

# PS.02

## Parametric Estimating Methodology for Transit Project Planning

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**T**ransit project planning is a critical step in the development of transit capital improvements. The planning process focuses on a specific transportation need, identifies alternative actions to address this need, and generates the information required to select an alternative for implementation. In the typical transit project planning effort, capital cost estimating plays an important role in the evaluation of alternatives and ultimately in the selection of the "best" alternative option. The paper will present a parametric estimating methodology for preparing capital cost estimates that follow the general guidelines established by the US Federal Transit Administration (FTA).

### THE TRANSIT PLANNING PROCESS

Transit project planning, in general, follows a five-phase Program Development Process that is managed and administered by the FTA. The five-phases can be described as follows:

- system planning;
- major investment study (MIS);
- preliminary engineering (PE);
- final design; and
- construction.

Within each of these phases are a varying number of intermediate steps as well as decision points that require action from the FTA for the process to proceed from one phase to the next. The estimating methodology that will be described in the following sections is primarily applicable to the second and third phases of the Program Development Process. Following is a brief description of the major elements that are part of each of these phases.

#### System Planning

Within each state and local metropolitan area are planning agencies known as metropolitan planning organizations (MPO). The MPO is responsible, in cooperation with state and key transportation providers, for developing a transportation plan which covers a 20 year period and identifies facilities (including but not limited to major roadways, transit, and intermodal facilities) that should function as part of an integrated regional system. This plan identifies both short term and long term actions that develop and

maintain an integrated transportation system that is accessible and also effectively moves people and goods. One of the products of this 20 year transportation plan is the preparation of transportation improvement programs (TIP). The TIP is a short-term document covering at least 3 years (updated at least every 2 years) that lists priority projects to be carried out in each of the 3 years. When the planning process identifies a problem in a transportation corridor that suggests the possible need for a major investment using federal funds, than a major investment study (MIS) is required. FTA consent is needed for the planning process to proceed to this next phase.

#### Major Investment Study (MIS)

The purpose of the MIS is to analysis solutions to address substantial transportation problems and present this information to decision-makers. During the MIS phase a number of elements are typically addressed. Some of these elements can included alternative screening and analysis, environmental impacts (in accordance with the National Environmental Policy Act (NEPA)), public involvement and financial cost effectiveness. Once the MIS phase is complete, the result is typically the selection of a locally preferred alternative (LPA) and the preparation of a draft environmental impact statement (DEIS). At this point the project is generally considered to be at about a 10 percent design level. Again, FTA consent is required for the process to proceed to the next phase.

#### Preliminary Engineering (PE)

The next phase of project development typically carries the LPA forward to approximately the 30 percent design level. Most of the elements that were addressed during the MIS phase are refined and advanced in greater detail. Once the PE phase is complete, the result is a set of 30 percent engineering plans and the issuing of a final environmental impact statement (FEIS). At this point the FTA consent (as expressed by a record of decision) is required for the process to proceed to the next phase.

#### Final Design

This phase of the project development process is simply the completion of the engineering effort, taking the design from the 30 percent to the 100 percent level. (This process depends on the

type of contracting method that will be used, i.e., design-bid-build, design-build, etc.). Typically, once this phase is completed, FTA will issue a full funding grant agreement (FFGA), which specifies the conditions and amount of federal funding that will be made available for the project.

### Construction

The ultimate goal of all of the previous phases is the successful construction phase.

## ESTIMATING METHODOLOGY

The parametric methodology to be used in developing capital cost estimates is developed in general accordance with FTA guidelines. Part of the general FTA guideline calls for cost components to be developed and summarized into one of eight cost categories. These cost categories will be described below.

