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Supporting Estimates with Effective Scope of Work Definition

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Abstract–Most estimators realize that one of the essential ingredients for preparation of an accurate cost estimate is the comprehensive and sufficient definition, and subsequent control of project scope. Numerous studies have identified project scope definition as one of the most critical factors that influence project success. In 1982, the Construction Industry Institute (CII) Business Roundtable issued a report stating that "poor scope definition at the (budget) estimate stage and loss of control of project scope rank as the most frequent contributing factors to cost overruns." [1] Nevertheless, obtaining adequate scope definition to support cost estimating continues to be one of the most persistent problems faced by estimators.

This paper discusses issues involved in dealing with scope development problems during the preparation of capital facility cost estimates. Topics to be covered include:

- Introducing a stage-gate project development process
- Identifying the minimum requirements to prepare various classes of estimates
- Communicating information requirements to project teams and estimate providers
- Corelating estimating techniques to the level of scope information
- Utilizing a *frozen for estimating* design basis and incorporating late changes
- Presenting the estimate in relation to the level of scope definition

This paper expands upon an earlier AACE International paper *Scope Development Problems in Estimating* [2], incorporating information from AACE International (AACE) recommended practices on estimate classification, as well as from other sources.

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Introduction

It is universally recognized that accurate definition and effective control of project scope are key to the successful outcomes of projects; [3] [4] [5] [6] [7] however, adequate scope definition to support cost estimating during the project development process leading up to project sanction (or authorization) continues to be one of the most persistent problems faced by estimators. Zaheer and Fallows stated that “[t]he single largest impact on quality of estimates (estimate accuracy) is project scope definition.” [8]

This paper discusses many of the issues involved with obtaining sufficient project scope definition to support effective cost estimating for capital facility projects (projects to engineer, procure, and construction capital facilities or assets). Topics covered include identifying the minimum requirements to prepare various classes of estimates, communicating information requirements to project teams and estimate providers, corelating estimating techniques to the level of scope information, utilizing the concept of a *frozen for estimating* design basis, incorporating late changes, and presenting the estimate in relation to the level of scope definition.

Although clearly focused on projects for the construction of facilities, the principles of identifying the project and technical deliverables required for each class of estimate and ensuring that the maturity of those deliverables meet the expectations for the desired class of estimate can be applied to other types of projects.

Project Development Process

For large construction projects, most owner organizations follow some form of a stage-gate (or phase-gate) project development process. This provides a governance process for the project development activities leading up to project sanction (authorization); and extending through project execution and eventual start-up of the facilities and turnover to facility operations. This process also supports effective risk management for the owner since funds for project development are “released in proportion to the decision maker’s understanding of and willingness to accept risk.” [9]

A key purpose of estimate classification, described later in this paper, is to align the estimating process with project stage-gate scope development and decision-making processes. The classes of estimates are correlated with the maturity of technical and project deliverables that are developed during each of the project development stages.

A generic stage-gate project development process is shown in Figure 1.

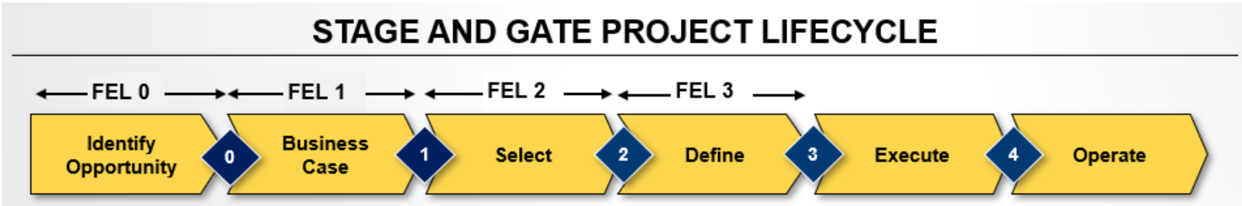

Figure 1–Stage-Gate Project Development Process

In this project development lifecycle, project and technical deliverables to define the project are developed incrementally in stages. At the end of each stage, a gate review is conducted, and a decision is made by the owner on whether to proceed (and fund) the next stage. The specific project and technical deliverables to be developed and an expectation of their maturity (or state of completeness) are defined for each stage.

