Federal Railroad Administration

U.S. Department of Transportation

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CAPITAL COST ESTIMATING

GUIDANCE FOR

PROJECT SPONSORS

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Introduction

FRA developed this guidance document on capital cost estimating for project sponsors and the industry as part of its continuing efforts to provide technical assistance and ensure successful project delivery. FRA's guidance emphasizes accuracy, comprehensiveness, and completeness of estimating materials, as well as credibility. These are all qualities highlighted by the U.S. Government Accountability Office (GAO) in its own capital cost estimating guidance,[1] which describes the same primary capital cost estimating methodologies and activities as stated in this document.

FRA's guidance focuses specifically on railroad projects; it provides examples of common estimating shortfalls in railroad projects; and it defines agency-specific requirements for project sponsors regarding format and submission of cost estimate-related materials.

FRA recognizes that it is not always easy to persuade stakeholders and funders of a project's merit, or to withstand criticism for capital costs that seem "too high" and schedules that seem "too long."[2] The pressures associated with project development and implementation can be immense. GAO recognized these pressures when it stated, "many organizations are not mature enough to acknowledge . . . cost risk realism because of the possible repercussions [and] . . . fear that the program could be canceled."[3] With this in mind, FRA's guidance asserts that true or "non-depressed" costs can get funded, and reminds us that delivering projects "as promised" increases industry credibility.

By following FRA's guidance, project sponsors should be better able to compensate for uncertainties, unforeseen conditions, and unknowns in capital cost estimates. Such should improve estimate reliability, and enable as-built costs to land within a reasonable range of the estimates generated at every project phase. With a consistent estimating approach, project sponsors should be better able to make useful comparisons among estimates, and to evaluate their own estimates.

This guidance will be incorporated by reference into FRA's Notices of Funding Availability/Opportunity and grant and loan agreements. FRA expects project sponsors to adhere to this guidance, and the principles and methods described herein.

FRA thanks project sponsors for their efforts to improve the reliability of their capital cost estimates and reminds them that their track records on capital cost estimating are seriously considered in FRA's decisions on funding and project advancement.

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[1] U.S. Government Accountability Office, "GAO Cost Estimating and Assessment Guide -- Best Practices for Developing and Managing Capital Program Costs, GAO-09-3SP," Mar. 2009.
[2] Note that in this document, "project" is used to mean programs of projects, planning studies, and individual projects.
[3] U.S. Government Accountability Office, "GAO Cost Estimating and Assessment Guide -- Best Practices for Developing and Managing Capital Program Costs, GAO-09-3SP," Mar. 2009. Chapter 9, page 81.

Cost Estimating Overview

GAO defines a cost estimate as “the summation of individual cost elements, using established methods and valid data, to estimate the future costs of a program, based on what is known today.” So one could say that cost estimating includes these steps:

- Subdivide the design into basic elements, such as alignment segments or type of component.
- Develop costs, based on similar recent projects or other valid information. Adjust for project age, duration, complexity, and geography.
- Total by category. Apply costs for professional services, sponsor management, and contingency.

However, that would be radically simplifying the process. At the very least, three additional considerations need to be taken into account.

1 Consider Costs Stemming from Outside of the Physical Design

The estimate needs to reflect the political and project management contexts, including conditions associated with the host railroad, funding entities, and stakeholder organizations. Also, it needs to reflect the selected delivery method and market conditions.

2 Consider the Cost-Impacts of Time

The estimate needs to reflect time. The project schedule, inflation, financing costs, and the intervals for release of funding have a tremendous impact on project cost.

Cost estimates are built up in direct relation to project phase durations. Without a schedule, the project manager is unable to access the checks and balances of program management’s “three-legged stool,” that is, scope, schedule, and cost.

Even if a fully detailed Critical Path Method (CPM) schedule is unavailable, the cost estimate must reflect critical path concepts, such as activity durations, dependencies, and float or schedule contingency. Schedule contingency should be quantified to cover expected delays, such as seasonal inclement weather, and the likelihood of unexpected delays—such as time needed to repackage and rebid construction, or to acquire permits for differing site conditions. An overly optimistic schedule sets up a project for cost overruns, because, like extending the schedule, accelerating construction adds labor and general conditions costs.

Other costs that are a function of time include inflation, finance charges, and funding intervals:

- If a project is stopped and restarted, the cost due to inflation alone can be significant.
- The entire cost of financing needs to be included in the project cost, even though payments may extend for years after project completion.
- Funding intervals can constrain cash flow and, as a result, project phasing.

3 EXTRAPOLATE BEYOND WHAT IS SHOWN ON THE PROJECT DOCUMENTS

To develop a comprehensive, accurate, and credible estimate, the estimating team needs to extrapolate—create a "total picture" of the project. Typically this has to be done before all of the design and project management decisions are made. For example, in Planning and Preliminary Engineering (PE), extrapolation is necessary to adequately estimate the cost of construction logistics, including access into an operating railroad.

Consideration of project risks is essentially extrapolation. Through a *risk review*, the estimating team is able to better consider the range of potential costs associated with project uncertainties. When risks are acknowledged, and appropriate levels of compensating mitigations and contingencies are factored in, the credibility, reliability, and accuracy of the estimate are increased.

Basic Estimating Activities

The following cost estimating activities are **required** for projects receiving FRA-funds. The remainder of this guidance details and expands upon these activities.

1 PREPARING THE ESTIMATOR'S METHODOLOGY MEMO

Identify the estimating methods to be used, and document these methods in the Estimator's Methodology Memo.

This Memo (also called the Basis of Estimate) is submitted with the cost estimate to FRA for review.

2 DEVELOPING THE ESTIMATE

Employ proven, professional-level quantity and cost estimating methods to develop the estimate.

Use a level of detail that is appropriate for the project phase and project design development. Use like-for-like historical project cost information, validate it through industry inquiries, and adjust costs for project-specific construction and management constraints.

At each phase or milestone, consider risks and uncertainties, and incorporate adequate amounts of contingency so the estimate will remain relatively unchanged (or will adjust to be slightly lower) as the project moves forward from design to construction, and ultimately to revenue operations. Develop the estimate in dollars from a single base year (e.g., 2016 Base Year dollars). Then, factor in inflation over time as indicated by the project schedule, to achieve a Year-of-Expenditure (YOE) Total Project Cost.

3 PERFORMING THE ESTIMATE CHECKS

Perform estimate checks at each phase or milestone.

Based on these checks, revise the estimate, as needed, and submit both the original and revised estimate to FRA, along with a description of the changes made.

Preparing the Estimator's Methodology Memo

The Estimator's Methodology Memo (Memo) is an essential roadmap. It is comprised of six sections.

Whether the project is estimated by one team or by multiple teams, this memo helps to ensure that a consistent, project-wide approach is taken, particularly with regard to the estimate structure and the sources and uses of pricing. This consistency can improve project coordination and completeness.

Before starting, consider that a well-developed cost estimate has the following characteristics:

CHARACTERISTICS OF A WELL-DEVELOPED COST ESTIMATE [4]
1) Uses a consistent estimating approach, 2) Is based on a schedule with all phases, 3) Is well documented and traceable (and includes assumptions and ground rules), 4) Includes contingencies (reflecting deterministic and probabilistic risk review results), 5) Uses justifiable inflation rates, 6) Sums to a Total Project Cost in YOE dollars, 7) Includes management reserve if necessary, 8) Is formally approved by the project sponsor.

The Estimator's Methodology Memo must be structured as follows:

1 INTRODUCTION AND PROJECT DESCRIPTION

This section must describe the current project phase, level of project development or implementation, and other information to put the estimate in context. An example:

The documents for the ABC Project are developed to 30% Design. This estimate is based on Preliminary Engineering documents, the Final Environmental Impact Statement, Basis of Design reports and project schedule. The project will be subject to a risk review workshop. Based on the results of the workshop, the estimate will be revised if necessary, so that it becomes a reliable starting point for Final Design.

