

PRACTICAL GUIDE TO COST ESTIMATING



2013 • FIRST EDITION

Contents

SUMMARY	xv
CHAPTER 1 Practical Guide to Cost Estimating Overview	1-1
1.1 Introduction	1-1
1.1.1 Background	1-2
1.1.2 Purpose	1-2
1.1.3 Audience	1-2
1.2 Project Development Phases	1-3
1.2.1 Cost Estimating Process	1-5
1.2.2 Estimating Focus	1-8
1.3 Overall Guidebook Structure	1-9
1.3.1 Part I—Key Estimate Techniques	1-9
1.3.2 Part II—Cost Management	1-10
1.4 Roadmap for Guide Use	1-11
1.5 Chapter 1 References	1-11

PART I. KEY ESTIMATE TECHNIQUES

CHAPTER 2 Conceptual Estimating	2-1
2.1 Overview	2-1
2.1.1 What Is It?	2-1
2.1.2 Why Use It?	2-2
2.1.3 When to Use It?	2-2
2.2 Key Inputs	2-2
2.2.1 Project Definition	2-2
2.2.2 Project Characteristics	2-3
2.2.3 Historical Database Requirements	2-3
2.2.4 Macro-Environment and Market Conditions	2-14
2.3 Prepare Base Estimate	2-14
2.3.1 Select Appropriate Estimating Approach	2-15
2.3.2 Determine Estimate Components and Quantify	2-18
2.3.3 Develop Estimate Data	2-19
2.3.4 Compile Cost Estimate	2-21
2.3.5 Document Estimate Assumptions and Other Estimate Information	2-21
2.3.6 Prepare Estimate Package	2-22
2.4 Determine Risk and Set Contingency	2-22
2.4.1 Contingency	2-22
2.5 Quality Assurance and Quality Control	2-23
2.5.1 What to Check?	2-24
2.6 Summary	2-24
2.7 Project Examples	2-24
2.7.1 Bridge Project	2-24
2.7.2 Asphalt Paving Project	2-26
2.7.3 Paving and Bridge Project	2-27

2.8 Chapter 2 References	2-29
2.9 Chapter 2 Additional Resources	2-29
CHAPTER 3 Bid-Based Estimates	3-1
3.1 Overview	3-1
3.1.1 What Is It?	3-1
3.1.2 Why Use It?	3-1
3.1.3 When to Use It?	3-1
3.2 Key Inputs.	3-2
3.2.1 Project Definition	3-2
3.2.2 Project Characteristics	3-2
3.2.3 Historical Database Requirements	3-2
3.2.4 Macro-Environmental and Market Conditions	3-6
3.3 Prepare Base Estimates.	3-7
3.3.1 Select Appropriate Estimating Approach	3-7
3.3.2 Quantify Estimate Components	3-8
3.3.3 Develop Estimate Data.	3-9
3.3.4 Compile Cost Estimate.	3-17
3.3.5 Document Assumptions	3-17
3.3.6 Prepare Estimate Package	3-18
3.3.7 Risk Analysis and Contingency.	3-18
3.4 Quality Assurance and Quality Control	3-19
3.4.1 How to Check?	3-19
3.5 Summary	3-19
3.6 Project Example	3-19
3.6.1 Excavation	3-24
3.6.2 Pavement Structure	3-24
3.7 Chapter 3 References	3-25
CHAPTER 4 Cost-Based Estimates	4-1
4.1 Overview	4-1
4.1.1 What Is It?	4-1
4.1.2 Why Use It?	4-1
4.1.3 When to Use It?	4-2
4.2 Key Inputs.	4-2
4.2.1 Historical Database Requirements	4-2
4.2.2 Labor Cost.	4-3
4.2.3 Equipment Cost	4-3
4.2.4 Material Cost Data	4-6
4.2.5 Subcontract Items	4-6
4.2.6 Macro-Environment Market Conditions	4-6
4.3 Prepare Base Estimate	4-7
4.3.1 Project Definition	4-7
4.3.2 Project Characteristics	4-7
4.3.3 Labor Pricing	4-8
4.3.4 Equipment Pricing	4-9
4.3.5 Material Pricing	4-11
4.3.6 Subcontract Pricing	4-12

