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JULY/AUGUST 2021

COST ENGINEERING

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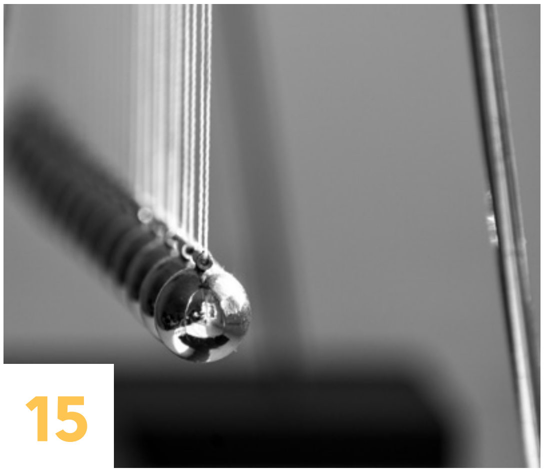

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TECHNICAL ARTICLES

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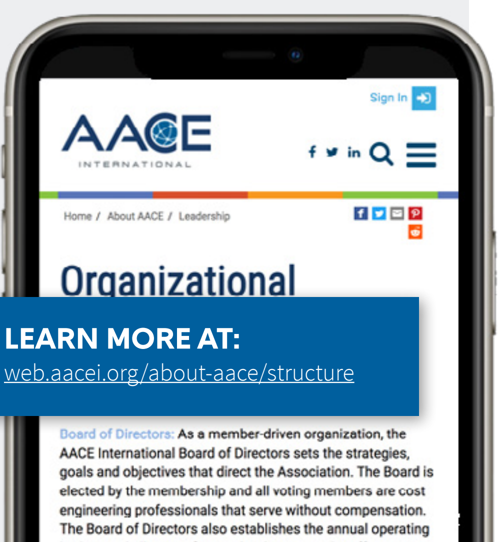

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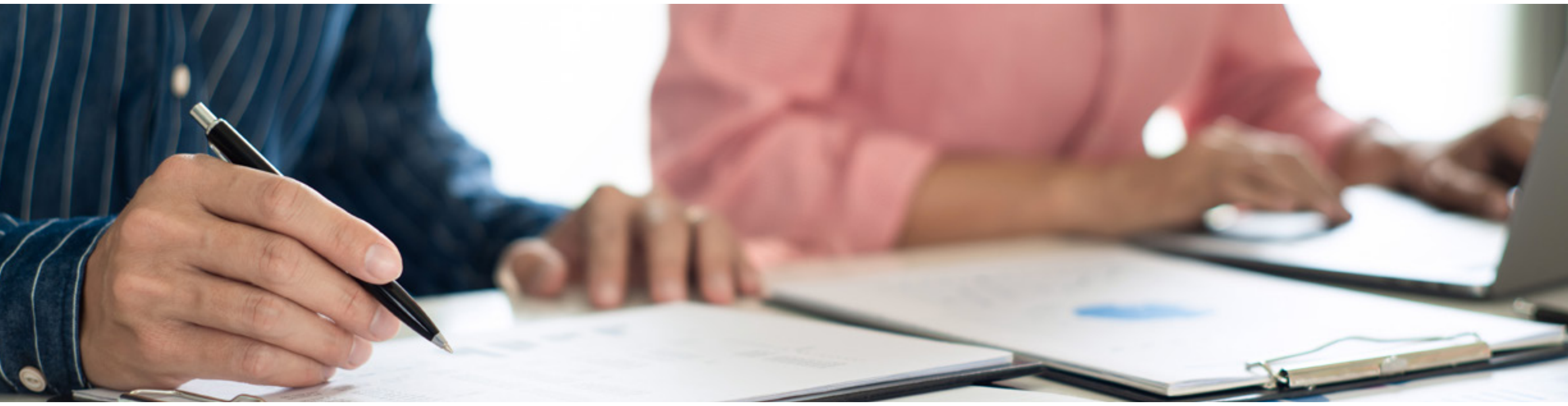
LETTER FROM THE

EDITOR

BY MANAGING EDITOR
MARVIN GELHAUSEN



Building a Technical Article

For the July/August Cost Engineering journal, we are publishing one claims/schedule control and two estimating articles.

TECHNICAL ARTICLE 1
CSC-3546, *Project Controls Reporting: Having the Message Heard,* by Chris Caddell, PE CCP DRMP; Charlene Sue DeBeer and Nataliya Rutylo

TECHNICAL ARTICLE 2
EST-3424, *Supporting Estimates with Effective Scope of Work Definition,* by Larry Dysert, CCP CEP DRMP FAACE Hon. Life and Todd Pickett, CCP CEP FAACE

TECHNICAL ARTICLE 3
EST-3542, *A Discussion of the Cost Estimate Classification System–As Applied in the Engineering, Procurement, Construction and Operations for the Environmental Remediation Industries,* by Dan Melamed, CCP EVP; Bryan Skokan, PE CCP; Greg Mah-Hing, PE; Rodney Lehman and Jake Lefman

The authors of each article were asked to respond to questions to give readers insights into how the article topics were selected, what main takeaways each author hopes readers gain insights into by reading this content, as well as a brief personal note to allow readers to better get to know the authors.

Taking a deeper dive into the behind the scenes on the who, what, when, where, why and how of each article, we see that:

TECHNICAL ARTICLE ONE

PROJECT CONTROLS REPORTING: HAVING THE MESSAGE HEARD, BY CHRIS CADDELL, PE CCP DRMP; CHARLENE SUE DEBEER AND NATALIYA RUTYLO

All three authors say the topic for their paper "organically evolved, based on our experience and challenges." Nataliya notes that, "Chris did the heavy lifting of bringing all together and dealing with submission and review process (thank you, Chris!)." The authors say feedback from presentation attendees was very helpful and encouraging. "The submission and review process were constructive and fair. The presentation attendee feedback was also constructive in making adjustments for future presentations," explains Chris.

> "Good project controls reporting has
> 1) been tailored to meet the needs of stakeholders,
> 2) includes 'key takeaways' and recommendations for actions, and
> 3) uses visual dashboards to help convey performance."
>
> **CHRIS CADDELL, PE CCP DRMP**

Nataliya adds, "we tried to take lessons learned throughout project delivery, share our experience and solutions." Chris says, "This paper was based on a compilation of past projects in terms or what works and what doesn't."

The takeaway Nataliya wants readers to get is that "You are not alone – Challenge and innovate!" Chris says the takeaways he wants readers to understand is that "Good project controls reporting has 1) been tailored to meet the needs of the stakeholders, 2) includes "key takeaways" and recommendations for actions, and 3) uses visual dashboards to help convey performance."

"This topic is applicable across all industries for any time of capital project," stresses Chris. His coauthor Nataliya adds, "We attempt to unify solution and provide suggestions that could be applied across various industries."

This article brought a mix of experience to the table. "So far, for a conference paper of this kind, this would be a first one for me," notes Nataliya while Chris says this was his 12th paper to present at the AACE Conference & Expo.

Having the experience of authoring her first conference paper, Nataliya says her advice to other potential new authors is, "Share your ideas and best practices, it will drive and enhance industry standards." Chris adds that his advice to new authors is that participation is, "is a great learning experience, but can be very daunting." To assist with this challenge, he says, "Get someone to mentor or work with you the first time (and maybe beyond). Draw on peers for review and feedback."

Something you may not know about Nataliya is that her first degree and initial career goal was to become a social psychologist. She says, "Little did I know how useful that academic knowledge will be in delivering project control service." Something you may not know about Chris is that his first project was "to construct modules to stack around a nuclear submarine in drydock to hide it from satellites and create a "stealth" sub."

As COVID-19 pandemic restrictions life, these three authors of technical paper 1 say they have been working remotely since March 2020, using available platforms for meetings with client and peers (Teams, Google meet, Zoom). Chris delivered this presentation in 2020, and Nataliya says it "was informative and engaging, it generated good questions from the audience." She says she had the pleasure to present this technical paper to the AACE Toronto Section, and she received good feedback from the attendees. Chris notes that he found the presentation format good but did miss the in-person interaction. He adds, "I found the 2021 virtual presentations to be good. One of my major concerns is the inability to provide a more "active" presentation due to the need to stay in front of the computer camera."

TECHNICAL ARTICLE TWO

SUPPORTING ESTIMATES WITH EFFECTIVE SCOPE OF WORK DEFINITION, BY LARRY DYSERT, CCP CEP DRMP FAACE HON. LIFE AND TODD PICKETT, CCP CEP FAACE

Author Larry Dysert says his and Todd Pickett's article is, "relatively industry-generic, although some of the specific terminology used comes from the process industries." He adds, "The article should be useful to the preparation of all cost estimates for capital projects."