The stages leading up to project sanction (the authorization of full funds to execute and complete the project) are known as the front-end loading (FEL) process (or sometimes as the front-end planning process), and are described below:

FEL 0: Identify Opportunity

This stage is typically performed by a business unit of the owner organization without support of a project team. This stage involves idea generation around opportunities to create a new asset, or to modify or retire an existing asset. It provides early shaping for the potential business opportunity and objective, usually at a very high level. A cost study (or unclassified cost estimate) may be prepared by the business unit to support the Gate 0 decision of whether to include the identified opportunity into the long-range capital planning budget of the organization.

In general, very little development of technical deliverables is accomplished to support a formal estimate, which is why the estimates during this stage or most often simply described as cost studies or unclassified estimates. Most often, these estimates are based on analogy estimating techniques, and may be just a subjective assessment of costs; quite often prepared by a non-estimator.

At some point, the owner organization may decide to further investigate the opportunity and will authorize funds to organize a core project team to begin the FEL 1 stage. Note that this is not authorizing full funding to develop the project, but only the funds necessary to complete FEL 1.

FEL 1: Business Case

This stage is used to identify potential alternatives (technical and non-technical) that may meet the business objectives. Overall project definition (such as capacity, technology, etc.) are established for each identified alternative. Project and technical deliverables are developed to the defined maturity level specified. A preliminary business case is prepared. Typically, an AACE

Class 5 cost estimate for complete development of the project is prepared to support the business case and Gate 1 decision.

Class 5 estimates are typically based on limited scoping information using a conceptual estimating methodology, such as analogy, capacity factoring, or parametric estimating. The purpose of the Class 5 estimate is to identify a reasonable cost assessment of sufficient accuracy to support the Gate 1 decision.

The Gate 1 review will validate that the stage deliverables (including the cost estimate) meet the requirements (maturity or level of completeness expected); and the owner will make a decision to proceed to the next FEL stage or not. If the decision is made to proceed to the next stage, then the owner must authorize the funds to expand the project team and support the FEL 2 activities. The funds to support FEL 2 are often based on a separate detailed estimate based on the scope of the FEL 2 activities.

At Gate 1, the owner may also make the decision (based on the FEL 1 activities) that the project is not justified to pursue and make the decision to cancel the proposed project. Alternatively, it may decide that other alternatives should be considered and may authorize funds to continue FEL 1 activities.

FEL 2: Select

During FEL 2, engineering is progressed, and scope is developed to generate sufficiently reliable cost estimates and schedules to support an updated business case. During this stage, selection of a preferred alternative is made. Integrated project plans are developed to a preliminary status. Typically, an AACE Class 4 cost estimate for the complete development of the project is prepared to support the updated business case and Gate 2 decision; and a more detailed estimate of FEL 3 activities is prepared to support the funding of FEL 3 if the Gate 2 decision is made to proceed.

Scoping information has typically progressed during this stage to provide confidence that all elements of projects scope have been accounted for, including all supporting utilities and infrastructure. Project plans have developed to indicate anticipated contracting, procurement, fabrication, and contracting strategies. This level of information supports the Class 4 project cost estimate, which typically employs a more comprehensive factoring approach than simply capacity factoring or simple analogy; and often some portions of the estimate may use more deterministic estimating methods. Once again, the goal of the estimate is to identify an evaluation of project costs of sufficient accuracy to support the Gate 2 decision.

The Gate 2 review will again assess that the project and technical stage deliverables meets requirements; and the owner will make the decision to proceed to FEL 3 or not. It the decision is made to proceed, then the owner must authorize the funds for the additional project resources to accomplish the FEL 3 activities.

At Gate 2, the owner again has the opportunity to cancel the project if it does not appear to be justified; or may decide to remain in FEL 2 to further develop project and technical deliverables before making the go/no-go decision.

FEL 3: Define

FEL 3 is often referred to as front end engineering and design (FEED). This stage is used to progress engineering and scope development to "freeze" overall design. This does not imply that design or engineering are complete, but that the key defining engineering documents (as an example for a process facility, this includes the plot plan, major equipment list, and piping and instrumentation diagrams) are finalized and approved for design; subject to only minor updates during detailed design. Comprehensive integrated project plans incorporating input from all stakeholders is finalized. An AACE Class 3 cost estimate is prepared to support the final project authorization request, project control during execution, and the Gate 3 decision.

For the owner, Gate 3 (at completion of FEL 3) is typically used to authorize full project funding, and thus is extremely important. Validating that the project and technical deliverables are of sufficient maturity and quality upon which to base the funding decision is critical. Ensuring that the project and technical deliverables can be used to adequately quantify the scope to prepare the Class 3 estimate is a responsibility of the cost estimator; and any exceptions to the expected maturity and/or quality must be identified by the estimator in the basis of estimate document [10] and considered during risk analysis to establish the expected estimate accuracy.

