Introduction

This Reference Guide provides instruction for the creation and management of construction cost estimates for roadway and bridge projects. This guide provides a framework of recognized and accepted processes and tools that each TxDOT district can adapt and use as appropriate for their situation.

The Reference Guide was developed to:

- Achieve accuracy, accountability, and consistency in cost estimation, and cost management efforts during the Planning and Programming, Preliminary Design, and Design phases of project development as well as in construction
- Acknowledge that uncertainty exists in all projects and how to account for and present the impact of those uncertainties within a cost estimate
- Define a process framework relating to cost estimating, and cost estimate management that can be consistently applied to ensure that TxDOT is thorough and transparent in the development of roadway and bridge projects
- Follow a framework based on national research and recommended best practices from other state departments of transportation and federal guidelines
- Include discussions and tools to address projects of different complexity/rigor levels

Components of a Cost Estimate:

**Base Estimate:** Will be developed and documented by the districts, engineering judgment will be applied. They will be developed and based on the best information known at the time and the phase of the project.

**Allowances:** Items known to be required on the project but at a particular project development stage are not yet known or quantifiable.

**Contingencies:** Costs for unknowns and uncertainties should be documented and included in the engineer's estimate.
**Risk and Contingency:**
Cost estimation considers uncertainties and related risks early and often in the project development process. Management uses identified risks and uncertainties to structure procedures that mitigate, eliminate, or account for the possible variation in the outcomes.

- Contingency is needed in an estimate to account for the second type of known unknowns.
- Risk management practices and tools can assist in the calculation of appropriate contingencies to account for these costs.

By their very nature, risks have a probability of occurring and if they do occur, will impact the project in a positive or negative way. A Project Contingency is used to capture the cost impacts associated with risks.

Contingency funds are incorporated into a cost estimate to account for the risks associated with the project.

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**Project Development Phases:**

**Project Phase:** The current project phase is used to identify necessary steps in developing the cost estimate. As shown in Figure 1: Project Development Process Phases, each phase builds on the previous phase’s information. Items listed for the Planning and Programming Phase are also used in the Preliminary Design and Design Phases.

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**Figure 1: Project Development Process Phases**

- **Planning and Programming**
  - Determine purpose and need, determine whether it’s an improvement or requirement study, consider environmental factors, facilitate public involvement/participation, and consider interagency conditions.
  - For planning and programming phase estimates, the contingency can be very large. In fact, the contingency can potentially be larger than the Base Estimate if very little is known about the project’s definition.

- **Preliminary Design**
  - In this phase the environmental analysis, schematic development, right-of-way impact, potential funding authorization, design criteria and parameters, survey utility locations and drainage, and alternative selections are developed.
  - For preliminary design phase estimates, the contingency will still be large but will reduce as the project develops and more knowns are identified with the scope. Allowances for categories of items will be identified (bridge, roadway, pedestrian...etc.)

- **Design**
  - Acquire right-of-way, develop plans, specifications, and estimates (PS&E), and finalize pavement and bridge design, traffic control plans, utility drawings, drainage design, and cost estimates.
  - For design phase estimates, the allowances will be very little as more known items will be come part of the base estimate. Contingency will also be significantly reduced as well at this stage of development.

- **Letting**
  - Prepare contract documents, advertise for bid, hold a pre-bid conference, and receive and analyze bids.
  - Estimate is based on actual bid items and quantities once the project has entered the Design Phase.
  - Contingency will be determined by FIN Engineering and Contingency percentages by project class. District adjustments within ranges will be allowed.
Construction Cost Estimate Development and Project Phase:

Project Cost Maturity is how the project cost develops over time with the project, the more developed a project is, the cost estimate becomes more defined. Until the final engineer’s estimate just prior to letting, an estimate is compiled with various levels of known and unknown information. Figure 2: Project Cost Maturity, combines the concept of accounting for the Base Estimate and Contingencies separately throughout project development as well as the idea that an estimate can fluctuate due to unknowns, risks, and variability. Notice how contingency reduces as the design matures because assumptions are resolved, risks are managed, and fewer unknowns remain in the estimate. As a project moves through the development process, the proportion of “knowns” to “unknowns” change so that, ideally, the project goes to letting with little contingency.