Next, develop the project description with the following parts:

PROJECT DESCRIPTION
1) Project scope, 2) Institutional and organizational context, 3) Entities performing administrative/management, professional services, construction, 4) Project schedule, major phases, year of anticipated completion, 5) Status of project support and approvals, 6) Status and timing of funding sources, 7) Year of Base Year dollars, and 8) Overall cost limits, if any.

[4] U.S. DOE, "Project Definition Rating Index Guide for . . . Construction Projects, DOE G413.3-12"

2 PROJECT TECHNICAL BASELINE

This section must describe the project documents and other materials, and address their quality and level of maturity. It must provide Web links to the principle reference documents, and include a list of cost sources. It must characterize the interaction between the estimating team and project personnel, as well as the availability of documents.

3 ESTIMATING METHODOLOGIES AND STANDARD COST CATEGORIES

This section must describe the selected estimating methodologies used on the contemplated project. In addition, it must describe the structure of the estimate, including either a fully integrated or matrixed relationship to the Standard Cost Categories (SCC).

4 SUPPORTING ASSUMPTIONS/GROUND RULES

This section, at a minimum, must describe the supporting assumptions and ground rules in this table. (See additional information on this in Using Supporting Information.)

ASSUMPTIONS AND GROUND RULES
1) Estimate inclusions and exclusions 2) Methods for inflating historical unit costs 3) Methods for calculating inflation 4) Methods for developing contingencies

5 ESTIMATE LIMITATIONS

This section must identify the estimate's limitations so that the estimate is more credible, comprehensive, and supportable. It must also advise specific investigations to be performed to reduce uncertainties.[5]

Project estimates can be weak in anticipating the costs of construction, site access, staging, and sequencing. Unfortunately, it is not uncommon for project sponsors to overlook and minimize uncertainties, and misjudge risks in these areas. The following table, organized by risk category, provides examples of risks, many of which also represent an optimism bias.

Risk Examples by Category

REQUIREMENTS RISK
• The host railroad has not yet agreed to the project. • Unstable soils exist, the geotechnical investigation is incomplete, the alignment location is therefore not finalized, but Preliminary Engineering is proceeding.

[5] Federal Railroad Administration, "Monitoring Procedure MP-40C Risk and Contingency Review," https://www.fra.dot.gov/Elib/Details/L16064.

DESIGN RISK

• Normal project design development:
  ○ Is this a risk, or should design evolution and the associated cost increases be covered through base costs and allocated contingency?
  ○ Do the contracts assign responsibility for cost increases due to design development?

MARKET RISK
• A delay in obtaining resource agency permits delays start of construction. • Other construction projects in the area reduce competition and labor availability. • Acquiring real estate is taking longer and costing more than estimated.
CONSTRUCTION RISK
• The host railroad limits work windows to only 4 hours. • Inadequate capacity of domestic steel fabrication causes delay in material delivery.

6 ESTIMATE CHECKS

This section must describe the estimate checks and include proposed dates for submissions to FRA.

Developing the Estimate

1 Introduction

The quality of a cost estimate depends heavily on the estimating team's experience, access to information, assumptions, and the extent to which the team is well grounded in state-of-the-art construction means and methods. Through discussions with the project design and management teams, cost estimators develop an understanding of the project and its conditions, and extrapolate when information is not yet developed or is limited, to produce an accurate, comprehensive, and credible estimate.

Even at the earliest planning stage, an estimate may be organized into typical and non-typical alignment segments and project-wide elements. Typical alignment segments will share a construction condition or relationship to topography. For typical alignment segments, the same composite cross-section applies, as does the same aggregated unit cost. Simple stations and support facilities can also be estimated as typical elements. Complex interchanges and stations, and cuts, fills, and embankments that vary by site condition, are treated individually. Elements that extend along the entire project corridor, such as trackwork and signaling systems, may be estimated on either a project-wide basis or as part of alignment segments. Throughout the estimate, a consistent use of units of measure should be employed.

Sources of cost information include completed passenger rail and rail transit projects. Project sponsors, such as Amtrak, states, transportation authorities, and transit rail agencies, can provide useful as-built construction cost information. Costs can also be obtained directly from host freight railroads and from Surface Transportation Board decision documents. Commercial databases for heavy civil and building construction costs can be valuable references, and of course, the experienced estimator is likely to have his or her own database. The Capital Cost Database, described below, is another source. Note that costs obtained from all databases should be carefully considered for accuracy and applicability.

2 Using FRA Standard Cost Categories in Estimating

2.1 Standard Cost Categories Format

The Standard Cost Categories (SCC) are both a structure and a summary for the capital cost estimate.

The SCC format must be used for FRA-funded railroad projects, to obtain important consistency in the reporting, estimating, and managing of capital costs. Often, the SCC format is the foundation or structure for the actual estimate. Sometimes however, the actual estimate is structured differently, and the SCC's categories and line items are cross-walked to the other structure. Either way, the SCC format facilitates comparisons among estimates, and, for an individual project, the consistency of the SCC makes it easier to track, evaluate, and control cost changes over time.

The SCC worksheets are available at https://www.fra.dot.gov/eLib/details/L16055.

Both the *FRA Main Worksheet* and *FRA Inflation Worksheet* include ten categories with sub-categories within each. The third worksheet, *FRA SCC - What to include Where*, provides direction on which categories and line items to use for the various project elements.

The SCC format is also a helpful project management tool. The *Main Worksheet*, facilitates cost estimate reasonability checks through its display of the percentage relationships among cost elements:

- Guideway and track, stations, support facilities, sitework, and systems: Each is calculated as a percentage of construction; and
- Construction, real estate, vehicles, professional services, unallocated contingency, finance charges: Each is calculated as a percentage of Total Project Cost (TPC).

For complex passenger rail projects, the following percentage ranges are fairly typical:

ELEMENTS	PERCENTAGE OF TPC
SCC 10 – 50 Construction	60 – 75%
SCC 80 Professional Services	20 – 35%
SCC 90 Unallocated Contingency	5 – 8%

On the *Inflation* worksheet, Base Year costs are distributed across time, according to the project schedule. Inflation rates are designated, multiplied by the base year costs, compounded, and summed to become a Year-of-Expenditure Total Project Cost. The inflated costs are automatically transferred back to the *Main* worksheet.

2.2 Base Year Dollars, Inflation, Year-of-Expenditure Dollars

Costs are typically estimated in Base Year dollars associated with a single year. When starting an estimate, it is important to inflate historical unit costs, allowances, and other costs, to a single Base Year—preferably the current year. Consider an estimate in Base Year dollars as a concept—it is "as if" the project could be planned, designed and built in only 1 year.

Inflation is a sustained change in the general price of goods and services in an economy over a period of time, due to changes in global or regional supply and demand for labor and materials. Typically, general price levels increase over time, and reduce the buying power of money.

To arrive at a Total Project Cost in Year-of-Expenditure (YOE) dollars, Base Year costs are distributed over time, according to the project schedule, and then multiplied by inflation factors for the various elements (or categories), and for the individual years in the schedule.

Note that the manner in which Base Year costs are distributed across time has as much and perhaps more influence on the inflation calculation than does the choice of the inflation factor. To illustrate this, consider that a 1-year project slippage in the advertisement for bids may increase the construction cost by 3+ percent, all other things being equal.

Note also that inflation can sometimes drive costs more than quantities or base pricing. Recall China's construction boom in 2006-2007 that increased the demand for copper, steel, and cement. This boom caused prices for these commodities and products to rise dramatically in the United States. Also, recall, when construction workers flocked to New Orleans after Hurricane Katrina in 2005, the cost for construction labor quickly rose in neighboring regions.

Not all project elements experience the same rate of inflation, so a discrete inflation rate should be forecast for each element (track, signaling systems, stations, etc.) for each year of the project. Refer to the Inflation worksheet in the MP-33 SCC Worksheets at https://www.fra.dot.gov/eLib/details/L16055.

