent chance of taking on a value that is greater and a 50 percent chance of taking a value that is lower. The mode and the mean of two example continuous distributions are illustrated in Figure 5-6.

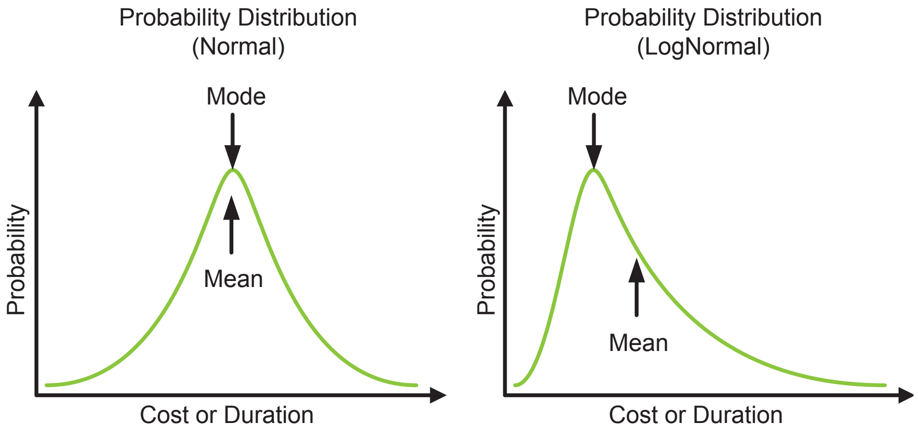


Figure 5-6. Mean and Mode in Normal and Lognormal Distributions

The other key consideration when defining an input variable is its range or dispersion. The range is the difference between the least and greatest values of all the values in a dataset. This measures the distance from the lowest value to the highest value. The common measure of dispersion is the standard deviation (σ), which is a measure of the breadth of values that are possible for the variable. Normally, the larger the standard deviation, the greater the relative risk. Probability distributions with different mean values and different standard deviation values are illustrated in Figure 5-7.

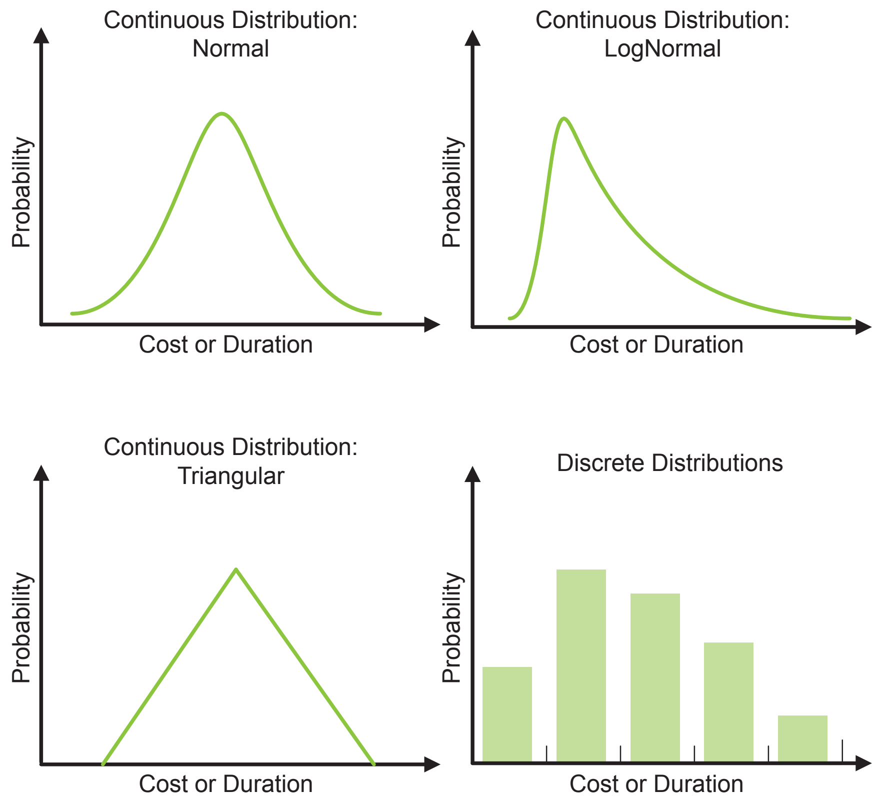


Figure 5-7. Distributions for Risk Analysis Input

All four distributions have a single high point (the mode), and all have a mean value that may or may not equal the mode. Also, some of the distributions are symmetrical about the mean, while others are not. Skewness is a measure of the asymmetry of the probability distribution. For example, the distribution in the upper right of Figure 5-7 has positive skew because the majority of data is to the right of the mean. Selecting an appropriate probability distribution is a matter of which distribution is most like the distribution of the actual data. For transportation projects, this is a difficult choice, for historical data on unit prices, activity durations, and quantity variations are often difficult to obtain. In cases where insufficient data are available to completely define a probability distribution, estimators must rely on a subjective assessment of the needed input variables. Elicitation of these subjective assessments in a group setting can increase accuracy.

5.3.2.3.2 Interpreting and Communicating a Probabilistic Risk-Based Estimate

The type of outputs that a technique produces is an important consideration when selecting a risk analysis method or tool. Generally speaking, techniques that require more rigor, demand stricter assumptions, or need more input data generally produce results that contain more information and are more helpful. Results from risk analyses may be divided into three groups according to their primary output:

1. Single parameter output measures.
2. Multiple parameter output measures.
3. Complete distribution output measures.

The type of output required for an analysis is a function of the objectives of the analysis. If, for example, an agency needs approximate measures of risk to help in project selection studies, simple mean values (a single parameter) or a mean and a variance (multiple parameters) may be sufficient. On the other hand, if an agency wishes to use the output of the analysis to aid in assigning a contingency amount to a project, knowledge of the precise shape of the tails of the output distribution or the cumulative distribution is needed (complete distribution measures). Finally, when the identification and subsequent management of the key risk drivers is the goal of the analysis, a technique that helps with such sensitivity analyses is an important selection criterion.

Sensitivity analysis is a primary modeling tool that can be used to assist in valuing individual risks, which is extremely valuable in risk management and risk allocation support. A tornado diagram is a very useful graphical tool for depicting risk sensitivity or influence on the overall variability of the risk model. Tornado diagrams graphically show the correlation between variations in model inputs and the distribution of the outcomes. They highlight the greatest contributors to the overall risk. Figure 5-8 is a tornado diagram for a portion of the San Francisco–Oakland Bay Bridge project. The length of the bars on the tornado diagram corresponds to the influence of the items on the overall risk (in this case, risk to schedule duration).

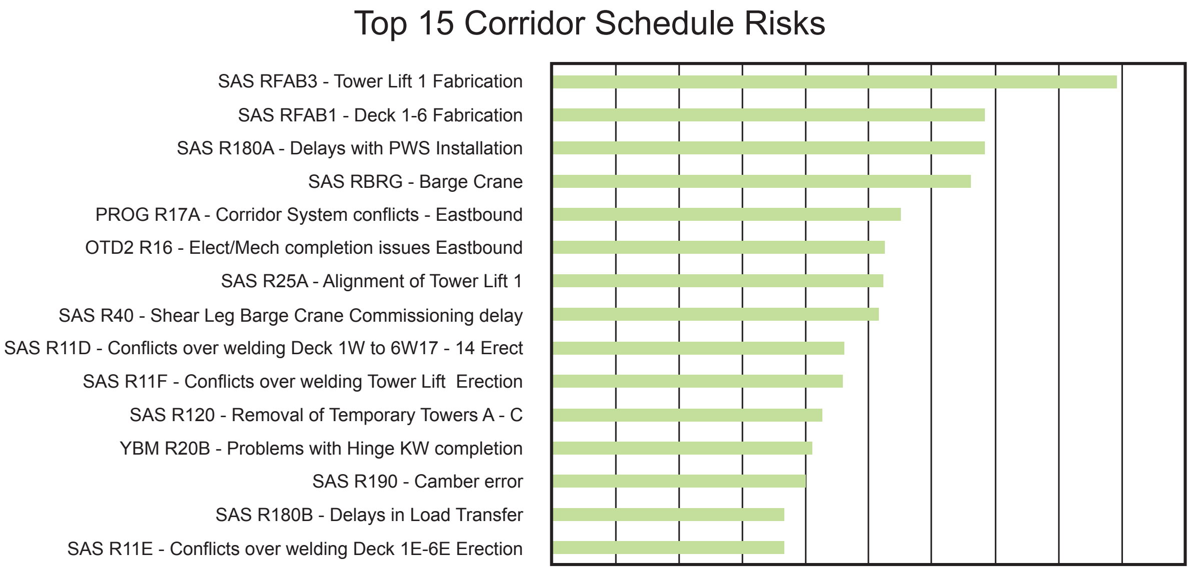


Figure 5-8. Example Sensitivity Analysis with Tornado Diagram

Figure 5-9 shows typical probability outputs from a probabilistic risk-based analysis. The histogram information is useful for understanding the mean and standard deviation of analysis results. The cumulative chart is useful for determining project budgets and contingency values at specific levels of certainty or confidence. In addition to graphically conveying information, Monte Carlo methods produce numerical values for common statistical parameters such as the mean, standard deviation, distribution range, and skewness.

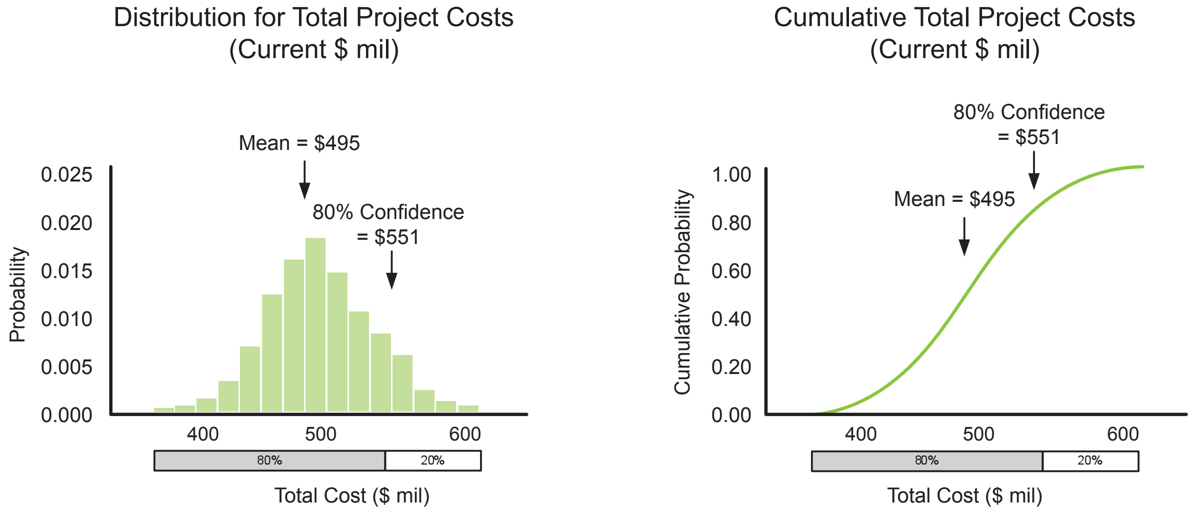


Figure 5-9. Typical Monte Carlo Output for Total Costs

Probabilistic risk-based methods are powerful tools for contingency estimation and cost analysis. However, these methods require knowledge and training for successful implementation. Input to Monte Carlo simulations requires the user to know and specify exact probability distribution information—mean, standard deviation, and distribution shape. Even so, Monte Carlo methods are the most common for project risk analysis, for they provide detailed, illustrative information about risk impacts on the project cost and schedule.

5.3.2.4 Relationship to Risk Management

Risk management is typically not the role of the cost estimator. Nevertheless, risk-based contingency estimates are a fundamental tool for risk management. The objectives of risk management and planning are to explore risk response strategies for the high-risk items identified in the risk analysis. The process identifies and assigns parties to take responsibility for each risk response. In the end, risk management assists in managing risks and retiring the associated contingency as the project progresses.

The primary tool for risk management is the risk register. A risk register is a tool that project teams use to address and document project risks throughout project development. Figure 5-10 provides an example of a portion of a risk management template from the California DOT (Caltrans; http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm). The risk register should be maintained as part of the project file that also includes information related to the cost estimate. A risk register often includes identified risks, causes, probability of occurrence, impact(s) on project/agency objectives, team responses, individual(s) assigned to monitor the evolution and the resolution of each risk, and current status. It is a comprehensive listing of risks and the manner in which they are being addressed as part of the entire risk management process. It is generally organized in the form of a spreadsheet so that it can be easily categorized and updated throughout the project development process.

DIST-EA 06-12345						Project Name:			Project Manager:				
						Co - Rte - PM:			Telephone:				
ITEM	ID #	Status	Threat/ Opportunity	Category	Date Risk Identified	Risk Description	Root Causes	Primary Objective	Overall Risk Rating	Cost/Time Impact Value	Risk Owner	Risk Trigger	Strategy
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
1	06-12345-01	Active	Threat	CON	03-26-07	Risk Description	Root Cause(s)	COST	Probability 3=Med (20–39%) Med Impact 3=Med	Cost/Time Impact Value	Risk Owner (555) 454-5454 (555) 454-5454 RiskOwner@dot.ca.gov	Risk Trigger(s)	MITIGATE

Figure 5-10. Example Risk Management Template

Risk response strategies focus on the high-risk items evaluated in the risk analysis. The highest risk items from the risk analysis are considered a priority, as their control or elimination provides the most benefit to the project. The project manager and the project team identify which strategy is best for managing each risk and determine specific actions to implement the strategy.

For threats, these strategies and actions could include:

- Avoidance—The team changes the project plan to eliminate the risk or to protect the project objectives from its impact. The team might achieve this by changing project scope, adding time, or adding resources (thus relaxing the so-called triple constraint). An example of this may be to alter a design to avoid possibly encountering contaminated soils. These changes may require upper-management approval.
- Transference—The team transfers the financial or schedule impact of risk by contracting out some aspect of the work to a party better able to control these items. Transference reduces the risk only if the new responsible party is able to control and reduce the risk.
- Mitigation—The team seeks to reduce the probability or consequences of a risk event to an acceptable threshold. Mitigation steps, although potentially costly and time consuming, may still be preferable to going forward with the unmitigated risk.
- Acceptance—Management and the project team decide to accept certain risks and their consequences to cost and schedule. They do not change the project plan to deal with a risk or identify any response strategy other than agreeing to address the risk if it occurs.

Acceptance is a strategy that must be quantified in the cost estimate. A project team adopts the acceptance strategy because it is either not possible to eliminate that risk from a project or the cost in time or money of the response is not warranted by the importance of the risk. When the project manager and the project team decide to accept a certain risk, they do not need to change the project plan to deal with that risk or identify any response strategy other than agreeing to address the risk if and when it occurs. A workaround plan may be developed for that eventuality. There are two types of acceptance strategies:

1. Active acceptance—the most common strategy is to establish a contingency reserve, including amounts of time, money, or resources to handle the threat or opportunity.

2. Passive acceptance—requires no action, leaving the project team to deal with the threats or opportunities as they occur.

Some responses are designed for use only if certain events occur. In this case, a response plan, also known as a contingency plan, is developed by the project team and will only be executed under certain predefined conditions, commonly called triggers.

A workaround is distinguished from a contingency plan in that a workaround is a recovery plan that is implemented if an event occurs, whereas a contingency plan is to be implemented if a trigger event indicates that the risk is very likely to occur.

Risk monitoring and control identifies and assigns parties to take responsibility for each risk. This process ensures that each risk requiring a response has an owner. It also:

- Keeps track of the identified risks, residual risks, and new risks.
- Ensures the execution of risk response plans and evaluates their effectiveness.
- Continues for the life of the project (the list of project risks changes as the project matures, new risks develop, or anticipated risks materialize or disappear).

Periodic project risk reviews repeat the tasks of identification, analysis, and development of response strategies. The project manager regularly schedules project risk reviews and ensures that project risk is an agenda item at all project team meetings. Risk ratings and prioritization commonly change during the project's life cycle. If an unanticipated risk emerges, or a risk's impact is greater than expected, the planned response strategy and actions may not be adequate. The project manager and the project team must then develop additional response strategies and implement them to control the risk.

5.4 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control are challenging in risk-based estimating due to the uncertainty in the items being evaluated. The estimator can never know if he or she has properly estimated all the risk and uncertainty in a project. Some identified risks may not occur, and other risks may be impossible to foresee. Therefore, quality assurance and quality control must rely on the estimator's judgment, expertise, and experience. The primary tools for quality control are risk checklists, historical contingency percentages, and peer review.

5.4.1 How to Check?

The best method to check a risk-based estimate is through a review by an experienced estimator who did not work on the original estimate. Experienced estimators can often determine if a risk is not present in the risk identification or if an error was made in the risk-based contingency calculation.

Risk checklists are a tool for quality assurance. Estimators use risk checklists in the risk identification process. However, estimators should not use them as the primary tool for risk identification. Risk checklists serve as an excellent tool for quality assurance after the risk identification process to ensure that no risks have been missed in the process. Table 5-2 can serve as a risk checklist.

All bottom-up risk-based contingency estimates should be checked against top-down historical percentage estimates for contingency. Bottom-up estimates quantify only the risks resulting from the risk identification process. If risks are missed, they will not be included. Therefore, a top-down check of all contingency estimates is an excellent quality assurance check.

Peer review is perhaps the best tool for quality assurance. Having a core group of estimators who are experienced in risk-based methods is suggested for all agencies. Estimators must use judgment to identify risks and quantify the probability and impact of their occurrence. Historical data simply do not exist for each risk. Therefore, a peer review by an estimator or group of estimators experienced in risk-based methods is essential.

5.5 SUMMARY

Risk-based contingency estimates result in an understanding of the uncertainty and risks inherent in a project. Risk-based estimates produce an expected value and range of project cost for contingency that can be applied to the base cost estimate. They can also provide a ranking of defined risks to monitor during the project development process. This helps estimators manage contingency and prevent cost and schedule growth. This chapter presented three forms of risk-based estimates: (1) percentage risk-based contingency estimates; (2) deterministic risk-based contingency estimates; and (3) probabilistic risk-based contingency estimates. The type of estimate used should correlate to the level of project complexity.

5.6 PROJECT EXAMPLES

This section presents examples from two projects from two different agencies. The first example is from WSDOT, and the second is from Caltrans. Information on their risk-based estimating programs can be found at the following websites:

- WSDOT Cost Risk Assessment: http://www.wsdot.wa.gov/Projects/ProjectMgmt /RiskAssessment/
- Caltrans Project Risk Management: http://www.dot.ca.gov/hq/projmgmt/guidance_prmhb.htm

5.6.1 WSDOT Cost Risk Assessment Example

WSDOT is one DOT which has implemented risk-based estimating methods for large and small projects. WSDOT has a developed its own spreadsheet to handle Monte Carlo simulations without the need of additional software beyond MS Excel. It is an example of one tool that is used in practice and is available at the following website: http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/ under the link "self-modeling tool."

The Risk-Based Estimating and Management Model for Small Projects is a tool created by WSDOT to make the implementation of risk-based estimating easier. The tool allows a regular Excel user to enter project-specific information related to the cost, duration, and risks.

The model uses an Excel workbook labeled Risk_Management_Plan (RMP) to define the risk management strategies and the project cost/duration range and shape. The RMP workbook allows the user to input project data and risk information. The workbook performs the Monte Carlo simulation calculations for 10,000 iterations. This number of iterations is necessary to develop output data with statistical significance for the complexity of the typical transportation project. Due to the continuous evolution of the tools in this field, it is suggested that users download the latest version of this tool along with its user guide for the latest information.

Figure 5-11 shows a communication tool that WSDOT has developed from the output of the probabilistic risk-based estimates. WSDOT refers to Figure 5-11 as its "one-page" output. The one-page output is used to communicate project scope, benefits, risks, and costs to the project team and stakeholders. The document is concise and communicates the most relevant information. While concise, the document requires significant effort to prepare.

SR 704 / Cross-Base Highway Project

January 2006

I-5 to SR 7

Project Description:

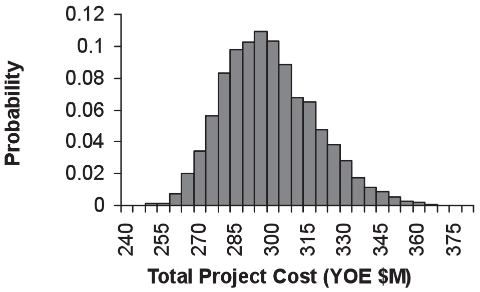
The Cross-Base Highway will provide a necessary link in the regional transportation system by connecting existing and future residential areas in mid-Pierce County and north Thurston County with two of the largest future employment sites in Pierce County, Fredrickson and Dupont. Cross-Base Highway will address the mobility deficiencies and level of service on existing SR 7, SR 512, SR 507, Spanaway Loop Road and 174th Street S by reducing projected traffic volumes and congestion with an alternative route.

CEVP® Schedule Range:

Construction Begins (Stage 1): 2007-2009

Project Complete (All Stages): 2015-2019

CEVP® Cost Range:



Project Benefits:

- Congestion Relief. The I-5 corridor, SR 512, and SR 7, along with county roads, will experience congestion relief and reduced delays as a result of this new project.
- Highway Safety. This new highway will be designed to modern safety standards with full-width lanes and shoulders. The remodeled interchange at Thorne Lane on I-5 will improve traffic flows and enhance safety.
- Environmental Benefits. This project will meet and exceed the latest environmental standards, including the development of a 358-acre habitat to protect and enhance the environment

Project Cost Range:

10% chance the cost < $273 Million

50% chance the cost < $294 Million

90% chance the cost < $322 Million

Project Risks:

- Traffic analysis may need to be revised, potentially resulting in design changes and increased costs.
- Changes to seismic design criteria or modifications to interchange design or alignment could increase bridge and structure costs.
- Increased use of consultant labor, due to WSDOT resource limitat ions, could result in higher design costs.
- Additional wildlife crossings may be required to provide adequate habitat connectivity.
- Acquisition of property may take longer and cost more than anticipated.
- Challenges to the project environmental documentation could delay the project and result in increased costs due to inflation.
- The price of asphalt may be higher than expected.
- Funding delays could impact the project completion date and result in higher costs.
- Higher than expected inflation rates could increase total project costs.

Financial Fine Print (Key Assumptions):

- Remaining funding for the project is provided separately for each stage. Full funding is available by May 2014.
- Project cost to complete (total estimated cost less funding to date), at 90% certainty, is $318 million.
- Additional funds (federal, state, regional and local) are needed to complete this project.

What's Changed:

- This project has not previously undergone a CEVP® analysis

Level of Project Design:

Low Medium High

January, 2006

Washington State Department of Transportation

Figure 5-11. Example of Probabilistic Risk-Based Estimate Output from WSDOT

5.6.2 Caltrans Probabilistic Risk-Based Estimate Example

Caltrans has developed a template for its probabilistic risk-based estimating, which is shown in Figure 5-12. The left side of the template contains the input, and the right displays the output. The input involves standard estimating inputs for contract item quantities and costs. When contract item quantities and costs are known, a deterministic value can be placed in the "likeliest" column for quantity or costs, or both. When there is uncertainty, the estimator can estimate the quantity or costs, or both, with a triangular distribution by completing the minimum and maximum costs. The same process is applied to the markups of time-related overhead and mobilization percentages. The output from the template is a range for total cost and a sensitivity analysis (tornado diagram) for the individual risks. The output also provides confidence intervals for the range of cost. For example, the cost with 80 percent confidence is $1,082,813 in the example provided. The Caltrans template provides a simple, one-page format for interpreting the inputs and outputs for a probabilistic risk-based estimate.

Figure 5-12. Example of Probabilistic Risk-Based Estimate Template from Caltrans

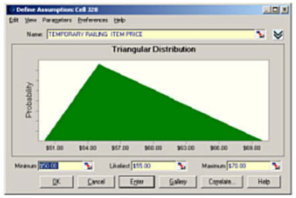
PROBABILISTIC STRUCTURE COST ESTIMATE

INPUT

[ ] GENERAL PLAN ESTIMATE   [X] ADVANCE PLANNING ESTIMATE

Revised - November 18, 2010

BRIDGE NAME:	CALIFORNIA AQUEDUCT BRIDGE - ALT 1	IN EST:	09/12/11
BRIDGE NUMBER:	42-0270	OUT EST:	09/19/11
TYPE:		DISTRICT:	06
CU:		CO:	FRE
EA:	06-0M250K	RTE:	198.00
PROJECT ID:		PM:	35.40
		DEPTH	
		LENGTH	262
DESIGN SECTION:	TLE	WIDTH	43
# OF STRUCTURES IN PROJECT :	2	AREA	11,222
		EST. NO.	1
PRICES BY :	RWP	COST INDEX:	297
PRICES CHECKED BY :		DATE:	
QUANTITIES BY:	M. Downs	DATE:	09/12/11



The Assumption Curves, unless noted otherwise, are modeled with a triangular distribution with the "Minimum, Likeliest and Maximum values."

