COST ESTIMATING MANUAL

Pennsylvania Turnpike Commission
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EXECUTIVE SUMMARY

Introduction

Estimating the cost of transportation projects is a critical function that supports the Pennsylvania Turnpike Commission's (PTC) project development process and ultimately the PTC's Capital Plan Program. The PTC's ability to successfully manage and deliver its Capital Plan Program is dependent on its ability to accurately estimate and manage project costs through the entire project development process. Significant increases or decreases to a project's cost estimate between the early development phases and when the project is let for construction can create a disruption in the PTC's planning program, since project funding is one of the primary variables in prioritizing projects during the Capital Plan development process. Developing cost estimates through a consistent process, providing timely estimate updates as scopes and schedules change throughout the design process, and managing updated estimates within the PTC's planning program must be implemented successfully in order to balance PTC project funding with the corresponding project letting and construction schedule.

Purpose

The purpose of this Cost Estimating Manual is to provide:

- A guide of recognized and accepted cost estimating practices that the PTC and its consultants can use when developing construction cost estimates
- A consistent process for estimating costs through a repeatable sequence of steps that are to be implemented, at a minimum, at each milestone phase of the project development process
- Guidance on identifying and adjusting estimates for recurring cost factors, common cost influencers, and other conditions that may be encountered in the estimating process
- A process for managing cost estimates through the project development process

It is important to understand that although this Manual provides a consistent approach and includes supporting information towards developing a construction cost estimate, the information provided is not all-inclusive. The estimator must think about each project, consider how this information applies, and clearly document findings and assumptions.

Project Development Process Summary

Cost estimates should be developed at various milestones throughout a project's development in order to support funding and programming decisions. The approach for developing each estimate must conform to the information available when the estimate is prepared. For example, early in project development when only conceptual information is available, conceptual estimating methods should be used to determine planning estimates. The types of estimates and their purpose will vary according to the project development phase and the level of project maturity.

Table ES-1 captures the various estimate types, their purpose, and the PTC's plans/programs supported during project development. Table ES-2 shows the level of project definition and implied uncertainty through an appropriate estimate cost range (as a percentage) related to the estimate type. Appropriate cost estimating techniques and tools vary based upon the project development phase. The estimate for each phase of project development has a specific purpose, methodology, and expected level of accuracy. As a project progresses, more of the project's parameters will be defined and the expected accuracy of the estimate should improve.

TABLE ES-1 COST ESTIMATE TYPES AND PURPOSES	
Project Development Phase	**Estimate Type, Purpose, and Plan/Program Supported**
Planning	**Conceptual Estimating –** Estimate Potential Funds Needed and Prioritize Needs for PTC Long-Range Plan and Capital Plan
Scoping	**Scope Estimating –** Establish Project Baseline Cost and Update PTC Capital Plan
Preliminary Engineering, Final Design, and Pre-Final PS&E	**Design Estimating –** Manage Project Budgets against Baseline Cost and Update PTC Capital Plan
Final PS&E	**Plans, Specifications, and Engineer's Estimate (PS&E) –** Compare with Bids and Obligate Funds for Construction and Update PTC Capital Plan

TABLE ES-2 COST ESTIMATING CLASSIFICATION				
Project Development Phase	**Project Maturity (% project definition completed)**	**Purpose of the Estimate**	**Estimating Methodology**	**Expected Level of Accuracy (Estimate Range)**
Planning	0 to 2%	Conceptual Estimating – Estimate Potential Funds Needed	Parametric, Analogous or Judgment	-50% to +200%
	2% to 10%	Conceptual Estimating – Prioritize Needs for PTC Long-Range Plan	Parametric, Analogous or Historical Bid-Based	-40% to +100%
Scoping	10% to 30%	Scope Estimating – Establish a Baseline Cost for Project and Update the PTC Capital Plan	Parametric, Analogous, Historical Bid-Based or Cost-Based	-30% to +50%
Preliminary Engineering	30% to 60%	Design Estimating – Manage Project Budgets Against Baseline Cost	Historical Bid-Based or Cost-Based (80/20 Rule)	-10% to +25%
Final Design	60% to 90%	Design Estimating – Manage Project Budgets Against Baseline Cost	Historical Bid-Based or Cost-Based (80/20 Rule)	-10% to +15%
Pre-Final PS&E	90% to 100%	Pre-Final PS&E Estimating – Manage Project Budgets Against Baseline Cost	Cost-Based or Historical Bid-Based Using Cost Estimating Software	-5% to +10%
Final PS&E	100%	Estimate Complete – Adjust for Addenda, Compare with Bids, and Obligate Funds for Construction	Cost-Based or Historical Bid-Based Using Cost Estimating Software	-5% to +10%

Planning: A Planning Phase estimate is developed during the initial stages of project definition and provides an approximate funding value as the project manifests on the PTC's Long-Range Plan or Capital Plan. At the Planning Phase, a cost estimate is prepared with minimal project definition and uses conceptual estimating methods.

Scoping: At the time of project scoping, the project should begin to have enough definition for the estimator to develop approximate quantities based on the estimated project length and major items of work such as conceptual structure/retaining wall sizes, earthwork, asphalt or concrete pavement, and median barrier. With more of the project definition known, it is important to clearly document the scope definition and assumptions while developing the Scoping Phase estimate as this estimate will become the baseline cost that all future construction cost estimates can be compared against. The Scoping Phase estimate is to be communicated to the PTC Planning Department towards updating the Capital Plan.

Preliminary Engineering (PE), Final Design (FD), and Pre-Final Plans, Specifications, and Estimate (PS&E): As the project design process continues, additional construction cost estimates will be prepared and updated at various design milestones. At each milestone, the known items of work and associated quantities and unit prices will be used to develop a more refined construction cost estimate. These milestone estimates will be compared to the programmed amount and differences that exceed the expected level of accuracy in Table ES-2 should be documented and communicated to the PTC Planning Department towards updating the Capital Plan.

Final PS&E: At the Final PS&E phase, the project is fully defined so that designers are able to specify all items of work required for the project and estimate quantities and unit prices. Items and quantities are to be finalized and contingencies should be reduced to zero for the Engineer's Estimate. Unit prices are to be compared against and updated to current market conditions and the potential for significant changes in cost for price-volatile items should be addressed. Cost modifications to existing pay items and/or the addition of new pay items can be included in this phase to cover information added or removed from the bid package by addenda.

Cost Estimate Management

Cost estimate management supports the development of cost estimates and ensures that programmed funding levels are in line with project costs. Cost estimate management should be implemented as projects are identified and includes estimate tracking, communication, and documentation. Procedures for cost estimate management are provided in this Manual.

Roles and Responsibilities

For projects on which a Design Manager (DM) and/or Design Consultant (DC) is under contract, the PTC Project Manager (PM) may delegate many of the tasks and efforts described in this Manual to the DM and as defined in the DM's scope of work. Where applicable, tasks that may be the responsibility of the PTC PM or DM, will be identified.

On projects that employ a DM, the DM will coordinate construction cost estimating efforts and responsibilities with the DC. This Manual is written assuming a DM or DC will perform the construction cost estimating efforts for the project. All references to the DM/DC regarding projects designed in-house would apply to the PTC PM and design staff assigned to the project.

Acknowledgements

This Cost Estimating Manual's procedures have been developed in accordance with Federal regulations, AASHTO Technical Committees on estimating, and NCHRP research and technical publications. Extensive research on cost estimating for transportation projects was performed to find information that could be used to develop this Cost Estimating Manual. Many excerpts and concepts from the following publications have been incorporated in the development of this Manual:

- *"Constructability Guide Book" (July 2010),* Indiana Department of Transportation
- *"Constructability Review Best Practices Guide" (August 2000),* AASHTO Subcommittee On Construction
- *"Cost Estimating Manual for WSDOT Projects",* Washington State Department of Transportation
- *NCHRP Report 574, "Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction",* Transportation Research Board
- *NCHRP Report 658, "Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs",* Transportation Research Board, 2010
- *"Practical Guide to Cost Estimating" (2013 First Edition),* AASHTO
- *Publication 10, "Design Manual Part 1 Transportation Program Development and Project Delivery Process" (September 2010),* Pennsylvania Department of Transportation
- *Publication 352, "Estimating Manual" (June 2014),* Pennsylvania Department of Transportation
- *"Tools For Applying Constructability Concepts In Project Development (Design)"* (November 2012), University of Kentucky, College of Engineering Research Report KTC-12-17/FR190-11-11

CHAPTER HIGHLIGHTS

- ***Chapter 1*** *- Terms and Definitions*
  - Provides a list of definitions used throughout this Manual

- ***Chapter 2*** *- Cost Estimating Methodologies*
  - Describes six of the more commonly used cost estimating methodologies

- ***Chapter 3*** *- Cost Estimating and the Project Development Process*
  - There are six primary phases to the project development process: Planning, Scoping, Preliminary Engineering, Final Design, Pre-Final PS&E, and Final PS&E. Table 3-1 provides an overview and associated information for each development phase
  - Typical estimating methodologies used for each project development phase are provided
  - Estimates should be developed, at a minimum, for each project development phase and incorporated into CRM for the 12Q Planning Schedule
  - Each time an estimate is updated throughout the project development process, the estimate needs to be updated in CRM for the 12Q Planning Schedule and communicated to the PTC Planning Department to update the Capital Plan

- ***Chapter 4*** *- Cost Estimating Process*
  - Figure 4-1 shows the process by which the PTC develops cost estimates; the process applies to all phases of project development
  - A Base Estimate should be created and updated following the steps in Figure 4-1
  - A Base Estimate document forms the beginning of the cost estimating file and once created should be prepared and updated, at a minimum, for each project development phase or milestone submission
  - Updated estimates are to be entered into CRM for the 12Q Planning Schedule and communicated to the PTC Planning Department to update the Capital Plan
  - Estimate approval should be documented through the Base Estimate document

- ***Chapter 5*** *- Documentation*
  - Provides a description of items that should be included in a properly developed Base Estimate document
  - Further details the process for obtaining approval for estimate and schedule changes

- ***Chapter 6*** *– Contingency, Allowances, and Risk*
  - Describes and provides guidelines for contingency and allowance amounts in an estimate
  - See the *"PTC Project Risk Management Process"* within the PTC Design Operations Manual (DOM) for further information on how the PTC addresses risk

- ***Chapter 7*** *– Cost Factors and Cost Influencers*
  - Cost Factors are more aligned with a project's contract procurement process/method and schedule
  - Cost Influencers tend to be more aligned with the physical construction aspects of a project
  - Cost factors and influencers and their impact on cost estimates are further detailed

- ***Chapter 8*** – *Independent Constructability Review and Cost Estimate*
  - Not all projects will include an independent constructability review and cost estimate
  - Independent constructability reviews utilize personnel with extensive construction knowledge and experience to ensure projects are biddable and buildable
  - Ideally, constructability reviews should be performed in both Preliminary and Final Design, long before the Pre-Final PS&E Submission, in order to allow for a sufficient amount of time to address any issues identified during the review
  - All documents prepared for and resulting from the review should be compiled by the PTC PM and added to the project cost estimating file as part of the permanent documentation

CHAPTER 1: TERMS AND DEFINITIONS

Listed below in alphabetical order is a list of definitions that will be used throughout this Manual.

Award - The Commission's written acceptance of a bid.

Advertisement - The public announcement, required by law, inviting bids for work to be performed or for materials to be furnished. The Commission's Notice to Bidders constitutes the advertisement for a project.

Allowance - An amount included in an estimate for items that are known but the details of which have not yet been determined. They cover the cost of known but undefined requirements for an activity of work.

Base Estimate - The estimated cost that can be reasonably expected if the project materializes as planned and designed. The Base Estimate is the most likely project estimate for known costs including design and engineering, right-of-way, environmental, utilities, preconstruction tasks, and construction work. The Base Estimate can contain allowances and may include a contingency prior to the Engineer's Estimate at Final PS&E.

Bias - A lack of objectivity based on an individual's position or perspective. There may be system bias as well as individual bias.

Bid-Based Estimating - Also known as Historical Bid Based Estimating, is a method of estimating in which historical bid data is used. This type of estimate tends to be a straight forward count or measure of units of items multiplied by unit cost. These unit costs are developed from historical PTC, PennDOT, or other similar bid data and may be modified to reflect project specific conditions such as location and project characteristics. This is the most common type of estimate preparation.

Bidder - An individual, firm, partnership, corporation, or joint venture, submitting a bid for the work contemplated and acting either directly or through an authorized representative.

Conceptual Estimate - Is prepared from only a conceptual description of a project and is most often used for planning and scoping estimates. This estimate is prepared before plans, specifications, and other project details have been fully developed. Parametric estimating and/or historical bid data is used to define the cost of a typical transportation facility segment, such as cost per lane mile, cost per interchange, or cost per square foot.

Construction Engineering (CE) - The budget or cost of the project management effort to take a project from contract execution through construction and project completion.