The Inflation Worksheet is structured to allow the application of inflation rates specific to each of the 10 cost categories, in each project year.

Sources of historical rates of inflation are the Bureau of Labor Statistics, ENR Building Cost Index and Construction Cost Index, and the Association of American Railroads Cost Index. None of these sources provides projections for the future.

The Consumer Price Index can be a useful reference in projections, but a truly thorough approach to forecasting inflation for a rail project is to engage the same professional organization that is projecting inflation rates for a project's revenues, and operations and maintenance costs, to project inflation rates for the project's construction costs. While not inexpensive, this approach has recently been used for a number of federally-funded passenger rail projects. These projections and market analysis would include an assessment of expected construction volumes in the region to identify overheating.

2.3 Capital Cost Database

The Capital Cost Database was established by the Federal Transit Administration (FTA) in 2009, to serve as an as-built capital cost reference, for use by grantees, consultants, and the U.S. Department of Transportation (DOT), in particular, FRA and FTA.

The Capital Cost Database is located at https://www.transit.dot.gov/funding/grant-programs/capital-investments/capital-cost-database. The database is structured around the Standard Cost Category format, that is, it pulls information from the SCC Worksheets, so that little cost reconstruction is required to input projects.

The database is currently comprised of costs for heavy, light, and commuter rail projects from across the country. As FRA-funded projects are completed, their as-built costs will be incorporated into the database, making it even more useful as a reference.

Project Sponsors are encouraged to open the database, and explore the information available there. Sample cost information from the Capital Cost Database, for illustration purposes only, is shown in this table:

Capital Cost Database sample

SCC	Element	Project	Qty	Unit	2015 Unit Cost
10.042	Viaduct	Chicago CTA Blue Line Douglas	26,400	LF Guideway	$5,901
10.042	Viaduct	Miami Dade Metro Heavy Rail	108,240	LF Guideway	$5,441
10.061	Cut and Cover, Soft Soils	San Francisco BART SFO Extension	30,242	LF Guideway	$17,399
50.03	Traction Power Supply: Substations	Hiawatha Corridor LRT	122,496	Track Feet	$290

3 METHODOLOGIES

The three commonly used estimating methodologies (analogy, engineering build-up, and parametric) are described and compared in GAO's cost estimating guide, as follows:

The three commonly used methods for estimating costs are analogy, engineering build-up, and parametric. An analogy uses the cost of a similar program to estimate the new program and adjusts for differences. The engineering build-up method develops the cost estimate at the lowest level of the [Work Breakdown Schedule] WBS, one piece at a time, and the sum of the pieces becomes the estimate. The parametric method relates cost to one or more technical, performance, cost, or program parameters, using a statistical relationship. Which method to select depends on where the program is in its lifecycle.[6]

Cost Estimating Methods Compared

Table 11: Three Cost Estimating Methods Compared

Method	Strength	Weakness	Application
Analogy	▪ Requires few data ▪ Based on actual data ▪ Reasonably quick ▪ Good audit trail	▪ Subjective adjustments ▪ Accuracy depends on similarity of items ▪ Difficult to assess effect of design change ▪ Blind to cost drivers	▪ When few data are available ▪ Rough-order-of-magnitude estimate ▪ Cross-check
Engineering build-up	▪ Easily audited ▪ Sensitive to labor rates ▪ Tracks vendor quotes ▪ Time honored	▪ Requires detailed design ▪ Slow and laborious ▪ Cumbersome	▪ Production estimating ▪ Software development ▪ Negotiations
Parametric	▪ Reasonably quick ▪ Encourages discipline ▪ Good audit trail ▪ Objective, little bias ▪ Cost driver visibility ▪ Incorporates real-world effects (funding, technical, risk)	▪ Lacks detail ▪ Model investment ▪ Cultural barriers ▪ Need to understand model's behavior	▪ Budgetary estimates ▪ Design-to-cost trade studies ▪ Cross-check ▪ Baseline estimate ▪ Cost goal allocations

Source: © 2003, MCR, LLC, "Cost Estimating: The Starting Point of EVM."

3.1 ANALOGY AND PARAMETRIC ESTIMATING

Estimating using the Analogy Method involves a comparison between two projects. Historical as-built cost information from a "peer" project is used to estimate the cost of a contemplated project. With a one-to-one comparison, the project being estimated represents a new combination of all or some elements of the other.

The Analogy Method can be developed quickly, at a low cost, and is easily understood. However, this method relies on one or a few points of comparison, and often true peer projects are difficult to find.

[6] U.S. Government Accountability Office, "GAO Cost Estimating and Assessment Guide -- Best Practices for Developing and Managing Capital Program Costs, GAO-09-3SP," Mar. 2009. Chapter 11, pages 107-108.

Estimating using the Parametric Method uses information from many projects. As with the Analogy Method, peer projects need to be investigated so their complexities and details can be taken into account in the comparisons.

The Parametric Method uses parameters from past projects that apply to a project under development. *Parameters* are variables, conditions, characteristics, or measurable factors. *Non-cost parameters* are technical, physical, and performance-based, programmatic elements, such as length of railroad, track, number of stations, passengers per hour. *Cost parameters* are cost-based, such as the average per mile cost for on-grade Class 4 track with a ballasted base.

Parameters are used in Cost Estimating Relationship (CER) calculations. A CER uses one or more independent variables to estimate a given cost element, using a simple ratio or a more complex equation derived from regression analysis. Below are examples of the two types of CER, cost-to-cost, and non-cost-to-cost.

Examples of Cost Estimating Relationships (CER)

Cost-to-cost CER:	**Non Cost-to-cost CER:**
Multiplier: A multiplier of one cost produces another cost. A cost multiplier can be used to factor in the difficulty of constrained construction sites, additional time to garner public support, limited work windows, additional labor crew costs to accelerate construction, and/or loss of efficiency in progressing the work. Example: A multiplier of 1.50 x labor costs yields an overtime rate. **Percentage:** A percentage of one cost produces another cost. Example: Steel on another project cost $X per ton. Given market conditions, we estimate that steel on our project will cost 110% of $X.	**Rate:** A rate applied to a non-cost element produces a cost. Examples: The rate applied is $50 per linear foot; $300M per station; $75 per hour. **Ratio:** One element in relation to another or a group, can yield estimating quantities and costs. Examples: For every X number of miles of railroad, X electrical substations costing $X each are required. For each component X of a project, X number of labor hours averaging $X per hour are required to build.

Confidence in the estimate depends on the validity of the relationships. Assumptions and cost sources must be regularly reevaluated for fit with the new project. Parameters from peer projects and the contemplated project are selected from the project technical baseline because they are “cost drivers,” that is, these parameters significantly affect cost. The project technical baseline must be sufficiently developed to make the cost drivers evident. And the estimating team must make adjustments, typically scale adjustments, for differences in design, size, technology, complexity, performance, or operations, between the set of peer projects and the contemplated project.

The largest variations between the peer projects and the contemplated project are typically found in foundation and subsurface requirements, and cost differences due to location or geography. For example, consider the construction cost difference between New York City at 31 percent above the national average, and Longview, TX at 74 percent of the national average. Another important variation is the difference between peer project inflation costs and the inflation-adjusted YOE cost of the project under development.

Comparisons with peer projects must be logical, credible, and acceptable to a reasonable person. For example, it might be reasonable to compare the historical costs of a 10-mile tunnel project with a proposed 10- or 15-mile tunnel, but it would probably be unreasonable to compare it to a 1-mile tunnel, because the same construction economies of scale cannot not be obtained. The Estimator's Methodology Memo should describe the peer projects and the scale adjustments made to the parameters.

Cost estimators typically use the Analogy and Parametric Methods in Planning/Concept Design, when key characteristics are known, and some technical definition exists. These methods can also be used as order-of-magnitude checks or "sanity checks" on Preliminary Engineering or Final Design estimates.