### General Approach

Each of the alternatives within a transportation corridor will have conceptual engineering plans and profiles developed for various transit technologies. There may be more than one alignment alternative for a particular technology and possibly different lengths and/or design features (at-grade versus aerial, for example). The alternatives will go through an initial screening process to reduce the number of alternatives to take into the conceptual planning analysis and evaluation phase. It is this reduced set of alternatives for which conceptual plans and profiles and capital cost estimates will typically be prepared. A significant part of the conceptual planning process will be to develop a common set of design standards, typical cross-sections and other facility elements for the transit technologies included in the various alternatives. These facility elements can be classified into one of two broad groups, either typical or non-typical facilities.

Typical facility costs are developed for items that can be defined by a typical cross-section that is applicable over a given length of alignment or based on a conceptual scope of work developed as appropriate for a specific typical facility. The typical facility unit cost is developed by combining the costs for all of the individual work items applicable to the typical cross section or facility and creating one composite unit cost (see figure 1 for an example). Typical cross sections for each alternative will be developed as the planning process moves forward. Non-typical facility costs will be developed based on conceptual design relating to the unique facility under consideration. For those non typical facilities elements that are necessary for overall system operation, but whose costs cannot be allocated to a specific geographic segment of the system (e.g., vehicles, storage and maintenance facility, etc.), their cost will be included at the summary level for each alternative. After details are prepared for both typical and non-typical facilities and the cost data is developed, it should be put into a cost stream format based on the stationing of the alternative alignments. This format relates the cost directly to the plan and profile drawings and assists in summarizing costs, and in the analysis of full length alternatives, minimum operating segment(s) (MOS), or mix and match alternatives.

## CAPITAL COST CATEGORIES

In accordance with recommended FTA estimating guidelines, capital cost components of the various alternatives should be classified into one of eight cost categories:

- guideway elements;
- storage and maintenance facility;
- systems elements;
- stations;
- vehicles;
- special conditions;
- right-of-way; and
- project soft costs.

The following provides brief descriptions of the eight cost categories and their constituent elements.

### Guideway Elements

Guideway elements are portions of the transit system that can be assigned costs at a fairly aggregate level with an acceptable level of accuracy. Most commonly these are line portions of each alternative that can be represented by typical cross sections. Guideway elements are subdivided into two primary sub-categories, guideway and trackwork.

### Guideway

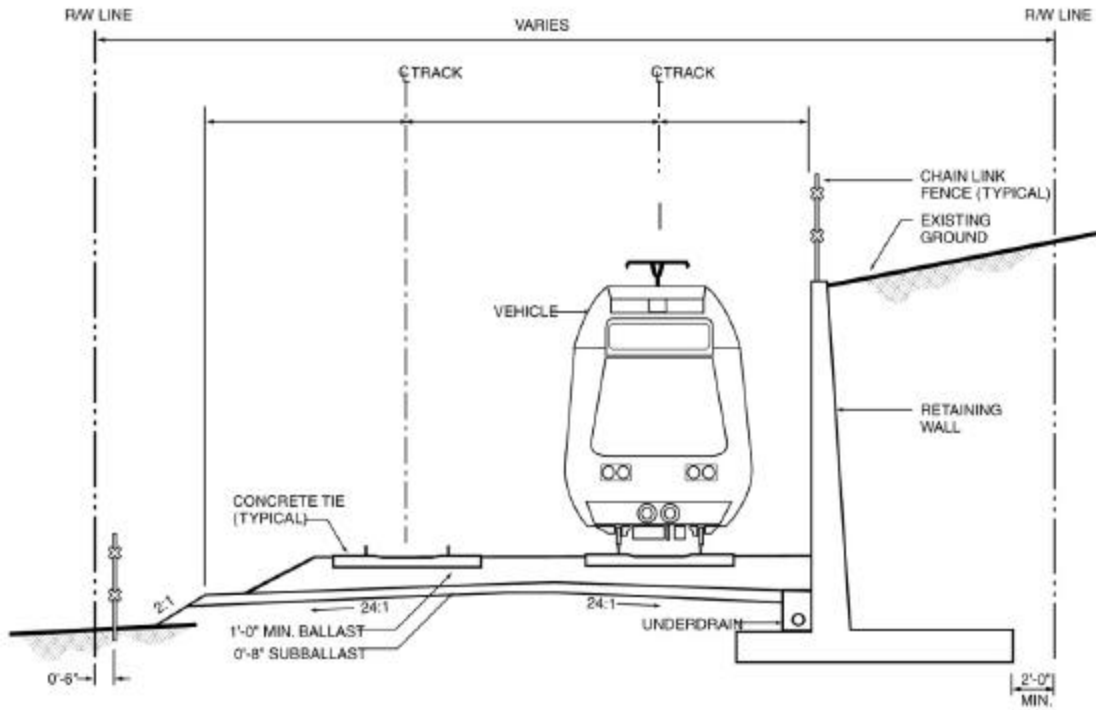
The guideway category consists of three primary elements, at-grade construction, aerial structure construction, and subway/tunnel construction. For rail technologies this category includes all the foundational construction elements up to the point where trackwork begins. For bus technologies this category includes all of the construction elements up to the travel surface for the vehicle. The guideway cost estimates are based on parametric unit cost information specifically developed for each construction type. Generally, each of the parametric guideway cost estimates provide for the following.