			QUANTITY RANGE			ITEM PRICE RANGE			
	CONTRACT ITEMS	UNIT	MINIMUM	LIKELIEST	MAXIMUM	MINIMUM	LIKELIEST	MAXIMUM	AMOUNT
1	BRIDGE REMOVAL (PORTION)	CY		307		$575.00	$650.00	$700.00	$199,550
2	STRUCTURE EXCAVATION (BRIDGE)	CY							
3	STRUCTURE EXCAVATION	CY							
4	STRUCTURE BACKFILL (BRIDGE)	CY							
5	PERVIOUS BACKFILL MATERIAL	CY							
6	CIDH CONCRETE PILING	LF							
7	FURNISH PILING	LF							
8	DRIVE PILE	EA							
9	FURN PC/PS CONCRETE GIRDERS	EA							
10	ERECT PC/PS CONCRETE GIRDERS	EA							
11	STRUCTURAL CONCRETE, BRIDGE	CY		364		$850.00	$900.00	$1,000.00	$327,600
12	STRUCTURAL CONCRETE, BRIDGE FOOTING	CY							
13	STRUCT CONC, APP SLAB (TYPE N)	CY							
14	PRESTRESSING STEEL	LB							
15	BAR REINFORCING STEEL (BRIDGE)	LB		131,000		$0.90	$1.00	$1.20	$131,000
16	FURNISH STRUCTURAL STEEL	LB							
17	ERECT STRUCTURAL STEEL (INCL PAINT)	LF							
18	JOINT SEAL ASSEMBLY (MR =) > 2"	LF							
19	JOINT SEAL (MR = 1")	LF		92		$25.00	$35.00	$40.00	$3,220
20	SLOPE PAVING	CY							
21	MISCELLANEOUS METAL (BRIDGE)	LB							
22	MISC METAL (RESTRAINER - TIE ROD)	LB							
23	CONCRETE BARRIER (TYPE 732)	LF		512		$85.00	$95.00	$110.00	$48,640
24	REMOVE EXISITNG BARRIER	LF		512		$50.00	$60.00	$70.00	$30,720
25	DRILL AND BOND DOWEL	LF		72		$35.00	$40.00	$45.00	$2,880
26									
27									
28									
29									
30									
								SUBTOTAL	$743,610
	Comments		TIME RELATED OVERHEAD				5%		$37,181
			MOBILIZATION			5%	7%	9%	$58,794
			SUBTOTAL BRIDGE ITEMS						$839,584
	TRAFFIC WILL BE DETOURED		CONTINGENCIES				25%		$209,896
								SUBTOTAL	$1,049,480
	BRIDGE REMOVAL (CONTINGENCIES INCL.)	SF							

Notes

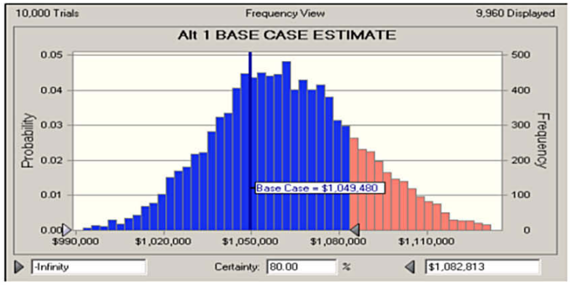
Highlighted cells represent the quantities and prices that are included in the model.
Base Case Estimate is the sum of the "Likeliest" Quantity multplied by "Likeliest" Item

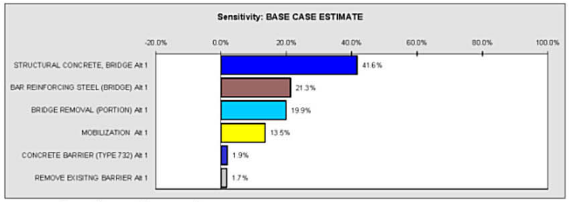
BASELINE ESTIMATE TO ASSUMED MIDPOINT OF CONSTRUCTION

BASE CASE ESTIMATE $1,049,480

OUTPUT

The estimate ranges generated below were prepared using Crystal Ball software. Crystal Ball software automatically calculates and records the results of thousands of different "what if" cases. Analysis of these scenarios reveals to you the range of possible outcomes, their probability of occurring, the inputs that most impact your model, and where you should focus your efforts.





Percentiles:	Forecast values
0%	$983,869
10%	$1,030,560
20%	$1,041,007
30%	$1,048,345
40%	$1,054,602
50%	$1,061,022
60%	$1,067,524
70%	$1,074,459
80%	**$1,082,813**
90%	$1,095,218
100%	$1,149,032

Recommended Range (70%–90%)

BASED ON THE ASSUMPTIONS USED TO CREATE THE MODEL, THE DES-STRUCTURE OFFICE ENGINEER RECOMMENDS THAT THE PROGRAMMING LEVEL BUDGET FOR THIS PROJECT BE DESIGNATED AT THE 80% FORECAST VALUE.

80% FORECAST VALUE = $1,083,000.00

***80% Forecast Value Escalated Budget Estimate to Assumed Midpoint of Construction**

Years Beyond Midpoint	Escalation Rate	Escalated Budget Est.
1	2.3%	$1,108,000
2	3.0%	$1,141,000
3	4.0%	$1,187,000
4	3.8%	$1,232,000
5	2.7%	$1,265,000

* Escalated structure cost is provided for information only, actual construction costs may vary. Escalated structure costs provided do not replace Departmental policy to update cost estimates annually. Escalation rate used are based on Global Insight data posted at http://www.dot.ca.gov/hq/oppd/costest/data.htm

80 % Forecast
BRIDGE COST PER SQUARE FOOT =
BRIDGE REMOVAL =

Bridge Cost per Square Foot and/or Bridge Removal costs modeled independently. Their 80% Forecast Values Provided for informational purposes only.

5.7 CHAPTER 5 REFERENCES

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CHAPTER 6

Inflationary Considerations

6.1 OVERVIEW

Programming the right number of projects for bidding and construction each year is a challenge faced by all DOTs. Projects can take several years to proceed through the process of planning, acquiring rights-of-way, and developing detailed engineering plans. Afterwards, the projects may have to wait for funding to become available. The typical DOT program budget will cover 10 to 25 years. Budgeting within such long time horizons requires assumptions about what the world will be like 3, 5, 10, or more years in the future.

The future cost of steel, cement, liquid asphalt, and diesel can be difficult to predict. Prices for these commodities have risen over time, but they have also experienced short-term increases and decreases within the same year. The art of budgeting for a construction program that spans 10 to 25 years is a challenge because of the price volatility in construction commodities. In addition, a boom in construction followed by a bust can change both contractor and supplier margins as markets move from being very tight to slack. For these reasons, and others not listed here, it is vital to account for inflation when preparing any estimates for a future project.

6.1.1 What Is It?

It is useful to distinguish between two concepts of inflation, monetary and material. Monetary inflation is primarily a result of national money supply considerations. Governments (the Federal Reserve in the United States) can produce a money supply sufficient to allow economic activity to take place, and this supply should grow in proportion to the growth in economic activity. There is normally a 1 or 2 percent inflation rate in a healthy economy. This type of inflation is often measured by some broad measure such as the Implicit Price Deflator or the Consumer Price Index (CPI), both produced by the Bureau of Economic Analysis (BEA) in the Department of Commerce. Historical monetary data adjusted for this type of inflation are called "real dollars" as opposed to "nominal dollars."

Cost of material inflation measures a specific industry's cost of labor and materials. This type of inflation is market driven: if there is a shortage of some particular type of economic input, the prices experienced by industries that use those inputs will rise. Due to changes in supply and demand of products in free markets, the price of commodities will not remain constant over time. Price changes, leading to inflation, occur for several reasons and can originate from either consumers or suppliers. For example, when the need for a product intensifies, the consumer is often willing to pay more for a product. As the price the consumer is willing to pay for the product increases, more suppliers become willing to sell the product, but only at the higher price. Alternatively, if suppliers should find their costs increasing, they will raise the minimum acceptable price at which they will sell their product. The result is a price increase. These same effects can be reversed, causing prices to fall, as well.

Product price fluctuations are not in themselves the result of inflation. Price volatility among inputs to highway construction causes substitution impacts, while overall or general inflation would have lesser or no substitution impacts. An index that tracks general inflation (affecting all prices) is one way to correct for the changes in overall prices over time, so it is valuable for correctly measuring costs in time series data when more detailed input price data do not exist.

Because DOTs want to understand the total change in prices for construction work, the term *cost escalation* is often used to represent the collective forces of supply, demand, and inflation that drive the net bid price changes DOTs experience. One accepted method for tracking cost escalation involves the use of indexes. By tracking all of these goods at once, DOTs mitigate the supply and demand movements that cause the prices of single goods to fluctuate and can observe a general increase or decrease in the cost of construction. It is this generalized increase or decrease in the cost of all goods that DOTs define as inflation or deflation.

6.1.2 Why Use It?

Having a clear definition and procedure for incorporating future inflation effects in estimates is of great importance to any organization and can improve estimate accuracy. Since the time between planning, scoping, design, letting, and construction completion can often be measured in years, a project's originally estimated cost can be significantly higher or lower than its final awarded price. A DOT that systematically underestimates the actual cost of its projects by failing to accurately account for inflation will hinder future project planning and financing.

Having a system for calculating and integrating inflation into estimates is vital for any organization. When there is no single system for DOT engineers or estimators to properly account for cost volatility, the possibility that price inflation will be accounted for multiple times, or not at all, in a project's estimate becomes a significant concern. Therefore, using a well-documented and standardized system for applying cost escalation helps ensure a more reliable DOT budgeting system. This will allow not only for current inflation to be properly accounted for in budget planning but, of equal importance, for changes in expected inflation to be systematically and properly addressed. Implementing a standardized system for modeling future costs also allows for sensitivity analyses by planning or budget offices, or both.

6.1.3 When to Use It?

Inflation is applied to all estimates prepared throughout the project lifetime. For example, estimates performed during planning, scoping, design, or letting phases, or some combination thereof, must all account for inflation. Inflation is incorporated in estimates by adjusting historical data to current dollar amounts. Additionally, indexing is then used to adjust cost estimates of projects planned to be executed at some future time. Depending on the specific technique, inflation could be added using a bid-based cost index, or a commodity-based cost index.

6.2 KEY INPUTS

There are a wide variety of inputs used to assess and measure inflation. Common measures of tracking inflation include the Consumer Price Index (CPI) and the Producer Price Index (PPI). Both are published by the Bureau of Labor Statistics (BLS), U.S. Department of Labor. These are national measures of inflation, and in select cases regional measures. Several DOTs have created their own indexes for tracking construction cost inflation using their bid data. The value of the index is recalculated at regular intervals such as weeks, months, or years with the new data being added to the data archives.

An index for measuring construction cost inflation is typically based upon a basket of goods and services—in the case of a DOT, the most frequent and costly purchases of materials for transportation work. Because DOTs are interested in the general price movement of the goods and services they procure, it is important for an agency to keep its basket of goods and services as consistent as possible. A change in a project's cost due to material costs, labor costs, and contractor margins are all factors that will be measured using this basket.

Many steps are involved in performing a forecast. The first step for the forecasting team is to understand the availability and limitations of the DOT data. Understanding and mastering the use of DOT data in this first step will profoundly influence all future steps in the process. It is essential to know the types of data collected by the DOT, the quality of the data collected, the consistency with which the data are collected, and the accessibility of the data from where they are stored. The forecasting team will need to know who collects the data, how they collect the data, what is being collected, and when and how often the data are collected and entered into the database before moving onto any further steps. How and what data are collected by the DOT will dictate which method(s) of analysis are available to DOTs for forecast modeling. The sections to follow present the next three stages of the forecast creation process: (1) data availability; (2) data collection approaches; and (3) analysis methods.

6.2.1 Data Availability

The data required could be available in various forms within an agency. However, if the data are deficient or cannot be found, a DOT may use external data sources. External data can be used as a substitute or in combination with internal DOT data.

6.2.1.1 Internal Data Availability Drives All Future Stages

The unit prices for in-place work include the contractor's cost for labor, materials, construction equipment, overhead, and profit margin. As a result, changes in material prices are masked within the in-place cost of a project. By tracking commodity prices and in-place costs, it may be possible for statistical models to isolate the impact from commodity prices on in-place costs. In an ideal situation, a DOT will electronically collect data containing specific information about work including project location, quantity, unit price, number of bidders, date of letting, and date work is performed. These important variables help a DOT understand which factors drive price changes. Highly specific and detailed information is good data for reliable forecasts. DOTs that use design-build project delivery approaches may find that their data are insufficient for producing a reliable cost forecast because they cannot isolate information specific to each type of work performed on the project, and it is not possible to separate construction cost from design costs.

6.2.1.2 External Data Availability

When internal data are lacking, DOTs can use external data sources as a proxy for their own cost data. External data may also be used in conjunction with DOT data to aid in understanding the division between material and labor costs when dealing with in-place cost data. DOTs can use third-party data as a proxy for information they do not collect internally. Much of these data can be found or purchased over the Internet. Some examples of external data sources can be found at the following websites:

- http://research.stlouisfed.org/fred2/series/GDPDEF
- http://www.bea.gov/national/index.htm
- http://www.referenceforbusiness.com/encyclopedia/Inc-Int/Index-Indexes.html

There are organizations that provide proprietary and non-proprietary construction market analysis and forecasting services. They employ macroeconomic experts who prepare construction-sector data. They generate econometric models that provide forecasts on numerous construction spending categories. Another source of third-party data comes from the U.S. Department of Labor's BLS. Its cost indexes track price changes for goods and services over long periods in history. BLS indexes exemplify the use of bottom-up data modeling. Each index is created using predefined data, and the predefined datasets act as basic building blocks that are compiled together to create a single index. The BLS's online databases along with other federal government databases are usually free and readily available. Other sources of data, such as the *Wall Street Journal*, may charge a subscription fee for their data. The Associated General Contractors of America (AGC) and the American Road & Transportation Builders Association (ARTBA) are other examples of organizations that provide such indexes. As forecasters familiarize themselves with external data sources, the difficulty will be in determining which datasets among the plethora available will best meet their needs.

There are indexes that are specifically relevant to the highway construction industry. The FHWA records and tracks its own bid price index (*Highway...* 2011). The FHWA has produced a price index for highway construction for many decades. However, the traditional method of collecting and reporting these data has been questioned and found wanting. The data used to produce the "Price Trends for Federal-Aid Highway Construction" are no longer being collected. At this time, the latest available cost index data from the old methodology are from the fourth quarter of 2006.

The FHWA has developed an improved cost index called the National Highway Construction Cost Index (NHCCI). The NHCCI is intended as a price index that can be used to track pure price changes associated with highway construction costs, to convert current-dollar expenditures on highway construction to real- or constant-dollar expenditures, and to enhance future cost estimation for better work programming.

The chosen indexing methodology is the Chained Fisher Ideal Index, and building this index involves two steps (*The Mathematics...* 2011). In the first step, the Fisher Ideal Index formula is used to calculate changes in aggregate price between adjacent periods using pay item bid quantity and cost data as inputs. This step is also an aggregation process. Calculated this way, changes in aggregate price are essentially the averages of quantity-weighted changes in the prices of the cost items for highway construction. In the second step, changes in aggregate price between adjacent periods are chained together through consecutive multiplication to form a time series of aggregate price indexes for highway construction as a whole.

The FHWA purchased a bid-tabs database from Oman Systems, Inc. (OSI) as the pay item database. These data capture state DOTs' web postings of bids submitted on highway construction contracts. As new data become available from the DOTs, OSI processes the data, and updates are provided to FHWA quarterly.

The OSI bid-tabs data represent a virtual universe of items of interest—the components of federally subsidized highway costs. The wealth of bid-tabs data allows the FHWA to derive a reliable indicator of highway construction costs that can be used for both general price comparisons and for DOTs to gauge changes in their costs against others in similar situations. The FHWA approach also eliminates pay items that may be defined too broadly to hold price-determining characteristics constant or have statistical properties that imply variable price-determining characteristics.

There are drawbacks, however, in using national data. National data gloss over regional and local factors, such as number of qualified firms or availability of mineral resources. Pricing changes in any single state can be affected by influences that are muted or lost in national prices and price indexes. One example of this is contractor competition, which has a strong influence on prices but has only a local or regional affect.

Figure 6-1 illustrates the disparity that can occur between state and national pricing. It presents asphalt data from 2002 through 2009. The figure shows that during certain periods of time, including 2006 and then again in the summer of 2008, national and Ohio prices moved independently of one another. These disparities may seem small; however, because asphalt is such a significant part of a DOT's budget, even small discrepancies such as those illustrated can make a significant difference in a state's inflation rate when compared to the national inflation rate.

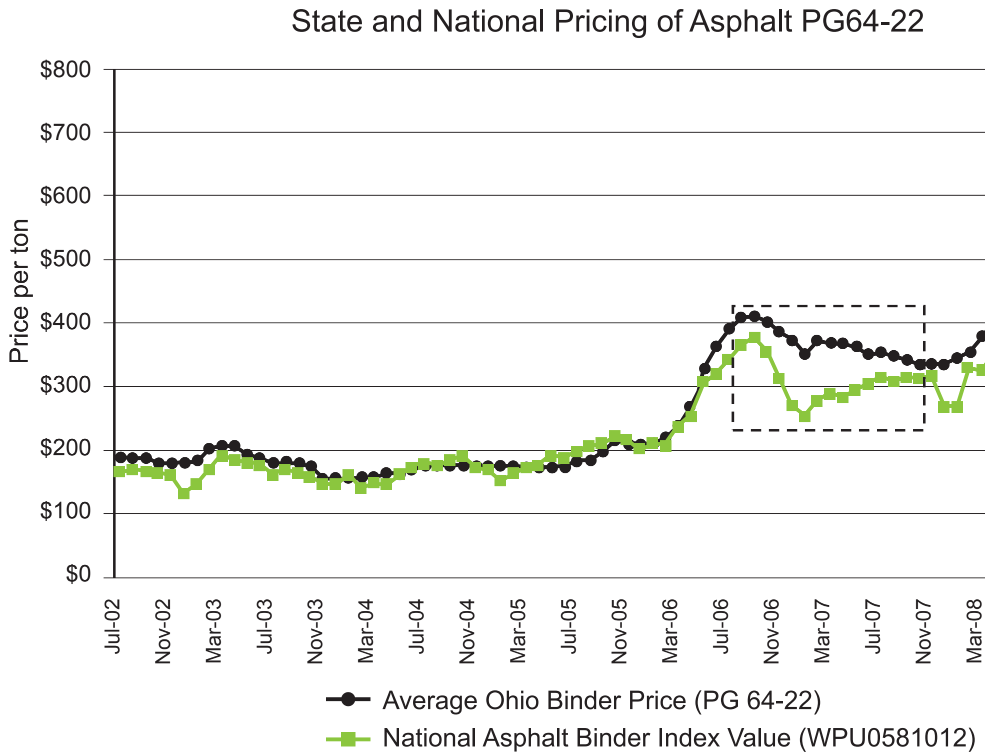

Figure 6-1. Asphalt Data from 2002 through 2009

6.2.1.3 How Much Data Should Be Collected?

Understanding historical price trends is a critical early step in price forecasting. A comprehension of the cause and effect principles influencing the construction industry is necessary to utilize these principles to look beyond the present. From experience, it is sometimes possible to use as little as 10 years of historical monthly data, equivalent to 120 points of information, for the purpose of statistical modeling. In contrast, annually released data will likely require many decades of historical data before any trends or cycles can be identified. When collecting historical data, the goal should always be to collect more historical data rather than stop data collection after the first trend is identified. There is no guarantee that the first trend found using a minimal amount of data will be significant rather than coincidental.

The amount of historical data necessary for forecasting purposes is dependent upon the frequency of data collection. Data are typically recorded daily, weekly, monthly, or annually. When data are collected more frequently, it is often possible to perceive relationships and patterns without having to reach into the distant past for information. In contrast, when there are long delays between recording periods, typified by annually recorded data, many events may influence the data between recording dates, which then blurs the ability to draw relationships between different data.

Finding relationships in the data is only one part of the forecaster's responsibility. Of even greater importance than finding patterns and trends is being able to use economic and business theories to justify and explain why the patterns exist. Finding a relationship, trend, or pattern without being able to explain or hypothesize its cause will preclude its rational use in forecast modeling. It is critical to understand why and how the data move and change over time in order to confidently believe that the pattern or relationship will continue into the future. It would be very dangerous and imprudent to use data that are not understood, even if the data perfectly track a DOT's construction price changes over time.

6.2.2 Conceptual Model Types

There are three types of models for understanding price movements and forecasts. Knowing which of these models the current data will support will save time and resources. The following models may provide insight on how a DOT may want to change existing data collection. Making changes to the data collection process today could allow for a wider array of modeling options in the future.

6.2.2.1 Program Model

A program model attempts to measure the influence that a change in a DOT's annual construction expenditure has on the price of goods and services. Program modeling relies on the assumption that the DOTs spending is a significant portion of all state road construction; therefore, changes in the level of the DOTs expenditure will cause pricing throughout the state to change. Program models can require as little data as the annual historical expenditure of the DOT and a highway construction cost inflation rate.

6.2.2.2 Project Model

Project models attempt to forecast the cost of a project based upon the unique attributes of the project. The DOT starts by entering attributes of a project, such as size, type, and location, into a model designed to generate a forecast of the project's cost in the future. These models require at a minimum historical data for each project attribute and the highway construction inflation rate. Project models may be ineffective for infrequently used project types for which there is little historical information. Project models rely heavily on internal DOT information.

As a next step, the DOT can aggregate the price fluctuation results from each project work-type model to create a single inflation rate for the entire DOT program. This requires creating project work-type models for each project work type. Once this is completed, the inflation rates of the work-type models are weighted and then added together to produce one price change rate.

6.2.2.3 Commodity Model

Commodity models attempt to forecast the changing cost of projects and programs using information about the prices for basic construction inputs including, for example, aggregates, asphalt binder, labor, concrete cement, diesel fuel, and steel. The advantage of using a commodity model is that historical and future prices and information for commodity products are often available free from many sources. The abundance of historical and forecasted commodity data means that models will have sufficient data to create credible forecasts.

Computer models using commodity data to model price changes do not need to rely completely on complex regression analysis. Inflation forecast models can be created using weighted measures of commodity data. Taking the percent of the total DOT's budget spent on goods composed of each commodity, it is possible to create a proxy for road construction inflation.

Many DOTs may use data from more than one of these levels to estimate future cost inflation. The Ohio DOT, for example, utilizes a combination of commodity data and program data to create a regression model that combines the advantages of program and commodity modeling to forecast price fluctuations. The Ohio DOT team also uses a weighted average model to calculate 5-year cost projections. Using both a regression model and a static model allows the Ohio DOT to compare the forecast results and build confidence in its projections. When multiple different forecasting models indicate the same future cost patterns, there is confidence in the predictions. Alternatively, using two different types of models is useful when economic circumstances make it inappropriate to use one model or the other. In January of 2009, the Ohio DOT chose not to utilize its regression model due to historically unprecedented changes in oil prices, which were significantly impacting the model's results.

6.2.3 Data Collection Approaches

Data collection relative to inflation forecasting can be either a top-down or a bottom-up approach. A brief discussion of each approach is provided below.

6.2.3.1 Top-Down Approach

A top-down approach begins with an examination of the overall system and then moves down to sub-levels for detailed analysis. As the work is broken down into smaller components, there are no limits or restrictions to the resulting look or appearance of the lower levels. This leaves the work at lower levels with less structure, giving rise to what is commonly referred to as black-box methodology because the techniques used at the sub-level are not always evident to the model user. The goal is to create results that explain or forecast the top-level numbers without being overly concerned about what goes on at the lower levels. An example of a top-down approach is to collect data on construction costs at a lower level of detail but only use total construction cost to develop the index.

6.2.3.2 Bottom-Up Approach

A bottom-up approach results from using predefined pieces at the bottom of the analysis to build the final system. This system works without regard to how the parts will work together as a whole in the end. Children's building blocks are an example of a bottom-up approach. At the lowest level, a single block, all components are predefined and cannot be altered by the user. With a bottom-up approach, the blocks are combined to make a larger object without concern for either how the blocks work together in the assembly or exactly how the larger object will appear at the end. An example of a bottom-up approach is to collect data on construction costs at a lower level of detail and create indexes for the lower level details such as excavation, asphalt pavements, and so on.

Other methods of data collection exist that can be considered variants of top-down and bottom-up approaches but may be less reliable. This applies to DOTs that do not have reliable internal data. When the DOT's data are unreliable due to a lack of data or poor data management, it may be necessary to use mostly or exclusively external data, which will bypass the top-down or bottom-up approach. How to apply the approaches outlined above is a matter of preference for each DOT. The next section presents several analysis types and analysis issues.

6.3 KEY ANALYSIS TOOLS

There are numerous analysis methods and references for identifying and assessing inflation. Three important tools are:

- Indexes
- Static analysis
- Regression modeling

6.3.1 Indexes

The cost index is any single number calculated from an array of prices and quantities over a period. In typical cases, not all prices and quantities of purchases can be recorded. Thus, a representative sample, or "basket of goods," is used. Conceptually, cost indexes are often thought of as tracking the cost of a consumer basket of goods, such as a set of line items in a typical project. The change in the total cost of the line items is then tracked by the cost index as the prices of the items in the basket change. Formulas like the Paasche Index, the Laspeyres Index, and the Fisher Index are used to calculate these prices indexes (Anderson and Damnjanovic 2007).

A cost index can be thought of as measuring a weighted average change in prices. While cost index formulas all use price and quantity data, they amalgamate these data in different ways. A simple cost index can be constructed using various combinations of base-period prices, current-period prices, base-period quantities, and current-period quantities.

State DOTs typically prepare a set of construction engineering design plans (PS&E), which include the construction plan, estimates of the type and quantity of materials, and specifications (grade, quality, etc.). These materials, along with other goods and services, become state-defined bid items. DOTs maintain long lists of these specific bid items, and the lists can often be found on DOT websites. Construction companies interested in the work then submit proposals based on the PS&E package. In these proposals, the price associated with each item includes the costs of materials and all additional costs for moving, placing, and installing the materials. The price also includes a component of profit and overhead associated with each item. Clearly in this usage, bid items include more than just the direct price of the item.

Price indexes in general combine prices of individual goods and quantity weights to track the percentage change in prices over time for a particular basket of goods. Implicitly, the quality of goods represented in a given timeframe is assumed to be constant. In the FHWA's NHCCI, individual goods on the bid-tabs data are represented by pay items for successfully bid contracts. Pay items are uniquely defined at the DOT level and so cannot be combined across states. During data preparation, each set of individual DOT data is processed before the data are used to create the national index, so a difference in state definitions is not an issue. For the FHWA's purpose, the relevant information that is included with each pay item is state, price, unit of measure, general expenditure category, and date the contract was awarded.

It is proper to think of the NHCCI as a construction (or output) cost index as opposed to an input price index. The NHCCI procedures are, therefore, in contrast to the procedures used by other price indexing agencies such as the BLS, which calculates the PPI for highways and streets.

Most cost indexes are normalized to a value of 100 in a base year to indicate the percentage level of the price index in each year relative to the base year. For example, a cost index value of 110 for a given year means that the price index is 10 percent higher in that year than the base year.

At the most rudimentary level, DOTs may use linear forecasting to account for price changes in the future. However, linear trend forecasting is not sufficient for calculating inflation. Linear trend forecasts use a single cost-escalation factor (i.e., 3 percent) for all years in the future to account for rising prices. Often, this rate is derived from the historical average of a cost index. Many forecasters create linear trends based upon indexes that are calculated by well-known and highly regarded institutions such as the BLS, which tracks national trends. Two BLS indexes include the well-known CPI and the lesser known but highly specialized Highway Street Construction Index (BHWY). However, the BHWY has been discontinued, replaced with an index on Other Non residential Construction (BONS) that covers a slightly wider industry category that includes work such as sewer and other heavy construction projects.

Figure 6-2 plots both the CPI and the BHWY over an 11-year period, and it demonstrates an example of the shortfalls of forecasting cost escalations using linear trends. Data for specific industries, including highway construction, tend to be highly volatile, making linear forecasting unreliable. On the other hand, data that are more predictable may have little to no relevance to highway construction, even though they are more tempting for undisciplined forecasters to use.

