AACE® International Recommended Practice No. 96R-18

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN POWER TRANSMISSION LINE INFRASTRUCTURE PROJECTS

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. October 5, 2018

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Any terms found in AACE Recommended Practice 10S-90, Cost Engineering Terminology, supersede terms defined in other AACE work products, including but not limited to, other recommended practices, the Total Cost Management Framework, and Skills & Knowledge of Cost Engineering.

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Disclaimer: The opinions expressed by the contributors to this recommended practice are their own and do not necessarily reflect those of their employers, unless otherwise stated.

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PURPOSE

As a recommended practice (RP) of AACE International, the *Cost Estimate Classification System* provides guidelines for applying the general principles of estimate classification to project cost estimates (i.e., cost estimates that are used to evaluate, approve, and/or fund projects). The *Cost Estimate Classification System* maps the phases and stages of project cost estimating together with a project scope definition maturity and quality matrix, which can be applied across a wide variety of industries and scope content.

This recommended practice provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for electrical power transmission lines infrastructure facilities. This document supplements the generic cost estimate classification RP (17R-97 [1]) by providing:

- A section that further defines classification concepts as they apply to power transmission lines
- A chart that maps the extent and maturity of estimate input information (project definition deliverables) against the class of estimate.

As with the generic RP, an intent of this document is to improve communications among all the stakeholders involved with preparing, evaluating, and using project cost estimates specifically for power transmission line infrastructure.

The overall purpose of this recommended practice is to provide a power transmission line definition deliverable maturity matrix which is not provided in 17R-97. It also provides an approximate representation of the relationship of specific design input data and design deliverable maturity to the estimate accuracy and methodology used to produce the cost estimate. The estimate accuracy range is driven by many other variables and risks, so the maturity and quality of the scope definition available at the time of the estimate is not the sole determinate of accuracy; risk analysis is required for that purpose.

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating processes and terminology, and may classify estimates in particular ways. This guideline provides a generic and generally acceptable classification system for power transmission projects that can be used
as a basis to compare against. This recommended practice should allow each user to better assess, define, and communicate their own processes and standards in the light of generally-accepted cost engineering practice.

INTRODUCTION

The term power transmission lines includes greenfield or brownfield sites for overhead, buried and submarine transmission of electrical power in the infrastructure industries. High voltage is typically >100kV but may be less (e.g., 33 or 66kv) if long distance with light electrical loads. This excludes power supply and distribution scope within a process plant, mining facility, building complex or other facility site. It also excludes power generation facilities and substations. The defining deliverables of those excluded project scopes are covered in other RPs (e.g., 18R-97 for process plants [2]).

Power transmission is considered an element of the infrastructure industry. The Construction Industry Institute has provided a good definition of infrastructure in its Project Definition Rating Index for Infrastructure Projects as follows [3]:

“A capital project that provides transportation, transmission, distribution, collection or other capabilities supporting commerce or interaction of goods, services, or people. Infrastructure projects generally impact multiple jurisdictions, stakeholder groups and/or a wide area. They are characterized as projects with a primary purpose that is integral to the effective operation of a system. These collective capabilities provide a service that is made up of nodes and vectors into a grid or system.”

Using this definition, power transmission lines are a vector or linear scope element that connects substation or other facility nodes at its terminations. The substation nodes may be part of or associated with a generation, consuming or interconnection facility. As such, transmission projects are often executed as part of a program that also involves node project scope or facility operational changes (at least considerations for integrated system commissioning and startup). As the definition states, a distinguishing feature of these projects is that they often traverse wide areas, cross country or subsea, which puts the basis on the definition of routing, land ownership and conditions, and establishing right-of-way (ROW). Associated scope definition challenges include defining stakeholder, permitting and regulatory requirements. Buried and submarine installations increase the focus on the protection philosophy and strategies affecting cable selection, armor and joint considerations. While many distinguish power transmission (higher voltage, long distance) from power distribution (short distance, lower voltage connections to retail customers), the principles of estimating these elements are similar; i.e., the RP applies to both.