- An estimate at any given point is made up of a base estimate, allowances, and contingency component. As the project progresses in development, the contingency and allowance amounts are expected to decrease because the project information is refined. The base estimate increases as some of the project contingency and allowances are realized and included as part of the base estimate.

![Figure 2: Project Cost Maturity](image-url)
Cost Estimating Framework

The framework for the cost estimating process presented provides a systematic approach for determining anticipated project costs, as shown in Figure 3: Cost Estimating Framework. The description of the steps are generic and applicable to the cost estimating process across each development phase. These steps convey the idea of a structured approach to cost estimation. The operational manner in which the steps are performed will vary depending on project development phase. (The level of completeness in the project scope and refinement of project design will drive these variations.)

Figure 3: Cost Estimating Framework
## Developing a Cost Estimate:

<table>
<thead>
<tr>
<th>Key Activities</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Review project definition and requirements.</strong></td>
<td>Collect and review relevant project information to gain knowledge of the project in order to identify the proper items and inputs that will serve as an accurate basis of the estimate and its updates.</td>
</tr>
<tr>
<td><strong>B. Review site characteristics.</strong></td>
<td>Helps the Estimator gain knowledge get a holistic perspective as well as, insight, and a better understanding of the project site characteristics and their impact on cost. <strong>Examples of cost increase</strong> – work adjacent to historic structures, environmentally sensitive or hazardous sites, and limited work space. Site Constraints that require a large amount of equipment or if the contractor will need to mobilize several times. <strong>Example of cost decrease</strong> – green field construction, limited traffic control devices.</td>
</tr>
</tbody>
</table>
| **C. Determine and quantify estimate elements for known items for the base estimate.** | Determine the categories and quantities for the known items in the base estimate at the time. Be certain to state and document any assumptions in determining pricing and quantities at the time.  
- Three point estimating will be done for determining the base estimate. Three point estimating is the utilization of three estimates (current or historical). This method will assist to improve the accuracy of a single-point estimate by considering price variability and takes into account uncertainty and risk, by evaluating the optimistic, most likely, and pessimistic cost outcomes. This provides an estimator to tailor the estimate costs to their location and have a more holistic approach to the pricing. Three point estimating defines a cost range for an activity's durations as well as item’s quantities.  
- Appendix A details how to conduct a three point estimate. |
| **D. Determine areas of known work but are not yet quantifiable for the allowances.** | Develop/update allowances for each category of work. Document any assumptions that are made for the project in determining the cost of the allowances at that time. Allowances can be determined for category of items for the project such as: roadway, pedestrian, safety items,...etc. based on the appropriate price unit. Appendix B will go into detail on determining allowances. For example: If a bridge is part of the project requirements, all bridge elements will not be individually detailed. The bridge cost can be estimated based on square foot of bridge deck area or based on historical bids from similar types of bridges. |

> Every project, regardless of size or complexity, needs an up-to-date Project Estimate File. Based on the maturing of project design and/or the amount of time that has passed since the previous estimate, a completely new estimate may be warranted.  

> Document all assumptions and changes. Documentation of assumptions and methods for identifying and accounting for allowances and contingency within an estimate is critical so contingency is not double-counted.  

> Getting input from others avoids unnecessary or inaccurate assumptions.  