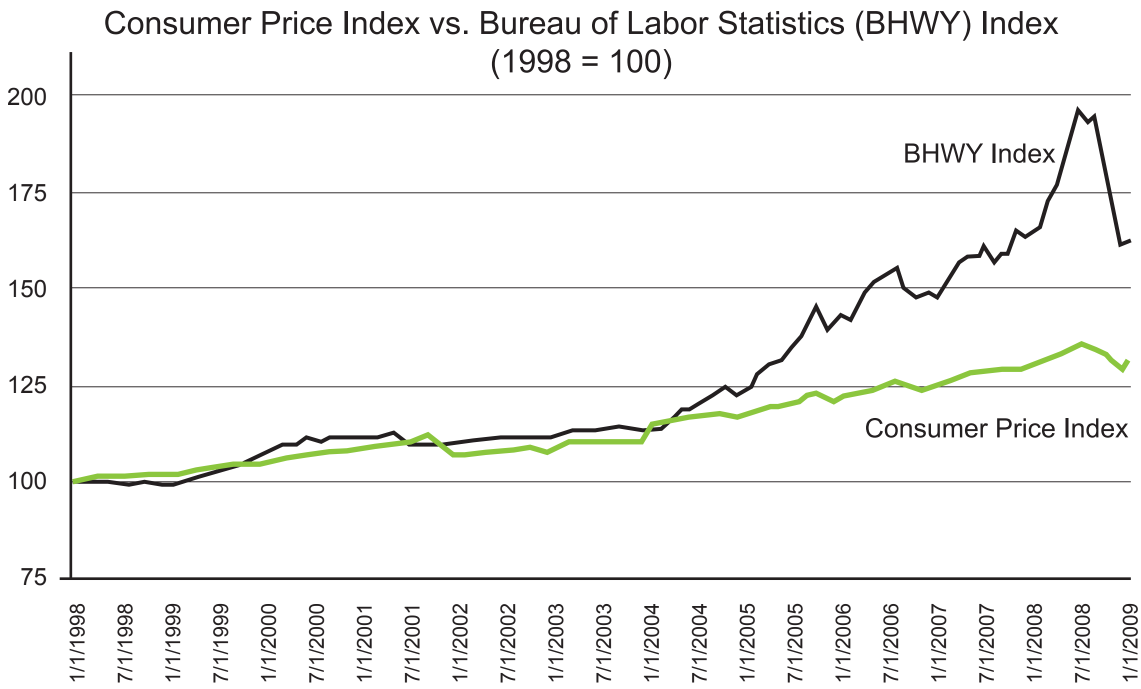

Figure 6-2. The CPI and the BHWY over an 11-Year Period

The BHWY Index specifically tracked highway construction costs nationwide, making it highly relevant to DOTs. Between January 1999 and December 2003, the average annual growth rate of the BHWY Index was 2.1 percent. Using the linear trend method of forecasting, a DOT in 2004 would have used 2.1 percent as the forecasted inflation rate for 2004 and beyond. In hindsight, this would not have produced good future estimates. The actual January 2004 to January 2009 average cost-escalation rate of the BHWY Index was over 10.3 percent, peaking at 22 percent for nearly 3 months in 2008.

In contrast, the CPI tends to be very consistent over time, allowing for greater success with linear trend modeling. Forecasting the CPI using the linear trend method, a forecaster would have had much more success forecasting the CPI growth rate between 2004 and 2008. From 1999 to the end of 2003, the average escalation rate was 2.5 percent, while from 2004 to 2008, the average rate was 3.1 percent. While there was clearly more success in using the CPI, the CPI tracks changing price of consumer goods such as DVDs, TVs, cars, and toasters, not highway cost changes. As a result, having such an accurate forecast is not so useful for DOT purposes.

6.3.2 Static Analysis

Every year, a DOT's list of projects constructed changes, resulting in changing quantities of construction inputs purchased, including asphalt, concrete, and steel. In a static analysis model, the inputs purchased are fixed across all years so that what is being measured is actually how much it would cost to build the exact same projects year after year. The Laspeyres Index (named for the German economist Etienne Laspeyres) also calculates in this manner. This analysis departs from the reality that each year's program is unique, causing the quantity and type of inputs purchased to vary on an annual basis. The advantage is that a static analysis allows the DOT to measure price changes without influence from changes in the DOT's program composition.

Table 6-1 illustrates one version of an aggregated static analysis table for the purposes of forecasting future cost changes. The column "Combined Weight" represents how much (expressed as a percent of the total program cost) of a DOT's budget was spent on each input during the base period. In this case, the base year used could have been 2008, the latest year for which there is complete information. Analyzing 2008 data allowed the DOT to know that 24.5 percent of its budget was spent on labor and 22.5 percent on construction equipment. A DOT can set its base period to any length of time. The base year simply needs enough construction data to be fairly representative of what the DOT considers an average year's worth of construction. If the data in the base period lack bid information on major work items, the base time period should be extended or shifted to another span of time. The base data and all data used in the analysis should be quantifiable; thus, lump-sum and as-per-plan type items are excluded.

As a result, this model works best when the composition of work in future years is similar to the composition of work in the base period. The question being answered by this analysis is not how much will it cost to construct next year's projects but rather how much would it cost to build the base year's projects all over again in a future year.

Table 6-1. Static Analysis Example

Component	Combined Weighting	2009	2010	2011	2012	2013
Labor	24.5%	3.8%	3.8%	3.9%	3.9%	3.9%
Construction Equipment	22.5%	2.0%	7.0%	8.0%	6.0%	5.0%
Materials (Steel)	13.5%	1.0%	8.0%	9.0%	6.0%	5.0%
Asphalt Binder	14.7%	2.5%	7.0%	9.0%	6.0%	6.0%
Materials (Aggregate)	10.9%	3.0%	6.0%	7.0%	5.0%	5.0%
Materials (Concrete) RMC	10.7%	2.5%	6.0%	7.0%	4.0%	4.0%
Materials (Misc.)	1.8%	2.5%	6.0%	7.0%	4.0%	4.0%
Materials (Paint)	1.3%	2.5%	6.0%	6.0%	3.5%	3.5%
Materials (Lumber)	0.3%	0.5%	0.5%	2.0%	3.0%	3.0%

Using Table 6-1 as an example, the portion of all construction money spent on steel will remain constant at 13.5 percent for each future year, the same percentage as calculated in the base year. In the forecast, the table predicts that the price of steel will increase by 1 percent during 2009, 8 percent in 2010, and so on. Lastly, the total weight of the construction program, or combined weighting, cannot exceed 100 percent. By multiplying the weight by the expected cost increase in each row and summing the columns, it is possible to calculate the DOT's overall cost-escalation rate. In this example, the 2009 and 2010 program rates of inflation would be calculated at 2.6 percent and 6.1 percent, respectively.

6.3.3 Regression Modeling

Many forecasts are created by the use of regression modeling. Regression models allow for statistical relationships to be made between a dependent variable and one or more independent variables. The dependent variable for the purposes of this guide is either the inflation rate or the cost index value that the DOT wishes to track and forecast in the future. The independent variables are the descriptive variables that will be used to calculate the dependent variable's value. Because it is necessary to have some form of a cost index before it is possible to know the actual inflation rate, most regression models are designed to predict the cost index at a specific point in time using independent variable values from prior time periods or from the current time period.

Only historical data are used when creating a regression model. Researchers on this topic essentially agree that cost changes among a series of construction inputs drive highway cost changes (Herbsman 1986, *Construction Costs Forecast 2007*, and Wilmot and Cheng 2003). Figure 6-3 is an example of a regression model created to model the Ohio DOT's cost index. The regression line was created using data from Table 6-2. The success of this regression model is dependent upon how closely it tracks the Ohio DOT's cost index. The six variables in this regression model were able to capture over 99 percent (adjusted R^2) of the movement in the actual cost index during the time period for which data are available.

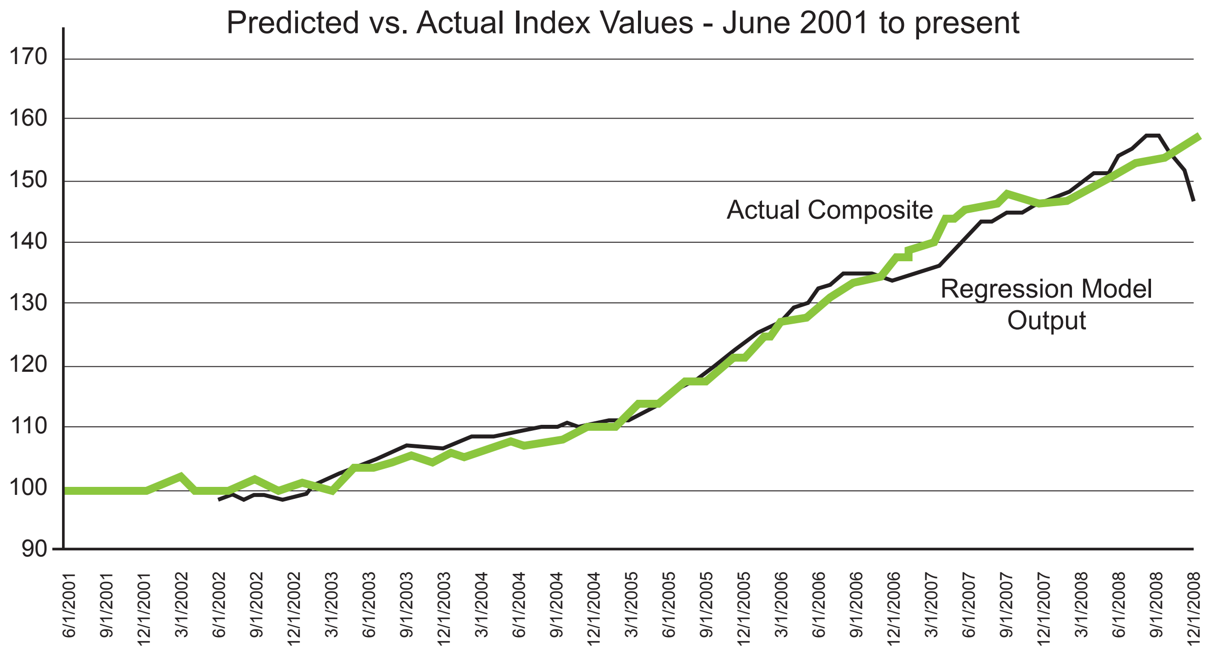

Figure 6-3. An Example of a Regression Model Created to Model the Ohio DOT's Cost Index

Once the model is sufficiently close to predicting the actual cost index, the next step is to use the regression model to forecast the cost index and ultimately the inflation rate. This is accomplished by estimating the future values of the independent variables in the model. When using commodity data as independent variables, such as in a bottom-up approach, it is possible to use the futures trading data provided by financial markets as a way to know the values of the independent variables in the future. Entering these future data into the model, the computer will calculate the future value of the cost index.

Table 6-2. Ohio DOT Regression Model—December 2008

No.	Independent Variable Name	Data Source
1	West Texas Oil Prices	*Wall Street Journal*
2	IronOre Index	National Bureau of Labor Statistics
3	PG 64-22 Asphalt Binder	Internal Ohio DOT data sources
4	Historical Ohio DOT Program Expenditures	Internal Ohio DOT data sources
5	Ohio Wage Rates	Ohio Contractor's Association
6	GDP	Bureau of Economic Analysis
Model Results:		
Root Mean Square Error	**Adjusted R^2**	
0.01042	0.9950 (99.50%)	

One important limitation to this approach is that predicted values of the independent variables must stay within their historical range of values. If an independent variable should move outside of its historical range, the model will no longer operate as effectively and may not be useful. For this reason, regression modeling works best under the assumption that the independent variables will not reach unprecedented highs or lows beyond their historical ranges. When such instances occur, market influences not present in the historical data can cause the model to lose its predictive power. This type of problem occurred in 2008 during a time of record-breaking $140/barrel oil prices. Regression models, including the Ohio DOT's, lost their predictive power in 2008, as evidenced by the diverging course of the actual composite and the regression model output lines in Figure 6-3.

The following sections identify additional ways in which regression models can be used to further explain cost escalations.

6.3.3.1 Regression Modeling: Whole Program

This method approaches the issue at the most aggregate level by examining the DOT's entire program. It applies a single rate of inflation for all projects regardless of each individual project's mix of inputs. Individual projects and project types are aggregated rather than separately queued.

6.3.3.2 Regression Modeling: Separate Inflation Rates for Construction and Maintenance Projects

This method acknowledges that maintenance projects are significantly different from other forms of DOT projects such that they warrant being treated separately for the sake of cost forecasting. By separately accounting for cost increases in these two areas, it may be possible for the DOT to better understand cost deviations in the future.

6.3.3.3 Regression Modeling: Separate Analyses for Mega Projects and All Other Projects

This method assumes that the largest projects in a fiscal year will have a significant impact on costs. Megaprojects can be either let as a single entity (a large bridge) or consist of the construction of multi-staged and multi-phased parts, as found when constructing a large urban corridor. Megaprojects can attract distant contractors and vendors that do not usually work in the state while excluding many vendors unable to bid large work due to prequalification restrictions or capacity. By forecasting the cost inflation for megaprojects separately from all other projects, the DOT may be able to better understand the cost risks of its overall program.

6.4 WHO DOES IT?

Each DOT must decide who will develop forecasting methods. This effort can be performed internally or through a consultant or some combination of the two.

6.4.1 Internal Agency-Developed Forecasts

The forecasts described above can be done using agency personnel or consultants. The primary advantage with an internal agency team resides in its institutional knowledge of the DOT. To take full advantage of this institutional knowledge, the team must be skilled in statistics, economics, and computer database management. Using a team approach allows for specialists in all three of these essential skill areas. Second, because forecasting is a subjective matter, it is important for multiple participants to be involved in order to challenge and test the theories and assumptions made by other members to ensure their validity. Performing this task internally will require significant dedication of the members involved, both in time and effort. Any analysis will only be as good as the data that are collected from internal and external resources. For this reason, members should be skilled at locating data sources.

The amount and availability of high-quality internal data is a critical determinant of whether to perform the analyses within the agency. Team members will need to have access to many databases from the DOT and other sources. DOT data must be accurate, current, accessible, and combinable with other datasets. Corrupted, incomplete, or incompatible data can stall internal forecasting efforts. For forecasting purposes, incomplete data are commonly recognized as data that lack date information. Incomplete data and datasets with poor documentation can render important data useless because their interpretation cannot be guaranteed to be accurate. Lastly, in order to combine data from many sources into one database for forecasting purposes, it is necessary to use a software program that can accept data in many formats and convert the data into a single compatible format. It is important for historical data to be recorded in a consistent manner so that data in one time period can be compared against data in another time period.

The greatest advantage to performing these forecasts in-house is that the staff members performing the analysis will gain valuable experience as they repeat the process over time. They will become experts in understanding cost changes and inflation for their specific construction market in a way that can only be accomplished by carefully studying the market over many years. An internal team will provide the DOT with a new depth and breadth of construction cost knowledge that would not exist if a consultant were hired for a specific project and presented the final forecast without detailed explanation of how the results were generated.

It is recommended that internal agency teams develop their forecasts as a result of consensus, which is not to be confused with a negotiation. Members should be allowed to debate which cost-escalation rates in each future year are most appropriate and why. As staffs approach a consensus on their world view of future commodity trends, this tends to narrow the variation in forecasted cost escalation, allowing for a predominant forecast to surface.

6.4.2 Consultants

Forecasting highway construction inflation is a challenging task. This makes the selection criteria for a suitable consultant an important and time-consuming process. Consultants perform a wide range of tasks for many clients; therefore, it is in their interest to use broadly defined or aggregated data. For this reason, consultants have a tendency to be very skilled in using national rather than regional or local data for forecasting purposes. A consultant's bias toward national data is problematic because price escalations for each DOT are often attributed to local or regional factors including competition, mineral resources, and labor availability. The sole use of national data in forming a forecast will likely overshadow these important regional and local variables, reducing the quality of the forecast.

6.4.3 Combined Internal and Consultant Efforts

A combination of both internal and consultant efforts can create efficiencies that allow for a best-of-all-worlds result. Agency staff can do preliminary work, providing local, regional, and state-specific data to the consultant group, which may have greater statistical expertise than the DOT's team. The result is a product that contains both the sophisticated statistical skills of the consultant with data collection efforts of the agency team for a reasonable cost.

6.5 CONSTRUCTION COST UPDATING FREQUENCY

The frequency of repetition is a matter of the DOT's institutional preference. During times when inflation is very volatile, it may be necessary to perform a forecast update much more frequently. Typical timeframes include the following.

6.5.1 Semi-Annually

Six-month intervals may be suggested as an upper bound because new data and new market developments are often reported in monthly intervals. The more data that are reported annually, the less useful 6-month forecasts become because of the limited amount of new data that are added to the model. One advantage to the 6-month forecasting interval is that it forces the agency team to constantly keep current on economic developments and provides the team with greater forecasting experience.

6.5.2 Annually

Annual construction inflation forecasts allow each forecast to benefit from new data. Typically, annual construction data are calculated at the end of each calendar year and published at the beginning of the following year. As a result, the timing of a DOT's annual update should coincide with the release of new data.

Regardless of the frequency of the updates, it is important that the forecasting team look back at its prior forecasts and compare its prior assumptions to reality. This allows the team to learn about which assumptions were right and which were wrong and why. Performing such reviews is critical for a team to improve its forecasting capabilities. Doing this requires detailed and specific documentation of the assumptions and theories used in creating each forecast.

6.6 SUMMARY

There are numerous methods for developing inflation percentages and sources that provide inflation indexes. As a result, this chapter described what inflation is and why and when it is incorporated into cost estimates. The chapter described the key inputs and the analysis tools used to derive inflation percentages. Finally, the two issues of who typically performs inflation forecasting processes and how often should they be updated were discussed.

Most estimates will require an adjustment for inflation. Unless the estimate has been recently prepared using current prices, and has been used for preparing the engineer's estimate, it will be necessary to account for inflation. This is true for most of the project phases in which the estimate is prepared, whether it is the planning, scoping, design, or construction phase. Every estimate has to include a percentage for inflation, whether prepared based on current data adjusted to forecast future costs or prepared using historical data adjusted to reflect current prices.

6.7 PROJECT EXAMPLE

Section 2.2.3.1.1 provides a project cost estimate example that was based on using a similar completed project. However, the similar project was constructed so the actual costs represent first quarter 2007 dollars for construction as shown in Table 6-2. This cost must be updated to current day costs such as 2010 dollars. A highway cost index can be used to assist in making this time adjustment. Table 6-3 includes a recent portion of a highway cost index. The base year for this index is 1987 with an index value of 100.0.

Table 6-3. Illustration of Construction Cost per Centerline Mile Based on Similar Project (same as Table 2-2)

ITEM DESCRIPTION CATEGORY	TOTAL COST $ × 1000 (early 2007 Cost)
Preparation	882
Excavation/Grading	5,560
Drainage/Storm Sewer	1,229
Structures	4,574
Pavement (bituminous)	12,926
Erosion Control and Planting	2,716
Traffic	5,937
Other Items	1,249
Mobilization	2,454
Total Construction	**37,527**
Cost per Lane Mile Calculation: **Cost per Mile—Construction = $37,527,000/(59.72 – 54.75) = $7,550,000 per centerline mile in 1st Quarter 2007 Dollars**	

Source: Minnesota DOT Training Course

Descriptor:
- City 1 on Trunk Line X to Interstate-Z Interchange

Location:
- County T
- Milepost 54.75 to Milepost 59.72

Existing:
- Two-lane undivided highway

Definition:
- Add two lanes between Trunk Line Y and Interstate I-Z to create a four-lane divided highway
- Replace one bridge over creek
- Remove and replace bridge at Trunk Line X and Trunk Line Y
- Build two new bridges at Road 3 and the Trunk Line X and Interstate I-Z interchange
- Implement full, partial, and modified limited access along the project limits
- Add turn lanes and acceleration lanes at various locations
- Resurface existing lanes

Current Estimate:
- The construction cost-estimate summary above was prepared when letting Project B for construction. Costs reflect early 2007 dollars.

Table 6-4. Highway Cost Index (Base Year 1987 = 100.0)

YEAR END	COMPOSITE INDEX VALUE
2000	133.91
2001	141.61
2002	140.73
2003	151.60
2004	149.61
2005	167.97
2006	197.10
2007	212.88
2008	234.22
2009	225.32
2010	227.40

The construction costs for the reference project can be adjusted to 2011 dollars by multiplying this cost by the rise in the index value between 2007 and 2011. The calculation is as follows:

Cost Increases Multiplier = 2010 Index Value/2006 Index Value or 227.40/197.10 = 1.154 or .154

Using this calculation of the cost increase the total amount of inflation added to the reference project would be:

Cost Adjustment 1st Quarter 2007 to End of 2010 = \$7,550,000 x .154 = \$1,163,000

The total cost for construction of the reference project in 2010 dollars would be:

Construction Cost \$2010 = (\$7,550,000+\$1,163,000) x (MP 59.72 - MP54.75) = \$43,300,000

The next step is to account for future inflation. This requires two inputs: 1) the mid-point of expenditure for construction; and 2) the future percent inflation rate. The mid-point of construction can be determined by using the expected letting date plus half of the estimated construction duration for the project. In this example, the mid-point of construction is estimated to be mid-2015. The inflation rate can be estimated using recent history from the highway cost index or provided by the agency based on an economic projection. This later approach is typically provided through agency economists. When using the index, the estimator must be careful in selecting years from which to develop a historical percentage. For example, if the last four years were used as the basis for calculating the average percent inflation, this number would be derived from the following formula:

Compounding Factor = $(1 + i)^n$

where the compounding factor is the index multiplier from the index value at end of 2010 divided by the index value at the end of 2010 or 1.154 as shown above, n is the number of periods or years in this example, and i is the average interest rate over the period. Thus, in this case the interest rate i would be calculated as:

1.154 = solving for i = 3.7%

This percentage appears to be influenced by an increase in the index value in 2007 and 2008 before U.S. economic growth slowed. If the same calculation was made for 2009 to 2010, then the interest rate would be:

227.40/225.32 = ; solving for i = 0.9%

If the inflation rate is expected to increase at about 1% per year the construction cost in 2017 would be:

Construction Cost mid-2017 = \$43,450,000 × $(1 + 0.01)^{4.5}$ = \$45,440,000

It is highly recommended that the estimator obtain this input from economists with the agency.

6.8 CHAPTER 6 REFERENCES

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CHAPTER 7

Letting Strategies for Cost Control

7.1 OVERVIEW

As a group, those projects in the advanced stages of design that have a target date for a construction tender are known as an agency's letting program. Management of the letting program is a challenge (*Statewide...* 2004). The most significant challenges are programming available funds and needing to satisfy many different constituents. The scheduled project letting date or the letting date for a group of projects has a significant impact on the quality of bids received and how well the bids compare to the projects' final PS&E estimate prepared by the agency. To improve project cost control and the validity of estimates, a DOT can use short-term and long-term letting strategies (Prasad 2006). Long-term strategies are fundamental changes in the bid letting process to include timing of lettings, balancing of lettings, and packaging of projects for letting. Short-term strategies include actions such as allowing contractor-selected packaging of projects, contractor self-imposed award limits, flexible notice to proceed, and contractor construction alternates.

The magnitude of a contractor's bid to construct a project represents the sum of the following:

- The estimated cost to actually perform the work
- Consideration of the economic environment
- An allowance for perceived risk

The risk component of a bid is increased when there is not sufficient time to carefully prepare the project estimate. Contractors understand competition, and when settling upon a final bid amount, they judge the competition in terms of the number of assumed bidders and known capability of those bidders. Nonetheless, other factors, like the need to deploy company assets, particularly costly equipment, and the opportunity for future returns, also drive bid prices. Actions by a DOT that reduce contractor risk and increase competition result in lower bid prices. Therefore, an appreciation of how all such price drivers interplay and influence bid prices allows a DOT to better structure its letting program.

7.1.1 What Is It?

Letting strategies that recognize the market and macroeconomic factors impacting project bid prices can lead to lower offers to construct a project. However, many constraints govern state letting strategies. DOTs have direct control over project design and specifications and the allocation of project risk, but there are other factors external to the project's physical features that affect bid prices. These are conditions beyond the DOT's direct control and can generally be termed macroeconomic (prices of material and labor) and market condition (contractor resources and capability) factors (Warsame 2006). By recognizing the effect of such factors on bid prices and then carefully structuring the schedule of project lettings and the number of projects bid in a specific letting, as well as providing contractors the opportunity to balance their workloads, a DOT can create a more competitive bidding environment.

7.1.2 Why Use It?

There are only a limited number of competent construction companies capable of bidding on any project, and even those contractors operate under constraints based on the availability of equipment, personnel, and materials; their backlog; and their need for future work. By carefully structuring their letting strategies, DOTs can encourage the maximum number of qualified contractors to submit bids that represent the fair market price for performing the work.

7.1.3 When to Use It?

To obtain the best possible project quality and price, a DOT should regularly evaluate the capabilities of the construction industry and material suppliers with the objective of balancing the agency's letting schedule with industry capacity. Projects must be packaged considering (a) the type of work, (b) the total cost of work, and (c) the distribution of work by geographic location. The letting program can usually be structured in a manner that balances program needs with the economic environment of the construction industry. Letting schedules should reflect the market capability to handle the work; therefore, before a project, particularly a major project, is included in the letting schedule, the agency should carefully evaluate the capability of the construction industry—prime contractors, subcontractors, and suppliers.

7.2 KEY INPUTS

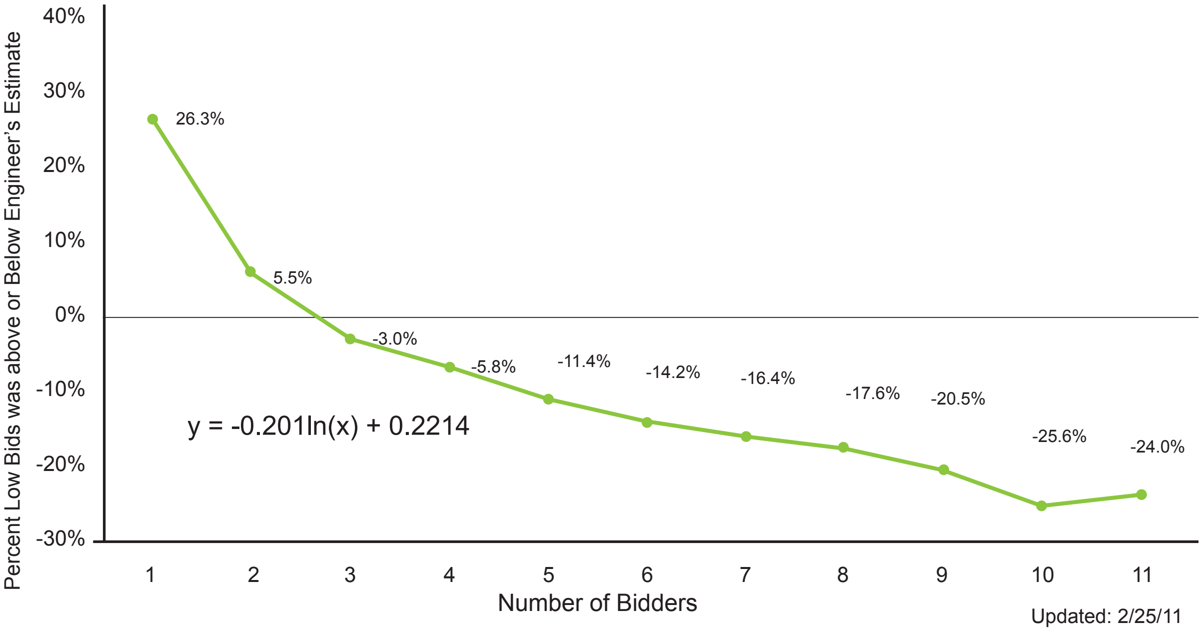
In game theory and similarly in decision theory literature, the term *auction* is often used in reference to a letting. A DOT can be considered a seller with a product that has no standard value, and it is the bidders who define the project's value based on their view of the marketplace. That value will depend on demand and supply conditions at a specific moment in time, but value is also influenced by prospective market developments and the macro-environment. The situation can moreover be considered from the contractor's perspective as a buyer who wishes to purchase the opportunity to build a project, in a marketplace that includes multiple owners offering a variety of projects. While there are usually a number of contractors seeking work or completion of a project, there is at the same time a mix of projects being offered by multiple owners. A DOT must recognize that it is not the only owner engaged in letting work. Therefore, the key input is an awareness of the marketplace.