Contingency - An estimate of costs associated with identified uncertainties and risks, the sum of which is added to the Base Estimate prior to the Engineer's Estimate to complete the project estimate. A contingency is usually an assumed amount or percentage of the entire estimate that accounts for uncertainties in quantities, unit costs, work elements, or other project requirements anticipated during construction.

Contract - The written agreement between the Commission and the Contractor. The contract includes the following: Proposal, Bid, Agreement, Performance Bond, Payment Bond, Insurance Certificates, Notice to Proceed, and all change orders that are required to complete the construction of the project.

Contract Plans - The approved documents or plans, or exact reproductions of them, for construction of the project. The contract plans show the location, character, dimensions, approximate quantities, and other details of the prescribed work, including layouts, profiles, and cross sections; contract plans also include cited Department and Commission Standard Drawings and specifications.

Cost-Based Estimating (Scratch Estimating) - A method of estimating the bid cost for an item of work by estimating the cost of each component to complete that item of work and then adding a reasonable amount for a contractor's overhead and profit. Cost-based estimates typically include material costs, equipment costs, labor costs, production rates, profit, and overhead for accomplishing an item of work.

Cost Escalation - Increases in the cost of a project or item of work over a period of time.

Cost Estimate File – File that contains a well-organized history of cost estimates starting with the Planning Phase estimate through the final Engineer's Estimate.

Cost Management - The process of managing the cost estimate through reviews and approvals, communicating estimates, monitoring scope and project conditions, evaluating impact of changes, and making estimate adjustments as appropriate.

Engineer's Estimate - The agency's official construction cost estimate that is used for evaluating bids received on a proposal. This estimate is prepared by the engineer/designer for the Final PS&E phase of the design process.

Equipment Cost- The expense associated with productive machine work. It will include both ownership and operating costs but not the operator, which is a labor cost. Equipment costs can be found in the Blue Book Rental book.

Estimate Basis - Documentation of the project type and phase for each cost estimate, including items such as drawings that are available for a particular phase, project design parameters, project complexity, and unique project location characteristics.

Force Account - A method of payment that pays a contractor actual expenses for labor, equipment, and material to complete the work, and includes a set percentage for overhead and profit.

Inflation - The rate that the cost of goods or services increases or, consequently, the decrease in purchasing power. Inflation is applied to costs and is accounted for in the development of the PTC Capital Plan.

Labor Cost - Work hours and wages, including fringe benefits, paid to onsite personnel working on a project.

Letting - A process that includes advertisement of a proposed construction project, receipt of bids, and the opening or posting of bids in a public setting.

Lowest Responsive and Responsible Bidder - The lowest bid that meets legal criteria for submitted bids.

Lump Sum Pay Item - A single pay item included in the contract work that is comprised of multiple work items.

Materials – Temporary or permanent substances specified and approved for use in the project construction.

Mobilization Cost – Typically calculated as a percentage of the total of the construction cost estimate and backed up with a cost-based estimate. A cost for mobilization is typically included in a project estimate to cover a contractor's preconstruction expenses and cost of preparatory work and operations, such as moving and staging equipment on site.

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, mobilization, communications, and utilities.

Pareto Principle – Also known as the "80/20 Rule", this principle states that 80% of the cost of a project can be found in 20% of the construction items.

Plans, Specifications & Estimate (PS&E) - The final contract plans, specifications package, and Engineer's Estimate submittal used for the project's advertisement and letting.

Pre-Determined Amount (PDA) - A set cost within an estimate or bid package for an item of work with an unknown quantity or scope. Payment can be made on a force account basis or as a negotiated price. Price adjustments are calculated.

Project – All of the work described in the contract.

Proposal – The documents, designated by the Commission, containing project requirements and other information upon which a bid for the project to be constructed is to be based. The proposal includes the Plans, Notice to Bidders, Specifications, Special Provisions, referenced Standard Drawings, Addenda, and all other documents referred to therein, whether or not attached.

Risk - An uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective. A positive effect presents an opportunity and a negative effect presents a threat.

Scope - Encompasses the elements, characteristics, and parameters of a project and the work that must be accomplished to deliver a product with the specified requirements, features, and functions.

Scope Change - Change 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 stormwater parameters.

Scope Creep - Scope creep is an accumulation of minor scope changes that incrementally change a project's scope, cost, and schedule.

Standard Pay Item - Designated bid component described by an agency's standard documents.

Subject Matter Expert (SME) - An individual who provides the knowledge and expertise in a specific area of a project and who can guide others to ensure the technical details are correct and costs are accurate.

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 contract unit price.

CHAPTER 2: COST ESTIMATING METHODOLOGIES

Throughout the life of a project a realistic cost estimate is important, as largely inaccurate estimates can have significant implications to the PTC's proposed investment program. Although there are several methods available for developing cost estimates, this chapter identifies and describes six of the more common estimating methods. The method to be used will vary depending on the project type and the project's current design phase, scope definition, and level of complexity. It's important to note that any combination of the methods described in this chapter may be used as part of any estimate; however, as a project progresses and more uncertainties are identified and accounted for, the expected accuracy range should narrow.

Six of the more commonly used cost estimating methods and their applications are as follows:

1. ***Analogous or Similar Project:*** Analogous estimating relies heavily on one project that is very similar to the project being estimated. Identifying similarities in a past project and comparing that project to the one that is being estimated can provide a realistic cost scenario for estimation purposes. The similar project is typically one that was previously constructed, is currently under construction, or was recently bid for construction. Lane-mile costs, square-foot bridge costs, and /or line item quantities and unit costs from a past similar project are used as a basis for estimating the current project. Caution should be exercised when selecting a historical project for comparison that the information being compared is still relevant in terms of unit prices for price-volatile items, design standards, construction standards, technology, and techniques. The analogous estimating method is often used as a tool to determine broad price ranges for simpler, more straight forward projects, or as a check to verify estimates prepared using other planning estimate methods. Similar costs from the past project can also be used to estimate costs for preliminary engineering, right-of-way, environmental mitigation, utility relocations, and general construction costs. In addition, using lessons learned from a similar past project (if available) to adjust a future project's estimate may help improve estimate accuracy.

2. ***Parametric:*** Parametric estimating identifies major project items or parameters (tons of asphalt, square footage of bridge deck, etc.) and then calculates the cost of those items based on historical statistical relationships and/or nonstatistical ratios that are available for those parameters. Parametric estimating is used most effectively on less complex projects that tend to be more standard in terms of project items and components, such as pavement preservation projects or bridge rehabilitation projects.

3. ***Historical Percentages:*** Historical percentages are considered as another form of parametric estimating and are used to estimate costs for items that are not typically defined in earlier project development phases. A percentage is developed based on historical cost information from past projects to cover vaguely defined items. This percentage is based on a relationship between the vaguely defined item and a total cost category, such as direct construction. Contractor mobilization, preliminary engineering, and construction engineering are often estimated based on a historical percentage of construction. There are circumstances when the estimator simply does not have sufficient time and information to detail all line items associated with a vaguely defined item. With a good database of historical bid prices used on past projects, combined with standard items for reference, developing percentages for a vaguely defined item,

such as mobilization, may take less time and be just as accurate as trying to estimate that item by breaking it down in to sub-items and associated costs.

4. ***Cost-Based (Scratch or Bottom-Up):*** This method does not rely on historical bid data, but rather is based on determining, for an item or set of items, the contractor's cost for labor, equipment, materials, and specialty subcontractor effort (if appropriate) needed to complete the work, and then adds a reasonable amount for the contractor's overhead (including risk) and profit. A cost-based estimate captures the cost of construction for each major item of work by estimating the anticipated labor and equipment production rates, labor and equipment costs, and material costs and then adds the contractor's anticipated overhead and profit for a total item cost. Resources are specifically identified for each item of work and then tied to the anticipated duration and productivity when these resources will be engaged on the project.

   Cost-based estimating is especially applicable for very large and complex projects with unique items, and is preferable where geographical influences, market factors, and volatility of material prices can make historical bid-based pricing an unreliable method of estimating project cost. Cost-based estimates require significant effort, time, and estimator experience to prepare as they are created from several sub-estimates of labor crews and equipment at assumed rates of production. The estimator should strive to create the most realistic estimate possible based on the most realistic production and cost data available. Production and cost data can be found in the following sources:
   - Estimators and other PTC/consultant personnel that have significant experience in the construction industry
   - Previous construction project data
   - R. S. Means Construction Cost Data (www.rsmeans.com)
   - Rental Blue Book, Green Guide (www.equipmentwatch.com)
   - Transportation Estimators Association (www.tea.cloverleaf.net)
   - AASHTO Technical Committee on Cost Estimating (design.transportation.org)
   - Suppliers/fabricators

   Cost-Based estimates should be limited to those items that comprise the largest dollar value of the project, typically the 20% of items that account for 80% of project cost (Pareto Principle). The cost of the remainder of the line items can be determined using a method that is appropriate for the phase in which the estimate is being developed. This approach provides for a more efficient use of estimating resources and helps to reduce the total time and cost of preparing a cost-based estimate. Although more time is typically required to prepare a cost-based estimate when compared to a historical bid-based estimate, once the appropriate components are in place, the labor and equipment cost data files are created, and the production data sources are identified, the process can become more routine and manageable. Cost-based estimating is also a good way to check a few large items of work in a historical bid-based estimate to ensure that the historical prices remain valid. For this reason, cost-based estimating should be used in the estimate review process. Many agencies require the use of this method to support and defend lump sum item costs. Most lump sum items are very different from one project to another, therefore using historical bid prices are often not a good indicator of the future bid price for lump sum items.

The following components are associated with a cost-based estimate:

- *Direct Labor Costs* – For any item of work, direct labor costs are developed by breaking down that item of work into smaller work tasks. A labor crew with equipment typically performs each work task. The crew must be defined and a production rate and associated cost must be established for the task. The production rate is the relationship of work-in-place and the time required to accomplish that work, usually measured in unit of work per unit of time required to complete that work. Crews may vary in size and experience, however the number of crews and size of each crew should be based on sufficient workers to perform the task within the required timeframe and available workspace. An estimator's construction knowledge and experience will be directly proportional to the accuracy of the estimated labor production, as the labor effort needed to perform a particular task can vary based on factors such as:
  - Task size and complexity
  - Labor crew experience
  - Topographic and climatic conditions
  - Degree of mechanization
  - Amount of task repetition
  - Traffic volumes and proximity
  - Time of day and year that work is to be performed
  - Potential utility conflicts

- *Indirect Labor Costs* – A contractor pays fringe benefits, taxes, and insurance on behalf of their workers to various agencies, which may include:
  - Social Security
  - Health insurance
  - General liability insurance
  - Pension
  - Federal and/or state unemployment compensation
  - Sick leave/workers compensation
  - Vacation/holidays

  Indirect costs are not paid directly to the employee, but may be applied as a percentage of labor costs and must be added to the direct labor costs.

- *Equipment Cost* – Construction equipment and plant refer to the machinery and tools needed to construct a project. A construction plant can be a concrete batch plant, aggregate processing plant, conveyor system, or any other processing plant that can be erected in-place at the job site. Equipment consists of items that are either portable or mobile, ranging from small hand tools to tractors, cranes, and trucks. For cost-based estimating purposes, plant costs and equipment costs are grouped together as equipment costs.

  The task of the estimator is to match the right machine or combination of machines to the work task that is to be completed. Construction experience is extremely important when selecting and estimating equipment, as equipment production is influenced by the equipment size, number of units, task size, availability of space to perform the work, and

the project construction schedule. Some factors to consider during equipment selection are as follows:

- Required production rate due to schedule
- Controlling piece of equipment related to production rate
- Space availability and equipment size/mobility
- Equipment capabilities
- Weather conditions
- Haul distance and restrictions
- Mobilization and demobilization costs

Two readily available publications, the "Rental Rate Blue Book" and the "AED Green Book", provide detailed equipment cost data. The "Rental Rate Blue Book" contains cost data reflecting ownership (owned by the contractor) of a machine with the intent of long term use. If the equipment is needed on the project for an extended period of time, the estimator should use the "Rental Rate Blue Book" and adjust the data by the appropriate regional factors. The "AED Green Book" provides monthly, weekly, and daily average rental rates for using a machine from an equipment rental firm for a short period of time for a particular task. If the equipment will be limited to a specific operation for a short period of time, the estimator should use the monthly, daily, or hourly rate of the "AED Green Book". Both of these publications contain introductory sections that indicate how to use the equipment cost information.

The cost of small hand tools and miscellaneous non-capitalized equipment and supplies are usually estimated as a percentage of the labor cost. The percentage must be determined by the estimator in each case, based on experience for the type of work involved. Such percentages can range as high as 12% of direct labor but is usually much lower. The estimator must make sure that this cost is not duplicated in the overhead percentage rate.