The Class 3 estimate is also used to establish the cost baseline (the control basis) during project execution; and thus, must be prepared at a detailed level to support effective project control. The estimate will be used to establish control budgets to support bid evaluations, monitor procurements, evaluate construction performance, track and manage change to scope and project execution strategies, etc. This reinforces the importance of finalizing the integrated project plans to support the Class 3 estimate, which includes many specific plans required to support effective project execution. These plans need to be comprehensive and finalized during this stage to support the Class 3 estimate as they establish much of the basis for the labor and material pricing, allowances, and assumptions incorporated into the estimate. When these plans are incomplete, they directly affect the uncertainty and risk associated with the Class 3 estimate used to support project authorization and establish the cost baseline for the project.

Gate 3 is typically used by the owner to support the final investment decision. If the established business case based on the Class 3 estimate cannot support approval, then the project should be cancelled. If the owner makes the decision to proceed, then the owner is typically authorizing the full project authorization amount to complete the project through turnover to operations.

Execute Phase

During this phase, detailed engineering and design, procurement, fabrication, and construction are performed through mechanical completion. Vendors and fabrication/construction contractors may be preparing detailed AACE Class 2 and Class 1 estimates to support their bids for services, and to support on-going project change management during the execution phase.

Gate 4, at the end of the execute phase, is used to validate that the project facilities are ready to begin commissioning and start-up, and eventual turnover to operations.

Class 2 and Class 1 estimates are generally very detailed as they are prepared based upon detailed engineering and/or issued for construction deliverables. As owners have usually authorized final project funding based a Class 3 estimates, generally the owner will not require a complete project Class 2 or Class 1 estimate to be prepared; however , some owners will require a Class 2 estimate to be prepared that incorporates all final vendor and construction bids received during this phase before making the decision to proceed to construction. More often, owners will require Class 2 or Class 1 estimates only for small portions of the overall project to be used to selected bid evaluations and for change order analysis; thus an owner may use a combination of the Class 3 project authorization estimate and Class 2 (or Class 1) estimates to support control during execution.

Vendors and construction contractors will generally utilize the more detailed technical deliverables developed during this stage as the cost basis for their bids; and as the basis for change requests as required.

Operate Phase

This phase includes the commissioning and start-up activities (typically funded as a part of the project authorization), and subsequent facility operations through the lifecycle of the asset. During operations, estimating will support on-going maintenance and sustaining capital projects.

Notes Regarding the Project Development Process

It should be noted that the project development stages discussed above do not indicate who is preparing the estimates. Although usually Class 5 cost estimates prepared during FEL 1 will be prepared by the owner, there are also situations where the owner will have a contractor or consultant prepare the estimate for them. For FEL 2, it is often more of a mix, where the estimates may be prepared by owner or contractor resources. Due to the size of the projects and the effort required for Class 3 cost estimates, most Class 3 estimates are prepared by engineers or consultants.

In any case, whether prepared by in-house or third-party resources, the estimates eventually become the property and responsibility of the owner. The owner is responsible for ensuring that the estimates include all scope (including all owner-related costs) and are appropriate for the gate decision at hand. During the gate review, it is the owner that must eventually determine that the project and technical deliverables meet the expected maturity and quality intended. If gaps exist, then the owner should (ideally) not proceed to the gate decision until the gaps are closed or, if the decision is made to proceed, then should identify, assess, and account for all risks associated with that decision. Edward Merrow of Independent Project Analysis states that “FEL is the single most important predictive indicator of project success.” [11]

Also, it is important to note is that if the estimate results in too high of a cost to justify the business decision, then the correct decision is to stop the project and consider that decision to be a success. One of the purposes of the stage-gate project development process is to halt the pursuit of uneconomic projects as soon as possible and divert resources to those projects that are economic and meet business objectives.

Cost Estimates Should Be Aligned with the Project Development Process

Project cost estimates are one of the primary elements in the decision-making process to eventually sanction (or authorize) projects. It is recognized that economics will drive most project decisions throughout the project process (i.e. during all stages of project development). Cost estimates are used in the early stages of project development to ensure that the *right* project is selected to pursue; one that best meets economic and other business objectives and provides the best overall return on the capital investment. Eventually the cost estimate must provide an achievable cost (in consideration of associated risk) to support the final investment decision and establish the baseline for project control during execution.

