AACE INTERNATIONAL RECOMMENDED PRACTICE

142R-26

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE TUNNELING INDUSTRIES

AACE INTERNATIONAL

Rev. August 6, 2026

AACE® International Recommended Practice No. 142R-26

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TCM Framework: 7.3 – Cost Estimating and Budgeting

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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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1. INTRODUCTION

As a recommended practice (RP) of AACE International, the *Cost Estimate Classification System* provides guidelines for applying the general principles of estimate classification to tunneling 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 into a generic project scope definition maturity and quality matrix, which can be applied across the tunneling industries.

This addendum to the generic recommended practice RP 17R-97 [1] provides guidelines to both owners and service providers for applying estimate classification principles specifically to project estimates for engineering, procurement, and construction (EPC) contracts, as well as other contractual arrangements and execution strategies, in the context of ongoing or developing tunneling projects. This addendum supplements the generic recommended practice by providing:

- Sections that further define classification and stage-gate concepts as they apply to the tunneling industries and their unique differences from other industries.
- A chart that maps the extent and maturity of estimate input information (for example, project definition deliverables) into the estimate class.

As with the generic RP, the intent of this document is to improve communication and consensus among all the stakeholders involved with preparing, evaluating, and using project cost estimates, specifically for the tunneling industries.

The overall purpose of this recommended practice is to provide the tunneling industries with a project definition deliverable maturity matrix that is not covered in RP 17R-97 [1]. It also provides an approximate representation of the relationship of planning, preparation, design input data and project scope deliverable maturity with the estimate accuracy and methodology used to produce the cost estimate.

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 its own way. This guideline provides a generic and generally acceptable classification system for the tunneling industries that can be used as a starting point for the basis of comparison. This recommended practice should allow each user to better assess, define, and communicate their established and developed procedures, considering generally accepted cost engineering practice.

2. RECOMMENDED PRACTICE

Tunnels are subsurface excavated and constructed civil facilities designed to enable the underground or subsea transportation of materials, vehicles, utilities, or fluids/gases. They serve primarily as linear, underground infrastructure for roadways and rail transit, water conveyance, power transmission, pipelines, or mining operations.

Tunnel projects typically include multiple components: the main tunnel bore(s), portal structures (entrances and exits), access shafts, ventilation chambers, pump station chambers, and underground spaces for equipment or storage. Portal areas, particularly those designed for tunnel boring machine (TBM) launch and retrieval, may involve extensive surface or near-surface structural work. Complex tunnel systems may feature interconnected tunnels, cross-passages, and chambers with challenging geometries and interfaces with existing infrastructure."

The RP is focused on major tunnel excavation/construction using a variety of technologies such as cut-and-cover, drill and blast, mechanical/boom header, and/or TBMs, with at least some construction workers located underground. Another tunnel type is immersed tube, which is somewhat analogous to cut-and-cover but involving pre-fabricated sections placed underwater by marine construction equipment (the immersed portion usually transitions to other tunneling methods at its ends). Each method has different planning considerations. Note that major excavation as a production process shares some similarities with underground mine development. Tunnels support and protect facilities such as roads, rail, pipelines, and other conveyances or act as conduits for water, gases, or other fluids.

The RP may address, but is not primarily focused on smaller diameter tunneling methods such as horizontal directional drilling (HDD), micro-tunneling, and related techniques where the excavation and associated equipment (e.g., pipe jacking) are typically operated or controlled from outside the tunnel. It is also not focused on trenchless technologies. These methods are more commonly applied in utility, pipeline, or power transmission projects where the tunneling cost estimates are generally integrated into the broader project estimates as a type of crossing (e.g., to pass beneath a roadway or similar obstacle).

The *tunneling industries* primarily consists of highly specialized consultants, engineering and construction contractors, and suppliers with expertise in underground or marine excavation and structural ground support, working with the asset owners/operators (e.g., transportation authorities, utilities, mining companies, etc.).

The scope of work addressed by cost estimates for tunnels typically includes elements such as the following:

- Geotechnical campaign (e.g., borings, analyses, etc.).
- Portal design.
- Tunnel excavation.
- Chamber excavation.
- Access shafts and other ancillary excavations.
- Equipment access/head room.
- Temporary ground control (e.g., grouting, freezing, etc.).
- Groundwater control and treatment.
- Ventilation.
- Fire and life safety/egress.
- Materials and spoils handling.
- Permanent structural support/linings placement/construction.
- Surface site development.
- Backfill (e.g., around a pipeline in a tunnel).
- Interference accommodation (e.g., interface with other structures, utilities, etc.).
- All associated civil, structural, mechanical, electrical, and control elements (that may interface with the transportation or utility scope elements).
- Site facilities such as offices, warehouse, fabrication shops, maintenance shops, and any other support infrastructure for the site operation (that are not dominant or major projects in their own right).