- *Material Cost* – Materials are typically defined as those items that are physically incorporated into the work and become part of the permanent final product. Supplies are typically defined as those items used in construction but do not become physically incorporated into the project, such as temporary traffic control barriers, dust control, concrete forms, and form liners. For the purpose of cost-based estimating, both can be considered materials.

  Prices for materials and supplies can be acquired by obtaining quotes from suppliers, fabricators, manufacturers, industry publications, catalogues, and historical data. The estimator should check the price quotes to confirm if they include delivery. The estimator should keep a log of material price quotes received from suppliers/fabricators for reference and as it may be necessary to adjust current prices to reflect the anticipated cost at the actual purchase date.

- *Indirect Costs/Overhead and Profit* – The contractor incurs additional costs that are not included in the activity 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

included in overhead costs. Overhead costs are typically divided into two separate categories:

1. Project Overhead
2. General Office/Administrative Overhead

Project overhead costs are a direct result of the project, are incurred at the project site, and should be estimated to a thoughtful level of detail. Temporary storage may also become an additional cost that should be considered. For construction items needing secure storage, the cost for a temporary building, security fencing, and material handling may be considered as an indirect cost and included in the job-site overhead cost. Project overhead may vary depending on the type and duration of the project and may include:

- Job Supervision
- Engineering and shop drawings/surveys
- Site security
- Project office and temporary facilities
- Temporary storage
- Temporary utilities
- Preparatory work and laboratory testing
- Telephone and communication equipment
- Permits and licenses
- Insurance (project coverage)
- Quality control

General office/administrative overhead expenses are those incurred by the contractor in the overall management of the business. Since they are general, and not incurred for any specific project, they must be applied to all of the contractor's projects.

Profit can be estimated, but is hard to specifically quantify. Profit margins generally range from 3% to 10%, but can increase or decrease significantly, depending on the contractor's assumed risk and overall workload.

- *Schedule* – Contract time is the time in which all physical project work is to be completed and involves developing detailed construction activities and applying anticipated rates of production to those activities to estimate their duration. Optimal contract time balances project cost against project quality and public impacts and ultimately depends on accurate estimates of construction productivity costs. Costs will increase if there is too little or too much contract time. If contract time is too short, bid prices may be higher due to paid overtime and other production-increasing methods, quality may be reduced, and the number of construction claims may increase. If contract time is too long, the public will endure unnecessary inconvenience, local businesses may suffer economically, and a contractor's overall costs will likely be excessive. The PTC uses a completion date within a construction schedule as a basis for contract time, which is the date by which all work is to be completed as stated in the contract, plus any time extensions and less any time reductions issued by the PTC.

  A construction project schedule should be broken down into a network of activities with relationships. The basic assumptions for creating a Network Schedule are:

  - The project can be broken down into a group of activities generally associated with bid items

- Each activity can be assigned a duration
- The logic relationship among activities is known and fixed in the network

Critical Path Method (CPM) schedules can also be used in construction and are developed based on productivity rates accompanied by labor, equipment, and material acquisition time needed for specific activities. For both Network and CPM schedules, production rates are applied to a project-specific construction activity to determine the duration of that activity. It is important for the estimator to allow for any time that may be required to acquire material in a schedule, especially material that requires fabrication, such as steel or pre-stressed concrete beams.

The estimator must establish a realistic production rate, taking into account direct labor cost factors such as those listed in the *Direct Labor Costs* section previously described. Once a production rate is established, the estimator will take the total quantity of an item divided by the production rate of that activity to establish the length of time required to complete that activity. Rounding may be necessary due to the fact that a contractor will most likely have to pay for labor and equipment in full-day increments. A cost for that activity can then be estimated by applying the length of time required to complete an activity with the cost per hour for the labor and equipment. Cost considerations should include overtime pay and different labor rates for work being performed at night or on weekends.

5. ***Historical Bid-Based:*** Historical bid-based estimating requires the estimator to identify items and quantities for each item so that historical unit prices can be used to calculate item costs for the project. After determining the quantities from the project plans, the estimator matches those quantities to the appropriate historical unit bid prices or average historical unit bid prices. Estimating software may be used as a tool to house historical item and bid data and then produce an estimate by taking the item quantities that are input by the project estimator and calculating item costs based on the historical bid data. Historical bid-based unit prices should be adjusted for project conditions (location, size, quantities, etc.) and general market conditions. To generate historical unit price data, the PTC systematically compiles bid data from past project lettings. The standard bid item unit prices are captured by the PTC's Electronic Bidding System (EBS), where they are stored for future queries.

6. ***Risk-Based:*** Risk-based estimating methods can involve simple or complex analysis based on inferred and probabilistic relationships between cost, schedule, and events related to the project. Risk-based estimating uses a variety of estimating types and techniques including historical data, cost-based estimating, and the best judgment of Subject Matter Experts (SMEs) to identify risks for a given type of work and to develop the base cost. Risk elements are defined as opportunities or threats and applied to the base cost through cost simulation models to provide a probable range for both project cost and schedule. The level of effort, time, and resources devoted to risk-based estimating can be significant and needs to be appropriate for the magnitude of the project. For major projects, a common approach is to develop an independent team of SMEs to review an existing estimate. These reviews often take on the form of a workshop similar to those used for value-engineering studies. Although beneficial, 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 individual project team members.

CHAPTER 3: COST ESTIMATING AND THE PROJECT DEVELOPMENT PROCESS

At each phase in the project development process, a cost estimate has a specific purpose, methodology, and expected level of accuracy. Table ES-2 and Table 3-1 present the relationships among these estimate components and the development phase of the project. Referencing Table 3-1, there are six primary phases as part of the project development process:

1. Planning
2. Scoping
3. Preliminary Engineering / Design Field View
4. Final Design
5. Pre-Final PS&E
6. Final PS&E

When an estimate is first developed and each time the estimate is updated throughout the project development process, the steps in the PTC's Cost Estimating Process, as described in Chapter 4, should be followed. In order to properly document and communicate estimate changes, the following key steps should be implemented as an estimate is developed at each phase of the project development process:

- A Base Estimate document, which is further detailed in Chapter 4 and Chapter 5, should be created for the initial estimate at the Planning Phase and saved to the project's cost estimate file
- The Base Estimate document should be reviewed and updated with each subsequent estimate submission through the final PS&E submission
- Changes in project cost should be captured through the Base Estimate document
- The updated cost should be incorporated into the Contract Status Database for the 12Q Planning Schedule and communicated to the Planning Department in order to update the Capital Plan as soon as possible

Planning

The Planning Phase estimate is used to estimate funding needs for programming purposes by estimating Total Project Cost (TPC) during a project's earliest stages of development, when very little project definition is available. TPC is broken down in to five standard engineering components per the PTC's LOPS-02 Manual: Study, Design, Construction, Right-of-Way, and Utilities.

Because planning estimates are produced before a Design Manager (DM) or Design Consultant (DC) is under contract, the Highway Program Manager and/or Category Managers should develop the planning estimate, work with the Planning Department to update the Capital Plan, and enter the estimated construction cost into the Contract Status Database for the 12Q Planning Schedule as the 'Planned' cost.

Parametric estimating and analogous (similar) estimating techniques should be used for planning estimates. Historical bid-based prices, historical percentages, and an estimator's judgment can also be used at this development phase. Given the large scale of assumptions that are inherent in planning estimates, the estimator should document all assumptions for a number of project disciplines such as structures, roadway, drainage, traffic, environmental, geotechnical, stormwater management, and utility relocations. Although costs for Study, Design, and Right-of-Way are typically not included in construction cost estimates, these components should be broken out and estimated for the planning

Estimate Process (Cost Estimating Milestone Phase)	Prepare / Update Base Estimate: Type	Prepare / Update Base Estimate: Method	Prepare / Update Base Estimate: Tool	Documentation: Complete Base Estimate Document: Document	Documentation: Complete Base Estimate Document: Cost Influencers Analysis	Misc. Items	Apply Contingencies	Review Estimate	Communicate Estimate	Approve Estimate
Planning	• Conceptual planning estimate	• Parametric estimating • Similar projects • Historical bid • Historical percentages	• Lane-mile cost • Square foot bridge costs	• Project Parameters • Anticipated design, right-of-way, and utility costs	• Assumptions • Risks • Long range forecast of trends in highway construction sectors	• Ensure that parametric costs are adequate to support miscellaneous items	• Up to 10% for non-complex projects • Up to 40% for complex projects	• Perform reviews at development phase or milestone submission following PTC Cost Estimating Process	• Communicate estimate to PTC PM to update the Contract Status Database for the 12Q Planning Schedule • Provide estimate to the PTC Planning Department to update the Capital Plan as soon as possible	• The Base Estimate document should be completed and the Design Manager (DM) or Design Consultant (DC) PM should approve and sign off on the new estimate • If estimate change is deemed significant, the Base Estimate document should be completed and approved by the DM or DC PM and PTC PM should notify PTC Category Managers
Scoping	• Baseline estimate	• Parametric estimating • Historical bid • Historical percentages • Cost-based	• Lane-mile cost • Square foot bridge costs • EBS design items	• Cost variances from Planning estimate • Additional known project parameters • Revised costs for design, right-of-way and utilities	• Assumptions • Risks • Reexamine long range trends in highway construction sectors	• Ensure costs for environmental and context sensitive solutions are included	• Up to 5% for non-complex projects • Up to 30% for complex projects			
Preliminary Engineering/ Design Field View (30% to 60% Submission)	• Mid-level itemized estimate	• Further define and develop cost categories and major items (80/20 rule) • Cost-based • Historical bid	• EBS design items • Estimating Software	• Account for cost variances from Scoping Estimate • Most assumptions should now be defined • Revised costs for right-of-way and utilities • Checklists	• Quantify assumptions • Quantify risks • Examine price trends for high cost items	• Incorporate constructability review comments	• Up to 5% for non-complex projects • Up to 25% for complex projects			
Final Design (60% to 90%)	• Itemized estimate	• Refine items/unit costs • Historical bid prices	• EBS design items • Estimating Software	• Account for cost variances from Design Field View estimate • Revised costs for right-of-way and utilities • Checklists	• Quantify assumptions • Account for risks • Monitor and adjust price-volatile items	• Check for any remaining items identified but not fully quantified • Incorporate constructability review comments	• Up to 5% for non-complex projects • Up to 10% for complex projects			
Pre-Final PS&E (90% to 100%)	• Engineer's Estimate (Pre-Final)	• Further refine items/unit costs • Historical bid prices	• EBS design items • Estimating Software	• Account for cost variances from 60% to 90% estimates • Revised costs for right-of-way and utilities • Checklists	• Account for risks • Monitor and adjust price-volatile items and adjust prices based on recent bid data	• Design items reflect all work detailed in plans and specifications	• Up to 5% for all projects			
Final PS&E (100% PS&E Submission)	• Engineer's Estimate	• Further refine items/unit costs • Historical bid prices	• EBS design items • Estimating Software	• Account for cost variances from Pre-Final PS&E estimate • Checklists	• Monitor and adjust price-volatile items and adjust prices based on recent bid data	• Design items reflect all work detailed in plans and specifications	• 0% contingency for all projects			

Table 3-1: Cost Estimate Components at Milestone Phases of Project Develoment Process

estimate using historical cost data in SAP for similar project components and documented. Properly documented assumptions, especially for large allowances that could erroneously inflate the cost estimate, are important to supporting a project's estimated TPC as the project becomes a part of the Capital Plan.

Due to lack of scope definition and design details, care should be taken to properly communicate planning estimates within the PTC and to project stakeholders. Planning estimates should be communicated as a cost range in terms of cost and schedule, as the cost will likely change as the project and schedule becomes more defined. An adequate contingency amount, of up to 40% for complex projects and up to 10% for non-complex projects, for project unknowns is appropriate in a Planning Phase estimate.

Scoping

After a project has been assigned to a PTC Project Manager (PM) and a scope of work has been established, a Scoping Phase estimate should be developed by the Category Manager and/or the PM following the process described in Chapter 4. A Scoping Phase estimate is important because:

- The project should have more definition than at the Planning Phase estimate
- Unknowns in the Planning Phase should be better identified, and the Scoping Phase should begin to provide a more realistic construction cost compared to the Planning Phase
- The PTC PM should enter the estimated construction cost into CRM for the 12Q Planning Schedule as the 'Original Estimate' cost, as the Scoping Phase estimate will be the cost against which all future estimates will be compared

During all phases of the project development process, any anticipated changes to the cost components of Studies, Design, Right-of-Way, and Utilities should be discussed with the PTC PM and relayed to the Planning Department in order to update the Capital Plan as soon as possible.

A combination of parametric, cost-based, historical bid-based, and risk-based estimating methods are typically used to prepare the scoping estimate. If enough of the project definition is known, the estimator should be able to determine approximate quantities for such items as asphalt, concrete pavement, structure, and roadway excavation. For such quantifiable items, historical bid-based or cost-based estimating methods should be used for pricing. Other items not yet quantified may be estimated parametrically or through the use of historical percentages. Larger, complex projects should go through a more extensive analysis during the Scoping Phase, commensurate with risk, so that a more accurate cost estimate can be developed.