The authors want the reader to understand the following takeaway points:

- Every cost estimate will be dependent on clear and comprehensive technical design and project planning deliverables.
- Work with the required engineering and project planning teams to ensure they understand the maturity of the deliverables expected for the class of estimate to be prepared.
- Evaluate the maturity of deliverables carefully.
- Identify gaps or exceptions to the expected maturity and completeness of the supporting deliverables and project scope information, and appropriately address their associated uncertainty and risks.
- Match appropriate estimating techniques to the level of scope definition.
- Ensure that the cost estimate and the Basis of Estimate provide meaningful information to support decision-making.

Larry notes that the article is based on 40 years of project and industry experience. He says, "The topic was suggested by the Chair of the Estimating Subcommittee; and designed to fit into a series of sessions that provide a comprehensive overview of cost estimating."

Larry has published and presented 20+ papers for AACE conferences, as well as many more for other organizations and publications. He believes that "The AACE submission and review process is excellent, providing feedback to make the papers as effective and beneficial as possible."

His advice to potential new author/presenters is to, "select a topic that you feel passionate about, as that will motivate the completion of a well-written paper." He explains that "Writing about a subject inspires the author to thoroughly research and investigate the topic, which enhances their professional development as well as that of those reading the paper.

Larry attended the in-person Boston Retreat, and says he missed the face-to-face component of the last two conferences; however, he believes the virtual sessions have been excellent. "I hope the 2022 Conference will be in-person, but I believe a virtual component will also be of benefit to the Association and its members," notes the seasoned author/presenter.

Larry has been working primarily from home throughout the COVID-19 pandemic. However, he says, "although we see an ease of domestic travel requirements that may provide opportunities to client sites within the US. Much of our work is Canadian-based, and strict travel restrictions remain. Virtual meetings remain key to communication with clients and project teams.

Something you may not know about Larry is that he recently purchased a pontoon boat to enjoy with his family's move to Lake Havasu, AZ.

> "Writing about a subject inspires the author to thoroughly research and investigate the topic, which enhances their professional development as well as that of those reading the paper."
>
> **LARRY DYSERT, CCP CEP DRMP FAACE HON. LIFE**

TECHNICAL ARTICLE THREE

A DISCUSSION OF THE COST ESTIMATE CLASSIFICATION SYSTEM—AS APPLIED IN THE ENGINEERING, PROCUREMENT, CONSTRUCTION AND OPERATIONS FOR THE ENVIRONMENTAL REMEDIATION INDUSTRIES,

BY DAN MELAMED, CCP EVP; BRYAN SKOKAN, PE CCP; GREG MAH-HING, PE; RODNEY LEHMAN AND JAKE LEFMAN





"Everyone has been very flexible in adapting to the challenges to the Covid pandemic," notes Dan Melamed, CCP EVP. He says, "Operating remotely has been challenging but the technological tools (such as Zoom and WebEx) have been an excellent support to this situation. However, I believe that there are advantages to in-person meetings that are desirable." Author Bryan Skokan adds, "Thanks to today's electronic office and WebEx, Zoom, etc., most aspects of our work productivity actually improved during the pandemic. The time previously spent traveling/commuting is now available for additional work and/or needed rest. On the negative side, the "virtual" reviews of our projects suffer a good deal from not actually being there." Dan Mah-Hing, PE says he has seen a couple of problems resulting from the COVID-19 pandemic. He says, "The inability to get to project sites has prevented me from mentoring staff. Plus working a lot of hours as everyone has different schedules, often starting at 6 am and on calls until 9 pm. His work around has been to use Teams and Zoom to stay in contact. Jake Lefman says the COVID-19 pandemic had very little impact on his work. He says he was able to telework effectively from home and he used all virtual technology including Zoom, WebEx, and Teams.

Dan notes that, "The virtual presentation format over the past two years has been very impressive in allowing for a large number of people to attend. We found that for the 2020 remote conference recording the presentation between the three authors presenting was challenging - involving separate recording sessions for each speaker to present their sections of the presentation. However, we feel that it was a worthwhile challenge, to produce a quality product. The live presentation for the 2021 Virtual Expo was much easier, especially with the previous years' experience. However, I believe that the main problem with a virtual format is the audience members were not able to ask questions directly. Instead, the audience member had to type their question for the room host to read to the speaker. This diminished the immediacy and directness of the conventional question and answer process."

Bryan agrees with Dan. He adds, "Our virtual presentation in 2020, as well as the 2021 AACE meeting, had the advantage that there was no limit to the number of attendees and the number of recorded viewings of our session; otherwise it would have been limited to a one time delivery and the and audience size limited by the physical constraints of an actual conference room. On the negative side, I believe it is far more impactful to physically attend an AACE meeting, both from the perspective of a presenter and as a member of the live audience."

Dan explains that this article, as is the environmental cleanup cost classification Recommended Practice 107R-19, are not project-specific but written to fully address the entire spectrum of soil and groundwater remediation and facility D&D. However, he notes, "we do discuss two completed environmental projects in this article to serve as case studies." Bryan adds, "Our topic was based upon a sorely needed cost classification Recommended Practice that we authored. Prior to this new RP, 107R-19, environmental cleanup project estimators used the normal construction cost classification RP, which was widely viewed with suspicion for this unintended use. Our paper, as was the RP, were well received and the feedback from both was indeed helpful." Jake adds that the topic is a

> "The AACE Conference and Expo offers tremendous value to all of its community members as a vehicle for sharing important information on our profession. All of us must contribute to continue this success."
>
> **BRYAN SKOKAN, PE CCP**

current topic of interest to the government and related agencies within the government. He says current and actual project data was used as the basis of the article.

Dan explains that the takeaway points he wants a reader to understand are to:

- Show the general process for environmental cleanup projects for their entire life cycle (within both a general engineering and project perspective, as well as a general regulatory framework).
- To help explain the wide range of costs inherent to environmental projects due to the wide variety of uncertainties inherent to this industry.
- To help the audience understand the content of the new RP 107R-19 and how it relates to the other cost classification Recommended Practices that apply to a wide variety of industries.

Bryan says the takeaways he loos for the reader to understand are:

- Publicize that this new Environmental Cleanup Cost Classification has been completed and is there to serve AACE members and others.
- To help explain to the audience the regulatory framework and constituent parts of an environmental cleanup project that affect cost classification.
- To help the audience understand the content of the new RP 107R-19 and how to it.

Bryan explains that the primary industries impacted by this paper and the RP are those associated directly with Environmental Remediation. Secondarily, this article may be of interest to other industries that may ultimately require some form of environmental remediation activities such as mining, Oil and gas production, and construction of facilities that may become contaminated through use. Jake says, "The applicable industries include environmental remediation (contaminated soil and water) and also nuclear decontamination and decommissioning."

Dan notes that he has presented about six papers since 2007, when he presented his first paper in Nashville TN. One of his papers was previously published in the Cost Engineering journal. Bryan has presented five or six AACE Conference papers over the more than 20 years that he has been involved with the AACE Conferences & Expos. None of these previous papers were published in the AACE Cost Engineering journal. Greg says he has been working in the environmental business for over 30 years. Jake says he has had four papers published.

Dan and Bryan share the same advice to potential new authors/presenters. Bryan speaks for both when he says, "If a potential author has been involved in an unusual project, learned a great deal about a specific project and/or have developed/discovered a methodology or technique that others may benefit from, they should write-up an abstract and submit their topic for presentation at the Expo. If their abstract is selected, they can then write and present their paper. The AACE conference and Expo offers tremendous value to all of its community members as a vehicle for sharing important information on our profession. All of us must contribute to continue this success." Greg explained that he did not understand the submission process when he started, but Dan guided him through the process. Greg's advice is "Have a mentor guide you." He concludes, "We really need to share our experience with others, this is the value of belonging to a professional group." Greg says he has been involved with AACE and the Conference & Expo for many years, but he has not yet presented a technical paper. Jake says, "The audience should gain a perspective of cost estimate classification system and how it applies to project phases. The audience should gain a better understanding of the GAO Cost Estimating Guide best practices and how it applies to various types of projects."

Something you may not know about Bryan is that although he did grow up on a small (30 acre) farm, farming was never his profession. He adds, "Yet, my son, who farms hundreds of acres and raises over 150 kinds of grains and vegetables, will still on occasions ask my advice on farming questions." Something you may not know about Greg is that he really enjoys cost estimating. He notes, "I get to see a lot of projects, review designs and technical approaches to solving problems." Jake says something you may not know is, "I managed many types of projects in the US and around the globe. I was involved with a project involving developing, installing, and commissioning a total security system for use in the Greek Olympics. One of the best things to experience is when the security blimp/dirigible flew over my house in Athens, was stationary and dipped forward and backward to thank us for development and inclusion in security. Very cool. The other great benefit was actually attending the opening ceremonies which were spectacular."