#### At-grade construction—

- All site work, including clearing, removals, and excavation.
- Borrow fill and soil stabilization.
- Seeding slopes and ditches.
- Drainage systems for the guideway.
- Pavement subgrade, base, and surface finish (concrete or asphalt) for bus technologies.
- Subgrade preparation and sub-ballast for rail technologies.
- Retaining walls where needed in cuts and fills.

#### Aerial structures construction—

- All site work, including demolition and clearing.
- Structural excavation and backfill.
- Foundation support (piling or drilled piers).
- Concrete footings, columns, pier caps, and superstructure.
- Steel reinforcement.
- Pedestrian barriers.



COST CATEGORY: GUIDEWAY

ESTIMATE WORKSHEET

DATE:

ELEMENT ID: GS01

ELEMENT NAME: Double Track, At-grade left / Retained Cut Right

CODE	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT COST \$	TOTAL COST \$
02230.02	Clearing & Grubbing, Moderate	sy	3.9	\$0.73	\$2.82
02273.01	Geotextile Fabric	sy	3.4	\$1.55	\$5.33
02310.01	Finish Grading	sf	31.0	\$0.54	\$16.75
02310.03	At-Grade Drainage Ditch	lf	1.0	\$4.62	\$4.62
02315.01	Common Excavation	cy	4.4	\$5.38	\$23.89
02315.02	Common Backfill	cy	1.5	\$6.28	\$9.29
02315.07	Structural Excavation	cy	3.3	\$7.18	\$23.89
02315.08	Structural Backfill	cy	3.3	\$13.45	\$44.80
02370.01	Soil Erosion and Sedimentation Control, Allowance	lf	1.0	\$23.11	\$23.11
02620.01	Retaining Wall Drainage	lf	1.0	\$35.55	\$35.55
02620.02	Trackway Underdrains	lf	2.0	\$17.77	\$35.55
02720.05	Subballast	cy	0.8	\$28.70	\$22.10
02820.04	6 ft. Chain Link Fence, Wall Mounted	lf	2.0	\$11.38	\$22.75
03210.01	Reinforcing Steel	lb	244.0	\$0.58	\$142.08
03300.51	CIPC, Retaining Wall Footings	cy	0.4	\$206.29	\$80.45
03300.52	CIPC, Retaining Wall Stems	cy	0.8	\$318.41	\$264.28
16060.01	Corrosion Control, At-Grade	lf	1.0	\$1.42	\$1.42
16130.21	Ductbank, At Grade Guideway	lf	1.0	\$35.55	\$35.55
<b>GS01</b>	<b>Guideway, At-grade Lt / Ret. Cut Rt.</b>	<b>RF</b>	<b>Route Linear Foot</b>		<b>\$794.23</b>

Figure 1

**Subway/tunnel construction—**

- All site work, including demolition and clearing and restoration.
- Structural excavation and backfill.
- Temporary excavation support and dewatering.
- Concrete footings, base slabs, stem or exterior walls, interior walls, and roof slabs.
- Tunnel excavation, support, lining, ventilation, life safety, etc.