7.2.1 Historical Bidding Studies

Many intuitive assumptions concerning the use of auctions to sell or obtain services have been proven using statistics and mathematical formulation of auctions models.

7.2.1.1 Competition Matters

Increasing the number of bidders reduces procurement cost (Holt 1979; see Caltrans data in Figure 7-1). As the number of bidders approaches infinity, the price tends to the lowest possible valuation (Holt 1979). Gaver and Zimmerman (1977) found that bids are reduced about 2 percent each time the number of bidders is increased by one. On the other hand, quality contractors recognize that an increase in the number of bidders minimizes their profit opportunity. In fact, Rothkopf (1969) demonstrated that in the case where each bidder has the same estimating accuracy and identical cost, profit decreases rapidly at first and then monotonically as the number of bidders increases. Profit "decreases approximately as the square of the number of bidders" (Rothkopf 1969).



Source: From OE Database FY 1993/1994 through FY 2010/2011, All projects, 10811 projects evaluated

Figure 7-1. Caltrans Comparison of the Low Bid vs. the Engineer's Estimate Based on Number of Bidders

7.2.1.2 Information Matters

An agency can reduce contractor bid amounts by publicizing any information it has about the true value of the work. Milgrom and Weber (1982) stated, "Resolving uncertainty by releasing information reduces the risk premium demanded by bidders." However, "For risk-averse bidders, it is not generally true that *partially resolving uncertainty* reduces the risk premium" (Milgrom and Weber 1982). The perception of risk has a significant effect on bid prices, and partial resolution of uncertainty can either increase or reduce a risk-averse bidder's average willingness to reduce a price. Risk aversion becomes extremely important in the case of projects that have a large monetary value relative to the contractor's assets; in such cases, solvency of the bidding firm becomes an issue (McAfee and McMillan 1987).

7.2.1.3 Project Risk and Contingencies

On federal-aid highway construction projects, the FHWA requires the use of standardized change condition clauses, 23 C.F.R. 635.109 ("Standardized..." 2006 and "Standardized..." 2011). These contract clauses were developed to provide a procedure for fairly compensating contractors for changed conditions; still, contracting agencies should use their best efforts to identify and allocate risks fairly in project proposal documents.

By following a policy of full disclosure and by assuming all unusual risks, an agency will improve its own estimate accuracy and also that of the bidders. DOTs should inform contractors about all project uncertainty so they are aware of risk elements (Crosby 1965). Contract relief should be granted for onerous risks. If onerous risks are laid on the contractor, bids will include large contingencies. When the agency assumes extraordinary risks, the contractor contingency/profit will decrease.

7.2.2 Macro-Environmental/Market Conditions

The number of available jobs in the market at a particular time can significantly affect competition (Wilmot and Cheng 2003). A study of San Francisco Bay Area Rapid Transit (BART) contracting experience provides a clear view of how the project contract requirements together with a contractor's work volume impact pricing. The BART contracting study by Gaver and Zimmerman (1977) focused exclusively on heavy construction contracts and did not include contracts to procure trains or train-control equipment. The model used in the study had the value of a firm's bid for a project as its dependent variable, while the independent variables were proxies for cost and the number of bidders for a contract. It was found that bids were higher when:

- The amount of BART work that a contractor already had under contract and in progress increased. As a firm approaches full capacity, its expected costs rise, as do its bidding prices.
- Contract-specified construction duration was limited. Longer-duration projects permit greater opportunities for better utilization of crews and equipment, including across multiple projects.
- The bidding firm's size was smaller. Marginal costs typically decrease with increased firm size. Factors such as scale economies, production technologies, ownership of materials' manufacturing plants, and location of plants relative to project site can affect a contractor's costs significantly.

Commenting on these findings, McAfee and McMillan (1987) noted that the first item listed "reflects the effect of a bidder's opportunity cost" and the next two items "affect production costs if it is presumed respectively that faster production is more costly and that there are economies of scale." It has even been proposed that agencies need to lengthen project construction schedules by as much as 25 percent to attract more competitive project bids. Such a general statement is not supportable, as the cost effect of a project schedule is really controlled by three factors:

1. Is it necessary to use more costly construction processes to achieve faster production (McAfee and McMillan 1987)?
2. Will a longer duration provide opportunities for spreading cost across concurrent projects (Gaver and Zimmerman 1977)? (This comes into play when there are multiple projects in an area.)
3. Does an agency have a high progress-payment rate? And how are mobilization payments spread across the project duration (Gaver and Zimmerman 1977)?

7.2.3 Letting Strategies

An agency's letting strategies should be structured to increase completion and encourage responsive bids. These objectives can be achieved by:

- Attention to the scheduling of project lettings and the lettings scheduled by competing agencies.
- Balancing of projects in a letting.
- Packaging of projects into proposals.
- Allowing contractors to selectively package projects.
- Permitting contractors to impose award limits when bidding multiple projects.
- Giving contractors the flexibility to specify project start dates.
- Seeking bids on alternate designs.
- Using price adjustment clauses to shift business risk.

7.3 STRATEGIES TO IMPROVE BID RESPONSIVENESS

A DOT's letting program is a pool of projects that are in an advanced stage of design. The PS&E is substantially or 100 percent complete for those projects in the letting program, and at this stage, the project is assigned a target date for letting. DOTs have processes for developing their letting programs. These processes are influenced by federal and state requirements, input provided by various agencies and the public, and capital budgets for funding projects (*Statewide*... 2004). How a project is scheduled for letting is a process typically built around go–no go checks or filters. The first and most important filter is design completion to include right-of-way acquisition and environmental clearance. The second filter is funding availability. The third filter is consideration of constraints. These can include geographical distribution of projects, project type, or other administrative issues. While all these criteria must be met before a project is placed on the letting schedule, it must be recognized that timing of when a project is let for bid affects the bidding competition and contractor pricing of the work. Consequently, it is imperative that DOTs consider market conditions when scheduling a project for bid.

7.3.1 Scheduling of Projects for Bid

The number of projects let at a particular point in time, together with the amount of work that is already under contract and engaging contractors for some period in the future, are market conditions that can significantly affect competition. DOTs have long recognized that the timing of the letting is a factor influencing the bid price, mainly due to too many or too few projects let across a time frame. Contractor responsiveness to the timing of a letting is very much a local phenomenon. For example, one agency found that contracts let in the fourth quarter of a fiscal year were likely to have higher bid prices compared to those let earlier in the fiscal year (Wilmot and Cheng 2003), while another agency received better prices in the late fall and winter. Thus, DOTs need to carefully monitor contractor responsiveness based on seasonality.

7.3.1.1 Scheduling Considerations

An agency will receive the best bid prices when contractors are in need of additional work. The corollary of this is also true—contractors will raise their prices when they have a backlog. Consequently, agencies should attempt to schedule project lettings when numerous contractors are actively seeking new work. The factors agencies must consider when scheduling projects for letting include:

- Amount of construction projects/work coming to bid by competing agencies. Florida has a statewide construction database that agencies can use to avoid bid letting conflicts.
- Amount of work currently under contract by the pool of potential bidders.
- Seasonal differences in competition. In some locations, late fall or winter lettings produce more competitive prices as contractors seek to build backlog for the next work season. This is especially true in the case of single-season projects.
- Projects that can be completed in a single season.
  - Single-season projects: need to be let so that construction will not be forced into a second work season. If a project is let at the wrong time of year, bid prices will reflect a two-season job.
  - Timing restriction projects: bridge work with in-stream restrictions or no-work periods during bird or animal nesting/mating seasons.
- Estimating capacity of the regional contractors. Contractors have finite estimating capability. As a result, when a larger number of projects are offered in one letting, competition is reduced because individual contractors will not have the capability to bid all of the projects that might otherwise draw their interest. This is especially true if all of the projects are of the same type, for example, bridge or paving.
- Provision of sufficient time between the availability of plans and the letting date. This is necessary so that contractors can properly review the project requirements and develop their approach to the work.
- Early notice of major projects. This provides contractors the opportunity to schedule their estimating resources for these more demanding efforts. It can be advantageous to make phone contact or to send electronic notices to suppliers and specialty contractors beyond the state or region. Figure 7-2 below, announcing a major project 6 months before the letting, was taken from the Iowa DOT website.
- Non-critical projects. These projects should be deferred to a time when there is a potential for improved competition.

Message of January 20th 2011 08:26 AM CST EST

US 34 MISSOURI RIVER BRIDGE

The Iowa Department of Transportation will be letting a contract for the construction of a bridge on US Highway 34 over the Missouri River in Mills County Iowa. The structure will be an approximate 3276' x 86' continuous welded plate girder bridge with pre-stressed concrete beam approaches. The welded plate girder unit includes two spans of 392'-6" and one of 515'-0". The pre-stressed units include fifteen spans of varying lengths.

It is anticipated that plans and estimating proposals will be available on May 17, 2011 with a bid deadline of July 19, 2011. Prequalification as a bridge contractor will be required to bid as a prime contractor. Interested contractors should contact the Office of Contracts at 515-239-1414 or dot.contracts@dot.iowa.gov to become prequalified.

Figure 7-2. IADOT Project Letting Announcement

7.3.2 Balancing of Projects in a Letting

Lettings should be coordinated based on the availability and capacity of contractors. Most contractors have limited estimating capability. Therefore, contractors may be forced to limit the number of projects they bid if an agency includes a large number of similar projects in one letting.

7.3.2.1 Number of Bidders' Effect on Prices

It is well understood that a greater number of bidders competing for a project will yield lower bid prices (see Figure 7-1). The results from a calibrated simulation conducted by Texas A&M researchers found that (with all things being equal) if there were eight bidders, the lowest predicted bid would be approximately 25 percent lower than the lowest bid with only two bidders participating (Damnjanovic et al. 2009). The Florida DOT found that when it received four or more bids for a project, the low bid was closer to the department's PS&E estimate (Damnjanovic et al. 2009).

A study of Texas DOT unit bid prices found a similar result at the unit price level. The results were consistent over the years, though the magnitude of the difference varied by year (Figure 7-3).

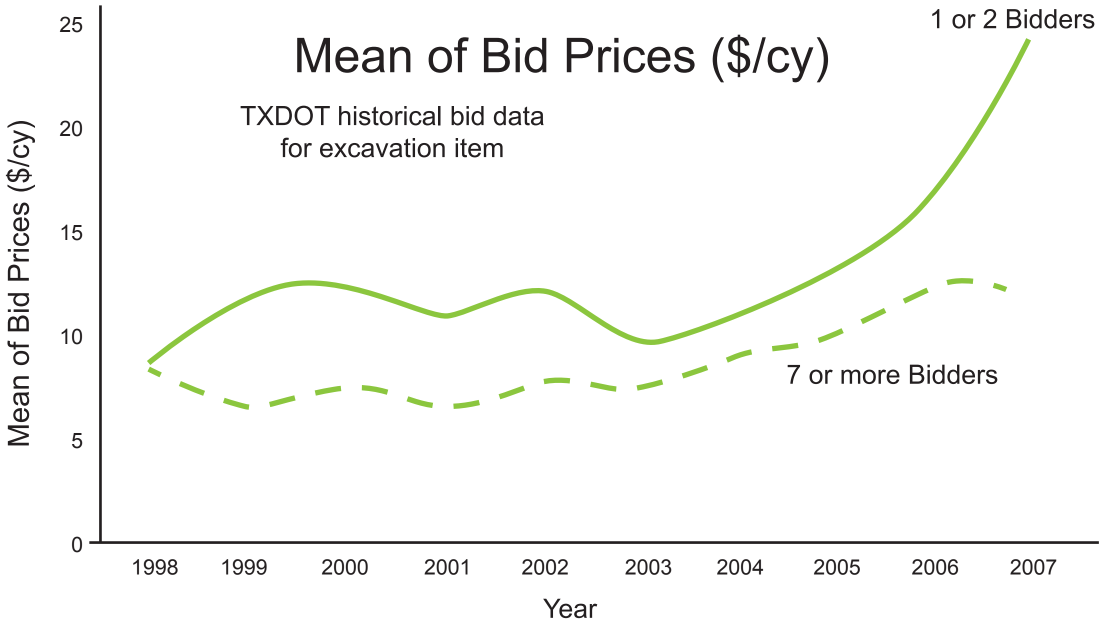


Figure 7-3. Effect of Number of Bidders on Average Unit Price (Damnjanovic et al. 2009)

7.3.2.2 Seasonal Considerations

When an agency includes a large number of similar projects in one letting, there is a risk that one contractor might be awarded more work than it can complete, while other contractors are left with little or no work for the construction season. Therefore, agencies should spread the letting of their major projects over several lettings. In addition, agencies should consider the order in which projects are let for an upcoming construction season. It is often advantageous to let larger projects first. Then, smaller projects can be scheduled for later lettings when contractors are trying to fill holes in their work schedules.

7.3.2.3 Market Conditions

To effectively schedule projects for construction, letting agencies should evaluate local market conditions for the availability of resources (Damnjanovic et al. 2009). The key is to look ahead at the letting schedule and move projects to future lettings or create additional lettings to spread out the work. Such actions can reduce cost without reducing project scope. Damnjanovic et al. (2009) ranked better planning of lettings with consideration of market conditions in the top 10 of programmatic ways to reduce project cost.

7.3.3 Packaging of Projects into Proposals

It is desirable to package projects to make them as attractive to bidders as possible, particularly in areas with limited competition ("Packaging…" n.d.). Sometimes it is necessary to consider the packaging strategies early in the development process so that environmental commitments, ROW activities, funding availability, and funding constraints may be accommodated in the project packaging. These constraints need be coordinated to provide the DOT with the maximum flexibility in the combination process. There are several packaging tactics agencies can use to increase competition and the receipt of responsive bids:

- Project packages should match contract size to local contractor capabilities. This sometimes involves breaking large projects into smaller packages. Projects with a large monetary value can eliminate small local contractors from the bidding because:
  - They have no interest in building parts of the larger package as a subcontractor.
  - Bonding larger contracts is difficult.
  - A large contract may threaten the firm's solvency.
- Project packages should seek to increase the unit quantities of the major cost items since unit bid prices typically decrease as the quantities increase. Large work quantities decrease unit prices because the contractor is able to spread the fixed costs, such as mobilization and traffic control, across more units of work (Knutsonet al. 2009).
- Projects should be packaged or bundled by type of work and geographical location in order to provide the contractor operational efficiencies.
- It is sometimes advantageous to combine projects that typically would receive only one bid with other similar projects in the same area. This technique encourages contractors to bid on projects they would not consider if the projects were packaged singularly.

The Missouri DOT and Iowa DOT guidance for packaging of projects is presented in Appendix 7A.

7.3.4 Contractor-Selected Packaging of Projects

Because of the numerous factors that come into play, it is difficult in many cases for an agency to determine the best packaging of projects that will induce contractors to bid competitively. Smaller contracts may attract more competition because they allow smaller contractors to compete; however, bundled proposals allow contractors to create an economy of scale. Consequently, bundling allows an agency to award the pooled projects at a lower cost than the estimated sum of the individual projects.

To accommodate both small and large contractors, some agencies allow contractors to selectively bundle projects to encourage a more responsive offer. This technique allows small contractors to bid on small projects but does not require them to bid on the large packages that are greater than their capability. At the same time, large contractors can compete for large packages without the risk of being awarded a single small project that would not be economical given their internal overhead cost structure and manner of project staffing.

Projects that can be bundled for bidding can be predetermined by the agency or done solely by contractors at the time of bid submission. If predetermined by the agency, contractors can only combine the designated projects. The agency predetermines permissible projects and offers those specific projects both as individual proposals and as an optional combined proposal. The award decision by the agency is based on least cost as determined by considering the total cost of awarding the individual proposals separately versus the cost of the combined project proposal.

Allowing contractors to select combined packages that fit their capabilities can increase competition. In cases tried to date, the available combinations all include work of a similar nature—bridges, culverts, or paving (The Virginia DOT has bundled bridge projects and culvert projects geographically and by type of work).

7.3.5 Contractor-Imposed Award Limits on Multiple Projects

Sometimes contractors will limit their bidding because they only have the resources to handle a specific amount of work. Bidding on most DOT projects requires a bid bond that guarantees the contractor will enter into a contract if determined to be the lowest responsive bidder. The bid bond also guarantees that the contractor will provide required payment and performance bonds (Knutsonet al. 2009). Bonding companies (sureties) evaluate contractors very carefully and limit a contractor's capacity to do work by providing bonds based on the contractor's financial capability. As a result, contractors cannot risk bidding on multiple projects that might, in the case of being successful on several, result in exceeding their bonding capacity. The bonding capacity issue forces contractors to bid a mix of projects that (assuming sum of awarded contracts) will still be within their surety assigned limits. This poses a dilemma for DOTs, as it limits project competition because qualified contractors do not submit bids on some proposals for fear of being the successful bidder of too many projects.

To reduce the risk to the contractor of obtaining too much work in a letting, some agencies allow the contractors to specify a maximum dollar amount of awarded contracts that the contractor will obligate itself to complete at the time bids are submitted. This limitation can be either by allowing contractors to establish a limit with the agency prior to the letting or by having the contractor include a limit with the bids. Requiring contractors to establish their own award (contract dollar) limit with the agency prior to the letting allows the agency to resolve any questions about the contractor's limit prior to the submittal of bids.

A self-imposed limit by the contractor can limit the total dollar volume of work awarded to the contractor in a letting or the number of contracts awarded to the contractor. Ideally, the agency should allow contractors to limit themselves to individual contracts or groups of contracts they would accept if judged the low bidder rather than having an overall limit on their award for the letting (see Figure 7-4).

Contract Number: DO00017 Page 93

*** AWARD LIMITS ON MULTIPLE PROJECTS ***

It is the desire of the Proposer to be awarded contracts, the value of which will not exceed a total of $____, for those projects indicated below on which bids are being opened on the same date as shown in the Proposal Form. Individual projects shall be indicated by placing the project number and county in the appropriate place below. Projects not selected will not be subject to an award limit.

______________________ (Project Number)	______________________ (County)
______________________ (Project Number)	______________________ (County)
______________________ (Project Number)	______________________ (County)
______________________ (Project Number)	______________________ (County)

* If a Proposer desires to limit the total amount of work awarded to him in this letting, he shall state such limit in the space provided above in the second line of this form.

It is agreed that in the event that I am (we are) the successful bidder on indicated projects, the total value of which is more that the above stipulated award limits, the Board of Transportation will award me (us) projects from among those indicated which have a total value not exceeding the award limit and which will result in the best advantage to the Department of Transportation.

____
**Signature of Authorized Person

** Only those persons authorized to sign bids under the provisions of Article 102-8, Item 7, shall be authorized to sign this form.

Figure 7-4. Bid Form for Award Limits on Multiple Projects (North Carolina DOT)

7.3.6 Flexible Start Dates

Flexible project start date is an approach that gives the contractor the option of selecting, within a specified period, when project work will begin (*Reducing*... 2000). Although the construction time duration is specified in the contract or the contractor may be required to bid time, a flexible start date is still allowed. With flexible starting provisions, the contractor is given a window to start work (*Alternate*... 1997). By allowing project work to start at the contractor's convenience, after the notice to proceed is issued, a

DOT encourages competition in the bidding process because it provides the contractor flexibility in scheduling the use of equipment and manpower. This approach can lead to increased competition and generate more responsive bids (*Selection...* 2008).

The North Carolina DOT has allowed periods of up to 6 months for flexible project starts (*Primer...* 2006). NCDOT uses flexible starts for small, non-critical projects, such as certain rural bridge replacement projects and guardrail projects.

A flexible start time can reduce the impact of competition on material costs, particularly when many projects are let simultaneously. Agencies should consider flexible start dates on projects that involve offsite preparatory work that can be accomplished prior to the starting date.

The Washington State DOT guidance on the use of flexible start dates says that the provision should be considered in cases where concrete or asphalt supply or labor force is limited and multiple contracts with concurrent working days may overtax the supply, increasing the overall duration of individual projects and associated costs ("Flexible..." n.d.).

7.3.6.1 Sample Flexible Start Date Special Provisions

Figures 7-5 and 7-6 provide examples of the flexible start date special provisions used by the Washington State and Florida Departments of Transportation.

Washington State DOT—Flexible Start Date Special Provision

Section 1-08.4 is modified as follows:

The Contractor shall begin onsite work on or before *** MM/DD/YYYY *** and shall notify the Engineer in writing a minimum of 10 calendar days in advance of the date on which the Contractor intends to begin work. The Contractor shall diligently pursue the work to completion within the time specified in the contract. Voluntary shutdown or slowing of operations by the Contractor shall not relieve the Contractor of the responsibility to complete the work within the time specified in the contract.

Section 1-08.5 is supplemented with the following:

This project shall be physically completed within ___ working days. Contract time shall begin on the latter of: the first working day following the 10th working day after the date the Contracting Agency executes the contract or the first day the Contractor starts onsite work. On site work is defined as work within the physical limits of the contract. In no case shall the beginning of contract time be later than *** MM/DD/YYYY ***

Figure 7-5. WSDOT Flexible Start Date Special Provision

Florida DOT – PROSECUTION OF WORK – FLEXIBLE START TIME.

(REV 2-24-04) (FA 4-23-04) (1-05)

SUBARTICLE 8-3.3 (Page 80) is deleted and the following substituted:

8-3.3 Beginning Work: The notice to proceed will be issued within 30 days after execution of the Contract by the Department.

For this Contract, a period of ___ calendar days will be allowed after the notice to proceed is issued. This period allows time for the Contractor to adjust work forces, equipment, schedules, and the procurement of materials, to proceed in a manner to minimize disruption to the public. Charging of Contract Time will begin when this time period ends or on the actual day that work begins at the site, whichever is the earlier.

Notify the Engineer in writing at least 30 days prior to beginning work on the project.

Figure 7-6. FDOT Flexible Start Time Provision

7.3.7 Use of Alternatives

With alternatives, the agency asks for alternate bids on specified designs, and at some point before awarding the contract, the agency will decide which alternate provides the best value. The objective is to achieve equal or improved performance at a lower cost (*Innovative...* 2007). Agencies use alternates to increase contractor interest in bidding on projects. Bidding both Portland cement concrete (PCC) and hot mix asphalt (HMA) paving alternatives increases competition by having PCC contractors and HMA contractors competing against each other for the work.

The FHWA's traditional pavement policy discourages the use of alternate pavement type bidding on the basis that it is difficult to develop truly equivalent alternative designs for PCC and HMA pavements. However, the FHWA has, under Special Experimental Project No 14 (SEP-14), allowed states to evaluate the use of alternate pavement type bidding with bid adjustments to account for differences in life-cycle costs. The Michigan DOT and the Louisiana Department of Transportation and Development (LA DOTD) have both used life-cycle cost estimates to determine the lowest bidder (*Primer...* 2006). LA DOTD has developed and published a process for competing pavement types through the solicitation of alternative bids (Temple *et* al. 2004).

The Missouri DOT experimented with five competitively bid pilot projects in 1996 using PCC and HMA pavement alternatives. The specifications for these projects included an adjustment factor added to each asphalt concrete bid to reflect higher future rehabilitation costs during the specified 35-year design period. Then, in 2002, MoDOT committed itself to an industry-changing program to develop a statewide fair pavement type selection process (*Missouri...* 2007). In the four fiscal years after beginning this pavement type selection process, MoDOT realized significant benefits, as evidenced by a review of the bid prices received. A total of 63 alternate paving type projects were let over the four years, with 58 being full depth and 5 being rehabilitation work. Of the 58 full-depth paving projects, 23 were awarded to the asphalt bidder and 35 to the concrete bidder. MoDOT's alternative pavement type pricing experience is detailed in Figures 7-7 and 7-8, and the number of bidders is illustrated in Figure 7-9.

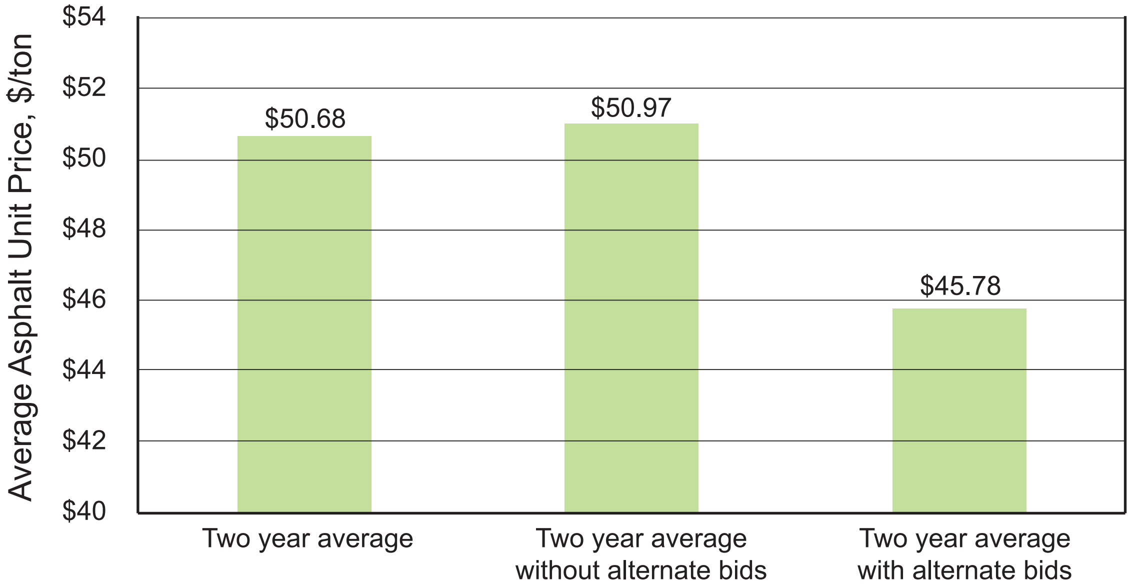


Figure 7-7. Asphalt Bid Prices—MoDOT Alternate Bidding Experience (*Missouri...* 2007)

Figure 7-8. Concrete Bid Prices—MoDOT Alternate Bidding Experience (*Missouri...* 2007)

Figure 7-9. Average Number of Bidders—MoDOT Alternate Bidding Experience (*Missouri...* 2007)

7.3.7.1 Applicable Projects for Alternatives

The use of alternatives is a viable method of increasing competition for the following (*Innovative...* 2007):

- Projects where the competition will drive the most cost-effective material choice or design approach (i.e., PCC vs. HMA pavements, steel vs. concrete bridges).
- Standardized projects that do not require a large design effort.
- Projects that are small enough to attract a large pool of bidders, but for which the potential cost savings are significant enough to justify the additional costs to develop plans and specifications for multiple construction alternatives.
- Projects that have a well-defined scope, for which viable alternates exist (i.e., PCC vs. HMA pavement, steel vs. concrete bridges).