> "We really need to share our experience with others, this is the value of belonging to a professional group."
>
> **GREG MAH-HING, PE**

Project Controls Reporting: **Having the Message Heard**

BY **CHRISTOPHER P. CADDELL, PE CCP DRMP; CHARLENE SUE DE BEER;** AND **NATALIYA RUTYLO**

ABSTRACT

Project controls reports during the lifecycle of a project are critical to helping the management team understand how the project is performing from a productivity, progress, schedule, and cost perspective. These reports provide not only information about performance to date but forecast the likely outcomes at the completion of work. However, all too often the critical messages in project controls reports are not heard or even worse ignored, negating the benefit they provide in helping the team manage the project to a more successful outcome. These reports often lack the necessary attributes to ensure the message is heard by the management team, such that they act on it. Best practice project controls reporting depends on having the right content, issued in a timely manner, formatted well, with the issues identified and recommendations provided where possible. A well-structured, well delivered project controls report is more likely to resonate with the management team and have the impact it should on their decision making. This article was first presented as CSC-3546 at the 2020 AACE International Conference & Expo.

Introduction

The development of a suitable project control system is an important part of the project management effort. [3] Project controls reporting is the output of that system to the rest of the project team and other stakeholders. Project controls reports during the lifecycle of a project are critical to helping the management team understand how the project is performing from a productivity, progress, schedule, and cost perspective. [5] Typically, these reports are the ones most valued by project managers to help understand how the project is progressing and what actions they may need to take to manage the project to a better outcome. These reports should provide not only information about performance to date but forecast the likely outcomes at the completion of work and what is driving those forecasts. However, all too often the critical messages in project controls reports are not heard or even worse ignored, negating the benefit they provide in helping the team manage the project to a more successful outcome. These reports often suffer from being too long, unclear, poorly organized, too detailed, lacking analysis, misleading metrics, or other attributes. As a result, the reader is missing the message they needed to hear to act. If project controls is the science of data gathering and analysis for managing a project's cost and schedule, the reporting is the ART, "a reporting tool", to convey the results in a meaningful manner that can best connect with the users of the reports.

For project controls reporting to achieve best practice levels, the report needs to have the right content, be issued in a timely manner, be formatted well, and with issues identified and recommendations where possible. The report needs to be crafted to provide information on how the project is progressing against its targets and presented in a way that is easy to understand and quickly absorbed. A well-structured, well delivered project controls report is more likely to resonate with the management team and have the impact it should on their decision making. To achieve this state requires up front work to define the information that is needed by the management team and others, but developed with the flexibility to adapt as the project evolves. [4] The resulting report will be concise, integrated feedback on the cost, schedule, progress, risk, and other performance factors to help the project management team understand the issues and make timely decisions to drive the successful outcome of the project.

Goals of Project Controls Reporting

When addressing the development of a project controls report, it is important to understand the goal of such a report. Ultimately, the report is intended to provide the project team and management the information needed to help achieve a successful outcome for the project. The goal is to provide them with the data and feedback to support proactive, informed decisions to drive toward or improve upon the project targets.

Actionable reporting is needed to help support that proactive decision making. It needs to include sufficient information to give the team direction on where to act. Saying the project completion milestone is slipping is not actionable. Saying that it is slipping due to the late delivery of a piece of equipment, provides the team with information on what is driving the delay and where to focus its attention on developing mitigation actions.

The reporting needs to identify current forecasts for both the project cost and schedule with trending from previous reports. The team needs to understand the current expected outcomes based on the trends identified to date and be able to assess if the cost forecast is increasing or decreasing. If the forecast is outside of, or trending to be outside of, defined parameters, management needs to be aware of that to either address additional funding requirements or intervene if necessary to improve the forecasts.

Performance issues, impacts, and drivers need to be highlighted in the report. The report should clearly identify issues that are driving changes in the forecast from the targets and if possible, what are the underlying causes of the poor performance. For example, the team needs to understand productivity is below target for a particular trade, the potential impact on the cost and schedule if the trend continues, but also, if possible, the reasons for that poor performance, such as unskilled craft, worker density, logistics, or other issues.

Often, as a part of the project controls analysis, the project controls team may be able to suggest recommended actions to address some of the performance issues or identify opportunities for improved performance. Through the gathering of data, discussions, and analysis, the project controls team often are either made aware of or able to develop potential actions to address performance issues. In addition, the project controls team be able to see areas for performance improvement that others have not realized. Sharing these observations in the report add value by helping the team drive toward the objective of meeting or improving upon the project targets.

Typical Issues with Project Controls Reports

The format and content of project controls reports differ from project to project, as there is no international standard, guideline, or process for them. This leads to a fundamental lack of common understanding for project controls reports, the purpose they serve, and the benefits they can provide. The result is project controls reports can be of varying quality, level of detail, and value to the project team.

Project controls reports may not be widely understood nor recognized as a critical tool in achieving successful project outcomes for cost and schedule, often due to its complexity and not being easy to follow. What contributes to the complexity is that the reports are often mainly data, and not supported by any analysis, conclusions, or recommendations. It may have numerous tables of data but few visuals or graphs. Often reports are providing some standard tables of detailed data, which may be important as a part of the project controls effort, but may not address the specific needs of the organization or address its strategic objectives.

Project controls reports often suffer from the following issues:

- **Convoluted:** Many reports can be extremely long, complex, and difficult to follow. They may not clearly identify performance that deviates from plan. Often the reports rely heavily on tables of data without clearly showing the row(s) or column(s) the user should focus on for the key performance data or providing any key bullets explaining what the tables demonstrate. The user will often not realize the important point that is demonstrated by the data as a result.
- **Lack of Focus on Objectives:** Reports will often provide traditional cost and schedule performance information, which is important, but it may not be structured to address the specific objectives of the project. The project KPI's, critical milestones, costs for certain

elements of the project, risks, and contingency may not be properly addressed in the report to help the user know how the performance of that aspect of the project is going or if action is required.

- **Inconsistent Terminology and Measures:** Each business seems to have its own set of terminology and measures used for projects, but given the varied experience of project personnel, there is often inconsistent use of terms and how performance is measured, creating confusion or misinterpretation of the information. Indicated total cost, estimate at completion, total forecasted cost, and current cost forecast can all mean the same thing depending on how each is defined. Actual cost can mean actual cash expended or cash expended plus accrued costs for work performed but not paid. Is measured progress based on cost or worker hours earned?
- **Lack of Political Awareness:** While project controls reports should be straightforward in the information provided to the user to make the best-informed decisions for the project, these reports may be reviewed by a broad audience. Often the reports do not necessarily consider the perspective of the reader and nuances of issues between the different stakeholders. Contingency (and who owns it) is often an area of contention between parties and how it is reported. Sometimes information can be presented in multiple ways, some of which may not be sensitive to some of these issues and cause users to argue over minor issues and miss the key point.
- **Data Tables in Lieu of Graphics:** As previously stated, many reports can rely heavily on data tables. It can be a time consuming and frustrating exercise to understand what the data is trying to highlight. Often data tables will also only reflect the current status of performance and not reflect the performance trends from previous periods. Data tables will typically include a significant amount of data that the reader does not need to see, it only serves the purpose as an input to the calculation of current performance but can distract the user.
- **Unreliable, Inconsistent Data Sources:** Project controls reports typically must draw data from multiple sources for progress, cost, schedule, risk, and other information. However, often these different sources can be inconsistent with each other or be unreliable in the accuracy of the data. The data sources may have different cut-off dates for reporting which can result in inaccurate calculations of performance. Errors in data, such as missing invoices or progress reporting, can also result in inaccurate results. Also, if the information is tracked at different levels in different systems, it may not support the detailed analysis needed.
- **Manual Intensive:** Many reports still rely on a significant amount of manual effort to compile and enter data and perform calculations in spreadsheets. This can result in limited time available for analysis, investigation for causes, and development of response recommendations. It also increases the likelihood of errors and omissions in the reporting. Given the pressure organizations are under to keep project team sizes lean, the project controls staff may not have adequate resources to support the manual effort required in compiling reports.
- **Lack of Analysis, Conclusions, and Recommendations:** As a result of the manual effort required for reporting, limited resources, lack of confidence in the analysis, or other reasons, reports often just provide the raw data without any analysis to indicate where there may be performance issues, lack of trending in the overall forecast, or recommendations. The data in a report may indicate a productivity issue in a particular area of with a particular craft, but not reflect the impact that poor performance could cost on the overall schedule or cost forecast. The report is left open to interpretation, with the user making their own assumptions. As a result, incorrect actions may be taken.
- **Untimely:** Often project controls reports can take weeks to issue once all the data is received, processed, and reviewed. In some instances, the report is not issued until the close of the next reporting period. The result is the project team and other users are constantly in a reactive position. The data may be a month old by the time it is issued and reviewed by the people that use this information to inform their decision making, meaning the project may have suffered another month of performance issues without even being aware of it.