4.3.7 Contractor Indirect/Overhead and Profit	4-12
4.3.8 Adjustments	4-14
4.3.9 Compilations	4-15
4.3.10 Document Assumptions	4-16
4.3.11 Risk Analysis to Set Contingency	4-18
4.4 Quality Assurance/Quality Control	4-18
4.4.1 How to Check?	4-19
4.5 Summary	4-19
4.5.1 Deliverables	4-20
4.6 Project Example	4-20
4.6.1 Concrete Estimate	4-20
4.7 Chapter 4 References	4-26
4.8 Chapter 4 Additional Resources	4-26
CHAPTER 5 Risk-Based Estimates	5-1
5.1 Overview	5-1
5.1.1 What Is It?	5-1
5.1.2 Why Use It?	5-2
5.1.3 When to Use It?	5-2
5.2 Key Inputs.	5-3
5.2.1 Project Complexity.	5-3
5.2.2 Design and Estimate Assumptions and Concerns	5-4
5.3 Determine Risk and Set Contingency	5-5
5.3.1 Determine Risk	5-5
5.3.2 Set Contingency.	5-8
5.4 Quality Assurance and Quality Control	5-20
5.4.1 How to Check?	5-20
5.5 Summary	5-21
5.6 Project Examples	5-21
5.6.1 WSDOT Cost Risk Assessment Example	5-21
5.6.2 Caltrans Probabilistic Risk-Based Estimate Example.	5-24
5.7 Chapter 5 References	5-26

PART II. COST MANAGEMENT

CHAPTER 6 Inflationary Considerations.	6-1
6.1 Overview	6-1
6.1.1 What Is It?	6-1
6.1.2 Why Use It?	6-2
6.1.3 When to Use It?	6-2
6.2 Key Inputs.	6-3
6.2.1 Data Availability.	6-3
6.2.2 Conceptual Model Types	6-7
6.2.3 Data Collection Approaches.	6-8
6.3 Key Analysis Tools	6-9
6.3.1 Indices	6-9
6.3.2 Static Analysis	6-11
6.3.3 Regression Modeling	6-12
6.4 Who Does It?	6-14

6.4.1 Internal Agency-Developed Forecasts	6-14
6.4.2 Consultants	6-15
6.4.3 Combined Internal and Consultant Efforts	6-15
6.5 Construction Cost Updating Frequency	6-16
6.5.1 Semi-Annually	6-16
6.5.2 Annually	6-16
6.6 Summary	6-16
6.7 Project Example	6-17
6.8 Chapter 6 References	6-19
CHAPTER 7 Letting Strategies for Cost Control	7-1
7.1 Overview	7-1
7.1.1 What Is It?	7-2
7.1.2 Why Use It?	7-2
7.1.3 When to Use It?	7-2
7.2 Key Inputs.	7-2
7.2.1 Historical Bidding Studies	7-3
7.2.2 Macro-Environmental/Market Conditions	7-4
7.2.3 Letting Strategies	7-5
7.3 Strategies to Improve Bid Responsiveness.	7-5
7.3.1 Scheduling of Projects for Bid	7-5
7.3.2 Balancing of Projects in a Letting	7-7
7.3.3 Packaging of Projects into Proposals	7-8
7.3.4 Contractor-Selected Packaging of Projects	7-9
7.3.5 Contractor-Imposed Award Limits on Multiple Projects	7-10
7.3.6 Flexible Start Dates	7-11
7.3.7 Use of Alternatives	7-13
7.3.8 Price Adjustment Clauses	7-15
7.4 Quality Assurance/Quality Control	7-16
7.4.1 Number of Bidders vs. Contract Amount	7-17
7.4.2 Ideas	7-18
7.5 Summary	7-18
7.5.1 The Strategies	7-18
7.6 Review Example	7-19
7.6.1 The Woodrow Wilson Bridge Experience	7-19
7.7 Chapter 7 References	7-20
7.8 Chapter 7 Additional Information	7-22
7A Appendix—Packaging of Projects Policy Guidance	7-23
CHAPTER 8 Analysis of Contractor Bids.	8-1
8.1 Overview	8-1
8.1.1 What Is It?	8-1
8.1.2 Why Use It?	8-2
8.1.3 When to Use It?	8-2
8.2 Key Inputs.	8-2
8.2.1 Historical Unit Bid Data	8-2
8.2.2 Letting Unit Bid Prices	8-3
8.2.3 Bid Documents	8-4