> Design alternatives need a documented base estimate, list of assumptions, and a list of considered risks for which the contingency is derived. This information should be consistent with the level of information available at the time of each estimate.
| **E. Determine contingency based on the project’s stage of development.** | Develop/update contingency based on the project phase of development. Document any assumptions that are made for the project in determining the contingency at that time and project phase. Contingency funds are incorporated into a cost estimate to account for the risks associated with the project. Contingency is meant to protect the project against cost increases that may arise when risks become reality. Contingency is not for overruns, inflation, or allow for scope creep. There are different methods in determining the contingency for a project.
1. **Letting Contingency** - A set percentage applied to the overall project cost to determine the Total Construction Cost Estimate. Contingency will default to Financial Management Division Engineering and Contingency data sheet (examples include safety contingency, change orders, etc.) based on project class.
2. **Risk Based Contingency** - An element of uncertainty is inherent in any cost estimate. In order to account for as much of the uncertainty associated with a project cost estimate as is practical, project teams will use a risk analysis to estimate the contingency amount to be included in the Total Construction Cost Estimate. Appendix C will go into detail in determining a Risk Based Contingency. |
| **F. Review documented estimate assumptions, inputs, and calculations.** | State the decisions and assumptions used in the estimate for communication to management in a structured format. Accumulate and organize all details, summaries, and assumptions made in completing the estimate. |
| **G. Communicate Estimate** | Estimates can be communicated and shared with confidence to internal and external stakeholders. This will reduce perception of cost increase as a project develops. Discussion of project cost and needs can be communicated in a confident and transparent manner with the public and our planning partners. |
Appendix A: Three Point Estimating

Utilization of three estimates is to define an approximate range for an activity's durations, quantities, and costs to improve upon the accuracy of a single-point estimate by considering uncertainty and risk. Concept originated from the Program Evaluation and Review Technique (PERT).

- PERT Beta Distribution Estimation Equation:
  \[ E = \frac{(O + 4M + P)}{6} \]

- Most Likely (M): Most realistic expectations of activity durations/quantities/costs
- Optimistic (O): Best-case scenario of activity durations/quantities/costs
- Pessimistic (P): Worst-case scenario of activity durations/quantities/costs

**Standard Deviation \( \sigma \):** A quantity calculated to indicate the extent of deviation from the mean.

\[ \sigma = \frac{(P - O)}{6} \]

- Optimistic (O): Best-case scenario of activity durations/quantities/costs
- Pessimistic (P): Worst-case scenario of activity durations/quantities/costs

**Confidence Level:** The probability that the value for the activity falls within a specified range of values.

- 68% confidence level = +/- 1 \( \sigma \)
- 90% confidence level = +/- 1.645 \( \sigma \)
- 95% confidence level = +/- 2 \( \sigma \)
- 99.7% confidence level = +/- 3 \( \sigma \)
A tool to assist with the calculations and determination of the estimate confidence level is available at the following link:
https://txdot.sharepoint.com/:x:/r/sites/office-epmo/intranet/_layouts/15/Doc.aspx?sourcedoc=%7B802E7503-E4A7-4E44-9D37-D940CD7DEC5B%7D&file=Risk-Based%20Cost%20Estimation.xlsx&action=default&mobileredirect=true

The following image is a snapshot of the tool that will assist with the three point estimating and determining the base estimate. In this tool the known and identified items will be entered at each phase of the project’s development. There are tabs for each stage to document the estimate.

Note: Considerations in determining the bid prices: geographic location, quantity of item, item availability, type of qty pricing such as lump sum.
Appendix B: Determining Allowances:

Allowances are for the known items that you have that are not yet quantifiable. For example, it is known that a project will need some traffic items (pavement markers, signs, lighting); however those items are not just yet quantified. We will apply the same concept of the most likely, optimistic outcome, and pessimistic outcome as we did in the Three Point for the Base Estimate.

The same tool that is used to determine the Base Estimate also has a section for determining the allowances as well. Below is a snapshot of the tool being utilized to determine the allowances for a project.

Tool to determine allowances: https://txdot.sharepoint.com/:x:/r/sites/office-epmo/intranet/_layouts/15/Doc.aspx?sourcedoc=%7B802E7503-E4A7-4E44-9D37-D940CD7DEC5B%7D&file=Risk-Based%20Cost%20Estimation.xlsx&action=default&mobileredirect=true

![Figure 1: Determining Allowances](image-url)
Appendix C: Risk Based Contingency

Evaluating the risk and applying the contingency formally and consistently will create a cost estimate that builds in all costs to match what you end up paying, not what you end up bidding.