The main physical power transmission line scope elements are conductors and their support structures if installed overhead. Main installation elements include land clearing if over land (including forestry if applicable), foundation and structure erection and conductor stringing if overhead, or trenching, laying and horizontal boring if subsurface or subsea. Special scope elements are involved with crossings of water, road, rail and so on and at terminations. Because conductor (e.g., aluminum) and structure (e.g., steel) material costs are usually a significant cost element, these project estimates are particularly sensitive to escalation uncertainty. In general, the more developed the route, the more complex the installation will be. In urban areas, visual appeal and concern for safety and health can be major issues. Installation in remote location and/or difficult or environmentally sensitive terrain creates its own challenges. Subsea installation adds the need for bathymetry1 and metocean2 studies and specialized installation equipment and vessels. Before any installation work can begin in an area, stakeholder consultation must be advanced (sometimes requiring agreements with local populations with rights), and appropriate land and ROW must be acquired which creates unique scheduling as well as cost challenges.

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1 The study of underwater depth of lake or ocean floors.
2 A combination of meteorology and oceanography.
For the purpose of estimate classification then, the main scope definition deliverables are associated with defining the power requirements (i.e., kV), the conductors and structure, and the routing. Conductors can vary widely in content (copper, aluminum, etc.) and insulation. Overhead structures may be wood, concrete, composite or steel in various configurations with various foundation designs including pilings, concrete and so on. The route’s land or subsea characteristics and the nature of developments drive the need for special design features and execution strategies. Operability and maintainability considerations may also affect ROW and access design. Brownfield and revamp projects add their own concerns for interface with existing elements, crowded working conditions, etc. For each scope definition decision, stakeholder requirements need to be considered.

Power substation projects are usually associated with transmission projects. However, substations being equipment-centric and located on a facility site have physical and defining characteristics similar to process plant projects (e.g., reliance on one-line diagrams, plot plans, etc.).

Power transmission is usually a regulated industry if not government owned. As environmental concerns increase, the design and installation becomes more complex (e.g., mitigation and management plans, construction plans with seasonality, etc.) and the regulation of projects becomes more rigorous. In respect to classification, the regulation becomes critical as the stage-gate process is increasingly driven by the regulators and not by owner economic concerns. For example, the regulator or agency with authority may dictate that final engineering cannot proceed until after the routing is finalized and the utility submits a maximum and reasonable cost to the agency. In some cases, this gate may require design deliverables be more or less advanced than the Classification Table 3 stages. In these situations, one should assess the governing stage-gate process and decide what class the estimate will be for each gate. For example, one may find the gate is somewhere between the RP’s class; say between Class 3 and 2. If so, one would designate the estimate as “Class 2 with Exceptions” and describe which deliverables are not to full class definition at that decision gate. This is also true if the stage gate system is defined by 30/60/90 percent design reviews (or other percentages) where percent design completion may not have much relationship to the status of any particular deliverable (e.g., definition at 30% design review may not be adequate for Class 3 and hence the associated estimate would be Class 3 with Exceptions as noted).

This guideline reflects generally-accepted cost engineering practices. It is based upon the practices of multiple major power utility companies as well as published references and standards [4]. Company and public standards were solicited and reviewed, and the practices were found to have significant commonalities. These classifications are also supported by empirical industry research of systemic risks and their correlation with cost growth and schedule slippage [5].

COST ESTIMATE CLASSIFICATION MATRIX FOR POWER TRANSMISSION LINE PROJECTS

A purpose of cost estimate classification is to align the estimating process with project stage-gate scope development and decision-making processes.