Separate parametric unit prices should be developed for various increments in the height or depth of typical sections for embankment, retained cut or fill, and aerial structures.

Once the composite unit cost for a particular guideway section has been determined, they may be subject to several allowance factors or percentages. These allowances cover items of work that cannot be quantified to any reasonable degree. Examples of allowance items are traffic control, mobilization, erosion control, etc. The trackwork unit cost for rail transit technologies is calculated separately from the guideway construction unit cost.

**Trackwork**

Trackwork includes the running rails, ties, ballast, direct fixation, embedded, and special work components (turnouts, crossovers, etc.) associated with the rail transit technologies. Trackwork unit costs are divided into the following four types of construction:

- ballasted track (used in at-grade construction);
- direct-fixation track (track fixed onto a structural concrete slab, used in aerial or subway/tunnel construction);
- yard track (used in storage area of maintenance facility); and
- shop track (used in the maintenance shop building).

The cost of constructing the supporting subgrade, subballast, or aerial structure is included in the guideway unit costs. The cost of the trackwork is a separate unit cost. The ballasted trackwork unit cost includes rail, cross ties with ballast, rail welding, rail fasteners, and rail anchors. For aerial structures the rail is attached on a second-pour concrete plinth pad with a direct fixation rail fastener. The costs for special trackwork are based on mainline construction and are either ballasted or direct-fixation construction as required. Special trackwork includes single and double turnouts, crossovers, wyes, pocket tracks, and rail crossings. The costs for special trackwork are applied on a per unit basis at specific locations. The trackwork costs for the storage yard or maintenance shop facility is included in the cost category for storage and maintenance facilities.

**Storage and Maintenance Facilities**

This cost category is applicable to both bus and rail technologies. It includes site development, parking lots, vehicle storage and maintenance buildings, trackwork for storage of rail vehicles, office support areas, maintenance of way facilities, major shop equipment, and operation control center. It covers the expansion (if required) of bus maintenance facilities or additional

bus garage and maintenance facility capacity and related office and communication control facilities for the bus technologies.

**System Elements**

This cost category includes four functional cost elements; control systems, electrification, communications and revenue collection.

**Control Systems**

Control systems cost includes the signaling and control systems required for safe and efficient operations of the transit technologies. It includes automatic wayside signals, automatic train stop circuitry in the track and vehicles, block supervision. The unit costs should include an allowance for testing, training, and startup.

**Electrification**

The electrification system provides the power for all train operations of rail transit technology. It consists primarily of substations, mainline track power distribution, transformers, switch gear, and tie breaker stations. Signal and communication power needs are also included in the traction power costs and therefore other transit technologies will also have a traction power cost category to cover this cost element only. Power supply or distribution for buildings associated with the storage and maintenance facilities or power for passenger stations is not included in this cost category. The unit costs should include an allowance for testing, training, and startup.

**Communications**

The communications system provides the necessary subsystems to support the total operational requirements of the transit technologies. The communications system costs provide for the following subsystems and/or functions.

Supervisory and control and data acquisition subsystems (SCADA) to enable the remote monitoring and control of vehicle/train operations, guideway/track conditions, substations, and station support facilities from the OCC using fiber-optic cable transmission systems.

Communications subsystems consisting of two-way radio, public address (PA), closed circuit television (CCTV) surveillance equipment, PABX (digital switch) telephone equipment, and variable message signs (VMS).

Automatic vehicle location (AVL) system for bus technology and an interface to the fare collection and ticket vending equipment.

Equipment for the hearing-impaired, reader boards, and associated wiring, as well as an allowance for testing, training, and startup is included in the unit costs for the above systems elements.