CER, integral to the Parametric Method, are key building blocks in all estimating approaches. As an example, professional services are typically estimated as a percentage of construction cost, and are also evaluated as a percentage of TPC.

3.2 Engineering Build-up Estimating

The Engineering Build-up Estimating Method is based on a project configuration and design that is advanced enough to allow accurate measurement of materials and quantities. This estimating method applies unit costs, not to composite cross-sections, but to discrete quantities.

Unit costs are applied to material, labor, equipment, overhead, and fees. Labor unit costs can be based on crew productivities, built up from wage rates, fringe benefits, insurances, and taxes. Material and equipment rental rates can be based on quotes or recent projects, and need to include appropriate waste factors, and sales taxes.

In the Engineering Build-up Method, estimates for work packages in a Work Breakdown Structure (WBS), are totaled to become the bulk of the project estimate.

The WBS is a deliverable-oriented hierarchical decomposition of the work to be executed by the grantee/program team, to accomplish the project objectives and create the required deliverables. The WBS subdivides the project work into smaller, more manageable pieces of work, with each descending level of the WBS representing an increasingly detailed definition of the project work. The planned work contained within the lowest-level WBS components (work packages) can be scheduled, cost estimated, monitored, and controlled.[7]

For more information on WBS, refer to Using Supporting Information, in this guide.

In the Engineering Build-up Method, the estimating team can determine what the estimate does and does not include based on a comparison with the project documents. The primary cost contributors

[7] Federal Transit Administration, "FTA Project and Construction Management Guidelines, 2016," pages 3-10.

should be evident. However, the detailed nature of the estimate can give a false sense of certainty and completeness. The estimating team must extrapolate beyond what is shown in the project documents. Because estimates typically source quantities from Building Information Modeling (BIM) models, missing scope or design information will not be estimated, unless, through its experience, the estimating team extrapolates. In addition, the estimate must be examined for an optimism bias in the unit costs, assumptions, and ground rules—as small errors compound when summed.

4 Expectations for Estimating by Phase or Milestone

The level of detail in the estimate changes with each phase. The appropriate level of detail is that which is relevant to the decisions at hand:

If a particular level of uncertainty is acceptable in making a decision, the level of detail that provides this level of uncertainty is acceptable. . . the estimator must have the vision to see beyond the obvious components. . . There may seem to be a conflict between the principles of completeness and level of detail, but there is none. By level of detail, an engineer describes detail only at the level appropriate to decisions; but by completeness, the engineer ensures that all costs are included. Therefore, the proper level of detail for a conceptual estimate may be a list of only the major items of equipment. Yet, at that level of detail, the cost of each item must include all construction costs. Similarly, level of detail precludes individual counting of builders' hardware or small tool items. However, their cost must still be included in the estimate in order that it be complete.[8]

This table indicates the estimating methods and estimate checks that are appropriate for the various phases and milestones. Additional information on cost estimating at each phase or milestone is available in this Section.

[8] Robert I. Carr, "Cost Estimating Principles," 1988. www.ricarr.com/Papers/Estimating%20Principles/Principles.pdf.

By Phase – Estimating Methods and Checks

<table>
<tr><td>Project Phase or Milestone
X % Percent – Maturity/Definition</td><td>Estimating Methods</td><td>Estimate Checks</td></tr>
<tr><td>Planning/Concept Design/Alternatives Analysis
0 – 15% Maturity
Critical Decision-1: Approval of alternative selection and cost range.</td><td>Primary: Parametric and Analogy Estimating

Secondary: Engineering Build-up Method</td><td>Estimate review by an independent party or FRA oversight contractor

Completely independent cost estimate</td></tr>
<tr><td>Preliminary Engineering (PE)
15 -- 30% PE Maturity
30 -- 60% Advanced PE Maturity
Critical Decision-2: Approval of project baseline, project scope definition, cost and schedule.</td><td rowspan="2">Primary: Engineering Build-up Method

Secondary: Parametric and Analogy Methods</td><td rowspan="2">Estimate review by an independent party or FRA oversight contractor

Completely independent cost estimate

Risk Review</td></tr>
<tr><td>Final Design
30 – 100% Maturity
Final Design - complete plans from which the project can be built.</td></tr>
<tr><td colspan="2">Bidding 40% Bid
(If 40% of the value of contract packages have been bid and awarded successfully, and within budget, this represents a significant reduction in Market Risk to the project.)</td><td>Risk “refresh”</td></tr>
<tr><td colspan="2">Construction 20% complete, possibly again at 50%, 75%, 90% complete (or one year before pre-revenue testing begins)</td><td>Risk “refresh”</td></tr>
<tr><td colspan="2">Construction Complete, Revenue Operations</td><td>As-built costs</td></tr>
</table>

4.1 Submissions in Response to a Notice of Funding Availability

Project sponsor’s responses to FRA’s Notices of Funding Opportunity/Availability (NOFO/NOFA) must include project cost estimates, the Estimator’s Methodology Memo, and, if a prior project phase was conducted, the estimate checks performed.

4.2 Planning/Concept Design

In Planning and Concept Design, as alternatives are screened, and as one alternative is selected, the capital cost is a key evaluation factor. The following excerpt from a Planning Study/Tier 1 EIS Final Technical Memorandum describes how capital costs can be estimated for alternatives:

> *For the Action Alternatives, the FRA completed more detailed cost analyses for typical right-of-way cross sections (typical cross sections), station layouts, trackwork configurations, rolling stock requirements, and maintenance and operations costs. Cost estimates address all key elements, such as station development, grade-crossing eliminations, vehicle and maintenance shop needs, supporting systems, right-of-way acquisition, and costs of linear or area-based infrastructure elements such as tunnel or aerial sections, or embankment or retained fill areas.*
>
> *The FRA increased the number of typical cross sections to reflect the more detailed analysis of likely construction configurations along the Representative Route of the Action Alternatives. Cost estimates were developed for each of the typical cross sections. Cost estimates for linear*

elements are based on applying the appropriate typical cross sections by the estimated quantity (i.e., length) of that typical cross section along the Representative Route. Costs for the various elements are expressed as cost-per-unit length for infrastructure.

The FRA developed lump-sum cost estimates for discrete items such as stations, railroad junctions, shops, and rolling stock purchases. These costs are drawn from standard cost libraries and derived costs for recently completed similar projects.[9]

In the project described above, from the various alternatives, a selected alternative will be the subject of a phasing plan and a refined cost estimate in a Service Development Plan (SDP) Individual projects (Tier 2 projects) will flow from the SDP. "An example of a Tier 2 project would be adding a new bridge at an existing river crossing."[10]

To be within an order-of-magnitude of future estimates and the ultimate as-built cost, Planning Phase cost estimates must include contingencies and inflation, based on a schedule—when necessary, on a hypothetical or contingent schedule. Through the schedule, and the overlay of inflation costs, decision-makers can better evaluate the costs of delay and postponement.

A Note about Planning Phase Estimates

An accurate project cost estimate is important for every phase of development. During Planning, however, when a single preferred alternative is selected, an accurate cost estimate is critical.

At the decision point, the cost estimate sharpens the debate among alternatives, reduces reliance on preconceptions, and helps in the evaluation of benefits. If the cost dramatically increases, the estimate becomes the focus of news reports and the project's management may be called into question.

4.3 Preliminary Engineering

After Preliminary Engineering (PE), FRA expects that the project cost, schedule, and scope will not be significantly modified in subsequent phases. So that this expectation is met, FRA requires funding organizations, host railroad, and railroads with operating rights, to commit to the sufficiency of the cost, scope, and schedule, through a sign-off on scaled drawings.