Cost estimates continue to be important during project execution to support on-going change and risk management; as well as during operations to support maintenance and sustaining capital projects to ensure the facility or asset operates effectively.

Figure 2 illustrates these concepts – essentially emphasizing that cost estimates matter.

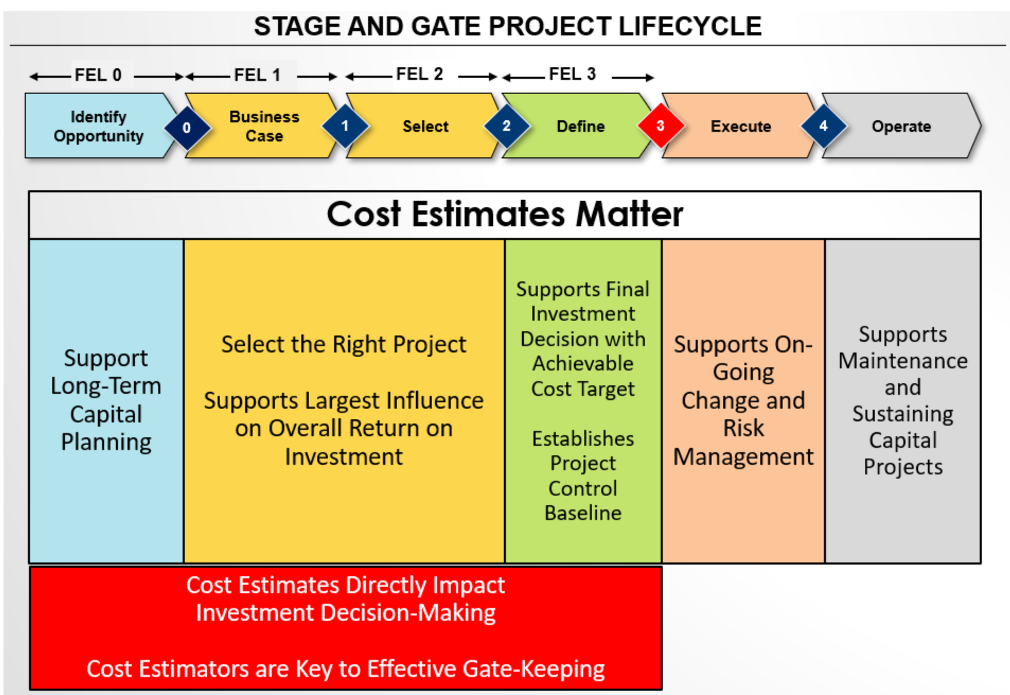

Figure 2–Cost Estimates Matter

Identifying the Minimum Requirements to Prepare Various Classes of Estimates

AACE has developed several recommended practices to support cost estimate classification based on the maturity of the defining project and technical deliverables available to prepare a cost estimate. AACE RP 17R-97 provides a summary of the general principles of cost estimate classification; and establishes the five estimating classes common to all of the recommended practices on estimate classification (Class 5 to Class 1, from least defined to most defined). [12]

There are several more industry specific (or "As Applied In") estimate classification recommended practices that provide detailed *Estimate Input Checklist and Maturity Matrix* tables for the indicated industry. Each of these tables identify particular project and technical deliverables for the applicable industry, and the associated maturity status that must be achieved for each class of estimate. This paper will utilize AACE RP 18R-97 (*As Applied in Engineering, Procurement, and Construction for the Process Industries*) for discussion and examples. [13]

Table 1 provides a table from AACE RP 18R-97 that summarizes the characteristics of the five estimate classes for the process industries:

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges at an 80% confidence interval
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1–Cost Estimate Classification Matrix for the Process Industries

It is critically important to understand that the determination of what class an estimate falls into is not made solely by reference to the percentage of complete definition identified in Table 1. Rather, it is the maturity level of project deliverables based on the status of key planning and design deliverables that is the determinant, not the percent complete. AACE RP 18R-97 expressly states:

> "*The maturity level of project definition is the sole determining (i.e. primary) characteristic of class. In Table 1* [of the RP]*, the maturity is roughly indicated by the percentage of complete definition; however, it is the maturity of the defining deliverables that is the determinant, not the percent. The specific deliverables, and their maturity or status are provided in Table 3* [of the RP]*. The other characteristics are secondary and are generally correlated with the maturity level of project definition deliverables, as discussed in the generic RP* [AACE RP 17R-97]."