8.2.4 Macro-Environmental/Market Conditions	8-5
8.2.5 PS&E Estimate and Supporting Data	8-5
8.2.6 Number of Bidders and Current Backlogs	8-6
8.2.7 Low Bidders' Performance History	8-6
8.3 Bid Review Process	8-7
8.3.1 Competition Review	8-8
8.3.2 Market Review	8-9
8.3.3 Distribution and Range of Bids	8-9
8.3.4 Unbalanced Cost Review Prior to Unit Price Comparisons	8-10
8.3.5 Unit Price Comparison with PS&E Estimate	8-11
8.3.6 Constructability Review	8-12
8.3.7 Collusion Detection	8-12
8.3.8 Review Team Recommendation	8-14
8.4 Project Sponsor Review and Response	8-15
8.5 Agency Decision	8-16
8.6 Summary	8-16
8.7 Review Examples	8-17
8.7.1 The Market	8-17
8.7.2 Very Low Bids	8-18
8.8 Chapter 8 References	8-19
CHAPTER 9 Performance Measures for Cost Estimating	9-1
9.1 Overview	9-1
9.1.1 What Is It?	9-1
9.1.2 Why Use It?	9-1
9.1.3 When to Use It?	9-2
9.2 Key Inputs	9-2
9.2.1 STIP Performance Measures	9-2
9.2.2 PS&E Performance Measures	9-3
9.2.3 Additional Cost Estimating Performance Measures	9-5
9.3 Developing Effective Performance Measures	9-7
9.3.1 Performance Measurement Program Framework	9-7
9.3.2 Major Characteristics of Effective Performance Measures	9-9
9.3.3 Analysis and Results	9-11
9.4 Summary	9-11
9.5 Chapter 9 References	9-11
9.6 Chapter 9 Additional Resources	9-12
CHAPTER 10 Definitions	10-1

List of Figures

Figure 1-1. Project Development Phases (NCHRP 8-49).	1-4
Figure 1-2. General Cost Estimating Process.	1-7
Figure 1-3. Application of Contingency.	1-8
Figure 2-1. Typical Section (NUU = New Construction Undivided Urban).	2-5

Figure 2-2. Bridge Cost Factors.	2-11
Figure 2-3. Lane-Mile Costs Based on Completed Projects Source: Cost Estimation... 2008.	2-12
Figure 2-4. Typical TRACER System Input for a Bridge.	2-16
Figure 2-5. Typical TRACER Beam Input for a Bridge.	2-17
Figure 2-6. Typical TRACER Output for a Bridge.	2-18
Figure 2-7. Project Estimate File Outline	2-23
Figure 2-8. Project A Location Map and Existing Cross Section	2-28
Figure 3-1. Typical Data Entry Form.	3-4
Figure 3-2. Spreadsheet Used to Import Bid Data.	3-5
Figure 3-3. Typical Database Query.	3-10
Figure 3-4. Historical Bid Analysis Using Regression.	3-11
Figure 3-5. Section NB 10+00 to NB 35+00 of the Roadway Plan.	3-21
Figure 3-6. Typical Pavement Cross Section.	3-22
Figure 3-7. Cross Section for Earthwork Calculation at NB 28+00 (Section A).. . . .	3-22
Figure 3-8. Cross Section for Earthwork Calculation at NB 23+00 (Section B).. . . .	3-23
Figure 3-9. Cross Section for Earthwork Calculation at NB 28+00 (Section C).	3-23
Figure 4-1. Earthwork Hauling Equipment vs. Haul Distance.	4-5
Figure 5-1. Refinement of a Cost Estimate.	5-3
Figure 5-2. Three-Tier Approach to Contingency Estimation.	5-8
Figure 5-3. Sliding Scale for Non-Complex (Minor) Projects.	5-10
Figure 5-4. Sliding Scale for Moderately Complex Projects.	5-11
Figure 5-5. Sliding Scale for Most Complex (Major) Projects.	5-11
Figure 5-6. Mean and Mode in Normal and Lognormal Distributions.	5-15
Figure 5-7. Distributions for Risk Analysis Input.	5-16
Figure 5-8. Example Sensitivity Analysis with Tornado Diagram.	5-17
Figure 5-9. Typical Monte Carlo Output for Total Costs.	5-18
Figure 5-10. Example Risk Management Template.	5-19
Figure 5-11. Example of Probabilistic Risk-Based Estimate Output from WSDOT.	5-23
Figure 5-12. Example of Probabilistic Risk-Based Estimate Template from Caltrans	5-25
Figure 6-1. Asphalt Data from 2002 through 2009.	6-6
Figure 6-2. The CPI and the BHWY over an 11-Year Period.	6-10
Figure 6-3. An Example of a Regression Model Created to Model the ODOT's Cost Index.	6-13
Figure 7-1. Caltrans Comparison of the Low Bid vs. the Engineer's Estimate.	7-3
Figure 7-2. IADOT Project Letting Announcement	7-7
Figure 7-3. Effect of Number of Bidders' Average Unit Price.	7-8
Figure 7-4. Bid Form for Award Limits on Multiple Projects	7-11
Figure 7-5. WSDOT Flexible Start Date Special Provision	7-12
Figure 7-6. FDOT Flexible Start Time Provision.	7-13
Figure 7-7. Asphalt Bid Prices—MoDOT Alternate Bidding Experience (Missouri 2007).	7-14
Figure 7-8. Concrete Bid Prices—MoDOT Alternate Bidding Experience (Missouri 2007).	7-14
Figure 7-9. Average Number of Bidders—MoDOT Alternate Bidding Experience (Missouri 2007).	7-15
Figure 7-10. Average Bidders per Project by Month.	7-17
Figure 7A-1. Iowa Department of Transportation, Office of Design Packaging of Projects for Letting	7-24
Figure 9-1. Graph of Final Engineer's Estimate vs. Low Bid.	9-5
Figure 9-2. Final Engineer's Estimate vs. Low Bid with Average Number of Bidders.	9-6
Figure 9-3. AASHTO's Performance Measurement Program (AASHTO, 2008).	9-8