Recommended Project Controls Reporting

William Pollard, a lecturer in the 1800s, recognized that "Information is a source of learning. But unless it is organized, processed, and available to the right people in a format for decision making, it is a burden, not a benefit." To meet the goals defined for project controls reporting, the project controls team need to develop leading practice project controls reports. Work culture and industry trends have shaped current project controls reporting. People, particularly managers, have less time to read detailed reports and do their own analysis of what is driving the trends on their projects. People are also subject to a large amount of data and other information, some important and some not. They struggle to find the time to sift through the data to make sense of it all and how they should respond to it. For the project controls message to be heard, it needs to address these issues to better support the project team. The analysis needs to be done by the project controls team with the result conveyed in the report. The report needs to home in on what the team needs to know, specifically, where the project is headed, what the performance issues are, what is driving those issues, and what the team can do about it. [1] While the analysis and back-up information supporting the report is important, it typically does not need to go in the report. But the team must ensure the analysis is sound and supports the conclusions.

The report needs to be easy to read and comprehend, clearly identifying what the performance issues are, why the performance is deviating, i.e., what is driving the variance, and what the project team needs to do to address the issue.

Specifically, project controls reporting needs the following attributes for the team to get the most out of the report:

- **Support Project Objectives:** While every project needs to understand total project cost and completion data forecasts, there are a number of other objectives or specific pieces of information the project team and other stakeholders may need to achieve a successful outcome for the project which will vary by project. The project controls report should address those needs if possible.
- **Clear Structure:** The report should have a clear structure that is consistently used, allowing the reader to quickly navigate to parts of the report of most interest to them or in their realm of responsibility. Typically, with a top-down approach, the report should provide the overall forecast and performance highlights first, then get more details in the later sections of the report. An executive dashboard or summary is typically the best approach to provide the highlights at the start of the report. Some users may never need to go beyond that to look at the details.

Type	Budget	Forecast	Variance
1.Direct	**223,000,000**	**250,500,000**	**27,500,000**
Equipment	80,000,000	82,500,000	2,500,000
Labor	68,000,000	87,000,000	19,000,000
Material	75,000,000	81,000,000	6,000,000
2.Indirect	**23,000,000**	**30,000,000**	**7,000,000**
Labor	12,000,000	15,000,000	3,000,000
Other Indirects	3,000,000	6,000,000	3,000,000
Temp. Facilities	8,000,000	9,000,000	1,000,000
3.Engineering	**18,000,000**	**20,500,000**	**2,500,000**
Engineering	18,000,000	20,500,000	2,500,000
4.Owner	**21,000,000**	**23,000,000**	**2,000,000**
Other	14,000,000	14,000,000	0
PM	7,000,000	9,000,000	2,000,000
5.Contingency	**28,000,000**	**14,000,000**	**-14,000,000**
Contingency	28,000,000	14,000,000	-14,000,000
Total	**313,000,000**	**338,000,000**	**25,000,000**

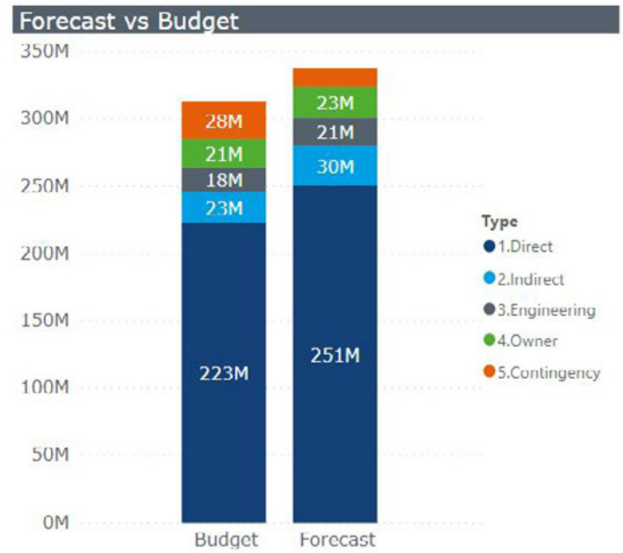


FIGURE 1 Example of Data Table and Graphic of Project Budget Vs. Forecast Cost

- **Defined Baselines:** Performance cannot be assessed without having a reference to measure against. The primary role of project controls reporting is to help the project team and others understand how the project is trending versus the cost and schedule targets that were established for the project. The original assumptions and metrics used to develop the project targets should be used to create baseline performance metrics, such as productivity, cost per unit, milestone tracking, monthly progress plans, etc. Observed or actual performance can then be compared against those baseline metrics to help assess if that metric is on target, performing better than expected or worse than expected.
- **Concise:** The reports need to be concise in providing the important information within the main body of the report and highlight what the user needs to pay attention to. The detail data supporting the analysis can be provided in an appendix if it needs to be included in the report. A report that is 2-5 pages long is much more likely to be reviewed by the user with limited time than a 20-40-page report. The longer report may be skimmed, but the level of detail used in such a report means the user will likely not identify the issues that may be hidden in the details.
- **Identifies Issues and Recommendations:** In addition to reporting on performance variances, the report needs to identify the issues driving the performance trend if they can be ascertained. In addition, the project controls report should include any recommendations that the project controls team have developed based on the information they have analyzed. Often the project controls staff can identify issues and make recommendations as they have access to all the detailed data and have discussions with project team members to understand what is causing the performance issues and what may improve performance.
- **Graphics instead of Tables:** While the saying "a picture is worth 1000 words" may be old, it is no less true today than when first used. The use of S-Curve charts, bar charts, pie diagrams, and other types of graphics allows the user to quickly ascertain the key points of the data. Most such graphics reflect the baseline metrics, current performance, and the performance trend. If performance is getting worse as the project progresses, the project team may need to intervene before it starts to have a significant impact on the project. Figure 1 offers a very simple example of a data table and graphic with the same information. The user can understand the magnitude of the variance much faster with the graphic than with the table and where the significant variances are.
- **Clear Terminology:** The reports should use clearly labeled graphs, charts, figures, and tables, so the user will understand exactly what they are looking at. The report should consistently use agreed upon terminology so the user will understand what is meant by each label and description used in the report. Performance measures need to be defined so the user will understand the basis for the measures.
- **Timely:** The sooner the report is issued relative to the close of the reporting period, the more proactive the project team can be in addressing any issues identified. While taking more time to issue the report can improve the accuracy of the reporting with more invoices processed and refined progress and schedule reporting, it may be more beneficial to the project to have the report issued faster for faster response to identified performance issues.
- **Conforms to Project Sensitivities:** Prior to finalizing and issuing the report, have discussions with the project team and others as necessary to understand any sensitivities in the report findings. This is particularly important if there is a new issue identified in the current reporting period that has not been previously identified. For example, the project manager would typically like to be aware of a performance issue prior to a report being issued to senior management so they will be prepared to answer any questions they may have.

How to Implement Good Practices

Good project controls reporting does not just happen, and you cannot just use what was done on the last project. Each project has unique characteristics with unique priorities and objectives that influences the structure of reporting and the specific content. While the principles for a quality project controls report remain unchanged, the report itself needs to be customized to the needs of the project or program.

Developing a quality project controls report requires a lot of work to define the requirements and format up front and then to set up the data structures and interfaces to support timely, accurate analysis and reporting; and this work cannot be performed by the project controls team alone. The project and owner management and other stakeholders must provide input on what they need to see in the report to help drive their decision making. At the same time, the project team must provide input on what information can be provided based on the contracting terms and data structures. For example, the owner may want to see details on a contractor's costs, but the contractor may not have any obligation to provide that data per the terms of the contract. The project team will need to work with the various parties involved to resolve these challenges.

In general terms, the implementation of good project controls reporting practices involves several steps. Figure 2 shows the basic steps involved with setting up a robust project controls reporting system.