And AACE RP 18R-97 adds:

> "*[T]he determination of the estimate class is based upon the maturity level of project definition based on the status of specific key planning and design deliverables. The percent design completion may be correlated with the status, but the percentage should not be used as the class determinate.*"

The process industry *Estimate Checklist and Maturity Matrix* from AACE RP 18R-97 is shown in this paper as Table 2.

The other characteristics associated with each class of estimate (shown in Table 1) including the end usage, methodology, and expected estimate accuracy are secondary; they are typically correlated with the class of estimate but not determinate of the estimate class. Also, note that "class does not speak to the requirements for or quality of an estimating process; i.e., class alone is not a valid contract specification for estimating services (e.g., 'Contractor will provide a Class 3 estimate' only requires what deliverables that must be used as the estimate basis.) To obtain quality, one must define, and assure, estimating requirements, processes, methods, and plans in detail." [9] AACE has a recommended practice specific to the preparation of an estimate requirements document. [14]

For all of the estimate classification recommended practices, a consistent principle is that "there is a level of scope definition at which the cost uncertainty (typically expressed as an accuracy range) is reduced to a point that most reasonably prudent decision makers can make a full-funds (sanction) project investment decision, at least in respect to the capital expenditure (capex) element. For each industry, this full-funding uncertainty level is expressed by Class 3. That is not to say that Class 3 is a standard; for example, in upstream oil, full funds may be committed early (Class 4) due to the need to sign development agreements. On the other hand, for government funded infrastructure, policy often dictates that commitment of funds be held off until tenders are received (Class 2)." [9]

As a secondary characteristic, expected accuracy range does not determine the estimate class, and conversely estimate class does not determine the estimate accuracy. AACE RP 18R-97 states that it:

> "*provides an approximate representation of the relationship of specific design input data and design deliverable maturity to the estimate accuracy and*

methodology used to prepare the cost estimate. The estimate accuracy range is driven by many other variables and risks, so the maturity and quality of scope definition available at the time of the estimate is not the sole determinant of accuracy; risk analysis is required for that purpose." [Emphasis added]

	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
General Project Data:					
Project Scope Description	Preliminary	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Preliminary	Preliminary	Defined	Defined	Defined
Plant Location	Preliminary	Preliminary	Defined	Defined	Defined
Soils & Hydrology	Not Required	Preliminary	Defined	Defined	Defined
Integrated Project Plan	Not Required	Preliminary	Defined	Defined	Defined
Project Master Schedule	Not Required	Preliminary	Defined	Defined	Defined
Escalation Strategy	Not Required	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	Not Required	Preliminary	Defined	Defined	Defined
Project Code of Accounts	Not Required	Preliminary	Defined	Defined	Defined
Contracting Strategy	Not Required	Preliminary	Defined	Defined	Defined
Technical Deliverables:					
Block Flow Diagrams	S/P	P/C	C	C	C
Plot Plans	NR	S/P	C	C	C
Process Flow Diagrams (PFDs)	NR	P/C	C	C	C
Utility Flow Diagrams (UFDs)	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Heat & Material Balances	NR	P/C	C	C	C
Process Equipment List	NR	S/P	C	C	C
Utility Equipment List	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
Design Specifications & Datasheets	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S	C	C	C
Spare Parts Listings	NR	NR	P	P	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Instrumentation/Control System Discipline Drawings	NR	NR	S/P	P/C	C
Civil/Structural/Site Discipline Drawings	NR	NR	S/P	P/C	C

Table 2–Estimate Input Checklist and Maturity Matrix [Identified as Table 3 in 18R-97]

What should be clear from this discussion is that for many industries, AACE has defined the project and technical deliverables, and their associated maturity levels, required for each class of estimate. Estimate classification correlates with the stage-gate project development process, with Class 5 through Class 3 estimates matching the FEL 1 though FEL 3 stages leading to project authorization, respectively.

The *Estimate Input Checklist and Maturity Matrix* tables in the estimate classification recommended practices have been developed to represent the needs of greenfield facility construction projects and are expected to be adapted to specific project needs. For example, a small revamp project to replace a few instruments and wiring may not have an impact on mechanical systems and therefore require mechanical design deliverables.

Also note that not all required deliverables and supporting information are necessarily technical in nature, or to be provided solely by engineering and design resources. Of critical importance is the status of the integrated project plan (or project execution plan). This plan documents the means, methods and tools that will be used by the project team to manage the project. It is an integration and alignment of individual project plans that addresses all project functions including engineering, procurement, contracting strategy, fabrication, construction, commissioning and start-up within the scope of work. It may also address stakeholder management, safety, quality, project controls, risk, information management, communication, and other supporting functions. The estimator requires much of this information to support preparation of the cost estimate, particularly in costing and pricing many of the technical scope items, as well as developing the estimates for project team activities during the project.