**Fare Collection**

Costs for elements in this category cover the fare collection equipment at transit stations. Ticket vending machines (TVM)

costs shall be based on a microprocessor-controlled coin or bill-accepting machine capable of optionally accepting credit, debit, and stored value cards. The number at each station will be based on the need indicated by passenger volumes. The unit cost for fare collection includes all equipment costs, and installation costs. The hardware includes provisions for fare vending facilities and access for the physically handicapped. The unit costs should include an allowance for testing, training, and startup.

- Vertical circulation elements (i.e., stairs, escalators and elevators).
- Employee washroom/janitorial area.
- Equipment room for train control and communication equipment.

Any station requirements that are unique to a particular site should be included as needed in this cost category.

### Stations

Station costs represent the fixed facilities and amenities for transit stations. The passenger station cost estimates are based on parametric unit prices developed for each type of station, which include at-grade, aerial and tunnel/subway stations, as applicable. Also included in this cost category are parking lots, parking garages or pedestrian overpasses that are adjacent to and part of a passenger station. Generally, all the parametric station cost estimates consist of the following.

#### At-grade stations—

- Station types will be either side or center platform. Platform length will vary by transit technology.
- All site work, including clearing, demolition, and excavation.
- Grading, borrow fill, and soil stabilization.
- Concrete footings, walls, platform slab, and roof.
- Surface treatment of platform and tactile warning strips.
- Allowance for benches, signs, artwork, etc.
- Lighting, electrical, and mechanical allowances.

#### Aerial stations—

- Station types will be either side or center platform. Platform length will vary by transit technology.
- All site work, including clearing, demolition, and excavation.
- Grading, borrow fill, and soil stabilization.
- Concrete footings, columns, pier caps, superstructure, platform slabs, steel reinforcement, and pedestrian barrier.
- Surface treatment of platform and tactile warning strips.
- Allowance for benches, signs, artwork, etc.
- Lighting, electrical, and mechanical allowances.
- Vertical circulation elements (i.e., stairs, escalators and elevators).
- Employee washroom/janitorial area.
- Equipment room for train control and communication equipment.

#### Subway/tunnel stations—

- Station types will be either side or center platform. Platform length will vary by transit technology.
- All site work, including clearing, demolition, excavation or mining.
- Grading, borrow fill, and soil stabilization.
- Concrete footings, walls, roof, platform slabs, and steel reinforcement.
- Concrete lining for tunnels, and steel reinforcement.
- Surface treatment of platform and tactile warning strips.
- Allowance for benches, signs, artwork, etc.
- Lighting, electrical, and mechanical allowances.

### Vehicles

This cost category is generally subdivided into revenue and non-revenue vehicles (where non-revenue vehicles include maintenance-of-way vehicles, and agency trucks and automobiles). Revenue vehicles for the alternatives will include costs for the required bus vehicles, rail vehicles, and supervisory/maintenance vehicles.

### Special Conditions

Development of a fixed guideway transit system often involves some mitigating requirements that are not directly related to transit system service, but which are required for transit system construction. Special conditions can include items that cannot be adequately represented by a typical section because of complexity, uncertain alignment, special site conditions, or other unique circumstances. Special condition elements can include:

- utility relocations;
- demolitions;
- roadway modifications;
- environmental mitigation; and
- landscaping.

### Utility Relocations

Generally one of the largest cost elements within this cost category is the relocation of existing utilities from within the guideway corridor. These relocations can include both public and private utilities, subject to any agreements that may apply to franchised utilities that exist within public right-of-ways. Typically utility relocation information is not available during alternative evaluation, therefore four levels of utility relocation with average unit costs based on historical experience have been defined. These levels will be applied along the various transit alignments based on an evaluation of the complexity of the utility relocations anticipated.

### Demolitions

This cost element generally include costs for the demolition of special features such as buildings (if not included as part of right-of-way), large structures (bridges or retaining walls), existing railway trackbeds or other existing unusual features.