The scaled drawings must show the track configuration, signal system, stations, utilities, real estate, the sequence of construction, including the effect, if any, on the traffic on the railroad, and finally, construction access points and staging areas for each phase in the construction sequence. Only after PE-level sign-off is complete may Final Design begin. When the project sponsor intends to use the Design-Build delivery method instead of Design-Bid-Build, sign-off may occur earlier than full completion of PE. For more information, see MP 32A Planning and Concept Design and MP 39 PE and FD, available at https://www.fra.dot.gov/Page/P0708.

The sign-off indicates that costs from any subsequent changes, will be paid for by the entity initiating the change; also, it indicates the host railroad's agreement to the estimate for its own construction activities.

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[9] Federal Railroad Administration, "NEC Future, Tier I EIS Appendix B.06: Capital Costs Technical Memorandum," Aug. 12, 2015, page 2.

[10] Federal Railroad Administration, "NEC Future Tier 1 EIS," Nov. 2015, Chapter 1, pages 1-12.

A typical organization for a PE cost estimate is illustrated here:

The cost estimate for the Final SEIS/SEIR uses three levels of cost presentation to provide cost information results in increasing levels of detail. The first level is the SCC form itself, where the cost and contingency for each category are presented. The second level is provided with in the SCC spreadsheet, where a detailed list of quantities for each category has been provided. Each item listed has its own quantity, unit price, total cost, and contingency for both quantity and unit price. This second level, with the list of quantities within the SCC spreadsheet, will enable the user to perform a quick review and check of the data.

The third level is a more detailed calculation of the quantities provided in the backup data where each item listed in the SCC spreadsheet is broken down into its component parts, with the unit prices that were derived from different sources . . .The unallocated contingency is calculated at 9.5 percent of the construction costs, right-of-way, vehicles, and professional services . . .Year-of-expenditure costs were based on inflation factors developed in 2013 and are based on the target revenue operations date of 2019.[11]

4.4 Final Design

During Final Design (FD), track structures, civil works, signaling, and stations are fully detailed. The documents prepared for bidding include drawings, specifications, invitation to bid, and the construction contract. Using the WBS, the estimate is organized by individual projects that together make up the larger project. Discrete quantities are measured from the drawings, and multiplied by unit costs to produce an estimate for each area.

Quotes should be obtained for specialty and price-sensitive materials. Contractor overhead, indirect costs, profit, and risk markup should be based on project duration, and local and regional construction market conditions.

Final Design costs should reflect the additional design detail in the construction documents, as well as cost assumption updates that have developed since PE. Using the WBS as a guide, changes from the PE estimate should be recorded for traceability.

5 Estimates with and by Host Railroads

For projects in which the railroad will perform some of the construction, the project sponsor should obtain from the host railroad its cost estimate, design standards, project plans, specifications, and schedule. The project sponsor must develop its own estimate of the work, and against this estimate, cross-check the host railroad's estimates for reasonability. Whether the host railroad or the project sponsor's contractor will perform work on railroad-owned property, the following items should be discussed and agreed to in writing:

[11] SANDAG, "Capital Cost Methodology/Estimate Report, 2014, MidCoast Corridor." yosemite.epa.gov/, Sections 3.6, 2.10, 3.2.

Items for discussion and agreement with Host Railroad

• Mutual understanding of the project scope and responsibilities of both parties in accomplishment of the scope.
• Host railroad's construction activities, fabrication times, delivery schedule for materials, and windows for construction during operations; availability of railroad's forces; project sequencing and phasing; and fit within the project sponsor's schedule. • Utility changes; site access for material transportation/handling/unloading costs and options; real estate acquisitions and impacts; use of vehicles, equipment, and facilities, including leasing or purchasing by the project sponsor.
• Costs to the host railroad for personnel for construction, flagging, roadway worker protection, power grounding; production rates for crews; and sequencing/flow of activities; labor rates including overhead and overtime; changes in labor rates over time; per diem/travel time guarantees; job site reporting/work day hours/start times; also for material, including overhead; for impact to operations (e.g., slowing or diverting trains). • Costs to the project for host railroad's time and labor to inspect, commission, and accept the work, and put the project into service; for construction down-time for passing trains; for buses that detour passengers to another station when construction limits passenger access.

Performing Estimate Checks

1 Introduction

The By Phase – Estimating Methods and Checks table above shows important points of change in project risk, which are points to reevaluate the cost estimate. The project sponsor's Estimator's Methodology Memo must set forth a plan to conduct estimate checks at these points. On completion of the checks, the revised estimate should be submitted to FRA, with a copy of the checks, and an explanation of the changes since the last submission.

Note that between milestone points, it is essential to do cost planning, trending, and reporting, to ensure a "no surprises" estimating process and a credible estimate. Consider the risks reduced through development of a credible estimate, as shown in this table which borrows from GAO's Cost Estimating and Assessment Guide:

Risk Reduction through Credible Cost Estimates

Characteristics of Credible Cost Estimates	Risks Reduced
• Clear identification of task • Revision of estimates for significant program changes • Availability of valid data including reasonable project schedule	Requirements Risk
• Standardized structure for the estimate • Provision for program uncertainties • Recognition of excluded costs • Independent review of estimates	Requirements Risk Design Risk
• Recognition of potential gaps in coverage among contract packages • Recognition of market conditions/escalation - labor/mtl shortages • Recognition of inflation	Market Risk
• Provision for construction uncertainties such as unforeseen site, geotechnical, or weather conditions; labor disputes; funding shortfalls • Provision for difficult construction such as during railroad operations (adjacency conditions, night work, and shortened work windows)	Design Risk Construction Risk

All estimate checks must include the following:

1) Verification of project quantities (length of tunnel, square foot area of major structures, number of bridges);
2) Parametric cost checks on structures, stations, tunnels, utility relocations, and environmental mitigations;
3) Checks for internal consistency, coordination, and reflection of current assumptions; and
4) Analysis of contingencies, and monitoring of the contingency drawdown.

The project sponsor may conduct the reviews with its own staff and consultant teams, or it may engage a peer review team. FRA's oversight contractors may conduct a review. Typically, in these cases, a sampling method is used, in which selected representative aspects of the estimate are checked. For an example of the sampling method, refer to Monitoring Procedure (MP-33) for Capital Cost Estimates, at https://www.fra.dot.gov/eLib/details/L16055.

The development of a fully independent cost estimate, by individuals having no affiliation with the project, can be a valuable as a point of comparison. A key recommendation for large, complex transportation projects is often to conduct an annual, independent cost-to-complete estimate to be used as a primary source of information for decision making.

Also, as stated earlier, the Parametric and Analogy methods, and the Capital Cost Database, can facilitate useful order-of-magnitude checks.

Finally, a risk review, conducted by FRA with the project sponsor, provides an invaluable cross-check on the scope, schedule, and cost estimate.

Variances between a project sponsor's estimate and a check done by others should be resolved through a meeting of the estimating teams. Differences should be identified, discrepancies corrected, and an agreement reached. If agreement cannot be reached, FRA should be brought in to hear both sides and make a decision regarding the cost estimate amount. If the amount decided is larger than the project sponsor's estimate, the project sponsor may be required to establish a capital reserve account, so funds will be available if needed.

2 Risk Review as an Estimate Check

A risk review can be performed at any point in project development, but is typically done before completion of Preliminary Engineering.

The risk review includes a series of organized exchanges and discussions, between the project sponsor's professional team and the FRA's evaluation team. The project scope, schedule, and cost are evaluated, risks are identified and quantified, and decisions are made regarding the management of risks. The risk "refresh," done typically during bidding and construction, is less robust, because it builds on previously completed risk reviews.

Typically, FRA's oversight contractor will conduct the risk review using Monitoring Procedure (MP-40c) for Risk and Contingency Review, available at https://www.fra.dot.gov/Page/P0708. All professional disciplines are engaged in activities to identify, quantify, and mitigate risk, as listed in the table.