The maturity of the deliverables is intended as a threshold to be met, and not regarded as a continuous metric to achieve. The estimate does not qualify as a certain class of estimate until all key deliverables reach the indicated state of completion. If some deliverables have not reached the desired status, then a determination needs to be made whether they are significantly deficient to only qualify the estimate as a lessor class of estimate; or whether they are minor enough to be described as *Class X with Exceptions*. In any case, the resulting class of estimate should be clearly identified in the Basis of Estimate document, and if the estimate is specified as a *Class X with Exceptions* then the specific exceptions should be noticeably documented for consideration by the estimate stakeholders and the gate review team. [10] It is important that the lead estimator make an unbiased determination and accurately represent their determination in the basis of estimate; it should not be the project manager or an engineering representative that makes the determination of estimate class. As noted in Figure 2, the input of cost estimators is key to effective gate keeping and ensuring that the status of project and technical deliverables are meeting the expectations of the project development process and supporting estimate preparation.

This is probably a good time to mention that until the project is fully funded and authorized (typically at Gate 3) there is no *project*, only a *proposed project*. It should always be kept in mind that the project and technical deliverables developed during the FEL stages need to support preparation of sufficiently accurate cost estimates (and schedules) to support the project decisions that may turn the proposed project into an authorized and funded project.

Communicating Information Requirements to Project Teams

As noted in the earlier paper, *Scope Development Problems in Estimating*, "One of the most common problems in estimating is obtaining the proper level of information upon which to base the estimate. Engineering may not necessarily understand the estimating process enough to know the type of information required to produce an estimate or to meet a specific estimating technique or methodology. It's important to convey both estimating information requirements and an understanding of the estimating process to engineering and project teams." [2] In many organizations, owner or contractor, the same issue persists; and the solution is the same as well, training and communication.

Whether owner or contractor, the estimating department within the organization should develop an *Estimate Input Checklist and Maturity Matrix* similar to that shown in Table 2, but adapted as necessary to their industries and project types, and aligned with their project development process. AACE RP 18R-97 provides a guideline, and serves as a great reference point; however, many successful estimating groups will use 18R-97 as a template but expand it to include more detail that is specific to their projects. See the AACE paper *Maturity Assessment for Engineering Deliverables* [15] as an example for expanding upon this checklist and developing a more robust method of scoring to ensure that project and technical deliverables support a specific class of estimate.

This checklist then becomes a part of the estimating department procedures, and obviously a part of the training program for all estimators in the organization. In many of the more successful organizations, this checklist is also a part of the project management and engineering training programs; and becomes a documented part of the overall project development process. It is also recommended that business unit management is trained on the checklist so that they also become familiar with the maturity of project and technical deliverables required to achieve each class of estimate. In this way, both management and the providers of the deliverables are aware of the technical efforts that will be required to support estimating.

It is always preferred when the project managers, engineering managers, lead discipline engineers and other project team members are already familiar with the expectation of deliverables to support estimating at the kickoff of each project estimate. Nevertheless, this information should always be reviewed and discussed among all estimate stakeholders at estimate kickoff meetings. It is the estimator's responsibility to ensure that the project team fully understand the required project and technical deliverables, and the maturity levels, to support the desired class of estimate. During estimate kickoff, the estimators should work closely with the information/deliverable providers to identify a schedule for when all the specific deliverables will be available to the estimating team.

Correlating Estimating Techniques with Improved Maturity of Scope Definition

As the level of project definition increases through the FEL stages of the project development process and the maturity level of the project and technical deliverables increases, estimating methodologies will evolve from factored (or stochastic) techniques to more deterministic techniques. This is a natural progression to utilizing the more mature and detailed information that becomes available.

Factored or stochastic estimating methods typically utilize cost estimating relationships in which the independent variables are something other than a direct measure of the units of the item being estimated. For example, we may factor piping costs (the dependent variable) from the costs for major equipment (the independent variable). These stochastic estimating methods may involve simple or complex modeling based upon inferred or statistical relationships between the costs of the dependent variable and the costs (or other technical parameter) of the independent variable.