### Roadway Modifications

Roadway modifications include all new and reconstructed highways, streets, parking areas or pedestrian walkways (outside of

station areas), sidewalks, curbs and gutters, traffic signal coordination, crossing protection, and related facilities. Generally, any roadway modifications that are an integral part of a guideway element as described above, will be included in the guideway cost. The roadway modification cost estimates described here will be based on parametric unit costs applied to quantities developed on location specific data taken from the conceptual engineering alignment plans.

**Environmental Mitigation Costs**

Any special environmental mitigation costs such as wetlands mitigation, noise or vibration control should be included under this category.

**Right-of-Way**

This cost category covers all land acquisition and acquisition related costs required to obtain various real property needed for the construction, operation, and maintenance of the alternatives. Costs include the fee acquisition of permanent and temporary easements, relocation costs, legal fees, business damages and other miscellaneous costs.

**Project Soft Costs**

This cost category includes allowances for engineering and management, contingencies (both design and construction), project insurance, and agency costs. They are computed by applying a series of multipliers to the base cost estimated in each cost category for each alternative as described in the following sections. Table 1 summarizes some typical percentage multipliers applied to the baseline costs to cover these items.

**Engineering and Management**

Engineering and management add-ons include the cost for preliminary engineering, final design, construction management and inspection services, and administration services required to implement each alternative. This category also includes system start-up costs as these activities as interrelated with the engineering and design work.

**Table 1—Soft Cost Factors**

Cost Category	Soft Cost Factor (%)					Total
	Engineering & Management	Design Contingency	Construction Contingency	Project Insurance	Agency Costs	
1. Guideway elements	20	15	10	5	5	55
2. Storage and Maintenance facilities	20	15	10	5	5	55
3. System elements	10	15	10	5	5	45
4. Stations	20	15	10	5	5	55
5. Vehicles	5	5	5	0	5	20
6. Special conditions	20	20	10	5	5	60
7. Right-of-way	10	20	10	0	5	45

**Design Contingency**

A design contingency will be included in the estimates to account for minor unforeseen items or minor quantity fluctuations and variances in unit costs that will develop as the project progresses through the various stages of development. This percentage will be reduced as the project progresses through the later preliminary and final stages of design. The design contingency should reflect the degree of risk associated with the level of engineering data available and design completion achieved for the various design elements.

**Construction Contingency**

A contingency will be applied to the cost estimates to cover the costs of changes in scope or changed conditions that occur during construction.

**Project Insurance**

Project insurance includes all premium costs to provide “wrap-up” insurance coverage through an Owner Controlled Insurance Program (OCIP). This includes professional liability, comprehensive general liability, builder’s risk, worker’s compensation and employer’s liability, construction equipment loss or damage, and automobile insurance. It should be noted that the project should be the subject of a later phase risk analysis by the client, project agent and broker to establish actual insurance costs. The self-insurance concept is used here as a means of capturing the cost of insurance.

**Agency Costs**

The add-on for agency cost includes the costs incurred by the implementing agency in administrating and reviewing the various engineering and management consultants involved in the project.

**Application of Soft Cost Factors**

Design contingency should be calculated on and added to the subtotal of construction costs since it represents an unknown portion of the expected total construction value. All of the remaining soft cost factors should be applied as a direct percentage of the total construction costs and not compounded. The construction and soft cost factor costs should then be totaled to provide a total project cost in current year dollars.

**COST DATA**

Cost data should be developed using several resources and then comparable to those seen in the project region for similar types of construction. The cost data should be refined and updated throughout the subsequent design phases as the project definition increases. The first task in developing the cost data is to prepare a list of work items that are typical based on the scope of work for the transit technology alternatives. Unit costs for these work items can then be estimated using various cost references and historical cost data and should then be compiled into a database format to form a unit cost library (UCL). The key elements of the UCL are an item code, item description, unit of measure, and unit cost. This UCL summary will include, but will not be limited to, those items typically found in a project of the scope being studied. All unit costs should include contractors direct construction cost plus all taxes, general expense, overhead and profit. The unit costs should not include items such as engineering, construction management, owner's administrative costs and allowances for contingencies. These costs will be included as percentage add-ons to the cost estimate under the cost category project soft costs.