Risk Review Activities

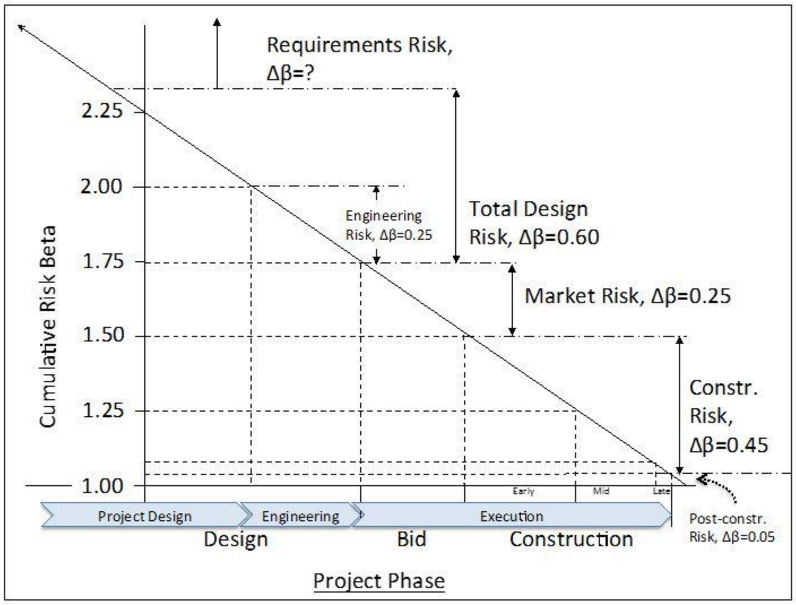
RISK REVIEW ACTIVITIES
Characterize the project Develop a robust status report. The rest of the review builds on this characterization review for project cost, scope, schedule, project delivery method, and the project sponsor's management capacity and capability.
Risk register Identify risks; document risks, assess them for likelihood of occurrence, and level of potential impact.
Strip out contingencies and adjust cost 1) Strip out hidden or latent contingencies in the estimate. 2) Adjust the cost estimate as needed to correct for items brought to light through preceding actions.
Beta factors Use the risk register as a reference; determine adjustments to the default "Beta factors" (shown below) for WBS items, at each project phase or milestone to indicate an amount of risk present. The broad nature of the Beta factor helps to reduce the effect of optimism bias.
Develop ranges of cost For line items, or elements, from lower to upper bound, to which a Beta probability distribution function will be applied, allowing the application of risk across the entire project.
Run the model Obtain results and check against "forward"/"backward" pass evaluations.
Identify mitigations Primary, secondary, tertiary – for risks on the register. Assign mitigation measures a cost value and a "sunset" date, after which they are no longer of use.

The risk categories are briefly described:[12]

- Requirements Risk – variability of fundamental goals and conditions of a project;
- Design Risk – performance and variability of design-related activities occurring after Alternatives Analysis;
- Market Risk – procurement of project management, right-of-way, design, construction services, materials;
- Construction Risk – variability in the project's environment and in performance of contractors.

[12] Federal Railroad Administration, "Monitoring Procedure MP-40 Risk and Contingency Review."

Graph of Risk Categories



During the risk review process, the Total Project Cost is “forecasted” as an upper bound, a mean, and a lower bound, through each phase or milestone, to reflect risk reduction as if all mitigation is successful, as illustrated:

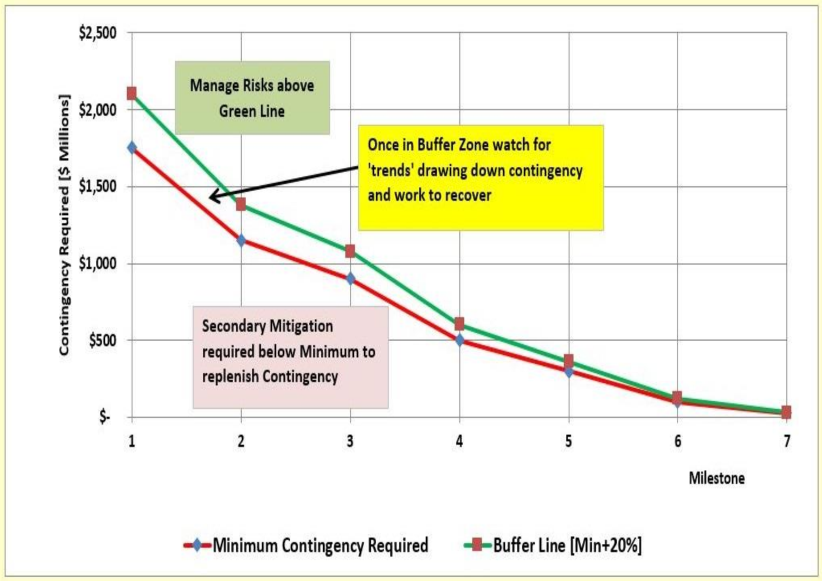
Project Cost Forecast - Upper Bound, Mean, Lower Bound Costs Across Time

Contingency curves are developed to step-down the amount needed at milestone points at which a significant project risk is reduced or eliminated, as illustrated here:

Cost Contingency Steps-Down at Milestones

Total Project Cost	$ 5,000,000,000	$ 5,000,000,000	$ 5,000,000,000	$ 5,000,000,000	$ 5,000,000,000	$ 5,000,000,000	$ 5,000,000,000
Phase	Prelimin Eng	Detailed Design	Bid / Market	20% Const	50% Const	80% Const	Revenue Service Date
Milestone	MS#1	MS#2	MS#3	MS#4	MS#5	MS#6	MS#7
Percent contingency	35%	23%	18%	10%	6%	2%	0.5%
Amount contingency	$ 1,750,000,000	$ 1,150,000,000	$ 900,000,000	$ 500,000,000	$ 300,000,000	$ 100,000,000	$ 25,000,000

Milestone Ref	Minimum Contingency Required	Buffer Line [Min+20%]
MS#1	$ 1,750	$ 2,100
MS#2	$ 1,150	$ 1,380
MS#3	$ 900	$ 1,080
MS#4	$ 500	$ 600
MS#5	$ 300	$ 360
MS#6	$ 100	$ 120
MS#7	$ 25	$ 30



3 General Questions to Ask

The following are important questions pertaining to the basis of estimate, cost drivers, deviations from the norm, uncertainties, and unknowns. These questions should be asked as part of any estimate check.

3.1 Basis of Estimate

- Do project requirements show consensus among stakeholders? Are objectives shared?
- Are solid analyses and studies the basis for key project choices (as opposed to biases)? Are technical solutions worked out? Has the design process been too rushed?
- Has adequate planning, time, and cost been given to the following:
    - Third party agreements
    - Obtaining environmental clearances and resource agency permits
    - Real estate acquisition
    - Vehicle procurements (requirements coordination, schedule)
    - Utility relocations (location and condition)
    - Hazardous materials (location, quantity, and support operations and facilities)

3.2 Cost Drivers

Are the cost drivers of the project evident? Does the cost estimate adequately reflect them? As an example, consider a station project whose foundation includes seventy, 250-foot deep, large-diameter piles. This foundation work is necessarily on the critical path of the schedule, and is a major cost driver.

3.3 Deviations from the Norm

Where in the cost estimate are there deviations from the norm (based on well selected peer projects)? Are these deviations explainable? As an example, if cost from built projects show the average linear route foot cost of a twin bore tunnel is between $X and $1.5X, then a cost of $.5X would be a deviation from the norm, and would warrant investigation.