List of Tables

Table 1-1. Development Phases and Typical Activities	1-3
Table 1-2. Estimate Types and Purposes	1-5
Table 1-3. Cost Estimating Classification	1-5
Table 2-1. Development of Lane-Mile Cost Factor	2-6
Table 2-2. Illustration of Construction Cost per Centerline Mile Based on Similar Project.	2-8
Table 2-3. \$/SF of Bridge Deck—Statewide Average Historical Ranges in 2011 Dollars	2-9
Table 2-4. Preliminary Engineering Costs' Average Percentage Ranges (% of Construction)	2-13
Table 2-5. Average Percentage Ranges for Right-of-Way Costs (% of Construction)	2-14
Table 2-6. Bridge Replacement Conceptual Estimate Example	2-26
Table 2-7. Asphalt Paving Project Conceptual Estimate Example	2-27
Table 2-8. Conceptual Estimate of Project A Using Similar Past Project	2-28
Table 2-9. Conceptual Estimate of Project A Total Project Cost	2-29
Table 3-1. Typical Items Included in a Historical Bid-Based Database	3-3
Table 3-2. DOT Statewide Bid Averages—2010	3-23
Table 3-3. Selected Item Numbers for Project Estimate	3-24
Table 3-4. DOT Selected Item Numbers with Quantities for Project Estimate	3-25
Table 3-5. Estimate of Costs for Selected Items	3-25
Table 4-1. Example of an Excavation Task Estimate Format	4-16
Table 4-2. Excavation Crew Documentation	4-17
Table 4-3. Reference Book Data for Concrete Placements	4-22
Table 4-4. Concrete Placement Production Using Reference Book Data	4-23
Table 4-5. Labor Rate Analysis	4-23
Table 4-6. Cost Estimate for Placing Wall Concrete	4-24
Table 4-7. Concrete Cost Estimate	4-25
Table 5-1. Example of Complexity Classification	5-4
Table 5-2. Common Transportation Risks and Risk Categories.	5-7
Table 5-3. Examples of Representative Risks for Project Complexities	5-9
Table 5-4. Description of Project Characteristics Relating to Sliding-Scale Contingency Values	5-10
Table 5-5. Simplified Deterministic Risk-Based Analysis Method Example	5-13
Table 6-1. Static Analysis Example	6-12
Table 6-2. Ohio DOT Regression Model—December 2008	6-13
Table 6-3. Illustration of Construction Cost per Centerline Mile Based on Similar Project.	6-17
Table 6-4. Highway Cost Index (Base Year 1987 = 100.0)	6-18
Table 7-1. WSDOT Letting Competition (Number of Bidders) by Project Size	7-17
Table 9-1. STIP Cost Estimating Performance Measures	9-3
Table 9-2. FHWA and Modified Guidelines for Evaluating Contractor Bids	9-4
Table 9-3. PS&E Estimate Performance Measures	9-4
Table 9-4. Competition Effects.	9-6
Table 9-5. Estimate Process Performance Measures	9-7
Table 9-6. Contingency Amount Performance Measures	9-7
Table 9-7. Data Tracking for Performance Measures	9-9
Table 9-8. Major Characteristics of Effective Performance Measures (Ryus et al. 2003)	9-10

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.