Deterministic estimating typically relies on quantifying and pricing the scope at a detailed level. The independent variables represent a (more or less) definitive measure of the item being estimated, such as the lineal measure of the piping being installed. Piping costs (the dependent variable) are then estimated by multiplying the unit costs for piping times the lineal measure.

Class 5 estimates (typically prepared during FEL 1) are often prepared using capacity factoring techniques (based upon historical data from similar projects), other analogy techniques, or specialized parametric models. Quantification to prepare the estimate is very high level, often comprised of identification of overall facility capacity, technology selection, location, and other key parameters developed during FEL 1 that describe the overall facility or asset.

Class 4 estimates (typically prepared during FEL 2) are generally prepared using equipment factoring techniques, and similar stochastic estimating methodologies. These methods may be supplemented with semi-detailed techniques for outside-the battery-limits and offsite areas of the facility, for which the factoring relationships may not be reasonable. Often, project management costs, engineering costs, and other non-direct costs will be estimated using ratios to the direct construction costs based on historical analysis for similar projects. Quantification to prepare the estimate is based on key FEL 2 technical deliverables such as preliminary process and utility equipment lists, plot plans, process and utility flow diagrams, and design specifications.

Class 3 estimates (typically prepared during FEL 3) are usually based on detailed or semi-detailed estimating techniques to prepare a line-time estimate (an estimate in which virtually all of the individual components of the scope are identified within the line items of the estimate). Generally detailed estimates for the supporting functions such as project management, engineering, etc. are prepared using manpower forecasts, and other detailed assessments of the required activities. Factoring and other conceptual techniques are minimized. Quantification to support estimate preparation is based on key FEL 3 technical deliverables that should include the completed process and equipment list, plot plans, piping and instrumentation diagrams, design specifications, general arrangement drawings, electrical on-line drawings, instrument lists; and may include preliminary discipline drawings. Often a bill of materials (detailed quantification) may be available from the engineering modeling tools (3D CAD or other modeling tools); although it is important to recognize the engineering models are still incomplete at this stage and will not include total quantities required for the facility.

No matter the FEL stage or class of estimate, it is always the estimator's responsibility to interface with engineering to identify and quantify all remaining scope that has not been identified in the engineering inputs and deliverables provided to support the estimate. It is important to recognize there may be a difference (sometimes substantial) between the scope as defined in the current technical documents and the scope required to meet the business objectives for the project. The estimator for a contractor that is preparing a bid estimate for services needs to ensure that the total scope as per the contract is identified and included in the estimate; whereas the estimator for the owner needs to ensure that the total requirements to meet the business objective (whether implicit or explicit) are reflected in the estimate.

An often heard saying that engineering is responsible for quantities (or for scope) in the estimate is not accurate. The estimator has full responsibility for scope, pricing, and any other element of the estimate.

Frozen Design Basis/Late Changes

For large projects, the project development stages described earlier in this paper can take weeks and sometimes months to complete, especially for the FEL 2 and FEL 3 stages. The associated estimate preparation duration can also take weeks or months for large projects; and in almost all cases the overall project schedule will not permit the FEL stages to complete their defined scope definition requirements before starting preparation of the estimate. Therefore, the estimate is often prepared in parallel with the scope development activities the estimate needs to rely upon. This results in an obvious dilemma.

It appears quite evident that if estimating activities are proceeding based on preliminary (early stage) engineering documents, and those engineering documents are then updated later in the stage, this may result in a large amount of rework in estimate preparation. In large, complex projects, it can be practically impossible for estimating to stay up to date with the thousands of engineering documents being updated throughout the FEL stage, particularly for FEL 3; and may lead to much confusion in current estimate preparation status.

It is important to realize that after estimating has received the *frozen* design basis, quantified the scope and entered that into the estimate, there is substantial time and effort to account for pricing of all labor and material requirements, apply project coding, evaluate required allowances, prepare estimate reports, prepare estimate benchmarks, support multiple reviews, prepare risk analyses to support contingency determination, and otherwise finalize the estimate.

If the design basis was not frozen, then the continual update of design information would interfere with all of these activities.

The recommended solution to this dilemma is to establish a *freeze* at some point during the FEL stage for the purpose of identifying the engineering and technical deliverables that will be used to prepare the estimate. Once again, this requires a significant amount of communication and planning between estimating and engineering to establish the best point in time to freeze the design basis for the estimate. It should be a point where the design is sufficiently developed to support the expected accuracy objectives of the estimate, while still allowing enough time for the effective preparation of the comprehensive estimate. The intended goal is to determine the optimal point of design freeze that will minimize the overall uncertainty of the estimate, given the tradeoff between scope quantification and all of the other pricing and estimate preparation activities required.