Risk and Impact to Construction Cost:

<table>
<thead>
<tr>
<th>Key Activities</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine Level of Risk Management Needed</td>
<td>Understanding the level of risk analysis needed for this project will help identify who needs to be involved in risk management and the level of effort anticipated. Tailor as needed and determine which elements will be used and not used within the Risk Register</td>
</tr>
<tr>
<td>Identify Any Known Risks</td>
<td>All projects—regardless of size and complexity—contain elements of uncertainty. These uncertainties can pose risks to meeting the project’s objectives including being delivered on budget. Identifying risk throughout project development helps TxDOT to eventually monitor and control those risks.</td>
</tr>
<tr>
<td>Determine Cost of Risks</td>
<td>The key purpose of this activity is to figure out the costs of your Event driven risks in order to determine the amount of contingency that should be carried in the estimate to cover these potential risks.</td>
</tr>
<tr>
<td>Determine Probability of Each Risks</td>
<td>Confidence level probability to associate the cost to the risk that is associated with the risk tolerance of your district administration.</td>
</tr>
<tr>
<td>Calculate Estimate</td>
<td>Total Estimate = Base + Allowances + Risk Based Contingency</td>
</tr>
</tbody>
</table>

We want to aim our estimates to get as close to the actual final construction cost as possible.

Tools:
- Project Estimate File
- Design Summary Report
- Annual Scope and Estimate Documentation Form
- Typical Sections on a per Mile Basis
- Similar Projects
- Historical Bids
- Parametric Estimating
- Cost Estimate Spreadsheet Template.
Determining Cost Associated with Event Driven Risk:

**Event Driven Risks** are identified risks that, when triggered, result in the predicted impacted event. To figure out the contingency needed for these unknown costs, you will figure out the **probability** and **impact** of these risks \((P \times I)\). Figure 1, has the Probability Rating to determine the risk based contingency.

**Event Driven Risk Example:**
- Problems with utility relocations
- If problems with negotiating with utility companies occurs, then there will be delay to the project schedule and change orders.
- You will figure out the \(P \times I\) for this as well as the contingency plan and cost.

![Table of Probability Rating](image)

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10%</td>
<td>30%</td>
<td>50%</td>
<td>70%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Figure 2, Risk Based Contingency Register, identifies the risk associated with the project that will have an impact to the construction cost. Determine the probability of each Event Driven risk in the risk register. This accounts for the probability and impact of that risk. The cost associated with the risk is then used to determine the contingency on a project. Like the Three Point Estimating, we will look at the:
- Most Likely (M) Outcome
- Optimistic (O): Best Outcome
- Pessimistic (P): Worst Outcome

The following spreadsheet tool can be used to determine the expected value of the risk. This tool is divided out to assist with developing the Risk Based Contingency for the different stages of project development.


<table>
<thead>
<tr>
<th>Number</th>
<th>Probability</th>
<th>Cost Impact</th>
<th>Amount</th>
<th>Expected Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Due to the variable and uncertain nature of subsurface utilities, major changes in foundation design during construction may occur resulting in construction delays and a frustrated public</td>
<td>100.00%</td>
<td>$2,000,000.00</td>
<td>$4,000,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Need to verify that the condition of existing bridge structure sufficiency rating is above 80 (HL-83), resulting in increased cost and delays due to bridge not being able to be widened</td>
<td>65.00%</td>
<td>$7,000,000.00</td>
<td>$10,000,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Due to lack of funding, project letting state may not be met, resulting in the project falling out of the current ITP/STIP year program</td>
<td>40.00%</td>
<td>$1,100,000.00</td>
<td>$2,000,000.00</td>
</tr>
</tbody>
</table>

**Sub-Total (Risk Items -- Contingency)**: $11,333,333.33

Texas Department of Transportation
Calculating Total Construction Cost Estimate with Risk Based Contingency:

Now, that the Base Estimate, Allowances, and Risk Based Contingency are determined, the total Total Construction Cost Estimate can be calculated. Based on the assumptions of the most likely, optimistic outcome, and pessimistic outcome we will determine the probability and confidence level of the entire construction cost estimate with the cost estimating tool.

Below in Figure 3: Probability Density Function, you will see the values of the estimate at the P10, which is a 10% confidence level of the estimate and the P90, which is a 90% confidence level. At the P50, this is the most likely expected outcome of the construction estimate. This will assist with determining the estimate that is used to request funding and entered for the project.