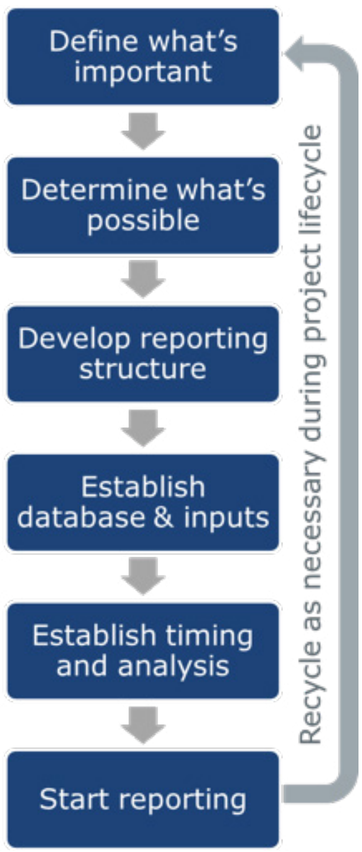


FIGURE 2 Process for Developing Project Controls Reporting

- **Important:** Early engagement with the project stakeholders to define what project controls reporting is required. Establish the main objectives and key performance indicators for the project in terms of the broader business.
  - What are the KPI's for the project?
  - What is driving performance for the business?
  - What are the project priorities?
  - Are there specific cost or schedule constraints that need to be addressed?
- Discussions should include the following stakeholders:
  - Project Management
  - Senior Business Management
  - End Users
  - Internal Finance Leaders
  - JV Partners
  - Financial Investors
  - Other stakeholders as needed
- **Determine What Is Possible:** To meet the reporting requirements defined by the stakeholders, the data has to be available to support it. The data that the project controls team will have available depends on several factors related to the project:
  - **Procurement and Contracting Strategy:** How items are procured, and services contracted for, will influence the data available. If some work or purchases are bundled, the detail for items within that bundle may not be available. The use of fixed price contracts will often limit the information available for costs within that contract.
  - **Contract Terms:** Some contracts may clearly define the cost, schedule, and other data that needs to be provided by a contractor to support project controls, while others may be silent. Without the supporting contract terms, contractors may not be willing to provide the necessary details to support some of the requested project controls reporting.
  - **Finance Systems:** Internal systems used for cost administration and finance can influence the cost data available to support reporting. It may either have a significant lag in data availability or may not support the desired breakdown.
  - **Cost Management and Systems:** How project costs are being tracked and managed using any cost systems will be instrumental in determining what reporting can be supported. The project team may have some latitude to alter how costs are being managed in the systems to support the reporting, but it may be pre-defined by the organization across the portfolio of projects or limited in what information is going into the system.
  - **Schedule Management and Systems:** The systems and process used to develop and manage the project schedule will also influence schedule data available. Typically, schedules are developed by multiple parties. If they are not integrated, the project may not have a single, dynamic schedule to support robust schedule reporting.
- **Develop reporting structure:** Once what is desired is defined and what is possible has been determined, the project controls team needs to develop a reporting structure for review and approval.
  - Any gaps between the information desired and what can be provided needs to be reconciled. Either the project controls team will need to find an alternative way to meet the need or update systems and contracts as necessary to have the data to provide the desired reporting.
  - The reporting needs to be consolidated down to the key parameters that need to be addressed in the main part of the report. Secondary or supporting parameters are important and need to be included but can go in a supporting or appendix section.
  - A draft report template should be developed to demonstrate the data that will be provided and how it will be presented. The project team and senior management should review this template to ensure it will meet their needs as the project progresses or provided feedback on how it needs to be adjusted.
  - If appropriate, selection of a dashboard reporting software may be necessary. The existing systems may already have that capability, but if not using a reporting software system will help consolidate

data and produce the reports, reducing the labor required to produce the reports and the risk of errors. Several such systems are currently in the market and can produce graphical reports that catch the user's attention and typically support callouts to draw attention to key attributes in the graphics.

- **Establish Database and Inputs:** Once the report structure is approved, the project controls team will know exactly what information will be required to support the reporting. While one or more databases will likely already exist, a consolidated database may need to be developed or updated to combine scope, cost, worker hours, productivity, progress, schedule activities, risks, and other data to support the reporting. The source of each piece of data will need to be determined (see Figure 2A). The process for collecting and compiling that data in the database will need to be clearly defined and agreed to by all involved parties. [2] Interfaces may need to be developed to collect the data automatically. It is important to ensure that all the data will be accurate and can be reliably provided per the required timing. Data from contractors should be subject to verification as needed to ensure it is accurate. It is also important to know how all the data is developed and what is included or not included so it can be accurately represented in the reporting.

- **Establish timing and analysis:** The required reporting frequency and timing is typically established early in defining what information needs to be reported. However, the detailed timing for collection, compiling, and analysis of data will still have to be worked out. It is important that reporting has a consistent data date for the cost, progress, and schedule reporting so they are aligned. It is also important to allocate time for the proper analysis of the data to ensure it is accurate, that the performance drivers are identified, and any recommendations or other information is developed. It is important to issue reports as close to the data date as possible to allow the project team to respond to performance issues as quickly as possible.

- **Start Reporting:** Once all these steps are complete, the project controls team can start the data collection and reporting. Typically, during the first few reporting periods, the team will determine certain adjustments are needed in the report format, the data structure, timing, or other elements. They will need to work these out as necessary to best meet the needs of the project.

- **Recycle as Needed:** As the project progresses, the needs of the project may change. The team may need to update the project controls reports at various points during the project to address the evolving needs of the stakeholders. The team should endeavor to modify the reporting structures and underlying data to need to new requirements. The focus early in the project is typically on design but will shift to construction as the project progresses.

These steps are presented in a very simplistic, sequential format, but the reality of most projects is much more complex. Most of these steps will overlap significantly with each other. Some aspects of project controls reporting may be implemented before others. Some gaps between what a stakeholder wants to see and what can be provided may never be reconciled. Some cost, schedule, and other data may never be aligned on periods covered, requiring adjustment of data. These complexities result in inefficiency in the process, but if the steps are followed as best as possible, the resulting project controls report will be a valuable tool to the project team and others, giving them information that they can quickly absorb and act on.

Example Structure

No single template for recommended project controls reporting exists and should not as each project needs a project controls report designed to meet the needs of that project based on how the project is structured. The structure and format of the report may vary by project, but here is a basic structure that will meet the needs of most projects:

- **Executive Summary:** The executive summary could consist of list of the project KPI's with a graphical score or dial for each KPI. Figure 3 shows an example of dials that can be used to quickly inform the user of how the project is performing against that target. The summary should also include a brief description of any major events or issues contributing to the current score. It should be one page in length, no more.

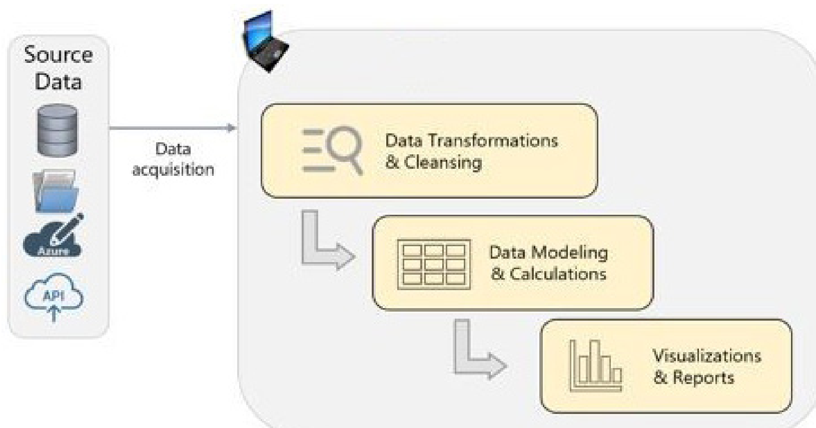


FIGURE 2A Establishing Database Structure

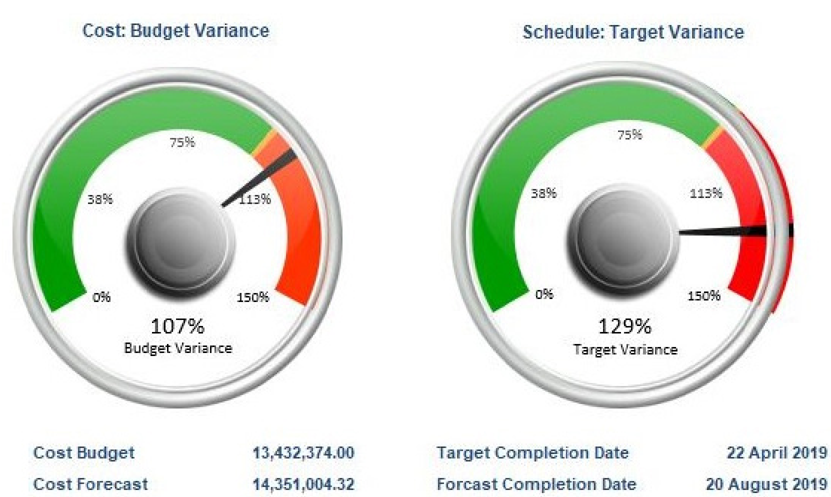


FIGURE 3 Dashboard Dial Examples

- **Primary Reporting:** The main section of the report would typically include key graphics reporting on the various aspects of project controls responding to the needs defined by the stakeholders on the project. It would be primarily graphics with limited text as needed to highlight the key performance issues, define the drivers or causes of the performance issues, and may any identified recommendations. This section may be 2-5 pages in length.
- **Sub-area Reporting:** Some projects need to report on performance by area of the project or by discipline/craft. This secondary level of reporting will either be used by some to understand what is driving the overall performance or by managers responsible for specific portions of the project.
- **Appendix/Back-up Data:** The detailed data and tables that support the graphics, if required, can be included in an appendix or back-up section.