7.3.8 Price Adjustment Clauses

Price adjustment clauses (PACs) provide contractors some protection against the volatility of commodity prices. They are set at the outset of a project and shift business risk (and potential rewards from falling commodity prices) from the contractor to the DOT. PACs may include an 'Opt In, Opt Out' feature where the contractor decides, with bid submission, whether they want the price adjustment provisions to be used or not. Such a shift in risk should increase a contractor's willingness to submit bids when the market prices for major construction commodities (cement, steel, liquid asphalt, and fuel) are unstable (Skolnik 2011). These clauses should identify the price guide to be used to measure changes in price and should detail how price adjustments will be triggered during the project. The use of PACs does mean that the agency faces greater uncertainty in budgeting and managing the final costs of a project.

PAC procedures have a long history and have been used by 47 DOTs on three quarters of their contracts. Besides the commodity cost risk that has been assumed, there is an administrative expense for such programs. Skolnik (2011) reported that the average number of man-hours per month spent by DOTs on administering theses clauses is 86 (with a minimum of 1 hr per month and maximum of 400 hours per month). DOTs believe overall that PACs yield benefits in terms of increased bidders, but 36 percent perceived no benefit while 40 percent saw only a small benefit. These DOT impressions seem valid, as a statistical analysis by Skolnik could not confirm whether PAC programs affect the number of bidders. Both the DOT perspective and the statistical analysis were looking for an increase in bidders.

The true benefit provided by PACs is that there is not a reduction in the number of bidders. Contractors, especially smaller contractors, cannot assume the risk of volatile commodity prices, and such economic conditions force them to restrict their bidding. PACs serve to protect the contractor's cash flow, prevent litigation, and preserve business relationships.

The effects of price adjustment clauses are much greater on smaller contractors or those specializing in fuel-intensive activities, or both, such as asphalt paving and excavation. PACs should be applied only to specific pay items. They should not be used for projects with small pay item quantities, small monetary size, or short duration. Fuel and liquid asphalt PACs are utilized by more than 80 percent of states nationwide and are the most responsive to fluctuating prices. The widespread availability of price indexes, the inability for contractors to control price, and the infeasibility of long-term storage further bolster the case for these PACs (Skolnik 2011).

7.4 QUALITY ASSURANCE/QUALITY CONTROL

Keeping very basic data can help DOTs make better decisions about scheduling projects for letting. By tracking the total number of projects in a letting and the total number of bids submitted each month, it is possible to create an easily understood graphic of when it is best to schedule projects for letting (see Figure 7-10). Figure 7-10 includes summary data from a single DOT, but it vividly illustrates for that particular agency the best time of year for letting projects. Such graphs can also be produced for specific types of projects.

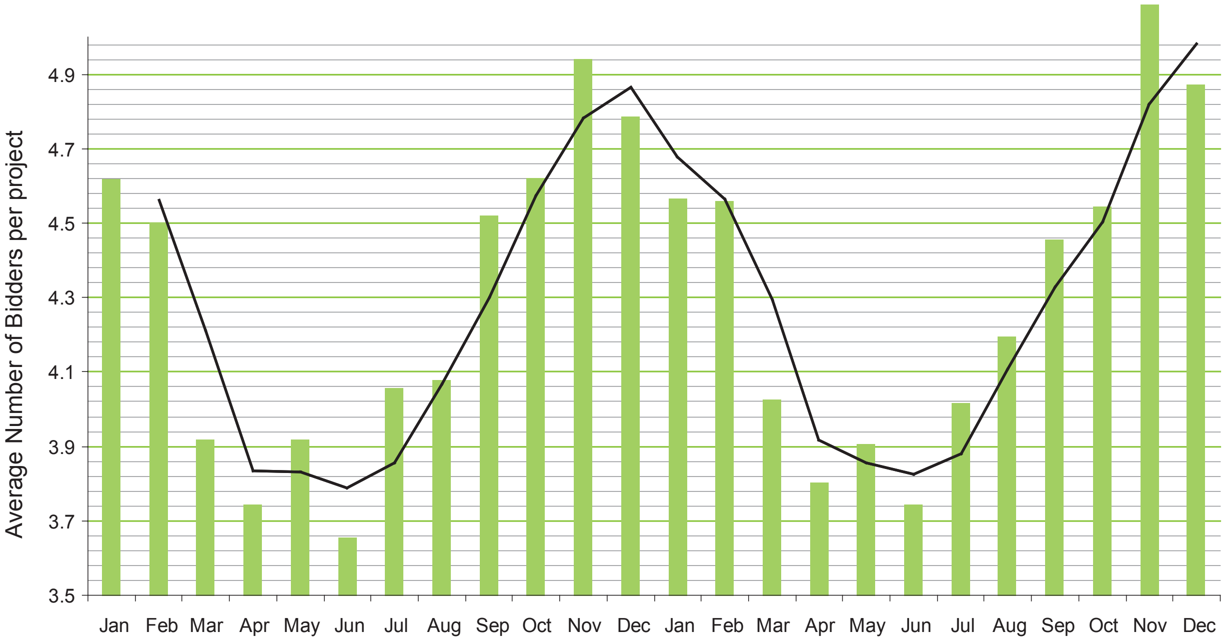


Figure 7-10. Average Bidders per Project by Month

7.4.1 Number of Bidders vs. Contract Amount

The Washington State DOT keeps letting data by contract size (Table 7-1). Such data can be very useful when packaging projects for letting. The Table 7-1 data clearly show that when projects are packaged to cost between $10 and $50 million, WSDOT can expect to receive a higher number of bids. In addition, WSDOT tracks the percentage of projects that attract only one bidder, as well as two, three, and more than three bidders. These are good performance indicators of how well the letting program is structured. By careful management of the letting program, the percentage of WSDOT projects receiving only one bid has been reduced from 12.6 in 2002 to 2.9 in 2010.

Table 7-1. WSDOT Letting Competition (Number of Bidders) by Project Size

Dollars	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<$1 M	3.7	3.4	4.2	3.8	3.4	3.1	2.9	3.4	4.1	5.4	4.9
<$5 M	3.7	3.8	3.8	3.7	3.8	3.5	3.3	3.2	4.4	4.7	5.7
<$10 M	4.8	5.4	5.8	5.7	4.5	3.0	2.7	4.3	4.8	4.0	6.5
<$25 M	7.3	6.3	4.5	7.3	5.5	3.0	3.3	4.8	6.6	8.0	8.0
<$50 M	—	5.3	6.0	5.0	6.0	5.0	3.5	4.9	5.7	5.8	4.0
≥$50 M	—	—	—	5.0	—	8.0	—	5.5	5.0	2.8	5.4
Average	**3.63**	**3.63**	**4.13**	**4.05**	**3.63**	**3.52**	**3.10**	**3.48**	**4.43**	**5.10**	**5.49**

7.4.2 Ideas

A survey by the AASHTO Standing Committee on Quality (SCOQ) noted that FDOT has developed a leading indicator report that provides insight into optimum contract letting opportunities (*Managing...* 2006). FDOT's leading indicator report is published monthly and provides department executives insight into the current state and direction of Florida's construction market (*Update...* 2007). Another DOT stated that agencies should consider placing preliminary plans on the Internet for review and comments.

7.5 SUMMARY

A U.S. Domestic Scan in 2009 found that most DOTs are concerned about their ability to fully control unanticipated project cost increases during the design phase, as well as at contract letting and award (*Best...* 2009). Agencies are sellers of a product that has no standard value, and it is the bidder who defines a project's cost in the marketplace. Increasing the number of bidders—competition—reduces procurement cost. Therefore, by focusing on letting strategies that encourage competition, the cost of delivering transportation construction projects can be reduced. When a DOT evaluates the local market conditions and schedules its letting based on an understanding of macroeconomic environment cost drivers, increased competition can be achieved. The project letting schedule must be developed based on the capacity of contractors in the region. All non-critical projects should be scheduled for letting when there is a potential for improved competition.

To make informed letting strategy decisions, DOTs need greater knowledge about their construction partners. Involving the contracting industry in discussions to understand why projects or the letting schedule causes them not to submit bids and asking for advice about the letting schedule can prove very beneficial for increasing competition.

DOTs need to track activity in the marketplace and understand that the marketplace is more than just the agency's program. There is also a need to monitor contractor response to different letting strategies.

7.5.1 The Strategies

A DOT must consider the impact of (a) the schedule (timing) of project lettings, (b) the number of projects bid in a specific letting, (c) contractor workloads when scheduling the letting of work, and (d) availability of DOT or consultant personnel, or both, for construction management and oversight. There is no standard or best letting strategy; each DOT has to develop strategies that are adapted to the local macroeconomic and market conditions.

Increased competition and responsive bids result when a DOT does the following:

1. Gives careful consideration to the scheduling of project lettings. The number of projects let on a particular date can significantly affect competition.
2. Makes the effort to balance the projects in a letting. Contractors have limited estimating capacity and may be forced to limit the number of projects they bid on if an agency includes a large number of similar projects in one letting.
3. Packages projects into proposals that fit the capabilities of the local contractors. It is desirable to package projects so as to make the work as attractive as possible.

4. Allows contractors to selectively package projects. To accommodate contractor resources and capacity, agencies sometimes allow contractors to selectively bundle projects.
5. Permits contractors to impose award limits when bidding multiple projects. To reduce the risk to a contractor of obtaining too much work in a letting, agencies can allow the contractor to specify a maximum dollar amount of work that will be accepted from a letting.
6. Offers contractors the flexibility to specify project start dates. Flexible start dates encourage competition in the bidding process because they provide the contractor control over the scheduling of equipment and manpower.
7. Seeks bids on alternate designs. The use of alternatives increases competition and drives the use of the most cost-effective material choice or design approach.
8. Is willing to use price adjustment clauses. Price adjustment clauses protect contractors against the volatility of commodity prices and thereby keep smaller contractors in the bidding pool.

7.6 REVIEW EXAMPLE

It seems that many times, lessons learned are not passed on to the next generation. When, in 1965, BART originally packaged its construction projects, the work was organized into relatively large projects. This was done in an effort to attract bids primarily from "major qualified contractors" (Gaver and Zimmerman 1977). However, when bids were opened for the first major project, the results were disastrous, with only two bidders and a low bid that exceeded the engineer's estimate by 28 percent. BART rejected the bids and repackaged that work into five-and-a-half projects. The total of the low bids for the re-let work was only 2 percent above the original engineer's estimate. After that experience, BART was very careful about packaging projects and, as a result, there were an average of six bids per project for the 77 contracts let between mid-1964 and 1971. Thirty-five years later, there was a similar experience on the east coast.

7.6.1 The Woodrow Wilson Bridge Experience

On December 13, 2001, the Maryland State Highway Administration opened bids for the Woodrow Wilson Bridge superstructure contract. A single $860 million bid was received. That amount was more than 75 percent higher than the engineer's estimate for the contract ("Lone. . ." 2001). Maryland formally rejected the bid since 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 submitted bid.

The committee interviewed contractors to determine the reasons they chose not to bid on the bridge contract and what might serve as an incentive to make them compete for the project in any re-bid scenario (Warne and Maryland 2002). One significant point raised by contractors was the fact that the Woodrow Wilson Bridge superstructure contract was let at the same time as the $1.04 billion Oakland Bay Bridge project in California. Even major contractors have limited estimating capability, and to estimate more than one megaproject during the same time frame is often not possible.

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 (Warne and Maryland 2002). The IRC then went on to state that the estimate did not sufficiently take into account the intangibles of market factors, specifically lack of competition, as there were several other large bridge projects bidding in the same time period.

There are only a small number of contractors who have the ability to take on very large dollar and technically challenging projects. The size and complexity of many projects necessitates that joint venture teams be formed in order to generate adequate bonding capacity and reasonable assumption of risk. As a consequence, there are fewer competitors and higher bid prices. Additionally, when material demands will be large over a short time span, either for one large project or a multitude of simultaneous projects, producers may also have to team together, thus reducing second-tier competition. In the case of the Wilson Bridge, the steel demand was so significant that fabricators needed to team together to meet the requirements (*Woodrow...* 2002).

Acting on the review committee's findings, Maryland officials decided to repackage the superstructure work into three contracts. Those contracts were bid in late 2002 and early 2003 ("Revised…" 2002, "Act…" 2003, and "Bids…" 2003). The first package came in 11 percent above the agency's estimate, but the second package came in 28 percent below, and the third 25 percent below. By packaging the work into three smaller contracts, letting them over a period of months, eliminating the union-only project labor agreement, and substituting plate girders for box girders, Maryland achieved a total price for the bridge that was only slightly above the 2001 estimate and about $360 million below the single large project bid of 2001.

The original contract and scope of work and what was bid in the three separate contracts did not exactly represent the same project conditions. But it is evident that a DOT can receive better value by carefully considering up front how to best schedule the letting of contracts and the packaging of contracts and by understanding the impact of the macro-environment on project cost bids.

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7A APPENDIX—PACKAGING OF PROJECTS POLICY GUIDANCE

Several DOTs have published formal guidance concerning the packaging of projects for letting. To support the concepts presented in Chapter 7, guidance from the Missouri DOT and Iowa DOT is reproduced here as examples to help other agencies to formalize processes that will lead to more responsive bids.

Missouri DOT, Engineering Policy Guide 103.1.5 Packaging Projects for Bid Opening

It is desirable to "package" projects to make them as attractive to bidders as possible, particularly in areas of the state with limited competition. Design is available for consultation in determining prospective bid competition. Similarly, the Design Division can assist the district in developing attractively packaged projects.

Small projects may need to be combined, while large projects may need to be split apart. The availability of materials is also a concern when scheduling certain work types. The number of different work types should be reduced as much as practical (i.e., a small quantity of asphalt with a small quantity of concrete). For certain particularly complex projects, there is a benefit to having one contractor in charge of the entire project. Permitted combinations are generally used when several similar type projects are to be constructed in an area with a good history of competitive bidding (i.e., both large and small contractors are available to do the work). This combination allows for the greatest competition among all contractors. Bidders may bid on any or all of the combination, and will usually bid "all or none." Required combinations are recommended for several small projects with similar work within a reasonable distance from one another. Packaging them together often makes them "economically attractive" to more bidders. Required combinations are also helpful when combining a medium to large project with a single small project in an area. The small project alone may not attract any bidders. Combining it with a more desirable project will increase its chance of being completed.

Alternate bidding allows a contractor to choose which material to bid for a project, for example pavement type can be alternately bid as either asphalt or concrete; or pipe can be alternately bid as metal, concrete, or polyethylene. An alternate technical concept is used in larger projects or design build projects; for example for the foundations for the new Mississippi River Bridge, alternate technical concepts were submitted that lowered the contractors' bids. An add alternate project includes base items to bid as well as additional sections of work that can be added on and bid by the contractor. This method provides flexibility for the contractor and helps the department maximize the budget for projects. Job order contracting is a new tool used for preventative maintenance work where the department establishes the base price per unit and the contractor adds their mobilization and multiplier factors and they bid a set price for a range of quantities. Whether it is pavement repair or guard rail replacement, if the volume is small the contractor gets a little bit higher price per unit than they would if it were a large volume. Design-build has been a successful procurement and delivery process in Missouri for I-64 in St. Louis and for the kcICON bridge project (http://www.kcicon.org) in Kansas City. It allows the contractor to use any design criteria approved by FHWA anywhere in the country with some review by the department to make sure it meets the climate issues in Missouri. Letting management is a strategic approach to packaging projects and timing the letting to allow more contractors to bid.

Iowa Department of Transportation
Office of Design

100B-5

Packaging of Projects for Letting

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Design Manual
Chapter 100
Office of Contracts Documents
Originally Issued: 08-31-10

The objective of project packaging is to have a project or a group of projects that are optimized according to several factors. One of those factors is the amount of competition obtained for the package. When a package consists primarily of one type of work and is within most contractors bidding capabilities, then there will be a larger number of bidders on the project. More bidders on a package should lead to better bid prices.

Craft Oriented Projects

One way to encourage more bidders on a project is to set up a contract where the bidders will actually be the contractor that accomplishes the work. This allows the contractor to control their own destiny and should eliminate any additional monetary mark-up due to sub-contracting. The industry has requested multiple times in the past that contracts be set up that allows them to bid on their own work and to limit the amount of work that has to be subcontracted out. Often due to staging or other reasons multiple work types must be on the same contract but whenever possible multiple contracts should be let for different work types. If there is coordination needed between several types of work, contract periods or proposal notes can typically be used to help coordinate several projects.

Optional Combination

To obtain the maximum number of bidders the package must be attractive to them, this would mean that it is large enough to entice them to bid but also not too large that it exceeds their bidding capacity. The attractive size range of a package will vary from one contractor to another and also from one type of work to another. At times there will be a group of contractors that only bid smaller projects and others that will only bid very large groups of projects.

To allow both of these contractors to bid, the Office of Contracts will occasionally offer an "optional combination". For example, four bridges can be let singularly and also all four as one large package. The contractor may choose to bid any of the single bridges and may also choose to bid the package with all four bridges. The Office of Contracts will decide if the four separate projects or the four combined are less expensive. The lowest dollar amount of the responsive bids is what will be awarded. Following are some of the criteria used in packaging various types of work:

Structures

Iowa has a lot of smaller contractors that build box culverts and bridges. Some of these contractors cannot bid packages that are extremely large; others aren't interested in smaller projects. RCB extensions and new RCB culverts in the same area should be combined on the same project especially if the total dollar cost is under $250,000.00. Multiple extensions and new culverts should be divided into separate projects if the total cost exceeds $500,000.00. Culverts should primarily be packaged by location, but if possible, same-sized culverts should be grouped together to help reduce contractors costs.

Bridge projects routinely obtain good competition except for those structures that are very large or very small. Single bridges are usually let as a separate contract except that two dual bridges (same width and length) are usually the same design number and therefore on the same project/contract.

Figure 7A-1. Iowa DOT, Office of Design Packaging of Projects for Letting

PCC Pavement

There are two distinct areas PCC pavers specialize in, urban type paving and rural type paving. Some contractors do only one or the other type while others can function well in either area. Generally speaking small PCC paving projects will cost more per area of pavement due to the mobilization costs. More complex construction/traffic staging will increase cost substantially. There does not seem to be a distinct dollar amount where competition increases or decreases, however the Office of Contracts will usually look to split a PCC paving project up into parts if it exceeds about 10 million dollars. These multiple paving projects will then usually be offered as an optional combination.

HMA Pavement

Smaller HMA paving projects will often have very few bidders. This is common due to the fact that there is usually only one local HMA plant and it may not be economical for another contractor to move in a portable HMA plant. Therefore, whenever possible, HMA projects should be grouped together to try and attract other HMA bidders to an area. When there are more than one or two HMA bidders, the bid prices are usually better.

Grading

Iowa is fortunate to have an abundance of good grading contractors that do both small and large projects. Most of the smaller contractors cannot bid projects over 2.5 to 3 million dollars due to their bonding capacity. Some of the larger contractors do not bid projects lower than 1.5 to 1 million dollars. The Office of Contracts has discovered that better bid prices are obtained from projects worth 2 to 3 million. When a grading project rises above 3 million dollars, the project may be split up into 2 or more projects to increase competition. These multiple grading projects will then usually be offered as an optional combination.

Other

When contractors can bid on their own work type rather than being a subcontractor, more favorable bid prices are usually obtained. Therefore it is preferred to have small items such as traffic signals, lighting, erosion control, fencing, landscaping let as their own separate projects. However there are times when construction staging or traffic staging will require having some small items included in a larger project of a different work type. Combinations of different work types are at times unavoidable but the designer should try their best to design a project that will separate work types resulting in the same quality project for a lower price.

Combining Metric and English on a single plan or proposal

There have been occasions when a single project had references to English and Metric on the same plan usually due to different areas being surveyed in different units of measure. On other occasions it has been necessary to combine two or more projects on one proposal/contract and they have different units of measure. Due to limitations in the computer system that the Office of Contracts uses to create the proposals/contracts, all the bid items on a single proposal/contract has to be either all Metric or all English. Therefore it will be necessary to convert some items from English to Metric or vice-versa so that all the bid items in a proposal/contract are in the same units of measure.

Combining of different routes or different counties on the same plan/proposal

It is acceptable to have multiple projects on a single proposal. It is also acceptable to have multiple projects in a single plan set. There are occasions when construction work is on two different routes or in different counties. To be able to track construction work on different routes it is required that there are separate project numbers for each route that has a significant portion of work on it. Occasionally one project number is acceptable, such as if it involves work at the intersection of two routes.

If construction work is in multiple counties and the work is continuous then only one project number/county is acceptable. The designer should indicate on the plan sheet all the counties affected but only the western or southerly most county would be indicated in the project number.

Figure 7A-2. Iowa DOT, Office of Design Packaging of Projects for Letting (continued)

CHAPTER 8

Analysis of Contractor Bids

8.1 OVERVIEW

A state DOT's procedures for reviewing and awarding construction contracts are significant components of the competitive bidding process. To ensure a competitive contracting environment, agencies must have effective and consistent bid review and award recommendation procedures. The procedures must be transparent in a manner that is publicly understandable, economically efficient, legally defensible, and socio-politically acceptable (Shubik 1983).

Review procedures serve to ensure a fair and reasonable price has been offered for performance of the work described. To be acceptable to the contracting community, all reviews of construction proposals must use standardized analysis methods that provide consistent and unbiased determinations of fair and reasonable bid prices. Establishing a consistent and reliable bid review process is also critical for detecting collusive behavior and ensuring the success of preparing estimates for future projects. FHWA guidance states, "The DOT should have written procedures for justifying the award of contract, or rejection of the bids, when the low bid appears excessive or rejection is being considered for other reasons" (*Guidelines* 2004).

Commitment and openness matter. Contractors must know that the agency will not change the award procedures after bids are received. Bidders (contractors) will only bid competitively in the future if they believe the agency will not renege on the current bids. An agency will lose future competitive bids by not awarding a project under the rules understood by the contractors. As noted in *The Strategy of Conflict* (Schelling 1960), "If the buyer can accept an irrevocable commitment, in a way that is unambiguously visible to the seller, he can squeeze the range of indeterminacy down to the point most favorable to him." A DOT is a buyer of construction services; therefore, it is critically important that bid review processes be understood by the contracting community.

8.1.1 What Is It?

A bid review analysis provides the basis for justifying contract award or rejection of the offers. Review procedures evaluate the competitiveness of the bid prices offered by contractors. The procedures specifically check for mathematical unbalancing, significant unbalancing, material unbalancing, and comparative cost. Additionally, the procedures test for patterns of bidding and pricing conduct that seem at odds with competitive behavior—price fixing, bid rigging, and other forms of collusion including market division or allocation schemes.

The analysis is part of the overall bid review conducted by the DOT that also incorporates checks for irregularities in regard to the agency's request for proposals and statutory legal requirements such as signatures of cooperate officers, bonding, and Equal Employment Opportunity (EEO) Certification Statements.

8.1.2 Why Use It?

Review procedures, specifically the analysis of bid prices, supports the determination as to whether a contractor's proposal is responsive and the recommendation to award or not to award to the apparent low bidder. In the case of a federal-aid project, the analysis supports a definitive statement that the low bid was reviewed for possible mathematical or material unbalancing per 23 C.F.R. §635.102 ("Definitions" 2011).

8.1.3 When to Use It?

Every proposal (bid) should be analyzed separately and against historical pricing data or estimate data developed using cost-based methodologies to determine if it appears to represent unusual pricing. The FHWA guidance states that "the analysis and award process for a project should be thorough even when the low bid is below or at a reasonable percentage above the engineer's estimate. It is reasonable, however, to expect that larger projects will receive a more thorough review than very small projects" (*Guidelines* 2004).

8.2 KEY INPUTS

Subsequent to a contract award or a decision not to award, there must be a careful analysis of all bids received for the project. The analysis processes should be conducted even when there appears to be good competition—multiple bidders—and the low bid is below the PS&E estimate for the project. Larger complex projects should undergo a much more detailed review. To support the necessary bid analyses, DOTs should (a) collect historical unit bid data and (b) compile unit bid prices from the current letting, while the reviewer or reviewing team should (c) have a complete set of the project contract documents, (d) have data on current market conditions and trends, (e) have a well-documented PS&E estimate, (f) have data on the contractor pool, and (g) have data on the capabilities of the bidding contractors. Items d, f, and g are also key inputs for developing letting strategies, as discussed in Chapter 7. Therefore, data should be collected and organized so that they will support two objectives—development or adjustment of letting strategies and analysis of contractor bids.

8.2.1 Historical Unit Bid Data

Historical bid item pricing data can be used both to create a DOT estimate of project cost and to test contractor-submitted pricing. Consequently, DOTs should give priority to maintaining and updating historical bid data. These data should be stored in a carefully structured database and tested to ensure they do not contain costs from noncompetitive bidders. To ensure consistency and accuracy, it is recommended that the DOT establish a standardized statewide historical database that is centrally managed.

In this database, individual pay item pricing information must be linked to the item quantity, contractor, and project type, location, size (total project bid), and bid date (Ramesh 2009). With such data, it is possible to perform simple comparisons of project bid item prices to the mean value of the most recent historical database prices. All bids should be subject to this type of analysis. Furthermore, the contractor's prices should be examined across all projects bid by the same firm in the letting and in the most recent lettings. When constructing the database, these typical analyses of prices should be kept in mind so the information is stored in formats that allow easy retrieval of data for multiple purposes. DOTs can develop such software internally or use a commercial vendor. In either case, flexibility must be built into the software so that reports and queries generate the appropriate comparison information.

The database average price information should reflect an average for normal conditions. In creating a project estimate, the cost of items with minor quantities is not so important because the item totals have little impact on the estimate total. However, when building a database, prices bid for small quantity items need to be filtered so they do not skew average item prices. One approach to eliminating skewing is to weight prices by quantity. Another database information issue is outlier prices. It is, therefore, necessary to have an algorithm to filter out extremely low or high bid prices.