Allowances are appropriate in a scoping estimate to account for any lack in scope definition and should be carefully thought through and documented. A contingency should be included, up to 30% for complex projects and up to 5% for non-complex projects, in a scoping estimate.

Preliminary Engineering / Design Field View Through Final Design

Construction cost estimates should be prepared, at a minimum, at the various milestone submissions (See Table 3-1) throughout Preliminary Engineering (PE) and Final Design (FD). The most recent milestone submission estimate should be compared to the previous estimate and the changes should be documented and included in the project cost estimate file and updated in CRM for the 12Q Planning Schedule. Updated cost estimates may be requested by PTC personnel for Capital Planning purposes if an estimate is more than one year old.

Historical bid-based estimating is often associated with estimates that are developed during the later stages of PE and throughout FD, as more design details and items become known. As quantities and unit prices become better defined, cost estimate accuracy should improve. Estimating software can also be used to develop the unit costs for those items for which the PTC has historical information. Historical costs produced for each item by the software should be reviewed against market conditions and industry trends for that item. Cost-based estimating can be used throughout the design phases as this method is often used to estimate larger lump sum component items or unique items with little or no bid history. If Cost-based estimating is used, all assumptions that are made when developing prices pertaining to labor, equipment, and production rates, as well as contractor overhead and profit, should be clearly documented.

Use of appropriate allowances and contingency will help to account for the lack of project definition, however allowances and contingency should decrease as a project moves from PE to FD (see Table 3-1).

Pre-Final PS&E

The Engineer's Estimate is prepared for the Pre-Final PS&E submittal. At the Pre-Final PS&E Phase, the project has reached a stage of maturity where there's a detailed understanding of the project's scope and designers, engineers, and estimators are able to specify and accurately estimate quantities and develop unit prices for all items of work that will be required for the project.

Historical bid-based, cost-based, and risk-based estimating methods can be used to prepare the Pre-Final PS&E estimate. Historical bid-based estimating should be used for most items of work where historical bid data is available. For the Pre-Final PS&E estimate, estimating software should be used to develop the unit costs for those items for which the PTC has historical information. All quantities, unit prices, and methods of construction should be clearly documented as this information will be needed for both the review of the estimate and the review of the contractor's bid. If a Risk Management Plan is part of this estimate, the Plan should be reviewed and updated accordingly.

Final PS&E

The Final PS&E estimate is prepared from comments received from the Pre-Final PS&E submission review and the Engineer's Estimate is finalized in preparation for advertisement. The Final PS&E estimate is used to obligate construction funds as well as to evaluate the bids received. Adjustments to the Final PS&E estimate are made for addenda as needed. Adjustments to the Final PS&E estimate should be completed by the Monday prior to bid.

CHAPTER 4: COST ESTIMATING PROCESS

Cost estimates should be developed in a consistent format that can be understood, checked, verified, and corrected. Consistency is achieved by implementing a process that will serve as a guide for cost estimating practices and cost estimate management. The schematic presented in Figure 4-1 describes the process by which the PTC develops its estimates. **This process applies to all phases of project development as described in Chapter 3**, starting with the Planning Phase (Conceptual Estimate) and ending with the Final PS&E Phase (Engineer's Estimate).

Each step in the cost estimate process is critical to developing consistent and accurate estimates during each phase of project development. **Although each milestone phase may require different estimating inputs, methods, and tools, the steps in the cost estimate process are repetitive for each phase of the project development process.** The cost estimate process is initiated with input from the project development phase for which the estimate is being developed, including project definition requirements (scope), project characteristics, and internal discipline group inputs/requirements. The output of the process is an approved cost estimate that supports the various plans and programs of the PTC.

A description of some of the key steps in the PTC Cost Estimating Process is listed below:

Determine Estimate Basis

This step in the estimate process focuses on identifying and gathering information about the project, including:

- Project scope and assumptions (will vary on project phase, type, and complexity)
- Project location and characteristics
- Schedule details
- Input/requirements from internal discipline groups
- Correspondence with external groups such as fabricators or suppliers
- Design parameters
- Conceptual or existing drawings

Project size and complexity are important to consider when identifying project characteristics. Larger, more complex projects will involve more unknowns and risks, which will require additional allowances and higher contingency values be included in the various milestone cost estimates.

The PTC Project Manager (PM) should gather the appropriate information and provide to the Design Manager (DM) or Design Consultant (DC).

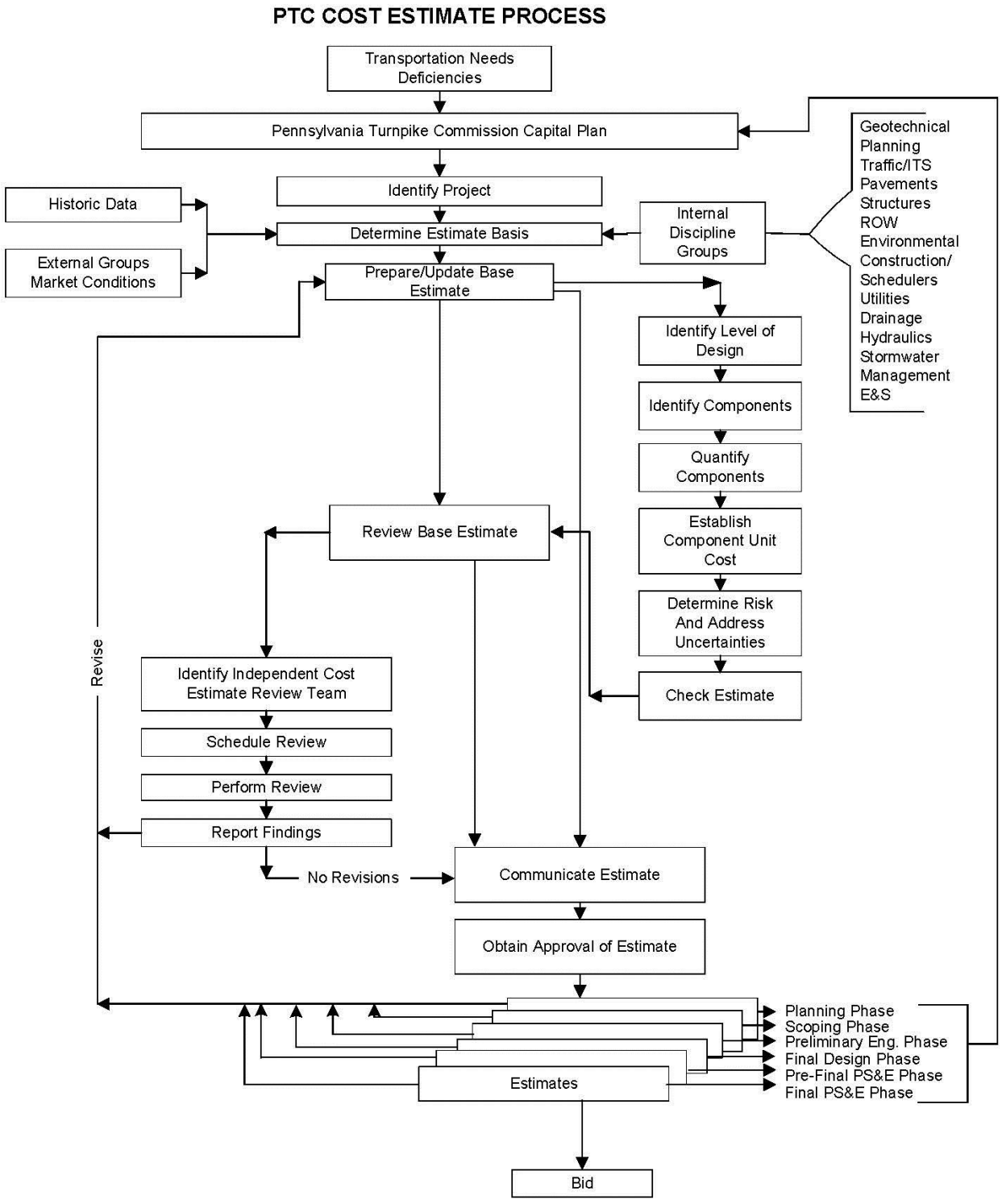

Figure 4-1: PTC Cost Estimate Process

Prepare/Update Base Estimate

This step in the estimate process focuses on the development of estimated costs for the anticipated components of a project. These components would have been identified in the previous step of Determining Estimate Basis and will be further assessed using different techniques depending on the level of scope definition, the size and complexity of the project, and the project development phase.

Within the PTC's Cost Estimating Process, there are six steps for preparing a Base Estimate. **These six steps also apply when preparing an estimate at any point during the project development process** and are as follows:

1. Identify level of design
2. Identify components
3. Quantify components
4. Establish component unit cost
5. Determine risk and address uncertainties
6. Check estimate

Note: The Capital Plan process will provide an adjustment to the estimate for inflation. All estimates should be prepared using present-day dollars.

Appendix A includes a summary break down of the six steps for preparing a Base Estimate and includes a listing of cost factors and cost influencers, which are further detailed in Chapter 7, that should be considered when preparing an estimate.

Appendix A can be used as a checklist towards preparing a Base Estimate document, which describes the project in words and includes underlying assumptions, cautionary notes, and exclusions and ultimately is able to support the estimate for which it is developed. **The estimator should provide a completed or updated Base Estimate document to the PTC PM at each project milestone submission.** The Base Estimate document forms the beginning of the cost estimate file, which will provide a traceable history for each estimate that is prepared as the project progresses. A well prepared Base Estimate document will:

- Document the key project assumptions and any items that are excluded from the project scope
- Identify other projects that were referenced or benchmarked during estimate preparation
- Identify potential cost risks and opportunities
- Provide a record of key communications made during estimate preparation
- Provide a record of documents used to prepare the estimate
- Provide historical relationships between estimates through the project development process

A sample Base Estimate document is included in **Appendix B**. Further information on estimate documentation and a Base Estimate document is included in Chapter 5.

Planning Phase cost estimates are typically created by the Highway Program Manager and/or Category Managers and can be documented through the Base Estimate document (see **Appendix B**), which should be completed during this phase and form the beginning of the cost estimate file.

Review Base Estimate

Cost estimates can be based on many assumptions which need to be justified, therefore estimates need to be independently reviewed and assumptions need to be verified through an unbiased analysis for completeness, ensure that they match the project scope, and are consistent with known site conditions, even when this information is limited. Cost estimate reviews are necessary to ensure that:

- Assumptions within the Base Estimate are an accurate reflection of the project's scope of work
- Cost basis and methodology are appropriate for the project phase and information available
- Item costs are calculated properly and required components are not missing or double-counted

The steps for a Base Estimate review are as follows:

1. Identify Independent Cost Estimate Review Team
    - The DM or DC should identify a team comprised of individuals that have construction, cost estimating, and scheduling knowledge, and who have not been involved with developing the estimate
    - The team may be as small as one person or could involve several people depending on the project's size, complexity, and unique features
    - Subject Matter Experts should be involved to provide clarification on specialty areas of concern or items of work that could have an impact on cost
2. Schedule Review
    - The DM or DC should distribute the project plans, special provisions, construction schedule, and Base Estimate document to the estimate review team and provide a date for when the review needs to be completed
3. Perform Review
    - Review the Base Estimate document
    - At a minimum, use the Pareto Principle (80/20 Rule) to check the quantities and unit costs
    - Confirm identified uncertainties are documented as well as any other uncertainties that result from the review and that contingencies are appropriate and not duplicated within the estimate
    - Ensure cost factors related to market conditions and the anticipated construction schedule is taken into account
    - Ensure comments from the constructability review, if performed on the project, have been incorporated
4. Report Findings
    - DM or DC should compile a summary of comments or differences found during the review and discuss
    - If necessary, the DM should meet with the DC to discuss any differences in the estimate and together work through the six steps towards resolution
    - Responses should be provided for each review comment and made part of the cost estimate file

Review of the Engineer's Estimate at the Pre-Final PS&E phase should be extensive and should include a final QA/QC review of the proposed items, assumptions, unit prices, and calculations. Since what is shown, described, and referenced in the contract documents will be the information that each contractor will use in developing their bid prices and construction/activity schedule, the contract documents, including plans, specifications, construction schedule, and estimate need to be thoroughly

evaluated and reviewed together to incorporate the standard and unique components of the project. The contract special provisions should especially be reviewed for non-standard provisions, conditions, or items that will impact the construction schedule. Unit prices within the Engineer's Estimate should be reviewed and adjusted based on any identified schedule impacts.

Appendix C provides a cost estimate review checklist that may be used when performing a Base Estimate review.