While there is not a standard for what content should be included in a project controls report, there are some common graphics that most reports should include. When these graphics are analyzed as a group, it can typically help what is driving cost and schedule variances.

- **Cost Forecast Tracking:** It is important to understand what the current cost forecast is versus the control budget and to see the trend over time. The same chart can also be used to track cashflow if desired to understand the current forecast for cashflow requirements.
- **Schedule Milestone Tracking:** The visualization of schedule milestones can help identify trends in schedule slippage easier than just using a table of milestones with dates listed.
- **Actual Progress vs Planned:** Actual progress tracking versus planned progress can also help predict schedule slippage as well as an evaluation of the cost forecast. Separation of design progress from construction progress will also support identification of problem areas faster.
- **Resource Tracking:** Tracking of staffing will help identify if resources are being supplied at the levels originally planned or what the variance is. Lower than planned resources may explain progress shortfalls.
- **Productivity Tracking:** Tracking actual productivity, be it either of design or construction, will identify if there are inefficiencies in the work being performed. It is extremely important to understand the drivers of productivity variances to be able to correct any performance issues.
- **Contingency Management:** Tracking the actual usage of contingency versus the original planned usage or rundown will help the project team assess if it has sufficient contingency to address the risks associated with the balance of the project work. If not, additional funds may need to be requested.
- **Risk Management:** Providing an update on the current significant risks facing the project and the associated risk response actions can support the team with reducing threats to the project while maximizing opportunities for improvement.

Conclusion

Too many project controls reports do not provide the value they should on projects. Project teams and other stakeholders do not use the reports in the way they should, to address areas of poor performance or support areas of good performance. They may not be able to understand what the report is saying about the project performance and forecast, get lost in the details and miss the big picture, don't have the time to review the provided details, or it just does not provide the information they need to see.

With proper engagement with stakeholders and other groups involved with the project, a project controls team can implement project controls reporting that will catch the attention of the users, quickly providing them the information they need to know about the project and provide insights on how to improve the performance of the project, potentially leading to better outcomes on the project. It is not an easy or quick process, but the value it will provide to the project team will far outweigh that effort.

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Supporting Estimates with **Effective Scope of Work Definition**

BY **LARRY R. DYSERT, CCP CEP DRMP FAACE HON. LIFE**;
AND **TODD W. PICKETT, CCP CEP FAACE**

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 article 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
- Using a *frozen for estimating* design basis and incorporating late changes
- Presenting the estimate in relation to the level of scope definition

This article expands upon an earlier AACE International article, Scope Development Problems in Estimating [2], incorporating information from AACE International (AACE) recommended practices on estimate classification, as well as from other sources. This article was first presented as EST.3424 at the 2020 AACE International Conference & Expo.

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 article 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, using 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 article, 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.

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 decide 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

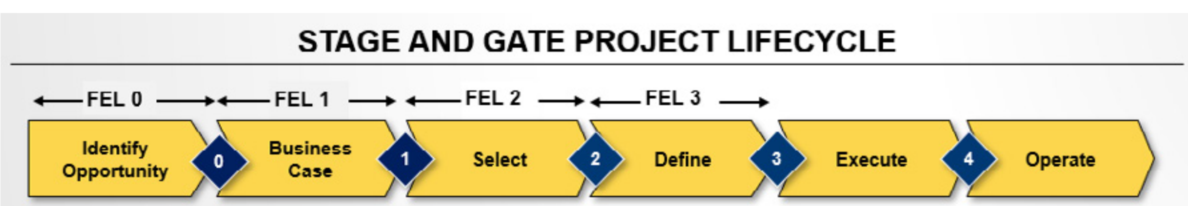

FIGURE 1 Stage-Gate Project Development Process

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 can 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.

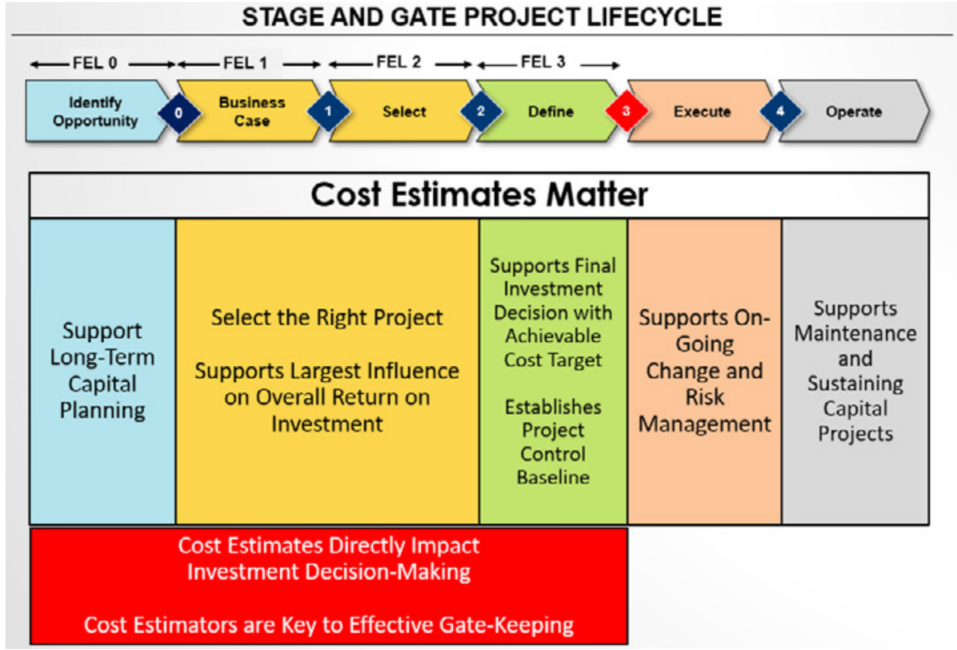

FIGURE 2 Cost Estimates Matter

	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

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.

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*

	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]

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 article 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 <u>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</u>." [Emphasis added]

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 article, *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* like 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 using the more mature and detailed information that becomes available.

Factored or stochastic estimating methods typically use 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 another 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 staffing 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 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 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 article, 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 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.

Use 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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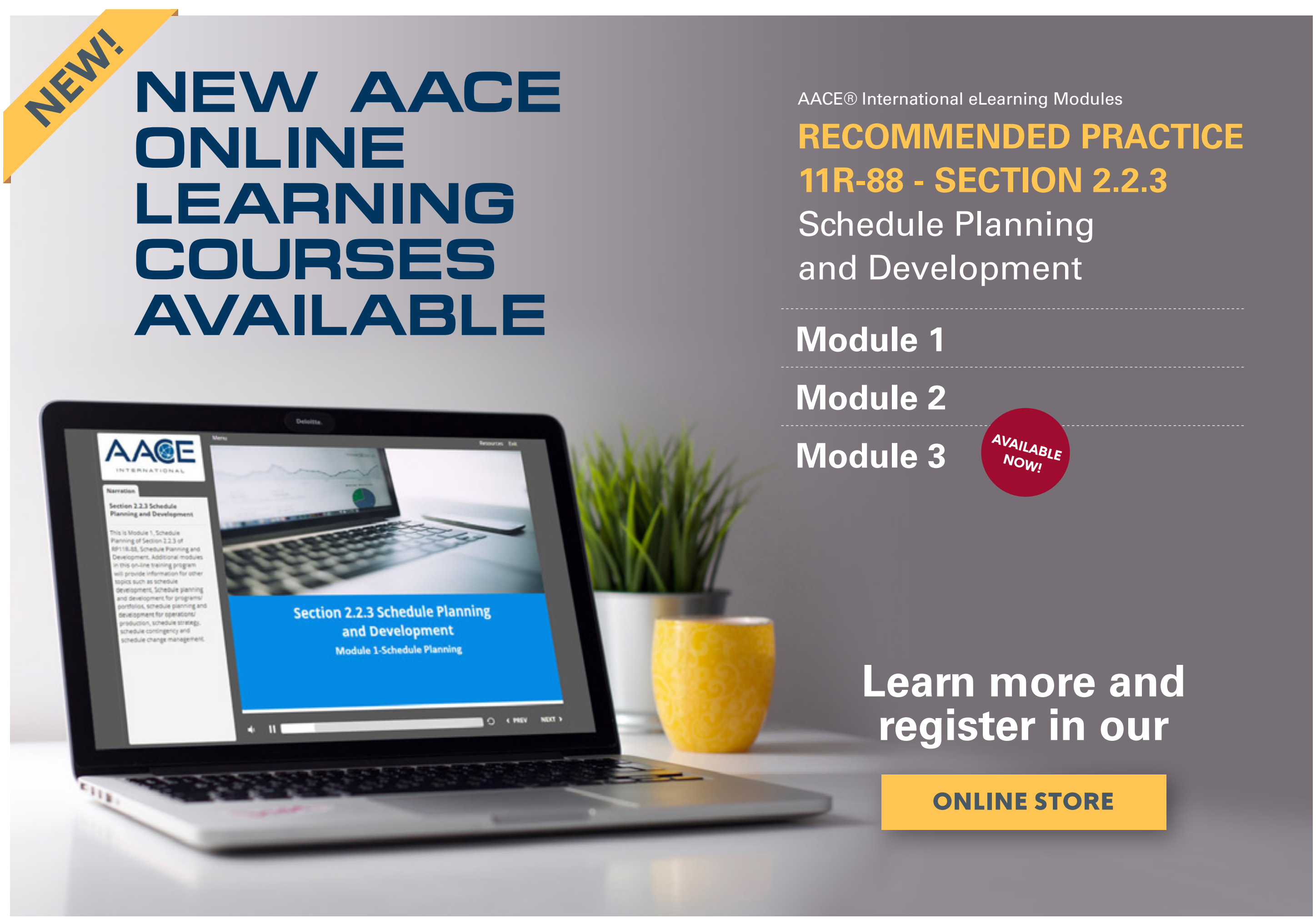