8.2.1.1 Problem Bid Items

For the majority of bid items, there should be sufficient historical data to support bid review processes; however, even with a good database, problems arise with items that are not bid frequently or those that are bid lump sum. This is particularly the case for special items and project mobilization. How mobilization is bid depends on how the DOT pays for the item and restricts the bid price. When the mobilization item is not restricted, it can be overpriced in a bid, resulting in the prices for other items being distorted.

To limit mobilization distortions, some DOTs specify (a) that mobilization payouts are staged; (b) that if mobilization is bid more than 10 percent of the total contract price, the amount over 10 percent is paid at end of project in lump sum; or (c) that if mobilization is bid above 5 percent, it is not paid until after 80 percent of the project is complete.

8.2.1.2 Commercial Databases

There are commercially available products/services that take state bid-tabs and store the data in electronic databases. Such databases are typically updated monthly, but some update daily. There is a user license fee to access these commercial web-based databases, but they are very well structured and allow a user to easily sort and search for item prices by name, item number, county, quantity, price, contract number, and letting date (Hanna et al. 2007).

8.2.2 Letting Unit Bid Prices

While the database of historical unit bid prices will provide one dataset for reviewing a contractor's bid, it is good practice to analyze bids against unit bid prices in the same letting. This could be a subset of the larger historical unit bid price database or a smaller database created exclusively with the data from the current letting. This database of corresponding bid item prices from the current letting makes it easy to compare low bidder prices to those of the other bidders on the project and with prices bid on other projects in the letting.

Therefore, it is good practice to record all of the letting pay items in the database. For each pay item, the database should contain the bid quantity, contract number, project location (county or DOT district, or both), and unit of measure.

8.2.3 Bid Documents

FHWA recommends that DOTs escrow bid documents where it is administratively feasible to do so (*Guidelines*... 2004). The AASHTO *Guide Specifications for Highway Construction* has guidelines in Section 103.08 for accomplishing the escrow of documents (*Guide*... 2008). The primary purpose for this escrow recommendation is the usefulness of the documents in resolving subsequent disputes, claims, arbitration proceedings, or litigation arising from the construction of the project. However, the escrow of documents also has value in discouraging noncompetitive behavior, the documents provide insight into how prices are developed. Document escrow should be considered for projects that are complex, have high construction cost, have major or significant item quantity uncertainty, or require new technology. The escrowed bid documents should include all quantity take-offs, calculations, quotes from subcontractors and suppliers, and other information used to arrive at the bid prices.

Agencies do not routinely escrow bid documents, and the practice should be selective depending upon the severity or significance of the following factors or combination of factors (*Memorandum* 2002).

- Projects containing item(s) that are subject to different interpretation.
- Projects with high construction cost.
- Projects that are complex, having:
  - Multiple alternatives, construction methods, or procedures available.
  - An urban environment with tight schedule, tight right-of-way, heavy traffic, or close proximity to businesses or residences.
  - Complex geotechnical formations, which could result in differing site conditions, different construction equipment or methods, or quantities.
  - Work in areas where there are potential severe environmental factors, such as flooding, unusually wet conditions, hurricanes, or tidal waves.
- Projects with a major or significant item whose quantity is uncertain, such as rock excavation.
- Projects with rarely used items, new items, or new technology.
- Projects that are fast-track.
- Projects that include milestone dates or completion dates falling near a critical time (holiday periods, major sports event).
- Projects with incentive and disincentive clauses.

Contractors are concerned about the potential risk of public or competitor access to their bidding strategy and production rates. The United States and many states have freedom of information laws allowing access by the public to information held by public agencies. The Federal Freedom of Information Act does, however, contain exclusion language for commercial trade secrets, which should protect the documents from unwanted disclosure.

8.2.4 Macro-Environmental/Market Conditions

Because both economic and natural events impact bid prices, the macro-environment needs to be carefully tracked. DOTs should have a standardized process for tracking external circumstances in terms of their effects on bid prices. The collected information must be carefully analyzed to understand the effects on project pricing. Many times, the analysis of natural disasters will forecast short-term price increases with respect to construction materials, with the issue being a producer's ability to deliver the commodities to the locations where they are needed rather than a question of ability to manufacture the required commodities. However, each event has different impacts. For instance, natural disasters that affect supply chains such as receiving ports can cause disruptions to the flow of construction material over a large area of the country and not just the area that experienced the event. Therefore, the analysis of event information is important to understanding bid prices.

8.2.4.1 Commodity Prices

Understanding bid prices begins with quantifying the future prices of key commodity inputs. Commodity prices, particularly for major items such as fuel, liquid asphalt, cement, and steel, impact bid prices and should be tracked by DOTs. During major building cycles, these commodities are major cost drivers. Additionally, volatility in the markets for these items is an issue that drastically affects total project bid prices. Historical data show that most bid prices increase at a rate faster than inflation because contractors are attempting to protect themselves, particularly in the case of long-duration projects.

There are some DOTs that incorporate price-indexing or cost-escalation clauses into their construction contracts and reduce the risk effects of such price fluctuations. Price-indexing and cost-escalation clauses shift business risk (and potential rewards from falling commodity prices) from the contractor to the DOT. While this shift in risk may benefit the agency through contractors' willingness to submit lower bids, the agency faces greater uncertainty in budgeting and managing the final costs of a project (Skolnik 2011).

8.2.5 PS&E Estimate and Supporting Data

According to FHWA, "The engineer's estimate serves as the benchmark for analyzing bids and is an essential element in the project approval process" (*Guidelines...* 2004). A quality review of a bid requires that the DOTs develops reliable project cost estimates. Therefore, DOTs must devote particular attention to the preparation of PS&E estimates.

All PS&E estimates must be organized so the basis of the cost calculations and all assumptions are clear to those who will use them to review contractor bids. Assumptions about what the contract documents require should be available as estimator notes. Pricing decisions and assumptions must be tied to specific statements (sections) in the contract documents, the standard specifications, or the plans.

DOTs benefit greatly by having estimate preparation guidelines that specify standard processes, procedures, and formats to be used by both DOT estimators and design consultants retained for estimating purposes. This guidance should specifically address preparation of the final engineer's estimate and should discuss how assumptions are to be documented. It should explain standard procedures as to how unit costs are to be derived from the agency's databases and the documentation necessary to support decisions to use other cost values (Anderson et al. 2007).

8.2.6 Number of Bidders and Current Backlogs

Because of the correlation between bid prices and competition (see Figure 7-1), DOTs should always be aware of the industry's ability to respond to requests for proposals. FHWA makes two very good suggestions for increasing competition (*Guidelines* 2004):

1. Advertisement should be widespread, and for complex projects, there should be an extended advertisement period.
2. Consideration should be given to structuring project cost/size to maximize the number of bidders. In some situations, it may be desirable to divide a project into several smaller contracts to foster competition.

To support decisions about the timing of lettings and project size, and for evaluation of bid prices, a DOT should maintain data on contractor capacity and backlog.

8.2.6.1 Contractor Capacity

Contractor prequalification is one method that can be used to determine the type and amount of work construction firms are capable of undertaking. Even if a DOT does not have a formal prequalification process, it can require that contractors, on a regular schedule, file information on financial resources, affiliates/subsidiary companies, and equipment fleet, and to identify projects under contract.

8.2.6.2 Contractor Backlog

DOTs should attempt to track contractor backlog—the amount of work under contract that has yet to be completed. A contractor's backlog includes signed contracts in process, awarded proposals, and some percentage of outstanding proposals relative to the firm's historical ability to win contracts. For those contractors that normally bid DOT work, data should be kept on every contractor's backlog of DOT projects. In the case of DOT projects, the agency can keep the backlog data current by applying a monthly burn rate or by using the contract invoice data. Data on non-agency projects can be obtained from commercial construction data providers.

8.2.7 Low Bidders' Performance History

Many DOTs evaluate the project performance of their contractors and use the data to track a firm's performance history over periods extending back as long as five years. Most of these evaluation systems are for the purpose of making adjustments to prequalification capacity. An NCHRP study found that "a rigorous post-project contractor performance evaluation system can replace many of the commonly used minor performance-based prequalification factors and thereby simplify the process" (Gransberg 2009). These performance data allow evaluation of how well a contractor has completed past projects in terms of schedule and bid amount. With such information, a DOT gains insight into a contractor's bidding strategies and ability to perform future work. Such knowledge can be used to support the analysis of a current bid submitted by the contractor.

8.3 BID REVIEW PROCESS

A DOT's bid review process may be by a committee or by individuals working in separate groups. In most cases, an initial cost analysis is the first step in reviewing a bid. Then there is a review by the project design team and possibly a response to the cost analysis findings. Those two steps lead to a final decision. The primary business decisions should be made by separate individuals to avoid ethical dilemmas and conflicts of interest. The decision process is as follows:

- Fair market analysis.
- Project sponsor review and response.
- DOT decision to award or reject.

The initial fair market cost analysis should be performed independent of the project sponsor and within the DOT to ensure consistency and security. The DOT staff responsible for developing or approving the agency's PS&E estimate normally performs the initial analysis and forwards an award/reject recommendation based on cost. If the economic recommendation is to award, then the authorization signatures of concurrence may become a simple formality. If the recommendation is to reject, then further review and comment is needed from the design team and possibly the project sponsor.

The project sponsor should evaluate the review process information. The project designer may often be called upon by the project sponsor to consult and comment on the quality of the design. The evaluation should include quality of the bid documents and a comparison of additional costs above fair market against the essential need for the project. The sponsor may then forward comments that would influence the award or rejection decisions made by the awarding authority.

The awarding authority will make the final award decision. The final decision will consider all relevant aspects of cost and other project considerations and the agency's policies and standards that form the basis for award decisions. The agency must also consider the impact of the decision on program success.

Decisions to award projects that are above market value (the PS&E estimate) require substantial justification, including demonstration of an essential need for the work where re-bidding would not be in the public interest. FHWA (2004) has classified the following as possibly being essential work (note: these 2004 guidelines replaced Technical Advisory T5080.4: *Preparing Engineer's Estimate and Reviewing Bids*, dated Dec. 29, 1980, and Technical Advisory T5080.6: *Guidelines on Contract Procedures with Emphasis on Bid Reviews and Evaluation*, dated Dec. 17, 1982):

- Safety projects necessary to correct extremely hazardous conditions where the traveling public may be in danger.
- Projects that perform emergency repair or replacement of damaged facilities.
- Projects to close gaps in otherwise completed facilities to allow opening to traffic.
- Projects that are critical elements in a staged or phased construction schedule, where a delay would mean substantial impact on the completion date of the facility.

Anticipation of higher bids is not necessarily considered a justification for award.

8.3.1 Competition Review

The initial review of bids involves a comparison of bid totals. The simple comparison of the low bid to the estimate has little or no value to the evaluation process and should not be used as the sole criteria for decisions to award a project. An appropriate review of all available data is always necessary. The distribution of bid totals should compare bids to each other and to the PS&E estimate. This distribution can provide insight on competition, project risk, and quality of the project documents. Very large deviations among bidders or with the PS&E estimate can indicate an issue with either competition or risk transference to the contractor.

Competition is reviewed from two perspectives—the current market and the potential bid market. The current market is the group of prime contractors that purchased plans for a specific project. In this case, competition is weighted by the comparison of actual bids received to the list of prime contractors on the plan holder's list. It should be understood that contractors with little backlog will accept work at lower margins in hopes of covering overhead. Conversely, contractors with a strong backlog frequently demand pricing premiums. Most general contractors consider a backlog of 6 to 12 months desirable, so long as adequate margins cover overhead and profit.

Contacts made with the non-bidding plan holders may reveal contractor concerns regarding market saturation, bid document quality, and available bid pool size together with reasons why contractors chose not to bid on the project.

The potential bid market includes the list of bidders that normally bid work by market sector and work region. Contacting prime contractors who did not choose to purchase plans can help in revealing market conditions and workload saturations that might not be recognized in the evaluation process. A market review will also provide data on potential bid pool size, which can have significant bearing on evaluations of fair market cost and the range of total bid distributions.

A post-bid review of the documents with non-bidding plan holders can serve to reveal issues of constructability, scheduling, document quality, design omissions, and risk transference. Review of projects with full competition may also be needed for specialty contract work. In these cases, contacting the high bidder may reveal problems with material costs or specialized equipment and construction techniques that may not have been considered in the development of the PS&E estimate.

If the DOT decides to re-bid a project, a forecast of the potential re-bid pool size may be required. In some cases, the re-bid pool might actually be smaller in size. This occurs when a number of higher bidders realize they cannot compete with others and simply do not choose to spend the time and money to re-bid a project. In some cases, the timing for bid is poor, project design is defective, and the documents shift too much risk onto the contractor. In many cases, a significant price change might only be obtained from a lengthy delay to the re-bid date and substantial change in the design. Two strategies to increase the number of bidders are to bundle the project with other similar projects or, to encourage bids by smaller contractors, split the project.

These types of review inquiries can best be conducted by those responsible for the PS&E estimate. The reviewer should keep detailed documentation of all competition issues to support the recommended decision to accept or reject a bid but also to support creation of better estimates for future projects.

8.3.2 Market Review

A significant difference between the PS&E estimate and bid prices can indicate issues with either commodity prices, regional work volume, or expected impact of external factors on delivery of materials. With steel, asphalt, and cement being large project cost drivers, local shortages of these items can have a large impact on bid prices. World economic conditions can impact supplies of oil, diesel, and liquid asphalt and, as a result, drive bid prices. Regional work volume will impact bid prices, driving them either upward when there is excess work or down when there are few projects in a market. Natural disasters have a large influence on regional work volume. Therefore, if there are large discrepancies between a contractor's bid item cost and the PS&E item price, the reviewer may have to check the documentation that supports the PS&E estimate to ensure that the agency properly adjusted its item cost based on a realistic evaluation of market conditions.

8.3.3 Distribution and Range of Bids

The analysis of the distribution of all bids and a comparison of variations from the PS&E estimate is important. The distribution of bidders provides a compelling summary of market conditions and competition relative to the project. Significant differences between the low bidder and the PS&E estimate may not, however, indicate a poor PS&E estimate. Averages of the second, third, and fourth bidders often provide a strong indication of fair market value when evaluating the PS&E estimate. Comparisons of the variations of bidders to each other are equally important.

Extremely low prices by one bidder while the other bidders average near the PS&E estimate may suggest a problem with the quality of the bid documents (quantity or specification error), or simply a contractor seeking to build backlog. Other considerations may be that the contractor has other work near the project site or may have stockpiles of excess materials from other projects. Extremely low bids need to be studied very carefully.

Larger spreads of bid item distributions will normally occur with specialty work (for example, bridge cables and cathodic protections). For normal projects, such as paving, the larger spreads indicate competition issues such as restricted sources of material or risk transference due to permits or site access issues. In this case, the PS&E estimate should fall within the distribution of the bids. A careful examination of the individual line items may reveal specific issues.

A low PS&E estimate (typically more than 10 percent below the low bid) with all bids spread approximately as a normal distribution can indicate a shift in market prices (see Section 8.3.2). In this case, the historical database structured on past bid item prices should be carefully reviewed. Another possible issue is a contracting community working at capacity, which can easily be checked (see discussion in Section 8.2.6.2). PS&E estimate adjustments for small project size and remote locations should be reviewed for those types of projects.

A very low PS&E estimate (typically more than 20 percent below the low bid) with all bids normally distributed may indicate a major flaw in the project documents or factors that were not accounted for in the engineer's estimate such as an unrealistic construction schedule or permit requirements that add undefined risk and cost to the contractor. Non-bidding and high-bid contractors should be contacted to identify any unaccounted for risks, and where possible, these should be documented in the award recommendation.

A high PS&E estimate (typically more than 15 percent above the low bid) with all bids normally distributed could indicate a flaw in the project documents (such as insufficient or missing pay items). While the first reaction would be that the DOT received a very good deal, the final project costs will probably include change orders that raise total cost significantly. Unbalanced bid prices will help in identifying the line items where quantities require verification.

8.3.4 Unbalanced Cost Review Prior to Unit Price Comparisons

Unbalanced unit pricing involves the shifting of dollars between bid line items by the contractor coupled with some discounting of the total price for competitive advantage. In the extreme, a contractor can bid significantly below costs with the knowledge that the changes in quantities will provide increased profits. The root cause of the unbalance is generally, but not always, an inconsistency between the bid summary quantity sheet and the true scope of work. Good quality control of project documents can prevent unbalanced bids.

Due to individual contractor competitive advantages, a simple comparison of the low bid to the PS&E estimate total does not provide enough information to strongly suggest unbalancing. However, a line-by-line, in-depth review of every bid item is neither practical nor productive in making evaluations of fair cost bidding and document quality control. A simple scan of all bid items by all bidders is the first review step and provides a general perception of document quality. Very high and very low bid item prices may point to the bid items with quality issues.

An unbalanced bid may be only mathematically unbalanced, or the bid may be mathematically and materially unbalanced. To detect mathematical unbalancing, which is when a price does not reflect a reasonable cost, the unit bid items should be evaluated for nominal conformance with the PS&E estimated item pieces and additionally compared with prices in the other bids that were received. There are no definitive parameters (i.e., an amount or percent of variance from the engineer's estimate) that constitute a mathematically unbalanced bid. While mathematically unbalanced bids are not prohibited per se, evidence of a mathematically unbalanced bid is the first step in proving a bid to be materially unbalanced. The U.S. Comptroller General defines a materially unbalanced bid as a bid that fails to provide an agency with the lowest ultimate cost for the project. An increase in project cost can happen because the bidder has increased the prices for items that will likely overrun (*Bid* 1988).

Bid item filtering that can easily be performed by computer provides additional insight into unbalanced bid items. Different criteria may be used by a DOT, though a simplified filter based on a total percentage and total dollar amount over/under the PS&E estimate establishes a standardized reporting process on document quality. One agency has adopted a ±20 percent and ±$25K filter for quality control reporting.

Computer software can easily produce statistical analysis and graphs of contractor bid item pricing in relation to data in an agency's historical bid price database. The statistical analysis examines how the bid prices for specific pay items compare to historical prices. Sophisticated analysis software can even be used to identify factors that affect pricing, such as relative project size, project location, or even economic conditions such as rising or falling commodity prices. However, such computer-supported reviews can only be performed if the DOT has a sufficiently large database of bid item data so that the necessary sample size can be obtained to perform the statistical analyses. Such reports provide a standard basis for price comparisons to detect pricing patterns and to support award decisions.

Quantity verification, triggered by apparent unit price unbalancing, involves contacting the designer to review quantities and provide written verification. In some cases, a simple review by the cost estimator may suffice to verify the quantity but may not reveal an error in item selection or a missing element within the item specification. One example would be rock excavation incidental to trenching, where the entire trench is in rock and a separate rock excavation item was warranted in the bid summary list but was not included.

If the DOT incorrectly states quantities in the bid documents, the corrected quantity must be used to calculate the corrected total bid for each contractor. If the order of bidders changes after the corrected quantities are applied, the procurement is normally deemed defective and all bids may be rejected. If no change to the order of bidders exists, the recommendation for award should indicate the revised total forecasted cost for the project. If the cost variation is significant, the contract should be reviewed to determine if re-bidding with the corrected quantities would be in the public's best interest.

A standard method for determining a potential change in the order of bidders includes:

- Identify total cost of project based on re-evaluated quantities
- Understand the tactics of the bidders in using the original proposal quantities to gain an offer advantage
- Identify other possible reasons to unbalance dollars
- Once understood, determine if there is a valid change in the order of bidders

8.3.5 Unit Price Comparison with PS&E Estimate

The selection of bid items for qualitative review is based on identification of line-item costs that are outside the normal statistical ranges. Software filtering tools and models can assist but do not replace an experienced review person or team in evaluating fair value of work.

Assessments of unit prices are made against the data in the DOT's bid item database and should include a review of line-item bid spreads for evaluations of quantity accuracy, correct selection of bid items, and risk transference to the contractor. Additionally, evaluations using cost-based estimating techniques may be helpful, particularly in the analysis of unusual factors that apply to unit price bid items.

Comparisons of hybrid lump-sum bid items based on bid history analysis can be difficult as these lump-sum items tend to be used for mathematical unbalancing. (Definitions of mathematical unbalancing can vary between DOTs. The interpretations of bid practices that constitute unbalancing are left to the individual DOT and frequently are guided by state statutes and procurement regulations. Definitions by the Code of Federal Regulations (CFR) and FHWA *Guidelines on Preparing Engineer's Estimates*, dated Jan. 20, 2004, are provided in Chapter 10.) These bid items utilize a reference quantity to assist in the development of a total cost from standard unit prices for the bid item. A much stronger grouping of bidder cost distributions is needed before quality control assessment of quantity and risk can be made. A strong background in cost estimating of these bid items is usually much more helpful in determining fair value of the hybrid lump-sum bid item. In some cases, a composite analysis of unit prices may be helpful for such bid items as retaining walls with backfill or a detour with excavation and paving elements.

In the case of standard lump-sum bid items, comparisons are extremely difficult, as reference quantities are usually not provided to assist in the development of the lump-sum total cost using standard unit prices. This type of bid item does not usually exhibit a tight distribution of bidders' prices. The PS&E estimate is generally based on some experienced evaluations from the designer based on past projects. Major variations in bid prices should always be referred to the individual in charge of developing the bid item cost. This type of bid item usually requires a very strong and prescriptive specification. The PS&E estimate should contain good documentation on how the lump-sum price was developed.

The bid summary quality review should include evaluations of missing bid items or incomplete designs that could result in substantial risk transfer to the contractor. Recommendations for corrections to the documents should be included with the recommendation of award, along with a recommendation for a period of delay to re-bid and a forecast of impacts to the future bid pool.

8.3.6 Constructability Review

Quite often, bidders will share their concerns over constructability of the project. Most often, these concerns come from high bidders and non-bidders. Information obtained from these sources can serve to focus the constructability review. Schedule restrictions should be evaluated, and it should be determined if bidders included liquidated damages within the bid for unacceptably aggressive schedules.

Overly restrictive traffic control impacts can affect bid costs. Work areas that are too small for productive work and unrealistic access to work areas are two constructability factors that can significantly affect bid prices. Remote locations will affect transportation and material costs, as well as labor efficiencies. Small projects in remote locations affect a contractor's willingness to bid. Small bid pools with high costs can be expected for this type of work.

Bidders have excellent insight into the constructability of a project. After the letting, the estimating group can contact the two or three lowest bidders and seek their view of the project, including concerns that impacted bid prices. The DOT estimators cannot negotiate prices with the bidders but simply seek information regarding constructability of the major items of work on the project. Input regarding the quality of the plans, schedule, and timing of the project may also be requested. Estimators must ensure that the bidders contacted are clearly aware that the reason for the discussion is to simply gather information regarding the project cost drivers and that it is up to them whether they want to respond. The discussion is in no way a guarantee that the project will be awarded or rejected, but simply a chance for the DOT to obtain additional information. The conversations should generally be one-sided, with the bidder describing how he/she saw the project.

8.3.7 Collusion Detection

Collusive bidding, price fixing, and bid rigging are common interchangeable terms for illegal, anti-competitive activity. The common thread throughout all of these activities is that they involve agreements or informal arrangements among independent competitors that serve to limit competition.

Detection of bid fraud and collusion relies heavily on analytical software and personnel specifically trained to evaluate bid proposals. The U.S. Department of Transportation's Office of the Inspector General provides guidance on fraud detection and on appropriate enforcement action. Many DOTs use the fraud and collusion detection BAMS/DSS® module that is included in the estimating software product AASHTOWare Project. As all the literature on statistical detection of bid collusion states, while these mathematical models focus on monitoring the contracting process for indicators of fraudulent activity, they do not provide positive proof of collusion; still, they can detect indicators of collusion, and such a warning should lead an agency to further investigate the contractor involved. The most common bid collusion activities are:

- Complementary bids—A pattern of consistently high bids or non-responsive bids made to give the appearance of competition in order to influence the award decision to a predetermined bidder.
- Territorial allocation—A pattern of consistent wins by a bidder within a specific area.
- Joint ventures—Submission of a complementary bid or other noncompetitive behavior by an eventual partner (i.e., subcontractor, supplier, etc.) to the successful bidder.
- Bid rotation—A coordinated pattern of winning and losing bid responses to assure that a predetermined bidder submits the lowest bid.

8.3.7.1 Misinformation

A group of independent competitors that joins together to limit competition is often referred to as a cartel. They have a monopoly on valid pricing information and seek to increase profits and mask their presence by passing misinformation to DOTs. Many DOTs create the PS&E estimate based on historical bid prices. After each letting, the DOT extracts prices from bids in order to improve future estimates. By manipulation of the number of bidders and individual bids, a cartel can increase the mean pricing of a bid item or decrease the variance of that pricing. Such manipulation of information affects the agency's future estimates and perception of project cost. Therefore, by the use of "phantom" bids, the cartel manipulates the agency's expectation regarding the price of future work (Feinstein et al. 1985).

This type of cartel activity transpired in North Carolina between approximately 1975 and 1980. While the cartel members did not always win the rigged bids, studies indicate that they were successful in raising bid prices 18 percent (Brannman and Klein 1992). Other studies of the situation found that the collusive contracts had an average of four bidders, showing there can be collusion even with a reasonable number of bidders. While later statistical models found indications of collusion, researchers were careful to note that these indicators are not an actual identification of collusive behavior. However, it was clear that a practice existed to actively engage in misinformation to the DOT (Feinstein et al. 1985).

Importantly, the researchers identified situations a cartel can use to convince a DOT of a one-time jump in costs. These are:

- Concealment of the real cost effect of technological innovations.
- Large shifts in demand when an agency embarks on a major program.
- A new product.
- Substantial and sustained inflation.

Under such conditions, a DOT must be very careful about using historical pricing to create estimates of future work.

8.3.7.2 Indicators of Collusive Bidding

Indicators of situations that may involve collusive bidding include:

- Bidders who are qualified and capable but who fail to bid, for no apparent reason. (This could indicate a deliberate scheme to withhold bids.)
- Certain contractors who always bid against each other or, conversely, certain contractors who never bid against one another.
- A successful bidder who repeatedly subcontracts work to companies that submitted higher bids or to companies that picked up bid packages and could have bid as prime contractors but did not.
- An apparent pattern of low bids regularly recurring, such as corporation X always being the low bidder in a certain geographical area or in a fixed rotation with other bidders.
- Failure of original bidders to re-bid, or an identical ranking of the same bidders upon re-bidding, when original bids were rejected as being too far over the PS&E estimate.
- A company who appears to be bidding substantially higher on some projects than on others with no logical reason for the differences.
- Bidders that have shorter haul distances who bid more than those who must incur greater expense because of longer distances.
- Joint venture bids where either contractor could have bid individually as a prime. (Both had technical capability and production capacity.)
- Bid prices that appear to drop whenever a new or infrequent bidder submits a bid.

These are all possible indicators of collusion but do not prove that illegal, anti-competitive activity is occurring. However, as with indicators from statistical analysis, these are sufficient to warrant referral to appropriate authorities for investigation.

8.3.8 Review Team Recommendation

Recommendations for award should include information related to mathematical unbalancing and material unbalancing.