Communicate Estimate

Changes in cost estimates can have significant implications to the PTC's Capital Plan and investment program, therefore it is important that changes in cost estimates be communicated to the PTC PM, at a minimum, at each milestone phase of the project development process in order for the PM to update CRM for the 12Q Planning Schedule.

The PTC Category Managers and Planning Department meet monthly to review and discuss Capital Plan costs. The PTC's Fiscal Year is from June 1st to May 31st and the Capital Plan is adjusted quarterly during the Fiscal Year for changes in project costs. If it is anticipated a project's cost is going to change significantly from the previously submitted estimate, the new estimate should be provided to the PTC PM one month before each quarterly Capital Plan adjustment. The PTC PM will determine when a current estimate is needed for the quarterly updates and will coordinate with the DM or DC, or PTC personnel, for obtaining the estimate. Once the current estimate is received, the PTC PM will update CRM for the 12Q Planning Schedule and should relay the revised costs to their Category Manager in order for those revised costs to be approved and incorporated into the quarterly Capital Plan adjustment.

Obtain Approval of Estimate

Each phase of the project development process requires that either PTC or Consultant management approve and sign off on the estimate once it has been developed, reviewed, and communicated. The review and approval of an estimate, including documented changes from previous estimates, ensures management accountability for the final cost estimate. The table below provides the roles for cost estimate approvals:

Development Phase:	Responsible Entity:	Approval By:
Planning	Planning Department	PTC
Scoping	Category Manager	PTC
Prelim Eng / Design Field View	Design Consultant	PTC / Design Manager
Final Design	Design Consultant	PTC / Design Manager
Pre-Final PS&E	Design Consultant	PTC / Design Manager
Final PS&E	Design Consultant	PTC / Design Manager

Approval can be documented through the Base Estimate document (see **Appendix B**), which should be updated during all phases and be placed in the cost estimate file.

If a project's scope and/or schedule changes and results in a significant difference in cost from the previous estimate, and if it affects the anticipated let date on the 12Q Planning or 5Q Planning schedules, the PTC's Date Change Request form should be completed by the PTC PM and submitted for approval. Chapter 5 provides further detail on this process.

CHAPTER 5: DOCUMENTATION

Documentation is an important element of an effective cost estimating process. Cost estimate documentation should be maintained in a project cost estimate file, which should:

- Provide a well-organized, easy to follow history from the first estimate in the Planning Phase through preparation of the Engineer's estimate at the Final PS&E submission
- Document differences, including those found in the scope, assumptions, quantities, prices, calculations, and risks, between the previous estimate and current estimate
- Be electronic and readily available at any time during the project development process

Clear documentation is especially important as the project passes from one design team to another, or as members of the design team change through the project development phases.

Base Estimate Document

The Base Estimate document, mentioned in Chapter 4, is important as it helps to capture the scope of the project in terms of cost, provides a record of pertinent communications that have occurred and agreements that may have been made between the PTC and other project stakeholders, and ultimately becomes the basis for which all changes in scope and cost can be compared against as the project progresses. A properly developed Base Estimate document will provide an effective tool for cost documentation in any phase of the project development process. Referencing the sample Base Estimate document provided in **Appendix B**, the following items need to be considered and included in a Base Estimate document:

- ***Purpose:*** Provide a brief and concise description of the project, including the project type, purpose, location, and development phase.
- ***Scope:*** This section should identify each major component (i.e. roadway, bridge, structure, etc.) of the project scope. A semi-detailed description of the scope of work should be provided for each major item of work. Work that is not anticipated as part of the project should also be included in this section. Be as thorough as possible so as to adequately explain and estimate the anticipated scope of work.
- ***Methodology:*** Describe the primary estimating method(s) used to prepare the cost estimate. This should include documentation of cost resources, historical data, and project benchmarking (type, overall value) for similar projects that have been used for reference.
- ***Design Basis:*** List the types and status of engineering and design deliverables such as drawings, specifications, or equipment lists that were provided to prepare the estimate, including any design assumptions. The PTC Standard Drawings and Design Consistency Guidelines will typically specify the technical information required for the elements being estimated. In addition, it may be useful for certain projects to document specific quantity metrics for major items of work, such as conceptual excavation and backfill quantities, concrete volumes, or pipe quantities. These items may be organized by the major component of work.
- ***Schedule/Planning Basis:*** Document the project management approach and anticipated durations for engineering and design, procurement, fabrication, and construction for the project. Where appropriate, the contractor labor and material resource strategies should be identified, as well as any assumptions that were made with regard to the work week schedule and planned use of overtime. The project schedule and key milestones should be identified in

this section as well as any assumptions regarding constructability or use of specialized construction equipment.

- ***Cost Basis:*** Describe the methods and resources used to determine the cost for each item listed. Identify the following pricing sources used (PTC historical, cost-based, etc.):
    1. Pricing source and methodology for anticipated contractual or procurement costs (project management, engineering, etc.).
    2. Escalation indices used to bring historical prices to current dollar and the method of calculation, including duration.
    3. ROW costs and the pricing source (including acquisition and relocation costs, if applicable).
    4. Utility relocation costs and pricing source.
- ***Allowances:*** List allowance amounts for items of work that have been identified in the scope but not yet specifically quantified, such as mobilization, traffic control, or erosion and sediment pollution control. Allowances can also be used to account for a lack of project definition during the preparation of planning estimates. Misuse and failure to define allowance funds can lead to estimate inaccuracies. Allowance funds should not be used to cover added scope as the allowance is then not available to cover the unquantified items of work for which it is intended.
- ***Assumptions/ Costs Influencers:*** List any other assumptions made but not documented elsewhere in the Base Estimate document, including those cost influencers described in Chapter 7 that are anticipated to have an impact on the cost of the project. Minor assumptions can change into major cost influencers throughout the life of a project, therefore it is best to document all assumptions.
- ***Exclusions:*** Include potential items that a reviewer might associate with the project, but for which no costs have been included in the estimate. Examples may include wetland mitigation or removal of hazardous material performed by others. Materials or other scope items that the PTC or a third party will be providing to the contractor should also be noted.
- ***Risk Allocation/Threats/Opportunities:*** Identify/list areas of the estimate containing significant risks (threats or opportunities) and included in the estimate as a contingency. If a risk analysis in any format has been prepared, such as a risk register, it should be included in this section. Refer to the *"PTC Project Risk Management Process"* within the PTC Design Operations Manual (DOM).
- ***Review Results/Changes:*** Provide an overview of the major differences between an estimate that has been reviewed and revised and the programmed estimate for the project. Changes should be identified, documented, and communicated per guidelines described later in this chapter.
- ***Specialty Group Inputs:*** Correspondence and costs received from specialty groups, such as environmental, right-of-way, and utility companies, need to be included.
- ***Estimating Team:*** All members of the estimating team should be identified and their roles defined.
- ***Attachments:*** The following supporting documents should be included with the Base Estimate document:
    1. *Reference Documents* - Document the drawings, manuals, texts, notes, specifications, and other references used in developing the estimate.
    2. *Schedule Documents* - Document the project design and construction schedule, including working days, shift assumptions, key milestones, and critical path.
    3. *Independent Constructability Review Documents/Checklists* - Documentation from constructability review meetings, including agendas, minutes, and completed checklists.

The amount of information and supporting documentation that will be included in a Base Estimate document will vary depending on the project development phase and estimator's experience. Although a planning estimate will be based on a limited amount of project definition, it may require more documentation than an estimate with a more defined scope because there are often more assumptions made at the conceptual level of a project that require greater documentation. There may also be times when the project definition is so complete that that a great deal of documentation is not needed.

Estimate Change Communication/Approval

Cost estimates can change for several reasons, including changes in scope, changes in schedule, and inaccurate estimates at earlier phases in the project development process. Changes in scope (and scope creep) and changes in schedule are to be documented in the Base Estimate document, which will provide a history of estimate details through the project development process. During the design development process:

- If the difference in cost from the previous estimate is not significant, the Base Estimate document should capture the reason for changes and the Design Manager (DM) or Design Consultant (DC) PM should approve and sign off on the new estimate. The new estimate should be communicated to the PTC PM in order to update the Contract Status Database for the 12Q Planning Schedule, and the new estimate should be included in the next cycle of the Capital Plan update
- If the difference in cost from the previous estimate is significant, in addition to the DM or DC approval described above, the PTC PM should contact their Category Manager to alert them of the difference
- If the difference in cost from the previous estimate affects the anticipated let date in the 12Q Planning or 5Q Planning schedules, the PTC Date Change Request form should be completed by the PTC PM and submitted for approval. The Reason Code in the Date Change Request form for a difference in cost should be noted as 'Other' and the previous and current cost entered in the comments section

The Base Estimate document and Date Change Request form will provide a tool for supporting PTC's Capital Plan by capturing information regarding increased/decreased project costs, delayed project lettings, and by providing a formal and consistent process for developing and evaluating project costs.

CHAPTER 6: CONTINGENCY, ALLOWANCES, AND RISK

Contingency

A project's development phase and the maturity of the corresponding information available must be accounted for when developing a cost estimate for that phase. The maturity of the information depends on the level of design details known at that time. Typically few design details are known during earlier development phases, however known design details should increase as a project moves through Preliminary and Final Design to advertisement. As a cost estimate is generated for each development phase, the estimate should account for design items or details that are not yet known. A contingency, in the form of an assumed amount or percentage of the total estimate, should be developed and added to the cost estimate to account for unknowns. In addition to the project development phase, the complexity of the project will also play a role in determining what contingency amount should be used. More complex projects will involve a greater amount of unknowns associated with the project. Conversely, if the project is relatively simple, the amount of unknowns associated with the project may be very limited. Figure 6-1 can be used as a guide toward selecting the appropriate contingency as a percentage of the project cost based on the development phase and project complexity. As known project information increases, unknowns begin to decrease, and the level (percentage) of contingency should decrease as well.

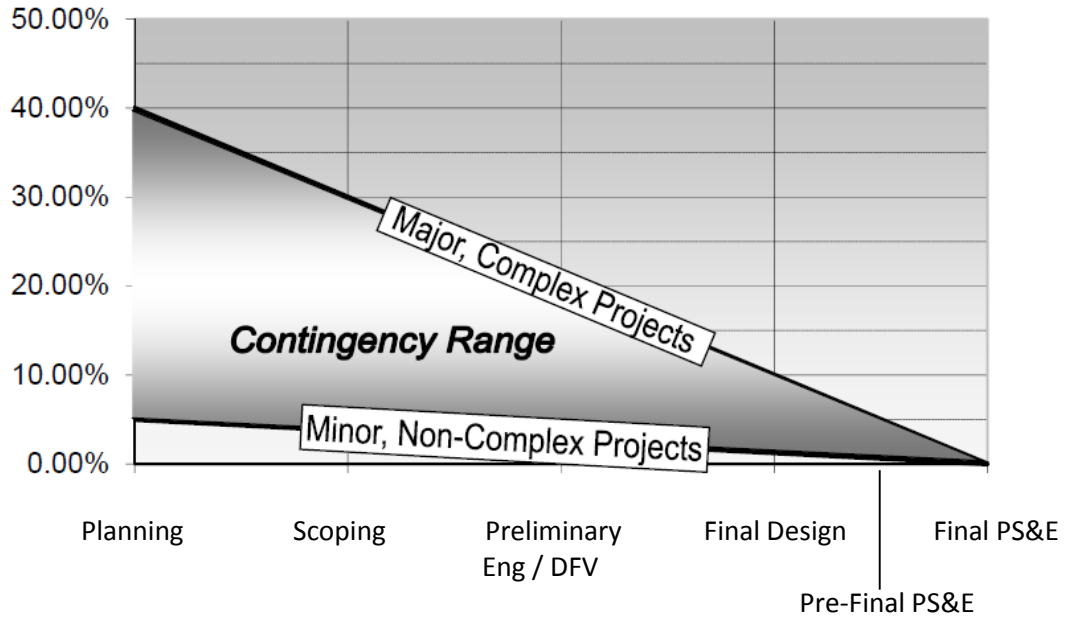

Figure 6-1: Contingency Chart

Inappropriate use of contingency, such as including multiple contingency factors, may lead to incorrect inflation of the project estimate. It is recommended that contingency be applied and carefully documented at the end or summary of the project estimate in order to prevent contingency duplication. Assumptions regarding the type and amount of contingency that was selected should be documented in the Base Estimate document in order for a reviewer to know how and why the contingency was chosen.

Allowances

Allowances are different from contingencies in that they are cost place holders for a particular item or activity that is anticipated for the project, however the details and costs for the item or activity are not yet known. The more allowances that are included in an estimate for anticipated items of work will help to reduce the amount of truly unknowns for the project, and ultimately should result in lower contingency levels. Allowances can be provided for items such as maintenance and protection of traffic, mobilization, clearing and grubbing, erosion and sediment pollution control, and stormwater management.