Being a subsurface or underground facility, tunnel scope definition is strongly dependent on site, geologic, hydrogeologic, and/or rock mechanics investigations (usually addressed in a geotechnical baseline report or GBR[1] [2]). For immersed tube tunnels, these reports may include meteorological, hydraulic, and oceanographic studies. There are multiple schemes used to classify the ground and rock conditions. Given its importance, the geotechnical and other studies can be considered controlling for estimate classification; *the overall estimate class cannot be considered more advanced than is supported by the definition of these studies*.

[1] For more information on the content of geotechnical baseline reports, refer to "Geotechnical Baseline Reports: Suggested Guidelines, MOP 154" prepared by the Task Committee on Geotechnical Baseline Reports of the Construction Institute of ASCE in 2022. [36]

Adverse conditions, such as soft ground with obstructions, hard rock, faulting and fracturing, excessive groundwater, gases, dust, and settlement, can significantly reduce excavation production rate and productivity, create safety issues and necessitate design modifications. In severe cases, such conditions may require TBM recovery excavations or extraction, alignment relocations, or even project abandonment. A study by Bernado et.al. demonstrated that actual tunneling costs per cubic meter can vary by a factor of 5:1 between the highest and lowest geologic strength indices (or rock mass type) [3]. When subsurface conditions are not adequately investigated and when geotechnical and execution risks are not properly assessed and incorporated into the estimate, the accuracy of early project estimates can vary dramatically, as is reflected in Table 1 of this RP. [4]

Where applicable (e.g., non-water tunnels), tunneling projects must be integrated with their associated transportation or utility systems such as roadways, railways, pipelines, conveyors, or power infrastructure. Accordingly, tunnel estimating may need to align the work breakdown structure with other relevant estimate classification guidelines. Tunnels are also typically integrated with ancillary facilities, including surface works (e.g., site development and tunnel operations buildings) and in some cases, subsurface structures (e.g., stations, pump chambers, or ventilation facilities). The other estimate classification RPs most often associated with tunneling work include[2]:

- Process Industries: 18R-97 [5]
- Road and Rail Transportation Infrastructure Industries: RP 98R-18 [6]
- Pipeline Transportation Infrastructure Industries: RP 97R-18 [7]
- Power Transmission Line Infrastructure Industries: 96R-18 [8]
- Mining and Mineral Processing Industries: RP 47R-11 [9]
- Building and General Construction Industries: RP 56R-08 [10]

Of the above RPs, the phase-gate deliverables related to road and rail in RP 98R-18 and underground mining in RP 47R-11 are perhaps most closely related to this RP[3]. RP 98R-18 is related with respect to dimensions and alignments, among other things, and RP 47R-11 is related with respect to the underground excavation and support work involved in tunnel construction. A good mining reference is a paper by Mulder and Bekker detailing a "Readiness Assessment Tool" based on the Construction Industry Institute (CII) approach to developing project definition rating indexes (PDRIs) [11].

The cost estimates covered by this RP are for capital expenditure engineering, procurement, and construction (EPC), or equivalent work only. The cost of excavation equipment and major support fabrications (e.g., linings) and their transport/erection are included. However, not included are detailed cost estimates of offsite equipment manufacturing and support fabrication processes. This guideline covers incidental support building and facility construction (e.g., water treatment, pump houses, ventilation systems, slurry systems, temporary storage). However, if those facilities are major or primary scope elements, the other classification RPs listed previously should be applied.

This guideline reflects generally accepted cost engineering practices. This recommended practice was based on the practices of international companies in the tunneling industries, published references and standards that were identified, and the existing AACE International RPs for related, integrated scope.

3. TUNNELING STAGE-GATE PROCESSES

A key purpose of cost estimate classification is to align the estimating process with the stage-gate scope development and decision-making practices typical of the respective industry. The tunnels most commonly

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[2] See Professional Guidance Document 01 (PGD-01), *Guide to Cost Estimate Classification* [33]
[3] Future updates to these RPs are expected to make a cross-reference to this RP.

recognized are those serving the road, rail, and public utilities sectors. These projects often affect communities and utilize public funds, thereby attracting significant input from local communities and their representatives. While many countries have established standards for stage-gate processes, such standards are generally applied consistently across all infrastructure and public works projects, with road and rail being the most common examples.

In the road, rail and public utility sectors, final investment decisions (FID) are typically deferred until construction tenders are received, commonly under a design-bid-build (DBB) contract strategy), thereby emphasizing the need for Class 2 estimates. By contrast, tunnels supporting privately funded industrial projects, such as oil and gas pipelines, may require earlier approvals. In such cases, the FID may be based on Class 3, or in some circumstances even Class 4, estimates if the pipeline venture must be sanctioned at an early stage. Accordingly, the stage-gate process for pipeline tunnel projects tends to align more closely with the broader pipeline scope development process.