8.3.8.1 Recommendation to Award

The following items should be considered in a recommendation to award:

- Identify project information, number of bidders, and percentage cost comparison to the PS&E estimate.
- Provide executive summary of accuracy of bid quantities and selection of bid items.
- Identify individual bid factors with high impact from the review of contractor bids.

- Provide a summary report of price comparisons (filter review items down to significant dollar thresholds or percentage cost above or below the PS&E estimate line-item values or by other statistical filter means).

8.3.8.2 Recommendation to Reject

Recommendations to reject should include information related to mathematical or material unbalancing and a review of the issues related to the cause for the rejection of the bid. There may be many reasons cited for rejection, each having its own weight for supporting the decision. If appropriate, a recommendation of corrective action to the documents and bid process should be included with the rejection. The following items should be considered in a recommendation to reject:

- Identify project information, number of bidders, and percentage comparison to PS&E estimate cost.
- Provide executive summary of conditions and quality of the bid, complexity of the project, competitiveness of the bidding, and degree of unbalancing in the bids.
- Provide executive summary of accuracy of bid quantities and selection of bid items.
- Provide summary report of price comparisons (filter review items down to significant cost thresholds above or below the PS&E estimate line-item values or by other statistical filter means).
- Provide recommendations for changes to bid documents.
- Provide cost assessment of risk transfer to the contractor based on the level of quality of the project design.
- Identify individual bid factors with high impact from contractor bids.
- Determine the potential for changes to the project that would result in savings if the project were re-bid.
- Propose ways to repackage the project with the aim of encouraging competition.
- Determine if the economic conditions would be different and could result in lower bids if the project were rejected and re-let, such as market conditions, contractor workload, temporary material shortages, etc.
- Determine if there was sufficient time allowed for the contractor to construct the project.
- Explain how rejecting all bids and changing the contract period will encourage lower bids.

8.4 PROJECT SPONSOR REVIEW AND RESPONSE

If the project sponsor or the design team opposes a recommendation not to award, a rebuttal document must include information related to all factors listed in Section 8.3.8.2. The response needs to discuss the following items:

- Compare the engineer's recommendations to pre-bid project development factors including the PS&E estimate.
- Rank and score recommendations for document changes based on:
  - Quantity accuracy.
  - Schedule constraints.
  - Competition forecasts.

- Compare the urgency of the project to cost deviations:
  - Are there safety considerations if the project is delayed?
  - Is the completion of this project critical to other upcoming projects?
  - Does this project complete a gap that is necessary to place a new facility in operation?
- Develop estimated costs that would result in changes to bid documents.
- Compare these costs to potential savings from design changes and future bid pool forecasts.

In the case of an engineer's recommendation for award, the DOT may still want to give the project sponsor the opportunity to express concurrence or to make an objection.

8.5 AGENCY DECISION

The highest delegated contract authority for the DOT should make the final recommendation for award. This is the authority that must weigh the recommendations from the reviewers against the spending guidance from the state legislature and the Federal Highway Administration partnership. This final decision evaluates all information provided by engineering and design, as well as consideration of the public trust, for best spending practices together with the state transportation system mobility infrastructure requirements. The items that should be considered include:

- Recommendations from the reviewing engineers and the project sponsor response.
- Project priority—consider those that are essential projects for safety or needed capacity, emergency projects, projects to close gaps, or critical stage element projects that would impact facility completion dates.
- Potential for savings if the project is re-advertised.

A final recommendation to award or re-advertise is made only after judicious consideration of these factors.

8.6 SUMMARY

DOTs employ a low-bid letting procedure because they do not know the exact cost (the cost experienced by a contractor) to complete a project. It is also true that even the contractor does not know the cost of a project until all work is completed; that is why bids are based on estimates and bid differences vary largely because of structural differences between contractors. Because of the limitations in predicting project cost, DOTs must have bid review procedures to ensure that offers by contractors are reasonably priced. These reviews provide the information necessary for making contract award decisions.

To verify the competitiveness of a bid and to ensure there has been no exploitation of bid item quantity differences, bid review processes rely on (a) historical unit bid databases, (b) unit bid prices from the current letting, (c) project contract documents, (d) current market condition information, (e) well-documented PS&E estimates, (f) available contractor pool data, and (g) bidding contractor capability data.

To ensure consistency and security, the fair market cost review of a bid should be performed within the DOT. The DOT staff responsible for developing or approving the cost estimate normally performs the initial analysis and provides an award/reject recommendation based on cost. In the case of bids above the PS&E estimate, the project designer may be called upon to provide an analysis of the additional costs above fair market against the essential need for the project. With that information, the awarding authority will make the final award decision.

When reviewing bids, the DOT should evaluate competition and possible issues of constructability, scheduling, document quality, design omissions, and risk transference. The next concern is the possibility of unit price unbalancing. Very high and very low bid item prices may point to the possibility of unbalancing within a bid. Using computer software, statistical analyses comparing bid items against data in the agency's historical bid price database can easily be done.

According to Porter and Zona (1993), "It is unlikely that any single test procedure could detect all collusive schemes without data on economic returns." This is because both competitive and collusive equilibrium depends to such a great extent on the economic environment. However, the BAMS/DSS® module of the estimating software product AASHTOWare Project has the ability to search for indications of bid collusion.

8.7 REVIEW EXAMPLES

Statistical analyses using historical pricing data are very good in answering most bid review questions; however, in the case of collusion, statistical techniques can only provide a possible indication of such activity. Researchers have warned that comparisons of winning bids and engineers' estimates may be unreliable because the agency's ex ante estimate (the PS&E estimate) can be unduly influenced by historical bidding patterns. In general, finding a single statistical test procedure to detect bid rigging is an impossible goal given available data (Porter and Zona 1993) and a cartel's ability to change the structure of the game. In consideration of these difficulties, the first case study is presented.

8.7.1 The Market

A cartel of construction contractors operated in one specific area of New York State for about six years. Cartel members submitted bids on most projects, but at meetings prior to the lettings, they designated a serious bidder and its bid. The total amount of contract awards over the period of interest was approximately $120 million and represented 186 contracts. In the case of the 161 projects having a value of less than $1 million, 66 different firms submitted bids. Yet, for the larger projects, those over $1 million, only 22 firms bid, and 45 percent of the bids were submitted by four firms (Porter and Zona 1993).

This particular case illustrates how specific market features are conducive to cartel conduct. The case specifics included the following:

1. Firms competed only on price. Agencies operate under the assumption that every qualified bidder will produce the same product. Product differentiation is not allowed, so a cartel needs to only coordinate price.
2. Plan holder lists provided ex ante knowledge of potential bidders.
3. The market was isolated geographically.
4. The number of bidders on large dollar projects in the geographical area was small.

5. Entry into the market was difficult because of ownership by incumbent contractors of local facilities—aggregate sources, asphalt plants, and concrete plants.
6. Local unions exerted significant control over production.

After one of the firms was convicted in federal court and four others named as participants in the bid-rigging scheme, a statistical study was made of the historical bid data. The researchers admit in their paper that "detecting bid rigging directly from bid data is difficult" (Porter and Zona 1993). The cartel was trying to create the appearance of competition and at the same time influence an agency's expectations about the cost of future projects. Additionally, the designated low bidder of the cartel had to bid competitively against firms outside the cartel. Therefore, the statistics used in this study sought to detect differences in the ordering of the higher bids. The analysis equations included a variable, "BACKLOG," that used the total dollar value of DOT contracts won but not completed assuming a constant rate of backlog burn. To capture differences between firms, there was a capacity variable that was a measure of the maximum backlog that a company exhibited during the sample time frame. The analysis also accounted for a firm's general geographical proximity to the job.

The conclusions based on the model were:

- The model fit the competitive data reasonably well. (Remember, this is an after-the-fact model, and researchers separated the cartel and competitive bids.)
- Bids from the cartel firms differed statistically from those of competitive firms.
- Cartel bids were generated by a different process depending on whether or not they were low.

Still, the strongest statement that could be made was that the researchers "found evidence of cartel activity" (Porter and Zona 1993). The first two case-specific points are common to almost all DOT work—because of the project specifications, firms are competing only on price, and potential bidders usually know their competition. However, when the last four points come into play, agencies need to exercise more care when examining bids. This is amplified by the fact that the study found collusion indicators only on the larger jobs that required access to more capital equipment. The study confirmed the fact that as backlog increased, capacity decreased and prices tended to rise about 7.5 percent. Consequently, it was clear that bidding patterns are affected by estimated project cost and company backlog, a factor that is constantly changing. Consequently, it is practically impossible to say bid rotation is per se evidence of collusive behavior (Hendricks and Porter 1989).

8.7.2 Very Low Bids

Very low bids must be carefully evaluated before making an award decision. In a recent court case, a contractor claimed unilateral bid error after failing to complete a project because of financial difficulty. The owner received four bids for the work with the highest being $6.7 million, the second lowest being $5.2 million, and the lowest at $3.4 million. The low bid was 10 percent below the project estimate. Because of the bid spread, the owner had a pre-award meeting with the low bidder, and the contractor gave three credible reasons for the cost difference: (1) he/she had a close disposal area for excess material; (2) he/she planned to rip instead of blast the rock; and (3) he/she planned to sell the excess material to a third party. It was only after the contractor failed to complete the work that he/she claimed a unilateral mistake on its bid and accused the owner of fraud because he/she awarded the contract when he/she knew the price was more that 50 percent lower than the second bidder (Loulakis 2011).

Because the courts found for the owner, it did not have to pay the contractor's claim. The owner did have to defend itself at the trial court and appeals court. The owner also had to engage a competent contractor to complete the work.

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CHAPTER 9

Performance Measures for Cost Estimating

9.1 OVERVIEW

Transportation agencies continuously strive to work more efficiently with limited available funding at both the federal and state levels. Likewise, estimators continuously strive to improve transportation cost estimating processes and the accuracy of estimates. The Transportation Research Board produced *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System* (Ryus et al. 2003) that laid the framework for DOTs to develop performance measurement programs. Since that time, DOTs have established performance measure programs, and these programs measure efficiency throughout agency processes (AASHTO 2008). To build on this framework, some DOTs have begun to develop performance measures specifically for cost estimating. This chapter discusses current cost estimating performance measures and presents methods to develop effective performance measures. The goals of this chapter are to present a state-of-the-practice overview of cost estimating performance measures and provide guidance for developing sound measures in the future.

9.1.1 What Is It?

The definition of performance measures is "the use of statistical evidence to determine progress toward specific defined organizational objectives. This includes both evidence of actual fact, such as measurement of pavement surface smoothness, and measurement of customer perception" (*Guidelines* 2004). Performance measures begin with the programmatic levels of service sought by the highway agency and impose, as broad classifications, desired outcomes required by the DOT. One example of a performance measure in highway cost estimating is a comparison of a project PS&E estimate to the low bid.

9.1.2 Why Use It?

There are three major reasons to use performance measures to improve and monitor transportation project cost estimating. First, the FHWA requires tracking and reporting of several specific performance measures in an effort to help improve effectiveness, efficiency, and public perception. Reporting and regulatory requirements dictate the use of a minimum number of performance measures (Ryus 2003). Second, performance measures provide useful information to agencies for continually improving their cost estimating processes. Third, performance measures are useful tools to communicate results to entities outside of the agency. Decision-making bodies, such as metropolitan planning organizations and FHWA, need to have access to accurate information to guide decisions (Ryus 2003).

9.1.3 When to Use It?

Due to the limited funds available for highway projects, estimates need to be as close to actual project costs as possible. A DOT cannot improve upon the accuracy of an estimate without tracking the accuracy of prior estimates. Development and use of performance measures can track and report on estimate accuracy. For example, consider a DOT that tracks the performance measure of PS&E estimates to low bids. The goal would be to have PS&E estimates equal to the low bid. If the performance measurement data show a trend away from this accuracy, a DOT may require a change in its cost estimating process. Another example relates to the use of performance measures when an agency seeks to increase competition through the letting process. Using performance measures that track the number of bidders per project type can assist in this process.

9.2 KEY INPUTS

Cost estimating performance measures require STIP and PS&E estimate values for each project. Comparisons are then made between the STIP estimate, the PS&E estimate, and contractor bids. It is also appropriate to compare the STIP estimate against the PS&E estimate. One can make comparisons between various design milestones and PS&E estimates, but consistent milestones can be difficult to identify, as the scope of projects and design processes can vary widely within an agency due to various factors, such as project size, location, and delivery method. Other key inputs for performance measures are the number of bidders per project, project location, description or classification of the type of work, the time required to complete the engineer's estimate, and the contingency amount included in the estimate at various design milestones. It is a good practice to collect the final project cost after construction and compare it to both the PS&E and contractor bids.

9.2.1 STIP Performance Measures

Performance measures at the STIP stage of design allow for understanding the accuracy of program estimates. At the STIP level (~4 years out from construction) of the development process, the program estimate includes the costs for the entire STIP as a whole as well as for individual projects included in the STIP. At this point in project development, estimating techniques such as parametric and risk-based estimating are typically used.

Performance measures for the STIP estimate should aim to evaluate the design and development process. These measures can focus on the level of scoping and quality of design that are the basis for preparing STIP estimates. Major changes to a project scope or to the programmatic packaging of projects can make performance measures difficult to track. Each DOT must consider how these issues are dealt with in its programming and performance measurement approach (i.e., removing a project from the STIP if there is a major change in scope).

STIP estimate performance measures can include comparisons to later design estimates, the final engineer's estimate at the PS&E level of project development, or contractor low bids. Using these comparisons, the agency can understand the accuracy of its STIP estimates and possibly the quality of its project scope definition process. When estimators understand the accuracy of current STIP estimates, it is possible to seek methods for future improvement. Table 9-1 shows three common performance measures used at the STIP phase of the project development process.

Table 9-1. STIP Cost Estimating Performance Measures

Performance Measure	Description
Initial STIP cost estimate vs. 60% design cost estimate	The initial STIP cost estimate comes approximately 4 years from the letting of project. During the 4 years, additional design is completed and a new estimate is created. These two estimates are then compared to find their percent difference.
Final STIP cost estimate vs. low bid	The final STIP cost estimate occurs when more design and scope is known but before final engineer's estimate. This estimate is compared to low bid amounts to find a percent difference.
Initial STIP cost estimate vs. final STIP cost estimate	This is a comparison of the initial STIP estimate to the final STIP estimate to find the percent difference.

9.2.2 PS&E Performance Measures

Final design performance measures focus on the final engineer's estimates and the low bid or awarded contract values. In the case of design-bid-build projects, the estimator performing the PS&E estimate has a complete project design and all of the project specifications. Due to the level of detail and known information, the final engineer's estimate provides the agency's best judgment of a fair market price for the work.

FHWA's *Guidelines on Preparing Engineer's Estimates, Bid Review, and Evaluation (Guidelines* 2004) states:

> *It is realized that estimate preparation is not an exact science; however, it is felt the engineer's estimate should be within +/-10 percent of the low bid for at least 50 percent of the projects.* ***If this degree of accuracy is not being achieved over a period of time****, such as one year, confidence in the engineer's estimates may decline. Further, if estimated total costs are made available to the public, even after the letting, and are consistently running well above the low bid (say 15-20 percent) when a sufficient workload is available, bidders may be cognizant of the higher estimates and may submit higher bids accordingly.*

This very broad performance measure is in use by many DOTs, either as an actual performance measure target or a benchmark for evaluating the quality of PS&E estimates. Some agencies use a tighter evaluation measure for award decisions. One example has a DOT using a ±7 percent target for testing the responsiveness of a contractor's bid. A low bid within the ±7 percent range as compared to the PS&E estimate receives a recommendation for award. If bids falls outside the ±7 percent range, the project is reviewed for missed scope, design, and possible errors. Such reviews can provide performance data for evaluating project designs and specifications.

Another example in using the FHWA guideline comes from another DOT. Engineers and estimators use a -15 to +5 percent range in lieu of the +/-10 percent range from the FHWA guideline. This adjusted range allows the DOT to accept more bids that are below the PS&E estimate. If a bid comes in between -15 percent and +5 percent, it receives a recommendation for award. If the bid falls outside this range, the agency thoroughly reviews the project.

Table 9-2 provides examples of using the federal guideline on final engineer's estimates when compared to low bids.

Table 9-2. FHWA and Modified Guidelines for Evaluating Contractor Bids

Performance Measure	Description
FHWA guideline for PS&E vs. low bid	Low bid to be within +/–10% of the PS&E estimate for 50% of all projects let
Modified guideline for acceptance of a low bid	Low bid to be within +/–7% of the PS&E estimate for 50% of all projects let
Modified guideline for acceptance of a low bid	Low bid to be within –15% to +5% of the PS&E estimate for 50% of all projects let

The most common performance measures used by DOTs currently involve comparisons of the low bid to the PS&E estimate. However, agencies can use other comparisons that are for evaluating the quality of a PS&E estimate. That is, agencies can fashion comparisons of the PS&E estimate to final project costs. It may also be appropriate to average the three lowest bids for a project for a better reflection of project cost. Using the average of several of the lower bids received for a project is probably a more valid evaluation of the PS&E estimate in terms of fair market value, but this is not a commonly used measure. Table 9-3 lists several alternative performance measures for PS&E estimates.

Table 9-3. PS&E Estimate Performance Measures

Performance Measure	Description
PS&E estimate vs. low bid	The most common cost estimating performance measure. A comparison of the PS&E to the low bid received at letting.
PS&E estimate vs. final construction costs	A comparison of the final engineer's PS&E estimate to the final construction costs when the project is complete.
PS&E estimate vs. STIP estimate	A comparison of the STIP program estimate to the PS&E estimate.

Figure 9-1 represents graphical results of the final engineer's estimate as compared to low bids per month from WSDOT. These data compile all bids and estimates for each month. These types of graphical representations clearly depict cost estimating performance measures.

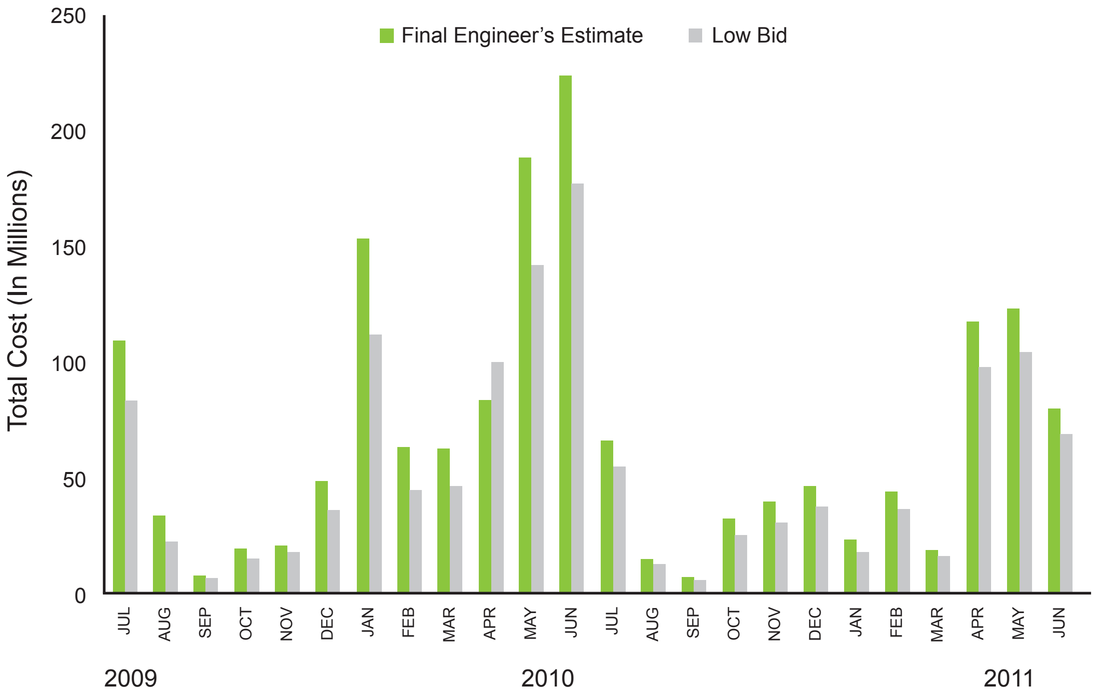

Figure 9-1. Graph of Final Engineer's Estimate vs. Low Bid
(Source: Washington DOT performance measures website—http://www.wsdot.wa.gov/business/construction/accountabilityandperformance.htm)

9.2.3 Additional Cost Estimating Performance Measures

The common cost estimating performance measures discussed thus far in this chapter seek to establish the accuracy of estimates compared to other estimates in the project development process, the low bid, or final project costs after construction. Other estimating performance measures look at aspects of cost estimating beyond accuracy.

Projects that solicit multiple bids provide the DOT estimator with data about market competition. Performance measures using these data track and monitor the number of bidders per project and provide for analyzing how competition affects bid prices. Figure 7-2 provides a graphical representation of the Texas DOT bid unit prices and the overall effect of the number of bidders. This figure provides a means for tracking the number of bidders per project and the associated unit prices. A DOT can also use these data to track the average number of bidders by contract size. This information can prove beneficial in establishing a competitive letting program for different sized projects. This information will also help estimators adjust estimates based on competition effects. Table 9-4 shows four competition effect performance measures.

Table 9-4. Competition Effects

Performance Measure	Description
Number of bidders and mean unit prices	The number of bidders per project and the associated mean unit prices.
Average number of bidders	The number of bidders on average for all projects in a specific period of time.
Average number of bidders by size of contract	The number of bidders based on contract amount. This could also be refined to types of work.
PS&E vs. low bid, segregated by number of bidders	A comparisons of the PS&E to the project low bid in the case of one, two, three, four, or more bidders.

To illustrate the effect of the average number of bidders on contract price, Figure 9-2 adds the average number of bidders to Figure 9-1 from WSDOT. This reveals how factors other than design and specification affect project costs. Figure 7-1 also shows the tracking comparison of the low bid to the PS&E estimate based on the number of bidders for Caltrans projects. Both Figures 7-1 and 9-2 show that the more bidders per project, the lower the unit cost or bid.

Creating estimates requires time for DOT personnel. Tracking and monitoring the time that estimators need to complete estimates at each phase of the project development process provides an agency with a helpful performance measure of its estimating processes. Table 9-5 provides a list of common estimator-hour performance measures that will help DOTs plan and account for their personnel time.

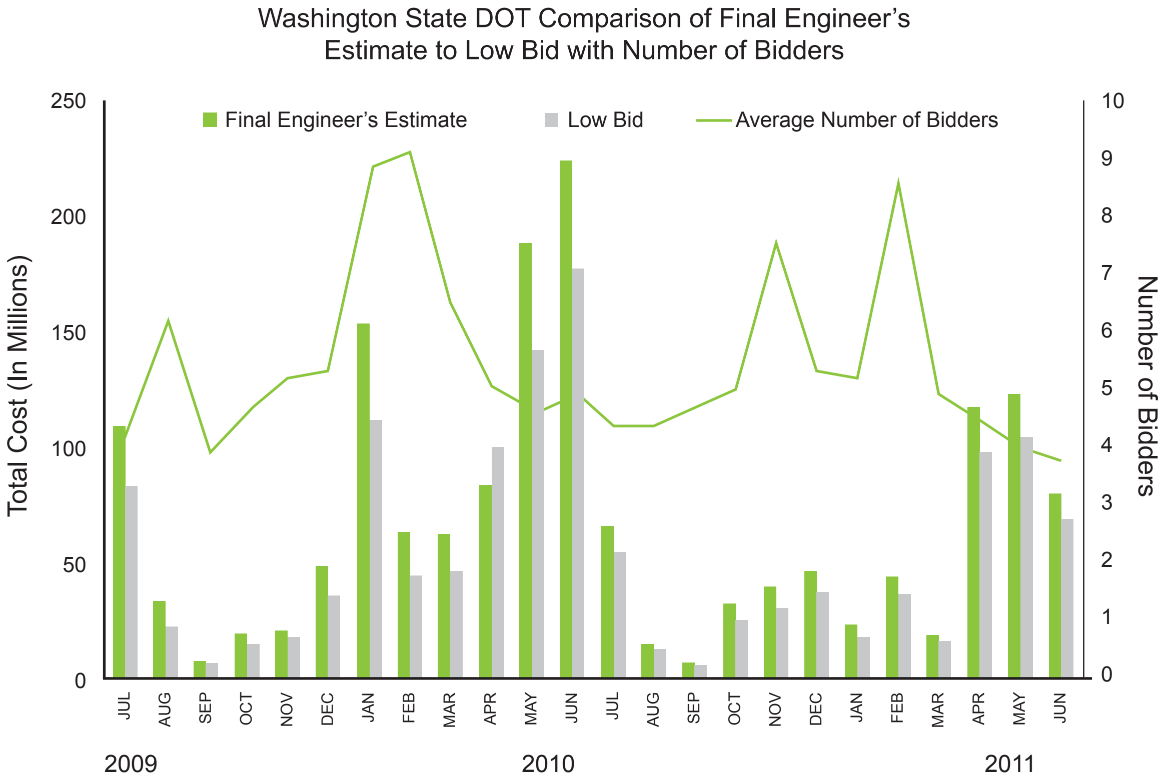

Figure 9-2. Final Engineer's Estimate vs. Low Bid with Average Number of Bidders
(Source: Washington DOT performance measures website)

Table 9-5. Estimate Process Performance Measures

Performance Measure	Description
Average time to complete an estimate (STIP, 60% design, or PS&E)	The amount of time on average to complete an estimate at any phase of project development process
Average time to complete an estimate based on contract size or type of work	The amount of time on average to complete an estimate at any phase of project development process based on contract amount of type of work

An important component of all estimates is contingency. Tracking contingency and the percent used to complete a project allows an agency to evaluate its procedures for setting estimate contingency amounts. Contingency performance measures can be broken into categories depending on project complexity. See Section 5.3 for a more detailed discussion of appropriate contingency amounts. Refer to Table 9-6 for a list of contingency amount performance measures.

Table 9-6. Contingency Amount Performance Measures

Performance Measure	Description
The average percent contingency used per project	The percent contingency of the total project cost. This includes all projects regardless of contract size. The amount of contingency is expected to be higher at early design milestones and decrease in the later stages of design.
The percent contingency used based on complexity or type	The percent contingency of the total cost by complexity or type. The amount of contingency is expected to be higher at early design milestones and decrease in the later stages of design.

9.3 DEVELOPING EFFECTIVE PERFORMANCE MEASURES

Effective performance measurement programs can provide estimators and DOT management with significant benefits. Proper planning and use of performance measures supports development of accurate and timely estimates. Performance measures assist DOTs in evaluating the quality of their estimating and project development processes.

9.3.1 Performance Measurement Program Framework

AASHTO provides a basic performance measurement program (AASHTO 2008). Figure 9-3 shows the AASHTO program flow chart. This figure explains the steps and process of developing and using performance measures discussed in this section. Estimators may want to refer to *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System* (Ryus et al. 2003). This report contains detailed information on the performance measurement program framework and individual program steps, as well as how to develop a new performance measurement program.