Various estimating methods can be used to generate an allowance cost for an item of work. For example, mobilization may be a percentage of the total cost of the project (typically 5%). Clearing and grubbing may be estimated as a lump sum item or a cost per acre. Maintenance and protection of traffic and erosion and sediment pollution control can be estimated from similar past projects or as a percentage of the total project cost. Allowances can also be included as a Pre-Determined Amount (PDA), which provides for the inclusion of a cost for an item of work with unknown quantity or scope where payment can be made on a force account basis or as a negotiated price. Price adjustments are calculated. Allowances can also be included for labor premiums, shift differentials, overtime and other specific labor rates that correspond to known anticipated construction activities.

Risk

Risk management is the systematic process of identifying, analyzing, responding to, and monitoring project risk. Risk assessment and risk management must be an integral part of a cost estimate's development throughout the project development process in order to keep project costs within budget. Risk potential grows with the complexity of the project. A good risk management strategy will identify the risks, quantify their impact on cost and schedule, and take action to mitigate the impacts of risks as the project is developed through the various phases of design. Risk assessment assists in deriving appropriate contingency amounts for cost estimates. Refer to the *"PTC Project Risk Management Process"* within the PTC Design Operations Manual (DOM) for further information on how the PTC addresses risk.

CHAPTER 7: COST FACTORS AND COST INFLUENCERS

The PTC's cost estimate process not only involves the collection and estimating of relevant costs related to project scope and design, but it also requires anticipating impacts to those costs that are caused by changes over time and related to changes in scope, available labor and material resources, and national and global market conditions. These anticipated impacts are typically classified as Cost Factors or Cost Influencers. **Cost Factors are more aligned with a project's contract procurement process/method and schedule while Cost Influencers tend to be more aligned with the physical construction aspects of a project.** This chapter will define some of the most common Costs Factors and Cost Influencers and the impact they may have on a project cost estimate.

Cost Factors

Cost Factors that can lead to escalated project costs have been identified through numerous studies and can be categorized into the following primary factors:

- ***Bias***: Bias is a systematic tendency to be overly optimistic about key project parameters and is often viewed as the purposeful underestimation of a project's cost to ensure that a project remains in the construction program.
- ***Project Delivery Approach:*** The decision regarding which project delivery approach (such as design-bid-build or design-build) affects the allocation of project risk between the PTC and contractors. When risk is shifted to a party that is unable to control it, project cost will likely increase. In addition to risk allocation, lack of experience with a delivery method can also lead to underestimation of project costs.
- ***Project Schedule Changes****:* Project schedule changes can be viewed in terms of the time value of money. Schedule changes, particularly schedule overruns, caused by funding restraints, design challenges, or environmental impacts can result in unanticipated increases in project overhead and/or inflation. This additional project overhead cost can impact the PTC's programming budget as well as the budgets of consultants and contractors working on the project.
- ***Engineering And Construction Complexities:*** Complexities caused by a project's purpose or location can make early design work very challenging and lead to internal coordination errors among design teams and components. Internal coordination errors can include conflicts or problems between the various disciplines involved in the project's planning and design. Constructability problems may also be encountered as the project develops. If design and constructability issues are not addressed early in a project's development, cost increases are likely to occur.
- ***Scope Changes:*** Internal and external (not controlled by the PTC) scope changes can lead to project cost increases. Such changes may include additions or deletions from the project scope. An example would be increasing the right-of-way required for the project.
- ***Scope Creep***: Internal and external (not requested by the PTC) scope creep is the accumulation of several minor scope changes that increase project scope. While individual scope changes have only minimal effects on project costs, the accumulation of these minor changes, which are often not essential to the intended function of the project, can result in a significant cost increase.
- ***Poor Estimating:*** Poor quality cost estimates, especially if underestimated, will likely translate into increases in project cost as errors and omissions are exposed. Estimate documentation must be in a form that can be understood, reviewed, verified, and corrected. The foundation of a good cost estimate is the format, procedure, and process used to arrive at the cost.

- ***Inconsistent Application Of Contingencies:*** Contingency funds are meant to cover a variety of possible events and problems that are not specifically identified or to account for a lack of project definition early in the planning, scoping, or preliminary design phases. Failure to define what items that contingency amounts will cover can cause confusion as to exactly what is included in the line items of an estimate and what is covered by contingency amounts.
- ***Faulty Execution***: This factor can include the inability of the PTC or project manager to provide information relative to the project, to make timely decisions, or to address difficulties as part of the design and construction caused by coordination of connecting design or construction work or work responsibilities. Cost overruns are typically related to this factor.
- ***Ambiguous/Conflicting Contract Documents:*** When core assumptions underlying a cost estimate are obscured by ambiguous or conflicting contract provisions, the accuracy of the estimate will be jeopardized. Providing vague information in the contract documents can lead to diluted responsibility among the contractual parties, change orders and rework during construction, potential construction claims by the contractor, and ultimately lead to cost overruns during execution of the contract.
- ***Local Concerns And Requirements:*** Mitigation efforts by the PTC are often implemented to minimize the perceived negative impacts of construction projects on the natural environment and the local community. These efforts, which are many times requested by the local government, neighborhoods, and businesses as well as federal, state, and local environmental groups can extend the project duration, add direct costs, and increase inflation allowances.
- ***Inflation:*** The time value of money can adversely affect projects when the project estimates are not communicated in year-of-construction costs. Likewise, if the project completion is delayed, the cost will be subject to a rate of inflation that is greater than anticipated in the estimate due to a longer duration.
- ***Market Conditions:*** Changes in the macro-environment can affect the cost of a project, particularly large projects. The size of a project affects competition for a project and the number of bids that the PTC receives. Inaccurate assessment of the market conditions can lead to inaccurate project cost estimation. Changing market conditions during the development of a project can reduce the number of bidders, affect the available labor force, or result in increased commodity prices, all of which can disrupt a project's schedule and budget.
- ***Unforeseen Events:*** Unforeseen events are unanticipated occurrences that are not controllable by the PTC, such as floods, hurricanes, tornadoes, or other significant weather-related incidents. These events can bring construction to a standstill and have the potential to destroy completed work. Other unforeseen events could include terrorism, labor strikes, and sudden changes in financial or commodity markets. These activities can have devastating effects on projects and project costs.
- ***Unforeseen Conditions:*** Unforeseen conditions are those conditions that were not anticipated during the project's construction and are notorious for causing project cost overruns. Examples include unknown soil conditions that affect excavation, compaction, and structure foundations, contaminated soils that result in the need for special mitigation, and utilities that are found during construction that are not described or are described incorrectly in the contract drawings.

Cost Influencers

Cost influencers are various activities associated with a project that can have an impact, either minimally or significantly, in the construction cost estimate development. The project manager should understand and document the anticipated impacts that cost influencers may have on the construction estimate in the Base Estimate document. The following are common cost influencers that must be considered to determine whether they will impact a project's construction estimate:

- ***Quantity of Materials:*** The quantity of a given material on a project affects the unit cost of constructing and/or supplying that item. This is not just a supply and demand issue, but also one of production efficiency and economy of scale.

  Typically, the unit price for larger quantities of a given material will be less than smaller quantities. Suppliers offer discounts for larger quantity orders, as mobilization, overhead, and profit are spread out over a larger quantity, thereby reducing the cost on each unit. Larger quantities also give rise to efficiency by gaining experience and expertise in completing the work. However, very large quantities of certain materials may actually cause an increase to the unit bid price. For example, a project with numerous or large structures may affect the market for a particular type of steel, availability of cement, or even tie up a region's labor resources. Also, the phasing or location of material throughout the project may also negate the cost efficiency of large quantities when those quantities are scattered throughout a project rather than continuous or when split between construction phases.

  Small quantities of items of work are less cost effective to construct and lead to higher unit prices. Not only do suppliers charge more for smaller purchases, 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 also frequently subcontracted out, this practice increases a contractor's overhead and they usually apply a markup to those items.

  The following items related to quantity of materials need to be examined to determine whether they were considered as part of the development of the construction cost estimate:
  - Earthwork
    - Additional excavation for stormwater management, slope rounding, borrow cap, and driveway connections
    - Grading considerations including classes of excavation and types of borrow
  - Structures
    - Bridges - individual location by ft^2 area of bridge
    - RC box culverts - individual location by ft^2 area of box culvert
    - Sheet piling and shoring
  - Paving / Roadway
    - Number of lanes, width, and length
    - Median barriers / guide rails
    - Pavement marking materials
    - Shoulder paving
  - Drainage / Pipes
    - Excavation / backfill
    - Concrete / miscellaneous structures
    - Pipe / structure cleaning
    - Endwalls, end sections and associated rock aprons
    - Inlets and manholes
    - Subsurface drains slope and channel linings

- ***Classification of Work:*** Work that must be performed by hand will be more expensive than similar work that can be completed by machine. In addition, separated operations will be more costly than contiguous operations. Finally, precise work, such as fine grade, will cost more per unit than bulk work, such as large fills.

  The following types of work conditions must be considered for items and how the items will be placed / finished when developing the construction cost estimate:
  - Hand work vs. machined
  - Continuous vs. separated operations
  - Precise vs. bulk work
  - Operation Specific considerations
  - Paving / Roadway (Reinforced Concrete Pavement vs. Bituminous Pavement)

- ***Price-Volatility / Availability of Materials:*** Materials are considered price-volatile when:
  - Based on monitoring of recent contracts, the price trend is extremely volatile
  - Suppliers provide a price quotation for a limited time frame that is shorter than the duration of the contract
  - The price quote may be based on date of delivery or spot market conditions
  - Potential shortages are possible

  Fuel, asphalt, and steel are items that can be considered as volatile, and fuel-intensive activities such as excavation, hauling, and paving should be considered for Complex and Moderately Complex projects. Cement may also experience volatility due to the availability or shortage of components, such as fly ash. Construction contracts for larger projects typically incorporate adjustment factors (with appropriate special provisions and PDAs) to account for the volatility of items such as diesel fuel, asphalt, and steel.

  The availability or shortage of materials can have a great effect on the cost of a project when developing the construction cost estimate. Material sources should be checked for stock inventory, production rates, and limits of supply (e.g., manufactured items such as pipe and traffic signals should be checked for availability and delivery time). Provisions should be made in the construction schedule for sufficient time for the successful bidder to order materials that are known to not be readily available such as steel fabrications, pre-stressed concrete I-beams, pre-stressed concrete box beams, and steel sheet piling. Material shortages can increase costs, cause construction delays and increase overhead by lengthening the contract time. Surpluses in materials can drive costs down due to competition between suppliers.

  For certain projects, the availability of materials will have an impact on the construction cost estimate. The following items should be considered:
  - Material shortage
  - Material acquisition time
  - Material cost increases for multiple season projects (note that the contractor may only receive supplier quotes for a limited time and will encounter risk for a cost increase on these short-term quotes on materials)

- ***Location:*** The location of a project can also affect the unit bid prices. A project's location, whether in an urban, suburban, or rural setting should be considered in establishing the construction cost

estimate. Depending on the specifications associated with the project, some of the cost considerations relating to a project's location may be accounted for in the mobilization bid item.

- Rural - Projects located in rural settings have factors that affect the unit bid prices contrary to projects located in urban settings. Construction operations 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 to the project site from out of the area, which may increase those costs related to transportation, support, wages, and per diem. Remote locations usually result in higher prices. When developing the construction cost estimate, consider sources of material, mobilization costs to the project site, and availability of local labor.
- Urban - In congested urban areas, the storage space for contractor's equipment and stored materials must be considered, along with borrow and waste areas if required and haul distances when developing the construction cost estimate. Work that is to be completed while public traffic is maintained will require adjusted rates of progress. A project in an urban setting generally has to contend with construction operations occurring in more confined work spaces, greater volumes of traffic, limited hours of operations, and night time work that can affect production rates and impact the construction cost estimate. Some of these factors may be offset by availability of local contractors, materials, equipment, and personnel.
- Other Locations - Consider any unusual conditions such as accessibility to work, unstable soil conditions (i.e., wetlands or landfill), and work areas subject to flooding. Terrain may also be a consideration in establishing the cost of an item. Mountainous terrain and steep grades cause production rates to fall whereas level terrain and straight roadways generally have the opposite effect. Difficult construction and site constraints will increase the cost of construction for a contractor. Placing piles under water, working near an active railroad, nearby historical buildings (possibly fragile), construction on or near culturally important or environmentally hazardous sites, and limited room to construct an item are all examples of constraints that should be considered.