A Discussion of the **Cost Estimate Classification System –**

As Applied in the Engineering, Procurement, Construction and Operations for the Environmental Remediation Industries

BY **DAN MELAMED, CCP EVP; BRYAN SKOKAN, PE CCP; GREGORY MAH-HING, PE; RODNEY LEHMAN**; AND **JAKE LEFMAN**

ABSTRACT

This article will discuss environmental restoration cost classification for projects within a regulatory framework that involves development of formal documentation, public input from external stakeholders, and ultimate approval by a regulatory authority. This regulatory framework has a specific focus towards environmental compliance under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). These United States (U.S.) federal laws are perhaps best understood as a generic framework for environmental remediation that can serve as a proxy for other regulations (at international, national, state, and local levels) through the organization of the necessary steps of an environmental cleanup though six consecutive phases, indicating increasing maturity, described in detail in this article. Also, the reasoning and support for the classification of environmental restoration project cost estimates in relation to their maturity will also be discussed. In addition, the role of risk in environmental remediation projects is discussed. This article was first presented as EST.3542 at the 2020 AACE International Conference and Expo.

Introduction

The cleanup of sites contaminated by human activity is an area of great activity, involving many US federal and private industrial facilities across the country [28] and throughout the world. [12,24] This includes industrial areas such as oil and gas [39], mining [36] in addition to US government activities remediating buried chemical weapons [30], contaminated US Naval facilities, [29] as well as cleaning up the former US nuclear weapons complex [14]. The cleanup of contaminated sites involves removing hazards to human health, safety, or the environment from specific building(s) and/or a parcel(s) of land. This article discusses the guidelines for applying the general principles of estimate classification throughout the phases that constitute the life cycle of environmental restoration project cost estimates.

The authors used these techniques to develop **AACE International Recommended Practice 107R-19:** *Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Environmental Remediation Industries*, that has recently been published [4] and that can be applied across a wide variety of environmental remediation projects. As the specific environmental remediation project scope definition and maturity evolve from preliminary investigations through remedy implementation, operations, and ultimate project completion, – the specific regulatory, engineering and project deliverables are analyzed to determine the cost classification, the application, and the estimate accuracy range. This work is based upon general principles of estimate classification to project cost estimates originally developed as **AACE Recommended Practice (RP) 17R-97:** *Cost Estimate Classification System* [3] which maps the classes of a project's cost estimate with a general project scope definition maturity. This methodology has been applied across a wide variety of industries. [1]

It is important to note that the methodologies outlined in this article are not for listing environmental liabilities that comply with a specific accounting standard (or standards). As an example, a conventional cost estimate produces a typical cost range; if the obligated entity is part of the US federal government or commercial organization, the liability reported in the financial statement is at the low end of the range. [8]

The Regulatory Framework of an Environmental Cleanup Project

In general, cleanup actions in the US operate within the framework of two US federal acts, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conversation and Recovery Act (RCRA) that may be distinguished as follows:

- CERCLA (also known as Superfund) locates, investigates, and cleans up the release of toxic and hazardous substances from soil, groundwater, and facilities.
- RCRA addresses the safe and protective management of wastes generated from currently operating facilities (including various wastes generated by CERCLA cleanups), as well as facilities where hazardous waste is stored.

Since it was established in 1980, CERCLA is the predominant legislation for regulating cleanup. At private sector sites, the US Environmental Protection Agency (EPA) may perform the cleanup with federal funds and seek cost reimbursement from the responsible party while at federal CERCLA sites, the federal party is responsible for cleanup, in coordination with the EPA. However, if the wastes associated with the cleanup site are listed on the RCRA hazardous waste list or if the contaminated facility is a RCRA permitted facility then that legislation applies. Depending upon the individual site history CERCLA sites may contain both RCRA and CERCLA components (e.g., CERCLA documentation may reference RCRA closure documents) that have to be addressed holistically.

In addition to the aforementioned legislative framework, other federal and/or local rules and regulations may apply. The CERCLA Framework also has a mechanism that allows for the incorporation of other regulatory requirements (discussed later in this article).

RCRA and CERCLA provide well understood frameworks for environmental remediation which, due to activities with a wide variety of sites across the country over many decades, reflect extensive experience of environmental cleanup including lessons learned. One definite result of this experience base is that environmental projects need to be tailored for each cleanup site. The nature and extent of contamination (e.g., asbestos, chlorinated hydrocarbons, heavy metals, and/or radioactive materials), the medium of contamination (e.g., a facility, soils, surface and groundwater), as well as the degree of the contamination can vary widely.

The Six Phases of an Environmental Cleanup Project

Environmental projects differ from traditional projects due to a number of factors:

- Almost all environmental projects operate within a legal and/or regulatory compliance framework, with extensive stakeholder involvement which can create schedule delays and work restrictions.
- The extent of contamination at a given site is difficult to define, which directly affects the scope, cost, and schedule of a cleanup project; and
- Challenges in accurately determining the types and concentration of all contaminants at a given site make the choices for effective and efficient cleanup technologies inherently uncertain.

In response to this challenge, the environmental remediation industries community developed a clear consistent structure that will allow for a rigorous analysis of a project's components. This began with the hazardous, toxic, and radioactive waste work breakdown structure [20]. Which was further developed and incorporated by ASTM International, an international standards organization, as: **ASTM Standard 2150,** *Standard Classification for Life-Cycle Environmental Work Elements–Environmental Cost Element Structure*. The environmental cost element structure (ECES) is a comprehensive, hierarchical list of cost elements (tasks, items, or products) that may be required to complete an environmental project. [7, 33] measured through the following phases:

- **Phase 1 - Assessment**–Evaluation and inspection.
- **Phase 2 - Studies**–Characterization, investigation, risk assessment, development and evaluation of remedial options, as well as treatability studies.
- **Phase 3 - Design**–The engineering design and pre-construction activities of remediation alternatives. This includes the evaluation of

remediation alternatives and the selection of the preferred alternative(s) for the cleanup.

- **Phase 4 - Capital Construction**–Construction of remediation alternatives (selected in Phase 3). Includes start-up but excludes all operations.
- **Phase 5 - Operations and Maintenance**–All operations and maintenance activities for the selected treatment or remediation alternatives.
- **Phase 6 - Surveillance and Long-Term Maintenance**–Operations (Phase 5) have ceased. This phase includes post closure surveillance and long-term monitoring.

A general description of the phases required to complete an environmental project is illustrated in Figure 1.

In order to best understand how to analyze the maturity of environmental remediation projects (and therefore accurately determine their cost classifications) it will be beneficial to understand how each environmental project fits within this framework. As discussed earlier, this article's focus is on the two most common regulatory frameworks used to manage environmental cleanups in the US–RCRA and CERCLA. Both follow very similar site closure processes that require contaminated site owners to:

- Assess the extent of environmental contamination and their associated environmental risks,
- Receive public/stakeholder input,
- Submit preferred remediation alternative proposals to regulatory agencies or a magistrate for approval; and
- Upon approval, carry out an executable project(s) to achieve contaminated site closure.