3.4 Uncertainties and Unknowns

The first line of defense against uncertainties is proactive project management—creative design and management, thorough investigations where needed, and rational development of allowances and contingencies. Defense against "unknowns" is built through pre-planning of possible scope reductions, schedule extensions, and reserve fund sources, to be called on, if necessary. "Unknowns" are events that arise seemingly "out of the blue." They can stem from the novelty of the type of project, and related technical challenges. They can be due to unexpected changes in project support. Earthquakes and other natural disasters also typically fall into this group. General questions to be asked include:

- Have uncertainties been identified? Has a strategy been formed to mitigate them?
- Have investigations been done to determine the scale of various uncertainties?
- Have other design and management efforts been engaged to minimize the effects of uncertainties?
- Have provisions been made to insure against "unknowns," or events that reasonably could not have been anticipated?
- Has the project team pre-planned measures to be taken, if necessary, for example, for scope reductions, schedule extensions, reserves or additional funding?

4 Railroad-Specific Questions to Ask

The following are questions pertaining to constructability and lead times for railroad projects. Project contingency can easily be consumed if these questions are not answered in Preliminary Engineering.

4.1 Constructability During Railroad Operations

On railroad project that are close to or interfacing with an active railroad, a constructability review should be performed. Through questions such as the following, this review helps to ensure that operational impacts and costs are agreed by all parties.

- Are the costs of stopping, diverting, or slowing existing trains included?
- Are the costs and risks associated with line closure windows included?
- Are the costs for the railroad's own forces included; will flaggers and signals crews be available?

Although daily work windows of 6 hours or less can usually be accommodated, the windows for major line closures are usually limited to 48 hours, and these are sometimes available only once a year. A window may be missed because of project circumstances or something beyond the control of the project. Either way, the cost of missing a window can be very high. Consider all the activities that need to occur within a line closure window, including the railroad's disconnection, testing, and reconnection of signals and power. For projects constructed during passenger rail operations, include the cost of buses to detour passengers around construction.

The constructability review also covers construction staging, sequencing, site access, and site utilities. During Preliminary Engineering, for all but the simplest of jobs, written agreement on construction staging is necessary. Complex track reconfiguration under heavy traffic conditions may involve temporary signal work, and modifications to electric traction systems, where they are present. Questions to ask include the following:

- Is construction staging, under operating railroad conditions, agreed?
- Is work site access agreed early in the design process? Consider that, among other things, temporary grade crossings may be required to get from one side of a main line to the other.
- Will sufficient commercial electrical power be available? Often power is not adequate. Installing a new higher voltage electric power line along many miles of track can be expensive.
- Will adequate quantities of spare parts be available if materials are lost or stolen at the job site.

4.2 Lead Times and Costs for Signals and Special Track

For projects with tight or integrated time constraints, research on lead times for procurement should be completed before bidding. The time required is often not fully appreciated until the order is placed and a delivery time is proposed by the manufacturer. Twelve to 24 months is often required for signal components, especially for those at complex interlockings. Consider the following questions:

- Does the estimate reflect adequate lead times for new signal systems, as well as the ripple effect to the existing signal system--changes that may cascade between 1 and 6 miles in either direction from a new interlocking?
- Are lead times for procurement of special track work items (double slip switches, crossing diamonds, and size of turnouts) adequate?

Supporting Information

1 Project Technical Baseline

The project technical baseline describes key system characteristics and performance parameters. It says what the project is supposed to do (the requirements); how, where, and when it will do this (purpose, technical characteristics, development plan, acquisition strategy and schedule); and, in the case of railroad projects, how the service will operate.[13]

Helpful technical baseline checklists are included in FRA Monitoring Procedures MP-32C Project Scope Review, MP-32A Planning and Concept Design, and MP-39 PE and FD, available at https://www.fra.dot.gov/Page/P0708.

Although the level of development of each component will vary with the project phase, the project technical baseline must include at least the following items:

- A statement of project goals/objectives including railroad service objectives,
- Project narratives,
- Drawings,
- Schedule, and
- Basis of Design. Included are design standards and guidelines for each design discipline, and for the major systems and structures in the project, relating to performance, appearance, safety, and maintainability. Some guidelines or parameters are set through assumptions and ground rules.

2 Estimating Assumptions and Ground Rules

Assumptions **"represent a set of judgments about past, present, or future conditions . . . founded on expert judgments rendered by experienced program and technical personnel. . . ."** ***Ground rules*** **are agreed "standards that provide guidance and minimize conflicts in definitions."**[14]

2.1 Examples of Assumptions

- The bridge foundations are in good structural condition and adequate to handle the new loads.
- No hazardous or contaminated material is present, except in rail yards and maintenance facilities.
- Labor availability: Adequate, experienced craft labor is available.
- Unit costs assume the best price procured from the CM/GC through a competitive bid process.
- Existing state-of-the-art construction technology and equipment will be available.

2.2 Examples of Ground Rules

- Design criteria and construction conditions / methods

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[13] U.S. Government Accountability Office, "GAO Cost Estimating and Assessment Guide -- Best Practices for Developing and Managing Capital Program Costs, GAO-09-3SP," Mar. 2009. Chapter 7, page 64.
[14] Ibid, Chapter 9, page 79.

- Track will be designed for an operating speed of X mph with a maximum horizontal and vertical curvature of Y, Z.
    - The project will comply with Buy America. It will use domestically obtained and produced materials.
    - Track will be installed using a Rosenqvist machine.
    - Turnouts and grade crossing panels will be prefabricated adjacent to the rail line and cut in during work windows.
    - Construction during railroad operations: For installation of new passing tracks, construction will be performed during daytime 8-hour windows, with worker protection provided by railroad forces.
    - Construction between MP 20 and 21 will be performed around the clock, for a maximum of 48 hours, during which the railroad will be shut down.
    - An allowance of X weather days will be included for each year of the construction contract. Bidders will be asked in the bid form to provide a unit cost for each day beyond the number in the allowance.

- Costs for labor and equipment
    - Local equipment, rental rates, and current fuel costs are estimated at X. Quotes for specialty equipment, such as tunnel boring machines, are based on Y.
    - Sales tax of X% has been applied to incorporated materials.
    - Productivity rates are based on rates historically experienced on similar railroad construction. This is one of the areas easily underestimated. Production rates for railroad projects are typically much lower than the rates that can be obtained on non-railroad projects. This is due in to tight working conditions and work stoppages for passing trains. (When estimating productivity rates, consider the availability and variability of utility and railroad outages and track time.)
    - State prevailing wage rates are assumed.
    - Labor rates for daytime 8-hr shifts/ night work / overtime / weekend work.
    - Labor rates for railroad force account work, including railroad protection personnel.
    - Labor rates for third parties working on utilities and railroads
    - Escalation for specific trades: An adjustment of X percent has been included in labor rates for concrete and steel workers because of three other large projects in the same region/same timeframe.
    - Contractor indirect/overhead, bonds, insurance, and contractor profit/risk costs, are V, X, Y, Z, respectively.

3 Professional Services Costs

A useful guide for estimating professional service costs was developed through the Transit Cooperative Research Program (TCRP) in 2010: Report 138 - Estimating Soft Costs for Major Public Transportation Fixed Guideway Projects is available at http://www.tcrponline.org/PDFDocuments/tcrp_rpt_138.pdf.

This guide provides basic information about professional services (soft costs), how these costs are estimated, and how project characteristics such as guideway length or project delivery method can drive these costs up or down. It includes a professional services cost estimation tool that takes into account both the characteristics of the project and the organizational attributes of its sponsor agency.

4 RANGES OF CONTRACTORS' OVERHEAD AND INDIRECT COSTS

Indirect costs are costs that are not directly accountable to a cost object (such as a particular project, facility, function or product).[15]

Indirect costs include administration, personnel, and security costs. These costs vary with the project's market conditions and selected delivery method. Below are typical ranges for overhead and indirect costs, as a percentage of direct costs for major corridor projects. These costs can be embedded in built-up labor rates, so care should be taken to avoid omitting or double-counting them.

- General Requirements, General Conditions including Field and Home Office Expenses, including project supervision. Supervision costs can vary greatly if the project is run on multiple shifts and includes weekend work. 18 to 23%
- Insurance, not including Worker's Compensation. 3.5 to 4%
- Performance Bond. 0.75 to 1%

5 WORK BREAKDOWN SCHEDULES

The following are two examples of Work Breakdown Schedules.