**Sources of Cost Data**

Unit costs to be used in the estimates can be derived from multiple resources. In addition to local municipal and transportation departments historical costs, information from other transit systems throughout the US should be compared and adjusted to specific alternative needs.

**Organization and Management of Cost Data**

The preparation of cost estimates for alternatives should involve development of a cost information database of considerable size and complexity. Procedures should be developed that streamline the estimating process and allow a thorough review and checking of the cost data in order to avoid clerical and mathematical errors. The proposed procedures should include:

- use of proven computer software for data processing and storage; and
- development of data in a cost-stream format and subsequently summarizing to higher levels.

**COST ESTIMATING RESULTS FORMAT**

The cost estimating methodology should use various levels of cost presentation to provide cost information results in increasing levels of detail. The costs will typically be developed by alternative and by segment, with each alternative consisting of several segments. The estimating process originates with the lowest level cost estimates and proceeds to higher levels of summary. This approach facilitates responses to different questions and enables users to focus only on the level of detail that meets their needs. These levels can provide an efficient and logical flow of data from the most detailed level to the summary level.

**ESTIMATE LIMITATIONS**

A recurring issue in the estimation of capital cost during the conceptual phase of a project is the evaluation and treatment of uncertainty. Uncertainty can result in a "difference" between the estimated cost of a project as defined during the concept phase and the actual cost of the project that is ultimately implemented. Four potential sources of uncertainty are generally recognized.

- Changes in project scope.
- Changes in design standards.
- Incorrect unit cost/quantity assumptions.
- Unforeseen problems in implementation.

**Changes in Project Scope**

During the EIS/PE phase, preliminary decisions on project scope are made on such issues as vertical and horizontal alignment, degree of grade separation and other significant alignment items. As a project progresses through the various stages of implementation many of the original project scope definitions that formed the basis of the cost estimate will be updated or revised.

**Changes in Design Standards**

Similar to the broader uncertainties on project scope but generally more specific in nature, changes in design standard during later phases of project development can lead to changes in project cost. Examples of changes in design standards would be changes in spacing of cross-overs, specifying a more sophisticated signal system, or changing the type of fare collection system, and so forth.

**Incorrect Unit Cost/Quantity Assumptions**

A variety of potential problems exist in the assumptions used in selecting unit cost or unit quantities. Issues that can effect the accuracy of unit cost include local demand for construction labor and its impact on wage rates, bid climate during the construction period and fluctuations in basic material prices. Errors in quantity assumptions are often related to changes in design standards as discussed above.

**Unforeseen Problems in Implementation**

Perhaps one of the largest sources of uncertainty is the difficulty to anticipate problems that will only be uncovered in later stages of project development. Areas that appear to be most susceptible are right-of-way acquisition, utility relocations, hazardous materials, and soil conditions. The estimating methods described in section 2 represent professionally accepted standards for preparing capital cost estimates to a level of accuracy that is consistent with the level of project definition. Accuracy is traditionally expressed as a +/- percentage range around the point estimate that has been produced and is greatest in the early stage of project definition and progressively decreases as project definition increases.

**F**or example, for typical transit projects, the expected accuracy range of an estimate prepared from final design documents is approximately +10/-5 percent. For projects at a level of project definition from 1 percent to 15 percent complete, the expected accuracy range is approximately +30/-25 percent. One of the primary techniques used to address the uncertainties inherent in the estimating process at the EIS/PE phase of project development is the application of appropriate design contingency. The use and application of contingency is further discussed in Section 3. As a project progresses through subsequent phases, the level of detail in the design will increase and the type, quantity and location of system elements can be better estimated. As that happens, the accuracy of the cost estimates will improve and the design contingency will be decrease.

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