In developing the construction cost estimate, the location of the project will impact the construction cost estimate. The following items should be considered when developing the construction cost estimate for the various categories of work:

- New location vs. existing location
- Day vs. night work
- Restricted hours
- Project duration (fast track or multi-season project) based on completion date
- Phased construction
- Remote location (higher mobilization costs and higher material transportation costs)
- Urban location (higher costs)

- ***Phasing of Operations:*** To be efficient and provide a more competitive bid, a contractor will typically try to optimize the scheduling of resources including labor, equipment, and materials. Therefore, the lead time for the resources needed for a particular task and when that task is anticipated in the construction schedule needs to be considered in the estimating process. For example, a project that is two construction seasons long may have the majority of its paving in either the first or the second year, and should be considered when estimating those paving-related tasks. Some additional phasing items to consider include:

  - Efficient Scheduling - Scheduling segments of work in the most efficient and orderly fashion will

aid contractors in achieving efficiencies that increase their profit and cut expenses. Any restrictions on the timing of operations will cause delays and increase costs.
  - Project Start - Timing of the start of work will also have a major effect on the cost of a project. If the construction cost estimate is based on an early spring letting and the project is not let until fall, the estimate will need to be revised to reflect the new phasing of operations that is required due to the weather and season. The project will need to be examined for any restriction or reason that will affect the phasing of operations and the estimate should be adjusted accordingly.
  - Dominant Activities - In most complex projects, one dominant activity, phase or controlling operation has substantial influence on the contract time. The types of phases or operations that are considered dominant include bridges, roads, resurfacing, and traffic operations. Structures phases will most often be dominant in determining total contract time in most complex projects. As a result, certain portions of the project will be constructed in a specific order, which may bring into effect other cost influencers.
  - Permit Restrictions - As part of developing the PS&E package, appropriate permits should be obtained. Environmental permits and/or mitigation commitments are among those that may require special attention when determining contract time. These permits or mitigation commitments may contain restrictions to be considered when developing the construction cost estimate. Mitigation commitments may also require coordination for NEPA and threatened and endangered species.

  In reviewing the pre-bid construction schedule, the impact of the phasing of operations should be considered when developing the construction cost estimate:
  - Start of work (anticipated start from developed pre-bid construction vs. anticipated Notice to Proceed)
  - Idle time
  - Conflicts between construction activities and nearby community/business activities
  - Local ordinances
  - Permits
  - Winter Shutdown

- ***Project Type:*** In the context of cost estimating, project type will influence the associated cost influencers. While new highway construction projects may have additional costs associated with right-of-way acquisition, it may provide more efficient construction access and allow the contractor to use larger equipment. In contrast, reconstruction projects on existing alignment pose construction access restriction and other costs associated with construction phasing and maintaining traffic.

  In developing the construction cost estimate, the type of project will impact the construction cost estimate. The following items should be considered when developing the construction cost estimate for the various categories of work:
  - Small vs. Large (potential economies of scale for larger projects)
  - New (planning, design, construction, right-of-way acquisition, annual maintenance, and operation costs)
  - Resurfacing / Reconstruction
  - Bridge rehabilitation or replacement (new)
  - Tunnels
  - Drainage issues (Pipe/Structure Cleaning)

- Subsurface Drains Slope and Channel Linings
- Operation Specific considerations
  - Base repair quantities
  - Pavement Removal
    -Milling or grinding of existing pavement when resurfacing existing roadway
    -Removal of existing pavement and curb
  - Structures
    -Removal of existing structures
    -Substructure Repairs
    -Cleaning and Painting Structural Steel
  - Paving / Roadway
    -Resurfacing existing pavement on widening projects
    -Removal of existing concrete barriers

- ***Maintenance and Protection of Traffic:*** The maintenance and protection of traffic through a project is a key consideration and can have a significant impact on the construction cost estimate, depending on the traffic volumes impacted and the Road User Liquidated Damages (RULDs) associated with the project. Construction in high-volume traffic areas will add substantially to project duration and the construction cost estimate. Similar projects with low-volume traffic areas will generally have shorter contract times. When new roadways are constructed, contractors may build with little interference from existing traffic areas. This situation permits the contractor to generally maximize production rates and minimize expenditures. MPT costs become pertinent when the roadway project requires traffic to be shifted or detoured around the construction site.

  During construction, Maintenance and Protection of Traffic (MPT) should be designed and implemented to minimize the inconvenience placed on motorists driving in high or low-volume traffic areas. Cost-effective MPT must allow the contractor procedures that maximize production rates and work zone safety, while minimizing contract time and impacts on the motoring public. If the Commission feels that certain limitations are of significant importance, then those limitations need to be identified and stated in the special provisions/specifications for that project. Items such as when lane restrictions can be imposed, duration that a detour can be in place, maximum length of work zone, etc., will all have a bearing on the minimum number and type of devices that are necessary to prosecute the work.

  When preparing effective MPT for a project, costs associated with the following items must be considered:
  - Half-width vs. open area construction
  - Night work vs. day and weekend work
  - Cost to maintain equivalent number of open lanes during construction
  - Complexity of traffic control (crossovers, ramps, etc.)
  - Lane closures / restrictions
  - Detours
  - Mobilization, demobilization and remobilization
  - Operation Specific considerations
    - Structures - Maintenance of traffic costs for work done on existing bridges
    - Paving / Roadway
      -Full depth shoulders on roadways with high truck volumes
      -Traffic barrier

- Traffic
  - -Special traffic requirements
  - -Number of signals
  - -Special requirements for signals
  - -ITS components

- ***Permit Conditions and Requirements:*** Permits (e.g., PA DEP, Army Corps of Engineers) are included as contract documents and are reviewed by contractors to determine the cost impact for a project such as permit conditions, environmental mitigation, and community impact commitments. Other requirements that affect costs could occur due to local policies, taxes, restrictions, and air and water quality. In addition, locally specific rules and regulations governing noise, pollution, disposal of materials, and working hours can all increase the cost of construction.

- ***Lump Sum Items:*** Lump sum bid items are often used when an item of work can only be defined in general terms, such as when the finished product can be defined but not all the components or details can easily be determined. The use of lump sum items in an estimate is appropriate at times, and benefits of lump sum items can include a reduction in administrative costs during contract administration and the allowance of a variety of work means and methods during construction. However, lump sum items are typically bid at higher costs than component costs due to the transfer of risk from the owner to the contractor.

  From an estimating standpoint, lump sum bid items can be difficult to price. If the work performed within a lump sum item can be quantified, such as the reconstruction of more than one bridge on a Total Reconstruction project, then a payment method that includes quantity should be used. An estimator should define a lump sum item in its simplest, most basic components. By breaking down a lump sum item into smaller items of work which have historical data, and then applying reasonable estimated prices to those sub units, an estimator can more accurately establish a price for the overall lump sum item. The more information and breakdown of a lump sum item that an estimator has available, the greater the likelihood that an accurate lump sum can be developed.

  In some situations, as may be the case for a time-based lump sum bid item such as temporary traffic control, the lump sum payment may provide the basis as an incentive, and may even cause the contractor to stay in the work zone as long as possible. However, in most situations using lump sum bid items will lead to higher contractor bids, therefore lump sum items should only be used when the following conditions apply:

  1. The lump sum item is a standard item with no appropriate alternative non-lump sum standard item available for use.
  2. The work is not easily defined. In other words, the final product is known, but the construction techniques or other components are difficult to determine.
  3. Complex items with many components (although designers are encouraged to break down constituent items if possible).
  4. The lump sum payment may be justified as an incentive to complete the work in a more timely or efficient manner than if other units of measure were used.
  5. The lump sum item may be justified as less expensive than a force account item or where the risk assumed by the contractor is low.

  The use of a lump sum item must be justified and the work breakdowns documented in the project estimate file.

- ***Timing Of Advertisement:*** The time of year when a project is advertised and subsequently bid has a major influence on bid prices. Contractors typically have a time of year that is busier than others, which normally directly correlates with the weather and occurs when conditions are the most conducive for construction activities. The best time to advertise a project is several months before the season for the anticipated type of work to allow time for contract execution and optimized contractor scheduling and mobilization, which should result in a more competitive bid climate and lower bid prices. Projects that are advertised for bids late in the season or after contractors have scheduled their work for the year, can expect higher bid prices due to the lack of competition or contractor availability.

  Multiple contracts being bid at the same time can influence bid prices in much the same way as lack of competition and availability. Contractors only have so many resources available to develop bids for projects, and in the case of large projects, may not have the resources to develop bids for more than one project at a time. The most prudent course of action for this scenario is to manage the program of projects to ensure that this does not become an influencing factor on the bids. The estimator should consider to what extent the reduction below the normal number of bidders will influence the bid amount. Typically with four or more bidders the effect on the bid is negligible. The probability of the occurrence of this risk should be evaluated by the estimator. Common mitigation strategies include timing of the advertisements and work packaging. Another factor to consider in a multiple contract environment is the resources required for the projects and if multiple active projects will create shortages in an area. 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 ability of the market to support multiple projects. Having multiple projects in an area may also create conflicts between projects. These could include traffic control, labor issues, and direct co-ordination issues. These conflicts need to be considered in calculation of production rates and subsequent bid item prices. Project managers should be aware of adjoining projects and nearby work. There may be opportunities for collaboration and co-ordination that will result in more competitive bids and better maintenance of traffic.

- ***Timing of Construction:*** The estimate should reflect prices that are realistic for the areas, times, and characteristics of the work to be done to account for a seasonal adjustment. The month of the year that work will proceed has a definite effect on the construction cost estimate for the project. It is best to start projects in early spring and/or can be finished before cold weather sets in. If the project cannot be completed before cold weather, rates of progress must be adjusted downward and the construction cost estimate revised upward. In addition, added costs, such as winter overhead, heating of materials and winter damage, must be considered when developing the construction cost estimate. For certain operations, temperature extremes will cause delays and raise costs, therefore, the construction cost estimate must be examined to determine if certain operations will be impacted by temperatures and the cost estimate adjusted appropriately.
  From the pre-bid construction schedule, the impact of the anticipated time of year for the project, the following items should be considered when developing the construction cost estimate:
  - Winter work
  - Availability of some materials is seasonal
  - Environmental permitting date restrictions

- ***Standard Item vs. Non Standard Item:*** Standard items should be used whenever possible as standard items are familiar to both the PTC and the PTC's contractors and typically represent a known quality who's quantity cost is associated through bid price history. When a standard item is

changed in some way to become a non-standard item, uncertainty is introduced and typically results in an increased item price. When a standard item is changed and becomes a non-standard item, the estimator should recognize that the price may differ from the historical bid price. In addition, the price of some standard items could increase if the item is scattered throughout a project rather than continuous, such as pavement patches or guide rail.

- ***Additional Items to Consider for Construction Cost Estimate:*** The following items may become defined and recognized as part of the project scope during the design phase. However, these items may also have a large impact on the project estimate and therefore must be considered and included as a cost in the estimate as early in the design phase as possible.

  - Earthwork
    - Unsuitable material removal and replacement using borrow
    - Borrow cap for non-stabilized soils
    - Foreign borrow requirements and logistics for bringing on-site
    - Chemically treated subgrade for soil stabilization
    - A cost for drying the soil when cuts go below the water table
    - Removal of existing pavement and curbs
  - Structures
    - Bridging wetlands
    - Electrification for signing and lighting
    - Stream maintenance for all structures in/over moving water
    - Permanent or temporary stream relocations
    - Retaining walls / noise walls
    - Higher unit costs for bridges over 20 feet above grade as these bridges require additional substructure
    - Piles
    - Erection and demolition work including crane type and placement
    - Higher unit costs for curved or skewed bridges
    - Dredging for bridge construction
    - Maintenance of traffic costs for work done on existing bridges (staged construction vs. detours)
    - Cost for removal of existing structures
    - Active rail line(s)
    - Temporary sheet piling during construction
    - Temporary structures
    - Bridge approach adjustments
    - Temporary causeways/diversion devices

  - Paving
    - Resurfacing existing pavement on widening projects
    - Milling of existing pavement when resurfacing existing roadway
    - Access roads to properties that are cut off by proposed improvement

  - Shoulders
    - Full depth shoulders on roadways
    - Median barriers / guide rails

        - Sidewalks
        - Removal of existing guide rail and/or concrete barrier
    - Landscaping
        - Cost per acre for reforestation
        - Cost per acre for wetland replacement based on the quality of the wetland
        - Temporary seeding
        - Mulching and straw mulching
        - Turf establishment, sodding
        - Woody shrub seeding, wildflower seeding
        - Additional landscaping in historic areas
    - Maintenance and Protection of Railroad Traffic (i.e., flagging)
        - Consider impacts construction schedule
        - Structures
        - With or without gates
    - Utilities
        - Manhole adjustments
        - Structure attachments
        - Underground facilities
        - Total replacement cost
    - Right-of-Way Impacts
        - Driveway and curb adjustments
    - Other Items
        - Improvement of intersecting roads for detours
        - Pedestrian overpass/underpass
        - Use of special equipment
        - Access to the work site

CHAPTER 8: INDEPENDENT CONSTRUCTABILITY REVIEW AND COST ESTIMATE

In order for the PTC to receive the best bid price for a project, the plans and specifications for the project must be both biddable and buildable. An independent constructability review and development of an independent construction cost estimate based on that review is a key method of evaluating the design against viable construction practices and techniques and to identify areas where cost benefits can materialize during construction. An effective independent constructability review and development of an independent construction cost estimate will ensure that:

- The project, as detailed in the plans and specifications, can be constructed using proven construction methods, materials, and techniques within the time frame and budgeted costs
- The plans and specifications provide the contractor with clear and concise information that can be utilized to prepare a competitive, cost effective bid
- The work, when constructed in accordance with the plans and specifications, will result in a facility that can be maintained in a cost-effective manner by the PTC over the life of the project
- Significant differences between the independent estimate and Engineer's Estimate are identified
- Redundancy should be kept in check to prevent conflicting data

Not all projects will include an independent constructability review and cost estimate. The Assistant Chief Engineer of Design and/or Construction will determine which design projects (typically larger projects) will have an independent constructability review and cost estimate performed as part of the project design. The timing of an independent constructability review is important, since projects become less adaptable to change as they approach construction. Ideally, constructability reviews should be performed in both Preliminary and Final Design, long before the Pre-Final PS&E Submission, in order to allow for a sufficient amount of time to address any issues identified during the review. Conducting a constructability review too late in the design process is not effective since, by that time significant costs have been incurred in developing the design and design revisions will likely be costly to implement, may conflict with already approved permits and commitments, may have a significant effect on the project schedule, and could delay the start of the construction.