Table 1 provides a summary of the characteristics of the five estimate classes. The maturity level of definition is the sole determining (i.e., primary) characteristic of Class. In Table 1, the maturity is roughly indicated by a % of complete definition; however, it is the maturity of the defining deliverables that is the determinant, not the percentage. The specific deliverables, and their maturity or status are provided in Table 3. The other characteristics are secondary and are generally correlated with the maturity level of project definition deliverables, as discussed in the generic RP [1]. The characteristics are typical for power transmission projects but may vary depending on the specific type and size of work.
This matrix and guideline outline an estimate classification system that is specific to electrical power transmission lines in the infrastructure industry. Refer to the generic estimate classification RP [1] for a general matrix that is non-industry specific, or to other cost estimate classification RPs for guidelines that will provide more detailed information for application in other specific industries (e.g., RP 18R-97 for electrical substation facilities [2]). These will provide additional information, particularly the project definition deliverable maturity matrix which determines the class in those particular industries.

Table 1 illustrates typical ranges of accuracy values that are associated with the power transmission projects. The +/- value represents typical percentage variation at an 80% confidence interval of actual costs from the cost estimate after application of contingency (typically to achieve a 50% probability of project cost underrun versus overrun) for given scope. Depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall into the ranges identified (although extreme risks can lead to wider ranges).

In addition to the degree of project definition, estimate accuracy is also driven by other systemic risks such as:

- Level of familiarity with technology.
- Complexity and condition influence on system/grid power conditions.
- Unique/remote nature of route locations and conditions, and potential lack of reference data.
- Complexity of the project and its execution.
- Regulatory, community, land owner, and political risks.
- Quality of reference cost estimating data.
- Quality of assumptions used in preparing the estimate.
- Experience and skill level of the estimator.
- Estimating techniques employed.
- Time and level of effort budgeted to prepare the estimate.

Systemic risks such as these are often the primary driver of accuracy, especially during the early stages of project definition. As project definition progresses, project-specific risks (e.g. risk events and conditions) become more
prevalent and also drive the accuracy range. Another concern in estimates is potential pressure for a predetermined value that may result in a biased estimate. The goal should be to always have an unbiased and objective estimate, including contingency. The stated estimate ranges are dependent on this premise and a realistic view of the project. Failure to appropriately address systemic risks (e.g. technical complexity) during risk analysis impacts the resulting probability distribution of the estimate costs, and therefore the interpretation of estimate accuracy.

Figure 1 illustrates the general relationship trend between estimate accuracy and the estimate classes (corresponding with the maturity level of project definition). Depending upon the technical complexity of the project, the availability of appropriate cost reference information, the degree of project definition, and the inclusion of appropriate contingency determination, a typical Class 5 estimate for an electrical transmission substation facilities project may have an accuracy range as broad as -50% to +100%, or as narrow as -20% to +30%. However, note that this is dependent upon the contingency included in the estimate appropriately quantifying the uncertainty and risks associated with the cost estimate. Research for power transmission projects has shown that industry has greatly underestimated risks and contingency for Class 5 and 4 estimates [4]. Environmental and political risk are increasing that becomes a particular concern when regulators require reporting of maximum costs or similar dictates related to accuracy. Refer to Table 1 for the generalized accuracy ranges illustrated in Figure 1.

Figure 1 also illustrates that the estimating accuracy ranges overlap the estimate classes. There are cases where a Class 5 estimate for a particular project may be as accurate as a Class 3 estimate for a different project. For example, similar accuracy ranges may occur for a Class 5 estimate of one project that is based on a repeat brownfield project with good history in an existing, approved ROW with few stakeholders, and a Class 3 estimate for a project involving new technology in a remote location, or environmentally sensitive region with stringent regulations and many stakeholders. It is for this reason that Table 1 provides ranges of accuracy range values. This allows consideration of the specific circumstances inherent in a project, and an industry sector, to provide realistic estimate class accuracy range percentages. While a target range may be expected of a particular estimate, the accuracy range should always be determined through risk analysis of the specific project, and should never be pre-determined. AACE has recommended practices that address contingency determination and risk analysis methods.

If contingency has been addressed appropriately, approximately 80% of projects should fall within the ranges shown in Figure 1. However, this does not preclude a specific actual project result from falling inside or outside of the indicated range of ranges identified in Table 1. In fact, research indicates that for weak project systems and/or complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 1.