In any case, tunneling scope development calls for significant, if not definitive, site, geologic, hydrogeologic, and other investigation, including the selection of excavation and support technologies at Class 4. Given long tunnel lifespans (e.g., 100 years), life cycle cost analysis (LCCA) [12] is also important for Class 4 options consideration. Given the relatively late FID (Class 2) for road, rail, and public works projects, they are more prone to having less focus and discipline during Class 4 and 3 stage project development and design. Design-build (DB), private-public partnerships or similar contract strategies with early contractor involvement tend to better emphasize early definition.

As suggested above, the tunnel stage-gate process application has largely been decided by the industry project type that the tunnel is part of. While the comparisons are not exact and are not guidelines, Table A compares AACE class designations to the typical stage-gate narrative designations/headings often used in these industries. [13]) The shaded boxes indicate the stage where the FID is usually made.

Several reference staging standards specific to the tunneling industries were identified. The first is the ITA-AITES/IMIA *Code of Practice for Risk Management of Tunnel Works* (ITA Code)[4] [14]. The ITA Code outlines a stage-gate framework generally aligned with public works infrastructure projects, with the FID typically occurring after receipt of construction tenders (i.e., at Class 2). However, the ITA Code is somewhat ambiguous regarding the sequencing of scope definition deliverables and gate decisions.

The ITA Code defines four main stages: project development, construction contract procurement, design, and construction. Within these, both project development and design are subdivided into multiple steps. For example, project development includes *feasibility* and *site and ground investigation,* while design encompasses *conceptual, preliminary,* and *detailed* phases. Yet, the ITA Code does not clearly describe how feasibility, investigation, and design activities are sequenced or integrated. Moreover, the ITA Code does not address environmental permitting.

Table B presents the RP contributors' interpretation of the ITA Code stages and key deliverables, mapped against the AACE classes. The table also references a similar guideline by DAUB, the German Tunneling Committee of ITA-AITES, titled *Recommendations for Project Risk Management in Underground Construction* [15]. Unlike the ITA Code, the DAUB guideline provides narrative descriptions of deliverables, including considerations of permitting.

[4] ITA-AITES/IMIA refers to the International Tunneling and Underground Space Association (ITA-AITES) and the International Association of Engineering Insurers (IMIA)

AACE	Pipeline/Process	Mining	Road and Rail/Utility
5	Conceptual	Scoping	Pre-design
4	Basic engineering	Pre-feasibility	Schematic
3	Front-end engineering and design (FEED)	Feasibility	Design development/ feasibility
2	Execution. No formal decision gate after the final investment decision.		Construction documents or tender/bid
1	No common name (engineering at or near 100%, primarily for change orders and similar).		

Table A. Comparison of Class Designations to Typical Stage-Gate Narrative Names in Various Industries [13] (*with permission*)

	ITA Code Stages			DAUB Guideline
AACE	**Project Development**	**Construction Contract Procurement**	**Design**	
5	Feasibility studies			Initiation
4	Preliminary site and ground investigations; Assess and select preferred option and form of construction contract		Conceptual	Feasibility design
3	Definitive site and ground investigation		Preliminary	Preliminary design Technical design
2		Preparation and issue of contract documentation; tender	Detailed	Detailed design Procurement Contract award
1	Construction stage focused, change orders and similar			Construction

Table B. Comparison of AACE Class to Interpreted ITA Tunnel Works Code and DAUB Guideline [14] [15]

Other infrastructure stage-gate processes often emphasize design reviews at 30/60/90 percent design completion as the primary demarcation of stages. Guidelines that apply these checkpoints generally align with the phase designations of feasibility, preliminary, and detailed design as reflected in the DAUB guideline shown in Table B. Where AACE classifications are applied, the 30/60/90 milestones are most commonly associated with Class 4/3/2, respectively, although at least one reference equates them to Class 3/2/1 [16].

This RP recognizes that there is no universal standard for 30/60/90 reviews, and practices vary widely across industries and organizations, making them an unreliable basis for stage or class delineation. Industry guidelines typically provide high-level narrative descriptions of the activities expected at each stage, but none offer detailed lists of deliverables or specify their expected level of completeness (e.g., which deliverables should be *definitive* at 30 percent design).

A US Federal Highway Administration (FHWA) guideline also provides the following summary list of "typical stages of a road tunnel project" [2]. The class designations in parentheses are the RP contributor's interpretation.

- Planning (Class 5)
- Feasibility study (Class 5)
- Corridor and alignment alternative study (Class 4)
- Environmental impact studies (EIS) and conceptual design (Class 4)
- Preliminary design (Class 3)
- Final design (Class 2)
- Construction (Class 1)