An independent constructability review and cost estimate should utilize personnel with extensive construction knowledge and experience. Since a Construction Manager (CM) is typically under contract for larger projects by the time a project is in Final Design, the CM can be used to perform the independent constructability review, or an independent consultant may also be used to perform a review. **The Assistant Chief Engineer of Design and/or Construction will decide which projects will undergo a review and who will perform the review.**

The PTC PM should compile and make the following documents available to the independent review team:

- Construction plans at the appropriate design level
- Construction specifications
- Traffic maintenance/management plan
- Construction phasing
- Erection and demolition plans (if available)
- Structure drawings
- Design exception(s)

- Environmental summary (may be a draft document)
- Description of permits
- Site investigation notes
- Legal and required right-of-way
- Utilities/railroad conflicts and coordination efforts

The PTC PM is responsible for tracking all comments from the independent constructability review, for developing a summary of potential issues and differences in cost that require a solution/response, and for addressing which solutions will be implemented or carried forward for further investigation as well as reasons for not including potential solutions. The Assistant Chief Engineers (Design and/or Construction) will resolve any disputes over incorporation/non-incorporation of solutions that came from the constructability review. All documents prepared for and resulting from the review should be compiled by the PTC PM and added to the project cost estimating file as part of the permanent documentation.

Accounting for constructability does not always occur naturally to designers, engineers, and non-construction personnel during plan, specification, and cost estimate development, so the PTC has developed a checklist of items to consider in preparation for and during a constructability review. The checklist can be found in the PTC's current Design Operations Manual (DOM) and provides a tool to help designers, reviewers, and estimators to focus on more common areas and issues of concern regarding constructability. The topics presented in the checklist are not all-inclusive and may not apply to all projects, however they provide an opportunity for a designer/estimator to think about each topic in terms of the project and to realize potential concerns and cost implications during a constructability review.

Base Estimate Process Summary Checklist

Developing a Base Estimate for a project involves trying to capture and estimate the realistic cost associated with as many of the components of the project as possible. These components may be estimated using different techniques depending on the level of scope definition and the size and complexity of the project. The number and detail of estimated components may vary depending on the project development phase. The preparation of the Base Estimate should include the following steps:

❖ STEP 1: IDENTIFY LEVEL OF DESIGN

- Project Development Phase (Circle One): -Planning
  -Scoping
  -Preliminary Engineering (_____% Submission)
  -Final Design (_____% Submission)
  -Pre-Final PS&E
  -Final PS&E

❖ STEP 2: IDENTIFY COMPONENTS

	Component	Yes	No	N/A	Comment*
A.	Earthwork				
	-On-site or foreign borrow				
	-Waste				
	-Known classes				
B.	Pavement				
	-Typical section known				
	-Curbs/gutters				
C.	Structures				
	-Replacement (type, span length/area, if skewed or curved, foundation type)				
	-Rehab (location and area)				
	-Walls (type, height, area, foundation type)				
	-Demolition				
	-Tunnels				
D.	Right-Of-Way				
	-Required ROW				
	-Temporary ROW (access, material storage)				
	-Environmental mitigation sites				
E.	Utilities				
	-Existing facilities and private easements identified				
	-High voltage lines or large				

	diameter (> 24") lines/ducts				
	-Relocations identified and party responsible for cost				
	-Railroad crossing impacts or track relocations				
F.	Traffic				
	-MPT method identified				
	-Approved haul routes or hauling restrictions				
	-Signs				
	-Signals				
	-Pavement markings				
	-ITS				
	-Traffic center and connectivity				
G.	Significant Miscellaneous Items				
	-Wetland banks/mitigation				
	-Mobilization				
	-Drainage structures				
	-Hazardous materials				
	-Guide rail/barrier				

*Attach additional back-up documentation as necessary

❖ **STEP 3: QUANTIFY COMPONENTS**

- Quantify those components identified under Step 2 according to the project development phase
- Attach back-up calculations for component quantities to this Base Estimate document

❖ **STEP 4: ESTABLISH COMPONENT UNIT COST**

- Establish unit costs for those quantities developed under Step 3 using the following checklist as a guide for items to think about related to unit costs:

	Cost Factor	Yes	No	N/A	Comment*
A.	Is the project delivery approach known (design-bid-build, design-build, etc.)?				
B.	Is the construction schedule compressed or are schedule delays or overruns likely or anticipated?				
C.	Are construction complexities anticipated and have they been coordinated with appropriate disciplines toward developing a realistic unit cost?				

D.	Are there federal, regional, or local concerns or requirements that may affect unit costs?				
E.	Based on the current Capital Plan, are there other major projects scheduled to be advertised or under construction in the area that would impact labor and material availability?				
F.	Is more than one bidder anticipated based on past projects in the area and on the time of advertisement and beginning of construction?				
G.	Were other projects used as metrics of comparison for the estimate? If so, please list projects.				

*Attach additional back-up documentation as necessary

	Cost Influencers	Yes	No	N/A	Comment*
A.	What is the project's location and has the impact to unit costs been considered?				
	-Urban				
	-Rural				
	-Is difficult terrain, unstable soil conditions, or limited constr-uction access anticipated?				
B.	Has material quantity and the resulting impact on unit costs been considered?				
	-Earthwork				
	-Structures				
	-Pavement				
	-Drainage				
	-Other:				
	-Other:				
	-Other:				
C.	Have classifications of work been considered?				
	-Hand work vs. machined				
	-Continuous vs. phased				
D.	Is price volatility a concern and has it been accounted for in items such as asphalt, concrete and structural steel?				

E.	For maintenance and protection of traffic have the type, phasing, duration, and restrictions been considered in the unit costs?				
F.	If the project is to be constructed in multiple seasons, has the effect on unit costs been considered?				
G.	Is disposal of hazardous material or removal/containment of lead anticipated?				
H.	Are there permit restrictions or environmental mitigation commitments, such as for wetlands, that could affect unit costs?				
I.	Are there noise or pollution restrictions or regulations on activities such as material disposal or working hours that could affect unit costs?				
J.	Have lump sum items been broken down or justified and documented in the estimate file?				
K.	Has the time of year when a project is to be advertised and bid considered with regard to unit costs?				
L.	Has the time of year when the project's construction will begin and end been considered in the unit costs?				
M.	Are premium work hours anticipated (night or weekend only work)?				
N.	Are unit costs for non-standard items realistic?				
O.	If a railroad crossing is involved, have the railroad's requirements, impacts to schedule, and resulting unit costs been considered?				

*Attach additional back-up documentation as necessary

❖ **STEP 5: DETERMINE RISK AND ADDRESS UNCERTAINTIES**

- Determine risks in accordance with the 'PTC Project Risk Management Process'
- Apply risk for factors or influences to item costs
- Using Figure 6-1, determine what contingency amount should be used based on the project development phase, project complexity, and associated risk

❖ **STEP 6: CHECK ESTIMATE**

- Check that the estimate quantities and unit costs correspond to each other and that the unit costs and supporting documentation are current
- Check the math, especially if subtotals for disciplines are tabulated throughout the estimate
- Verify a contingency is only applied once at the end of the estimate

Base Estimate Document

A required component of the Base Estimate is the preparation of a Base Estimate document that describes the project in words and includes underlying assumptions, cautionary notes, exclusions, and ultimately is able to support the estimate for which it is developed.

PROJECT

Sponsor (Lead Agency):	*Pennsylvania Turnpike Commission*
Project Name and Location:	
PTC Project Manager:	*Name and Contact Info*
Design Manager:	*Name and Contact Info*
Design Consultant:	*Name and Contact Info*
Estimator's Name and Organization:	*Name and Contact Info*
Project Development Phase:	
Total Estimated Cost of Project:	
Approved By / Date:	

PURPOSE

Describe the project, including the project type, purpose, location, and development phase.

SCOPE

Describe in paragraph form the basic scope of the project.

METHODOLOGY

Describe the primary estimating method(s) used for the cost estimate. Also list the level of effort spent for developing the estimate.

DESIGN BASIS

Describe the types and status of engineering and design deliverables used to prepare the estimate, including any design assumptions.

SCHEDULE/PLANNING BASIS

Describe the project management, engineering, design, and construction approaches used to prepare the estimate. This should include proposed or assumed working schedule, construction sequence, etc. List project milestones and project schedule.

COST BASIS

Describe methods and sources for determining listed item pricing. Provide detailed backup and the date in the attachments.

ALLOWANCES

Describe allowances in the cost estimate. Include their purpose and how the allowance amount was determined.

ASSUMPTIONS/COST INFLUENCERS

Discuss all assumptions not covered in other areas of the Base Estimate document.

EXCLUSIONS

List those items NOT INCLUDED in the cost estimate. Include those things that an outside person might think are included but are not.

RISK ALLOCATION/THREATS/OPPORTUNITIES

Describe all threats and opportunities that surface during the preparation of the cost estimate. This can become the basis for a risk management plan.

ESTIMATE REVIEW/QUALITY ASSURANCE

Describe the quality assurance plan for the estimate. What reviews or benchmarking has been done on this estimate?

REVIEW RESULTS/CHANGES

How were review comments incorporated into the estimate? How does this estimate compare to the previous one performed for this project? What are the differences and how are they explained?

SPECIALTY GROUP INPUTS

Discuss relevant input from specialty groups that will affect cost including environmental, right-of-way, and utilities. Include any meeting minutes that may be available.

ESTIMATING TEAM

List all parties involved in preparing the Base Estimate. Phone and email records should be kept for all the people that had input into the estimate.

ATTACHMENTS

Attachments should include:
Attachment A: Reference Documents
Attachment B: Schedule Documents
Attachment C: Independent Constructability Review Documents/Checklists

Cost Estimate Review Checklist

TYPE	YES	NO	N/A	COMMENTS	RESPONSE
Background Data and Conditions					
1. Is there complete technical scope documentation, including the following elements:					
a. Description of the work to be performed					
b. Performance criteria and requirements					
c. Discrete tasks and deliverables					
d. Resource requirements					
e. Sequence of events and discrete milestones					
f. Work not included in the original scope					
2. Have milestones descriptions been developed for each milestone associated with the project?					
3. Does the technical scope documentation for the estimate include descriptions of support associated with the work to be performed?					
4. Is the technical scope for the estimate consistent with the site, regulatory requirements and constraints (e.g., permit conditions, regulations) identified during the planning process?					
Cost Estimate					
1. Are appropriate historical cost data used in the estimate?					
2. Are direct costs that are associated with individual activities included in the cost estimate clearly and individually identified?					
3. Are indirect, overhead, or other costs clearly and individually identified?					
4. Does the estimate development history include an itemized and chronological list of the changes made to the cost estimate since initiation of its preparation, and the rationale for each change?					
5. Are the assumptions and exclusions upon which the cost estimate is based clearly identified and defined in the estimate?					

TYPE	YES	NO	N/A	COMMENTS	RESPONSE
6. Are significant estimator findings identified during preparation of the estimate documented?					
7. Have risk factors/contingency been used to adjust the costs? If so, have they been appropriately applied and adequately documented?					
8. Have escalation factors been used to escalate the estimate?					
9. Are the escalation factors adequately documented and appropriately applied?					
10. Are estimate summary and detailed reports included, and do they provide costs totals for each cost element in the estimate?					
11. Is a schedule included with the estimate?					
12. Are activities and duration included in the schedule consistent with those included in the technical scope?					
13. Are milestones and deliverables included in the schedule consistent with those included in the technical scope documentation and the estimate?					
14. Are previous estimate reviews and constructability reviews findings and recommendations documented and included in the estimate file?					
15. Have the findings and recommendations of the reviews been addressed in revision to the cost estimate/schedule?					