At the point of the freeze, all required technical deliverables are provided to estimating to begin preparation of the estimate (and all revision numbers/dates of those deliverables are identified). Estimating then prepares the estimate on this static set of technical deliverables; and in in parallel, engineering continues to update and develop the technical deliverables to the completion objectives and status for that FEL stage. This allows estimating to prepare a complete and comprehensive estimate without a significant amount of rework due to supporting technical deliverables changing on a day-by-day or week-by week.

The technical differences between the static *frozen* design basis and the final revisions of the technical deliverables at the end of the stage are not ignored. Instead, estimating and engineering should work together to identify the key changes to the scope definition deliverables between the *frozen for estimating* and final design basis; and the estimated costs for the updated scope are incorporated as *late changes* to the estimate. Often, the cost estimates for the late changes will be based on (conceptual) estimating techniques that are less deterministic than the balance of the estimate, especially at FEL 3. If the design changes or potential cost are particularly significant, then a more deterministic estimating technique may need to be used in order to satisfy the intended classification of the estimate.

It is very important for the estimator to determine the significance of the difference of the scope between the *frozen for estimating* design basis and the final *end-of stage design* basis, and of the resulting cost for late changes. If these can be considered relatively minor, then they may not result in a change to the classification of the estimate or may require that the estimate be identified as *Class X with Exceptions*. If either the difference in scope or the estimated costs are significant, it may require that the estimate be identified as a less-developed class of estimate (e.g. Class 4 instead of Class 3). Regardless, the differences in scope, and a description of the estimating techniques and costs to account for the updated scope need to be clearly identified in the basis of estimate document and considered during the risk analysis that should be prepared to determine estimate contingency.

Present the Estimate in Relation to Scope Definition

Cost estimates are prepared to support decision making by the organization. An effective project development process, such as described earlier in the paper, supports staged decision making to make the best use of limited capital investment expenditures. As indicated, classification of estimates and a stage-gate development process work collectively to support management decisions. Thus, when management evaluates the gate documentation at the end of a project development stage, they are often inclined to assume that a specific level of project scope definition has been achieved and is reflected in the supporting costs estimate. The project environment is not a perfect world; however, and project teams may be pressured to obtain project approval without meeting the expected minimum levels of project scope definition.

The estimator should play a critical role in all gate reviews. It is the estimator that must describe the level of project definition that is used to prepare each and every estimate (documented in the basis of estimate). Despite the desire that a specific class of estimate be prepared at each stage of project development, the estimator has the responsibility to identify the actual class of estimate achieved based on the project and technical deliverables provided to support estimate preparation. The estimator should clearly identify any exceptions to deliverables that did not meet the intended level of maturity or completeness (including documenting estimation of all late changes); and if necessary, classify the estimate as *with exceptions* or as a less defined class of estimate. Estimating supports decision-making, and that requires that all information to support that decision is provided accordingly. It is recommended that a detailed list of all project and technical documents (with revision numbers/dates) be attached to basis of estimate documents as an attachment.

The estimate should always be presented in relation to the level and maturity of scope definition used to prepare the estimate. The estimate may be used to support a decision to proceed to the next stage of project development or to provide project authorization and full funding to complete a project. In this way, management is informed as to the actual level of project definition maturity, and any associated deficiencies, in order to make an informed decision. If management chooses to proceed to the next stage or full authorization based upon an estimate *with exceptions*, they do so in consideration of the risks involved.

Conclusion

Obtaining adequate scope definition to support cost estimating has always been one of the most persistent problems faced by estimators. A formalized project development process in combination with a cost estimate classification system is key to solving this problem. With communication, all supporting project-related departments and project teams will have a clear understanding of the project and technical deliverables and the expected maturity that is required to support each class of estimate. Estimating techniques can be adapted to the maturity of the project and technical deliverables for each estimate. Close coordination between estimating and engineering (as well as other information providers) will help to establish when deliverables will be available during the estimate preparation lifecycle, including establishing the *frozen for estimating* design basis and incorporation of late changes.

Utilization of a stage-gate project development process and defining the level of maturity of scope development to support each class of estimate provides management with better information to support decision-making in relation to the gate decisions to proceed to the next stage or to fully authorize projects. By identifying those areas of the estimate that may be lacking in scope development or maturity, estimators play a critical role in supporting the decision-making process.

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