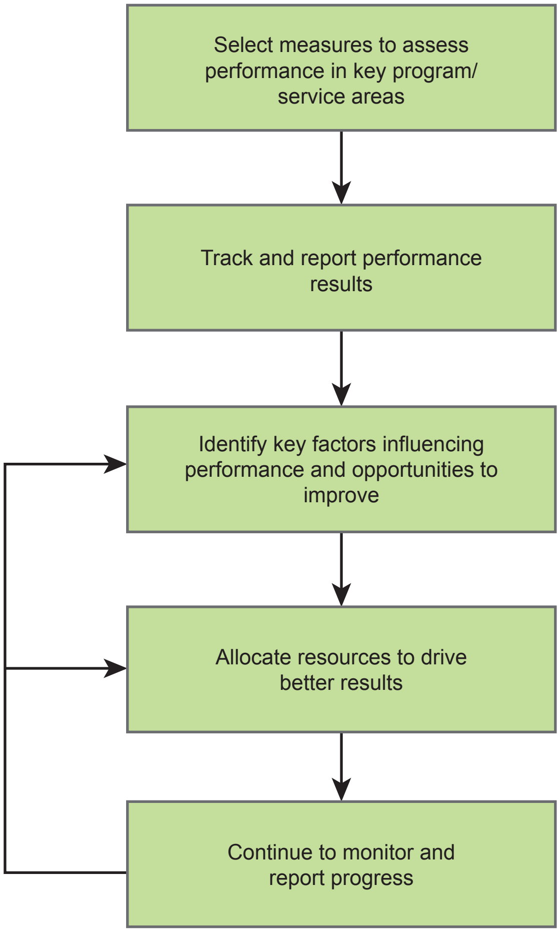

Figure 9-3. AASHTO's Performance Measurement Program (AASHTO, 2008)

DOTs develop strategic goals and performance objectives to help improve the overall performance of the agency. Statewide strategic goals typically include areas such as safety, congestion and mobility, environmental compliance, stewardship, and preservation (Ryus et al. 2003). Performance objectives are, in essence, DOT mission statements or objectives for each state policy area. Performance objectives are to guide the decisions made by both the DOT and contractors over the course of the project development process and the project (Crossett and Hines 2007). These goals and objectives should be consistent for the entire agency and applicable to specific agency functions, such as estimating.

For a performance measurement program to work successfully, a DOT needs to have the ability to analyze goals and objectives and whether these goals and objectives are being achieved (Page and Malinowski 2008). Therefore, DOTs must link performance measures to the agency's goals and objectives to obtain valuable information. Keeping performance measures linked to goals and objectives helps estimators and management understand the analysis and results of the performance measure.

To follow performance measures correctly, estimators will want to monitor certain vital information, often called key performance indicators. Key performance indicators typically include but are not limited to elements such as targets, benchmarks, milestone dates, numbers, percentages, variances, distributions, rates, time, cost, indexes, ratios, survey data, and report data (Molenaar and Navarro 2010). These data provide a DOT with tangible figures as to the performance of a program or project. They allow the agency to determine whether it achieves its set performance measures based on the positive and negative contributions of the key performance indicators. In simplest terms, key performance indicators are the data estimators used to reveal if DOTs are achieving the set performance measurement targets.

To understand and compute performance measures, tracking and collecting specific data must occur. However, the personnel collecting the data need to use a consistent tracking system to collect that data. The tracking system can be as simple as using computer software spreadsheets, but the data need to be easy to collect and access. Table 9-7 shows an example of data taken from one DOT and illustrates tracking data using MS Excel.

Table 9-7. Data Tracking for Performance Measures

Year	Month	Key Performance Indicator		Performance Measure Avg Bidders per Project	Key Performance Indicators		Performance Measures	
		Number Projects	Number Bidders		Estimated Costs	Low Bids	Low Bids Over+/Under(–)	% Difference
FY2009	JUN	10	40	4.00	$ 40,769,027.92	$ 44,747,811.11	$ 3,978,783.19	9.8%
	JUL	9	31	3.44	$ 8,212,049.40	$ 8,374,813.19	$ 162,763.79	2.0%
	AUG	8	29	3.63	$ 22,988,623.11	$ 16,115,015.80	$ (6,873,607.31)	–29.9%
	SEP	9	46	5.11	$ 11,731,668.46	$ 10,062,396.80	$ (1,669,271.66)	–14.2%
	OCT	4	18	4.50	$ 56,466,096.15	$ 50,007,896.36	$ (6,458,199.79)	–11.4%
	NOV	5	20	4.00	$ 11,856,271.52	$ 10,567,533.94	$ (1,288,737.58)	–10.9%
	DEC	1	3	3.00	$ 251,512.00	$ 584,171.00	$ 332,659.00	132.3%
	JAN	16	53	3.31	$ 65,532,887.98	$ 50,226,902.92	$ (15,305,985.06)	–23.4%
	FEB	19	59	3.11	$ 63,191,596.48	$ 54,350,329.77	$ (8,841,266.71)	–14.0%
	MAR	16	46	2.88	$ 90,913,463.85	$ 84,777,695.50	$ (6,135,768.35)	–6.7%
	APR	11	37	3.36	$ 38,088,067.63	$ 34,716,884.59	$ (3,371,183.04)	–8.9%
	MAY	38	80	2.11	$ 161,497,969.26	$139,817,352.27	$ (21,680,616.99)	–13.4%
FY2010	JUN	15	52	3.47	$ 71,912,360.06	$ 64,434,457.34	$ (7,477,902.72)	–10.4%
	JUL	14	62	4.43	$ 37,540,698.84	$ 31,752,957.53	$ (5,787,741.31)	–15.4%
	AUG	14	59	4.21	$ 84,539,198.26	$ 72,165,665.20	$ (12,373,533.06)	–14.6%
	SEP	8	41	5.13	$ 46,983,605.16	$ 41,526,149.04	$ (5,457,456.12)	–11.6%
	OCT	14	50	3.57	$ 58,304,286.79	$ 34,062,305.70	$ (24,241,981.09)	–41.6%
	NOV	5	25	5.00	$ 11,883,562.69	$ 11,230,678.07	$ (652,884.62)	–5.5%
	DEC	1	6	6.00	$ 2,621,500.00	$ 3,633,894.00	$ 1,012,394.00	38.6%
	JAN	14	48	3.43	$ 26,887,684.58	$ 23,137,300.79	$ (3,750,383.79)	–13.9%
	FEB	10	38	3.80	$ 29,513,466.73	$ 25,624,548.93	$ (3,888,917.80)	–13.2%
	MAR	14	52	3.71	$ 80,492,286.68	$ 72,936,455.62	$ (7,555,831.06)	–9.4%
	APR	20	90	4.50	$ 106,909,486.98	$106,039,817.46	$ (869,669.52)	–0.8%
	MAY	16	66	4.13	$ 63,022,108.78	$ 61,710,870.03	$ (1,311,238.75)	–2.1%

9.3.2 Major Characteristics of Effective Performance Measures

Different performance measure types and metrics allow DOTs to develop an effective system for managing and improving their estimating functions. The challenge is creating performance measures that are both effective and useful. Performance measures have value only if they are useful—the performance measure must accurately reflect what is happening in the system. This allows for proper performance monitoring and improvement. Along with usefulness, good quality performance measures need to be clearly defined, concise, and easy for non-specialists to comprehend (*A Manual* 2007). Table 9-8 lists the major characteristics of effective performance measures.

Table 9-8. Major Characteristics of Effective Performance Measures (Ryus et al. 2003)

Characteristic	Definition
Useful	The performance measure must reflect what is happening in the system.
Timely	All performance measures need to have an established beginning and end so a finite amount of information is tracked and monitored.
Significant	The performance measure has to provide information that represents the current state of performance.
Measurable	The data needed for a performance measure need to be available from common resources and databases.
Attainable Targets	Established targets of performance measures need to be currently unattained but reachable in the near future.
Reasonable Results	The results of a performance measure must be understandable, make sense, and provide clear information on areas in need of improvement.

A good performance measure must provide timely information. The performance measure must have a specific end date or conclusion point. Recording and tracking data indefinitely does not help estimators to understand performance. The data analysis has to have a cut-off date so that the DOT can determine the performance for a specific time period. In addition, the tracking of data should take place at regular intervals. The intervals can be monthly, yearly, or multiyear periods depending upon the performance measure. The intervals depend on the resources available to collect that data and the durations necessary to accumulate sufficient data to draw conclusions.

Performance measures need to be useful, timely, and significant. Significant performance measures are measures that truly represent performance. For example, estimators can measure and track data for various levels of estimating as well as for specific parts of estimates, such as general conditions or a specific AASHTO guide specification section. However, the agency will need to determine which measures are appropriate for its particular operating situation.

A DOT should design its performance measures so that it is feasible to collect the necessary data. The data for a performance measure must be available and collectable in a reasonable manner. It is important to use existing data sources. DOTs often assume that new performance measures require new data sources, when existing sources can often suffice (Cameron et al. 2003).

Effective performance measures need to have a forecasted target that is currently unattained but achievable. Common targets are specific quantities, a range of values, a moving average, incremental improvement or trending, and modifiable over time (Ryus et al. 2003). The difficult part for management is determining what the target should be for a specific performance measure. Estimators and management need to evaluate current goals and objectives to determine what is not being accomplished. Forecasting targets below current accomplishments or setting the target too high will result in failed performance measures, and nothing worthwhile will come of the effort. An example of a target is a PS&E estimate vs. award bid cost performance measure having a target of the bid award amount within ±10 percent of the PS&E estimate. This example is an industry standard. Once that target is reached, the goal can be lowered to ±9 percent, something that is still achievable. In fact, agencies try to work in the ±5 percent range or closer.

Another aspect of developing an effective performance measure is the ability to understand reasonably the successes and failures at the conclusion of the performance measure program. A performance measure must show that an area needs improvement or is achieving the process goals and objectives. A performance measure that does not produce a conclusion has little value.

9.3.3 Analysis and Results

After collecting and measuring performance data, an estimator can review and analyze the data to create the performance information. Timely and consistent reporting of performance measures is vital to an effective program (Gransberg and Villarreal-Buitrago 2002). The more data available, the better the analysis and results.

One way to analyze performance measures is to compare past data with current data (Gransberg and Villarreal-Buitrago 2002). This comparison allows personnel to know the performance of current work against past work. Other comparison options for analyzing results include comparing data from the beginning of a project or program to final data or comparing similar information with other DOTs and agencies.

Another way to analyze performance measures is by evaluating the established target. A target in cost estimating is a financial benchmark or a percent. A financial target benchmark is a set cost budget that estimators try to match or come close to. A percent target benchmark would be a percent over or under project costs when compared to design estimates.

9.4 SUMMARY

Performance measures are powerful tools for establishing the quality of DOT project cost estimates. Federal requirements mandate minimum performance measures, and DOTs establish additional measures to continuously improve their estimating process. Comparisons can be made to evaluate STIP, design, and PS&E estimates and an agency's estimating processes. This allows for analysis and improvements in the overall estimating process.

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9.6 CHAPTER 9 ADDITIONAL RESOURCES

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Definitions

Authorization Estimate—Cost estimate used for federal authorization and advertisement.

Award of Contract—Acceptance by a governing agency of a bid proposal.

Advertisement—The public announcement, as required by law, inviting bids for work to be performed or materials to be furnished.

Allowance—An amount included in the base estimate for items that are known but the details of which have not yet been determined.

Base Estimate—The most likely project estimate, exclusive of project contingency, for known costs for all known design, engineering, cooperative agreements, right-of-way, environmental, utilities, preconstruction, and construction work.

Bid-Based Estimating—Method of estimating in which historical bid data are used.

Bidder—An individual, partnership, firm, corporation, or joint venture formally submitting a proposal for the advertised work or materials. In order for bidders to be eligible for award of a contract, bidders must meet specified qualification requirements.

Conceptual Estimate—(also known as "**Parametric Estimate**") A cost estimate prepared from only a concept description of a project. This estimate is prepared before plans, specifications, and other project details have been fully developed.

Confidence Level—The probability that a range will contain the value under consideration, for example, "There is a 90 percent probability that the ultimate project cost will be less than $(number)."

Contingency—An estimate of costs associated with identified uncertainties and risks, the sum of which is added to the base estimate to complete the project cost estimate.

Contract—The written agreement between an agency or governing body of an agency, or both, and a contractor, setting forth the obligations of the parties, including but not limited to the performance of the work, the furnishing of labor and materials, and the basis of payment. The contract includes the invitation for bids, proposal, contract form and contract bond, specifications, supplemental specifications, interim specifications, general and detailed plans, special provisions, notices to bidders, notice to proceed, and any agreements that are required to complete the construction of the work in an acceptable manner, including authorized extensions thereof, all of which constitute one instrument.

Contract Plans—The signed and sealed documents prepared during the design phase and used by construction personnel to build a project.

Cost-Based Estimating—Method of estimating that uses material, equipment, labor costs, production rates, profit, and overhead for accomplishing a task to derive cost.

Cost Escalation—Increases in the cost of a project or item of work over a period of time.

Cost Management—The process for managing the cost estimate through reviews and approvals, communicating estimates, monitoring of scope and project conditions, evaluating the impact of changes, and making estimate adjustments as appropriate.

Direct Pay Items—Those pay items for which payment is based on the quantity of the item completed.

Equipment—The expense associated with productive machine work. It will include both ownership and operating cost but not the operator, which is a labor cost.

Estimate Basis—A documentation of the project type and scope for each cost estimate, including items such as 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.

FHWA Major Project—A project receiving federal financial assistance with a total estimated cost of $500 million or more, or a project that has been identified by the DOT leadership as a result of special interest.

Force Account—A method of payment that pays a contractor actual expenses for labor, materials, and equipment to complete the work and includes a set percentage for overhead and profit.

Fringe Benefits—Employee benefits that an employer must pay in addition to an employee's base pay. Typically, these may be paid directly to the employee or they may be paid to various agencies on behalf of the employee. They would include health insurance, pension plans, and certain taxes.

Historical Bid-Based Estimating—(also known as "**Bid-Based Estimating**") A method of estimating using data from past bids as a basis for estimating current unit prices.

Inflation—The rate that the cost of goods or services increases or, consequently, the decrease in purchasing power. Therefore, an estimated cost must be adjusted for the time difference between historical cost data and the assumed date of project execution.

Initial Estimate—The first estimate released publicly by the DOT. This estimate is usually made with only minimal scope definition.

Labor—Work hours and wages, including fringe benefits, paid directly to onsite personnel for installing permanent materials.

Letting—A function that includes advertisement of proposed construction projects, receipt of bids, and the opening and reading of the bids in a public setting.

Letting Schedule—A document that lists projects and specific dates on which the projects will be let for construction (month, day, and year). Typically, it includes projects that will be let in a period of one year or less.

Lowest Responsible Bid—The lowest bid that meets legal criteria for submitting bids.

Lump-Sum Pay Item—A single pay item included in the contract for work that otherwise would be multiple work items. The grouping of multiple work items may be done for efficiency of administration or because it is difficult to quantify the individual items.

Major Pay Item—An item whose total monetary value, determined by multiplying the proposed quantity by the contract unit price, is equal to or greater than a significant percentage (agency dependent) of the original total contract amount.

Mass Diagram (Mass Haul Diagram)—In earthwork calculations, the mass diagram is a graphical representation of the algebraic cumulative quantities of cut and fill along the centerline, where cut is positive and fill is negative. It is used to calculate haul distance.

Materials—Items that are installed permanently in the completed project.

Mathematically Unbalanced—A unit price or lump-sum bid that does not reflect a reasonable actual cost plus a reasonable proportionate share of the bidder's anticipated profit, overhead costs, and other indirect costs (note: per 23 C.F.R. §635.102).

Materially Unbalanced—A bid is materially unbalanced if there is reasonable doubt that award to a bidder submitting a mathematically unbalanced bid will result in the lowest ultimate cost to the agency.

Minor Pay Item—An item whose total monetary value, determined by multiplying the proposed quantity by the contract unit price, constitutes an insignificant percentage (agency dependent) of the original total contract amount.

Notice to Contractor—A document that lists pay items with significantly unbalanced bids that requires an explanation and confirmation of the unit price bid from the contractor.

Official Estimate—(also known as "**Engineer's Estimate**") Agency's official construction cost estimate that is used for evaluating bids received on a proposal.

Overhead Expenses—Costs incurred that are not identified with one specific bid item or project. Rather, these costs support an entire project or many projects. They reflect expenses for such indirect costs as rent, insurance, communications, and utilities.

Plans, Specifications & Estimate (PS&E)—The contract plans, specifications package, and estimate submittal used for project authorization, advertisement, and letting.

Preliminary Estimate—Any estimate after the initial estimate, which precedes the PS&E estimate. These estimates can be made with anywhere from 10 percent to 95 percent complete plans. It may be desirable to categorize these estimates to indicate the completion level of project documents used to compile the estimate.

Probability—A measure of how likely a condition or event is to occur. It ranges from 0 to 100 percent (or 0.00 to 1.00).

Program Estimate—A preliminary estimate used in the STIP or agency multiyear program. This estimate may be in current-year dollars or year-of-expenditure dollars.

Project—Planned construction activity with set limits and scope including approaches or temporary works, or both, together with all appurtenances and construction to be performed thereon under the contract.

Proposal—Project or group of projects prepared for construction cost estimating and bidding purposes.

PS&E Estimate—The construction cost estimate used as a benchmark to compare against contractor bids. This estimate is prepared using 100 percent completed plans with all itemized pay items, quantities, and contract documents.

Risk—The uncertainty of an event or condition that, if it occurs, has a negative or positive effect on a project's objectives.

Scope—Encompasses the elements, characteristics, and parameters of a project and work that must be accomplished to deliver a product with the specified requirements, features, and functions.

Scope Changes—Changes in the requirements, features, or functions on which the project design and estimate are based. Examples would include changes to project limits, work types, or capacity factors such as traffic loads, vehicles per lane, or storm water factors.

Scope Creep—As opposed to scope change, which is a major change affecting project cost and schedule, scope creep is an accumulation of minor scope changes that incrementally change project scope, cost, and schedule.

Significantly Unbalanced—A mathematically unbalanced bid that is significantly lower than the statistical average, such as a penny or zero bid. (Agencies can have their own specific definition, such as "unit bid prices that are 75 percent below the statistical average.")

Statistical Average—The average of all unit price bids plus the estimate for a specific pay item excluding outliers as determined by the department's unbalanced bid algorithm.

Standard Pay Items—Commonly used items as described in the DOT's standard specifications.

Unit Price—The price (including materials, labor, equipment, overhead, and profit) in a contract for a specifically described unit of work. This is also known as the in-place cost or contract unit price.

AASHTOWare Project—An AASHTO suite of software products that facilitates contract estimating, bidding, award, and construction administration.

> **AASHTOWare Project Cost Estimation** (Cost Estimation System)—A module in the AASHTOWare Project suite that is used by estimators as a tool for pricing construction proposals.
>
> **Trns•port LAS** (Letting and Awards System)—A module in the Trns•port System suite that is used for bid lettings and contract award.
>
> **Trns•port PES** (Proposal and Estimates System)—A module in the Trns•port System suite that is used to summarize the design-related pay items and quantities on a proposal.

ExeVision's integrated Project Development (iPD) software:

The iPD (integrated Project Development) solution is a comprehensive project development application designed specifically for state and local departments of transportation that fully integrates all functional aspects of road and bridge construction—from estimating and electronic bidding, through final contractor payment and project closeout. This includes a fully integrated construction process, start-to-finish and a single database with single data-entry point.

Oman Systems software applications:

BidTabs Professional Windows-based software program combines a search engine with DOT bid tabulation data. With this program, the user can analyze, sort, search, and find information about market trends or specific contractors, pay items, or projects.

BidTabs PLUS is an add-on module (program) to BidTabs Professional, allowing the user to set up a spreadsheet of pay items with multiple columns of prices. The user can import the pay item data for an upcoming job from an electronic format such as Expedite or Excel and then load pay item prices (averages) from BidTabs Professional into different columns.

ProEstimate-HEAVY is a program specifically designed for heavy/highway contractors and sub-contractors to assist in the preparation of a bid. The program contains multiple levels of options which provide varying levels of detail. The estimating techniques used in the program are those used throughout the construction industry.

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Summary

AASHTO "PRACTICAL GUIDE TO COST ESTIMATING"

A state department of transportation's (DOT) ability to successfully manage and deliver its program is largely dependent on an ability to develop realistic estimates of project cost. Cost estimating involves not only the collection of relevant factors relating to the scope of a project and the cost of resources, but it also requires anticipating cost impacts that may occur due to changes in project scope, available resources, and national and global market conditions.

Responding to this need for accurate cost estimates, the American Association of State Highway and Transportation Officials (AASHTO) Technical Committee on Cost Estimating (TCCE) was charged with developing "practical" guidance on preparing estimates. Once their work began, it became apparent that little existing guidance was available to aid their efforts. The TCCE had to prepare guidance from scratch calling on the expertise of the various members and their agencies to document the best practices in use by DOTs.

At the same time the TCCE began its work, the National Cooperative Highway Program (NCHRP) was focusing on the issue of project cost escalation and published Report 574. That Report, *Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction,* provides appropriate strategies, methods, and tools to develop, track, and document realistic cost estimates during each phase of the project development process. It is a strategic view of how to produce project estimates.

Since the publication of the NCHRP Report 574, two other NCHRP estimating projects have produced reports on the subject. NCHRP Report 625, *Procedures Guide for Right-of-Way Cost Estimation and Cost Management* and NCHRP Report 658, *Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Cost.* Both reports provide special topic information that supports development of accurate and reliable cost estimates.

All of these parallel cost estimating guidance efforts and knowledge bases were married together to produce this "practical" guidance that serves those charged with the development of DOT cost estimates and with the management of the estimating process. This guidebook has two parts. Part I focuses on key cost-estimate techniques and Part II focuses on cost management activities.

KEY ESTIMATE TECHNIQUES

Part I of this guide covers in separate stand-alone chapters the following cost estimating techniques:

- Conceptual Estimating
- Bid-based Estimating
- Cost-based Estimating
- Risk-based Estimating

Conceptual or parametric estimating techniques are primarily used to support development of planning or early scoping phase estimates when minimal project definition is available. Statistical relationships or non-statistical ratios, or both, between historical data and other project parameters are used to calculate the cost of various items of work (i.e., center lane miles or square foot of bridge deck area).

Historical bid-based estimating relies heavily on element or bid items, or both, with quantities and good historical bid data for determining item cost. The historical data normally is based on bids from recent projects. The estimator must adjust the historical data to fit the current project characteristics and location. The historical data must also be adjusted to reflect current dollars. With the use of historical bid data, estimators can easily and quickly prepare estimates.

Cost-based estimating considers seven basic elements: time, equipment, labor, subcontractor, material, overhead, and profit. Generally, a work statement and set of drawings or specifications are used to "take off" material quantities required for each discrete work task necessary to accomplish the project bid items. From these quantities, direct labor, materials, and equipment costs are calculated based on calculated or assumed production rates. Contractor overhead and profit are then added to this direct cost.

Risk-based estimating combines (1) traditional estimating methods for known items and quantities with (2) risk analysis techniques to estimate uncertain items, uncertain quantities, and risk events. The risk-based portion of the estimate typically focuses on a few key elements of uncertainty and combines Monte Carlo sampling and heuristics (rules of thumb) to rank critical risk elements. This approach is used to establish the range of total project cost and to define how contingency should be allocated to critical project elements.

Each of these four techniques is discussed in detail in Chapters 2, 3, 4, and 5, respectively.

COST MANAGEMENT

Cost estimating is closely tied to cost management. Part II of this guide covers the following topic areas:

- Inflationary considerations
- Letting strategies for cost control
- Analysis of contractor bids
- Performance measures for cost estimating

Inflation is critical to estimating costs in the future. Inflation covers changes in cost over time. Adjustments for inflation include converting historical data to current dollars. Adjustments for inflation also include converting current dollars to future dollars based on a rate of inflation and the midpoint of construction expenditures. Indexing uses several tools such as cost indices, statistical analysis, and other modeling techniques. Experts in economics should be consulted when establishing future inflation rates.

Letting strategies are an important component of the estimating process. The use of both short- and long-term strategies will improve project bids and the validity of cost estimates. Long-term strategies are fundamental changes in the bid letting process and include timing of lettings, balancing of lettings, and packaging of projects for letting. Short-term strategies include such actions as contractor-selected packaging of projects, contractor self-imposed award limits, flexible notice to proceed, and contractor use of construction alternatives.

Analysis of contractor bids by a state department of transportation is a significant component of the competitive bidding process. To ensure a competitive contracting environment, agencies must have effective and consistent bid review and award recommendation procedures. The procedures must be transparent in a manner that is publicly understandable, economically efficient, legally defensible, and socio-politically acceptable.

Performance measures entail the use of tools to better understand and control cost estimating outcomes. Cost estimating performance measures track the attainment of cost estimating and project delivery functions. Tracking and evaluating cost estimating data allow efficient allocation of estimating resources while assisting in the development and justification of budgets and project proposals.

AUDIENCE

This guide offers comprehensive, consistent, and proven guidance on structured approaches to project cost estimation. It sets forth practical steps for preparing estimates during the planning and preconstruction phases of project development, and summarizes information from the main findings of the previous NCHRP studies combined with the information provided by the AASHTO TCCE.

The intended primary users of this guide are estimators that prepare estimates during specific project phases or across the entire project development process. An estimator would use Chapters 2, 3, 4, and 5. Managers involved in project development should review Chapter 1 to gain an overall perspective of project cost estimating. Further, there may be others who require knowledge of the cost estimating process but do not necessarily prepare cost estimates. As such, the guide is a resource for professionals involved in project development.

Agency management and project managers should read Chapter 7 to determine bidding strategies that will aid in controlling costs. Chapter 8 should be of interest to construction engineers and estimators, as evaluation of bids can aid in cost control as well as provide valuable information for estimating future projects. Finally, agency management would be interested in Chapter 9, which provides insights into program and project management by providing concepts around performance measures.

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ACKNOWLEDGMENTS

This guidance is the result of several years of hard work that began with the AASHTO Subcommittee on Design Technical Committee on Cost Estimating (TCCE). TCCE members drafted the content of the guidance in 2004, working on two to three chapters a year based on personal experience as cost estimators, while continuing to do their full-time jobs. In an effort to expedite the production of the document, TCCE utilized the NCHRP 20-7 process, specifically Tasks 278 and 308, to take the initial guidance and complete the guide. TCCE would like to thank Keith Molenaar and Christofer Harper from University of Colorado, Stuart Anderson from Texas Transportation Institute, and Clifford Schexnayder from Arizona State University for their contributions and co-authoring the completed guide. TCCE would also like to thank Andrew Lemer from NCHRP. This guide would not be in existence today without the dedication and passion from both the past and current TCCE members who often worked nights and weekends to make the publication of this document possible.