Example 1 – WBS

	Level 1	Level 2	Level 3	Level 4
SCC	Element	Work Package (Contract Package CP)	Management	Detail
10 - 50	Construction	Examples: CP1: MP451-496 new railroad CP2: MP496-530 rehab existing railroad, add sidings CP3: Station at Town at MP470 CP4: MP440-550 new signaling system	Civil Architectural Structural Mechanical Electrical	Design drawing lists, specifications
60	Real Estate ROW	Examples: CP1: Parcels 1-50 CP2: Parcels 51-60 CP3: Parcels 61-63 CP4: Parcels 64-65	Acquisition Relocations Easements	Real Estate Acquisition Plan and Cost Template
70	Vehicles	Procurement Contract	Design Manufacture Test	Schedule Drawing Lists
80	Professional Services	Agency staff Consultants for PE, FD, Design during Const. Project Management Construction Management Insurance Legal Counsel, etc.	Civil Architectural Structural Mechanical Electrical	Staffing Plans

[15] https://en.wikipedia.org/wiki/Indirect_costs.

Example 2 – WBS

Level 1	
Should not change throughout the project	Funding Preliminary Design Environmental process Geotechnical Final Design 3rd Party Agreements ROW acquisitions Early Utility Relocations Main Construction Permits Procurement Main Construction (on large projects may expand into major geographic or contract areas) Start-up and Testing Pre Revenue Operations
Level 2	
Typically changes as Contract Packaging Plan matures	Main Construction organized by: Geographic Area Design Area Operational Area Major Component and formulated into Major Contract Works Packages. Note: Cost estimate also transitions while maintaining SCC traceability.
Level 3	
Should not change throughout the project	Key advance works (e.g. Major Utility relocations) Individual tunnels Individual bridges, Viaducts Track Systems installations Individual Stations 3rd Party interface projects Station area improvements Start up

6 CONTINGENCIES

Contingencies address project conditions that are not known, were not anticipated, or were incompletely defined or omitted for a variety of reasons.

An allocated contingency typically covers design evolution and uncertainties related to a specific project element. It may be estimated through the calculation of specific risks for a particular element, or it may be calculated simply as a percentage of the cost for the element. Ideally, the estimating team takes both approaches and cross-checks the results.

The unallocated contingency covers unforeseen conditions, particularly during procurement and construction, and is typically established as a percentage of the Total Project Cost.

Establishing the amount of contingency funds for a group of projects, or a program of projects, is a difficult judgment call. A quantitative risk review helps to define contingencies at both the project and program levels. Consider how much contingency will cover cost overruns without making the estimate unnecessarily high. Consider that many large projects have found themselves without sufficient contingency. On the other hand, consider how likely it is that each project within the program will consume all of its contingency.

The contingencies shown in this table should be considered rules-of-thumb or "default" percentages for the various phases and milestones. The percentages should be refined by the project sponsor through the risk review process.

Cost Contingencies – Rules of Thumb

Milestones	Allocated	Unallocated	Total
Completion of Planning/Concept Design (15% Design)	25-35%	10-20%	35-55%
Completion of PE (30 – 60% Design)	20-30%	7-15%	27-45%
Completion of Final Design (preparing documents for bidding) Ready to procure / bid construction in DBB At partially bid: *For work already bid* *For work ready to bid* *For work not yet ready*	15-20% *10%* *15%* *25%*	5-10%	20-30%
Start of Construction	10-15%	3-7%	13-22%
At 20% Construction Complete	7-10%	5%	12-15%
At 50% Construction Complete	5-7%	2-5%	7-12%

6.1 Increase Contingency or Shift the Risk?

Project sponsors should evaluate their own capacity to manage the project, deal with unforeseen construction conditions, and manage contingency funds successfully. Whether the project sponsor decides to shift the risk of unforeseen conditions to construction contractors, or to retain the risk, the bid documents must be clear about the assignment of responsibility.

If bid documents are, or a Request for Proposal (RFP), is ambiguous the result will likely be bids higher than expected. Bid documents or an RFP that clearly defines the project, its operational/quality requirements, and explicitly states how the bids or proposal will be evaluated, generally results in a bid *or proposal that will best meet the needs of the owner. This minimizes the risk of changes, and the cost associated with those changes, and reduces the amount of contingency needed by the contractor.*[16]

6.2 Contingency for Subsurface Conditions

Subsurface conditions are a high risk on nearly every project, and unless the risk can be entirely shifted to the construction contractor, a large contingency is warranted. It is said that the "project owner owns the ground," meaning the project sponsor typically bears the risk of geotechnical conditions, not only for unforeseen construction conditions, but also for settlement to structures above or adjacent. For site utilities, to avoid complications during construction, investigation during Preliminary Engineering must be done. Even with thorough investigation, an allocated contingency is necessary.

6.3 Contingency for Construction in an Active Railroad Environment

When construction is done during active railroad operations or in restricted work windows, the project can be subject to large costs for repeated site access, temporary power, multiple mobilizations and demobilizations. A constructability review performed during Preliminary Engineering can help prepare for and limit these costs, but an allocated contingency is still necessary.

6.4 Cost and Schedule Contingencies for Real Estate / ROW Acquisition

The risk for real estate acquisition tends to be higher and survive longer than the risk for most other project elements. The time to acquire real estate is often under-estimated: A year is almost the minimum; 18 months is considered good; and 2 years is average in some parts of the country. Delays and increased costs are typically due to unanticipated property owner expectations, constitutional protections of property owners, lesser known rules regarding relocations, higher than expected appraisals, and, market fluctuations of parcel values.

Eminent domain proceedings can be extremely costly, especially when compared to the difference in sales price typically under discussion between a property owner and the project sponsor. Also consider the time required to bring a suit to court. Preparation of a real estate acquisition and management plan, as described in FRA's Monitoring Procedure MP-23 Real Estate, can help to set an organized framework for acquisitions and relocations, increase awareness of potential adverse conditions, and suggest proactive mitigations. Nevertheless, an allocated contingency is still necessary.

7 Unit Costs

Unit costs are costs per a unit of measure, such as linear foot, ton, square foot, and hour, or per manufactured item, such as an electrical substation.

Unit costs typically include costs to produce, store, and install elements, components, subcomponents, and include fixed costs such as plant and equipment, and variable costs such as labor and materials.

The table below includes examples of unit costs for items where the quantity is uncertain. To create allowances for use during construction, this format can be used in a bid form, in which the bidder inserts pricing for the indicated quantities and units.

[16] Federal Transit Administration, "FTA Project and Construction Management Guidelines, 2016," pages B-2.

Unit Cost Examples

SCC Code	Description	Est Qty	Unit	Unit Cost estimate or price	Total Cost	Source
10.06	Daily Stand-by time for Cut & Cover area	20	Day	$X	$20X	State DOT agency database
40.03	Incremental cost for excavation, exceeding 700,000 tons	100,000	Tons	$X	$100,000X	State DOT agency database
10	Class 2 aggregate base	5000	CY	$X	$5,000X	Consultant database

8 EXAMPLES OF ALLOWANCES AND PROVISIONAL SUMS

Allowances and provisional sums are included in cost estimates to cover elements for which not enough is known for bidders to set a price. The following are examples are for illustration purposes only.

Allowance Examples

SCC Code	Description	Est Qty	Unit	Total Cost
10.07	Removal of below-grade obstructions not identified in Geotech Baseline Report	1	Allowance	$X,000,000
40.08	Fabrication of Signage, Electronic Public Info Displays	1	Allowance	$X00,000
40.03	Treatment and disposal of hazardous ground water above that noted in Geotech Baseline Report	1	Allowance	$X00,000
40	Hazardous material removal in train yard	1	Allowance	$X,000,000