In its most expansive state, an environmental site closure usually involves D&D (deactivation and decommissioning) which usually includes deactivation, decommissioning, decontamination, and demolition of a facility, as well as remediation of the underlying and surrounding land.

Although this article is written through the framework of RCRA and CERCLA, the treatment of two regulatory regimes through the ECES phase system can serve as a general model for the functions of other local (e.g., state and city), as well as international environmental cleanup laws and regulations. This is illustrated in Figures 2 and Figure 3. Figure 2 shows a general CERCLA environmental restoration project related to the environmental cleanup phase, while Figure 3 shows a general RCRA environmental restoration project related to the environmental cleanup phase. This demonstrates how the ECES six phase life-cycle system can be readily applied to two different regulatory frameworks.

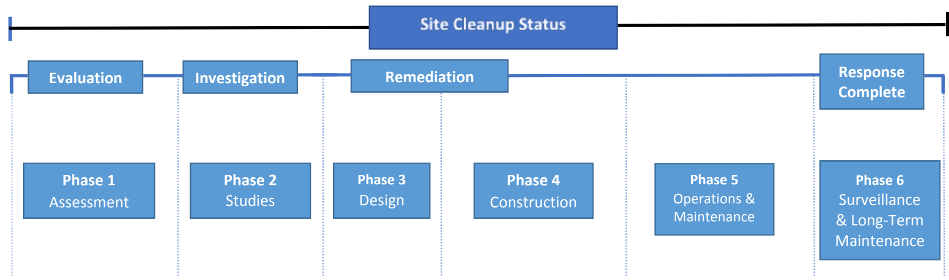

FIGURE 1 The Life Cycle Phases Required to Complete an Environmental Project

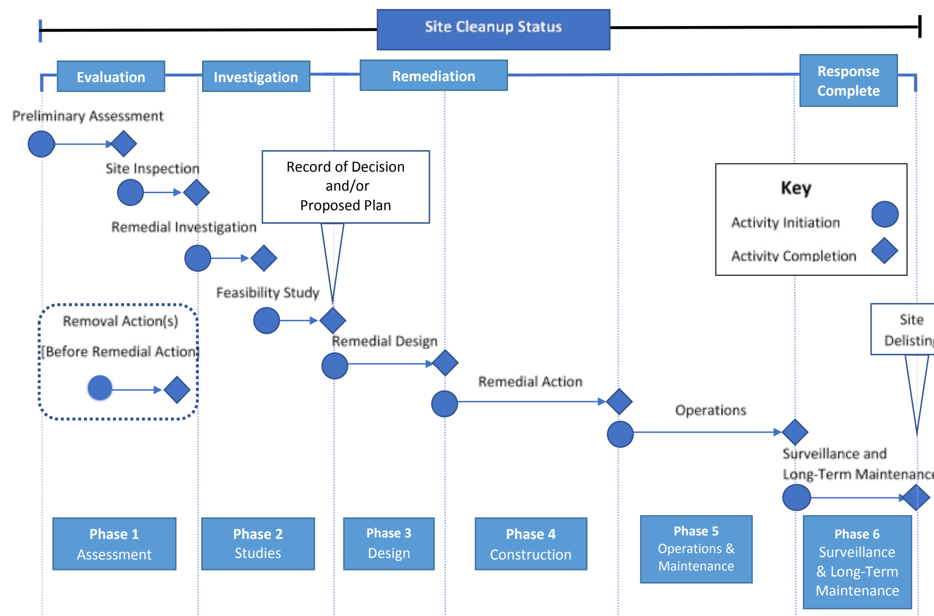

FIGURE 2 The Major Activities of a CERCLA Environmental Restoration Related to its Life Cycle Phases

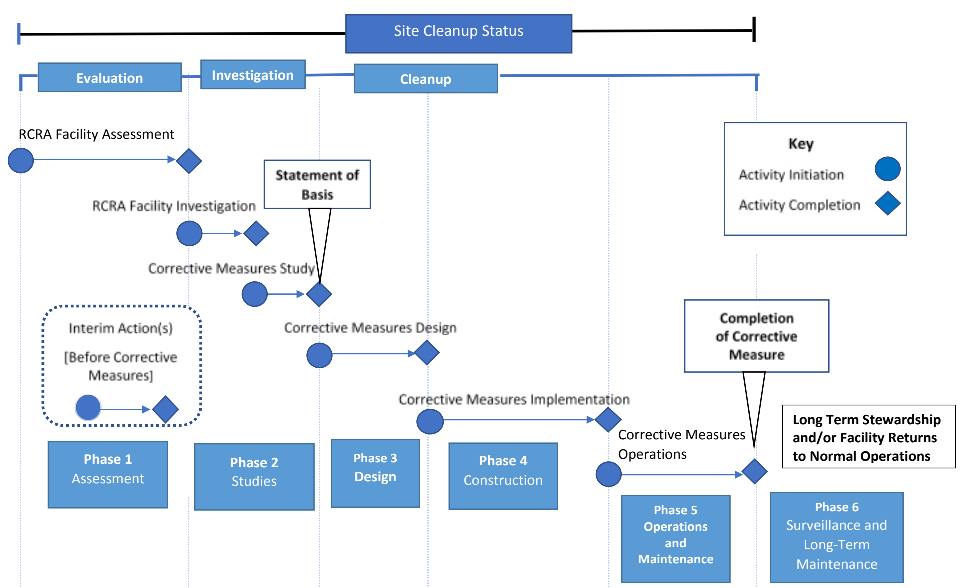

FIGURE 3 The Major Activities of a RCRA Environmental Restoration Related to its Life Cycle Phases

The following sections provide a description of the six phases required for an environmental cleanup for both CERCLA and RCRA frameworks.

PHASE 1: SITE INVESTIGATIONS - ASSESS AND INSPECT SITE, AND PREPARE SITE INSPECTION REPORTS

The first step determines if potential contamination exists on the property due to the possible or actual release of hazardous substances, pollutants or contaminants. In CERCLA, this includes the preliminary assessment (PA) and the site inspection (SI). The PA consists of collecting the available historical property information and conducting a site visit. Once it has been determined that there is a potential contamination release on a property, an SI confirms and supplements information obtained through limited environmental sampling that determines whether the release constitutes a significant risk to human health and the environment.

In RCRA, analogous work to the CERCLA preliminary assessment/site inspection (PA/SI) is performed through RCRA facility assessment (RFA); when information is gathered on releases and a preliminary determination is made about the need for further investigations and interim actions.

PHASE 2: CONDUCT DETAILED SITE INVESTIGATION AND CHARACTERIZATION

This phase includes continued characterization, investigations, development, and analysis of treatment or remediation options where the feasibility of various remedial alternatives is evaluated, as well as risk assessment is performed.

In CERCLA this is managed through the remedial investigation/feasibility study (RI/FS) process where information is gathered and studies conducted in order to provide the analyses needed to select a specific remedy (or remedies) for the site. This ensures that the chosen remedy will meet technical cleanup requirements and satisfy the requirements of the stakeholders.

This process includes gathering and addressing all applicable or relevant and appropriate requirements (ARARs) that apply to this project, and is where many of the other regulatory requirements (such as RCRA, applicable state and/or other local regulations) are incorporated. When reviewing the selection of alternatives, the cost-effectiveness of site remediation needs to be considered while also ensuring reliable protection of human health and the remediation of the environment. [37] The feasibility study also includes a review of alternatives based on how well they satisfy the compliance criteria with respect to their costs, which is an important step of environmental cost estimating. This comparison of alternatives is always done on a life-cycle cost basis. This can be seen through the comparison of two of remedies for buried waste:

1. Contain the contamination and leave it in place; versus
2. The complete removal and disposal of the contamination off-site

Containing the contamination and leaving it in place may have a lower initial cost compared to excavating, characterizing, transporting as well as disposing of the waste. However, this remedy requires an engineered cap to prevent migration in addition to continued monitoring of groundwater for an indefinite period to detect any migration of contamination or changes in contaminant concentrations. Therefore, life-cycle costing is the best way to accurately compare these cleanup alternatives.

The RI/FS is followed by the proposed plan for implementing the preferred alternative. The public is then offered the opportunity to comment on the proposed plan prior to a final decision. The record of decision (ROD), approved by the appropriate regulatory authority, is the final step in the remedial alternative selection process.

In the RCRA corrective action process, the nature and extent of contamination is evaluated through a RCRA facility investigation (RFI), which is followed by a corrective measures study (CMS). The RFI/CMS is analogous to the RI/FS process under CERCLA.

The Decision Document

In CERCLA: Following the public comment period (initiated during the proposed plan) a proposed remedy is considered prior to developing the final cleanup technology (or technologies). The final remedy is required to be selected from a variety of technologies that are protective and address all ARARs. Compliant alternatives are evaluated based on:

1. Long-term effectiveness and permanence;
2. Reduction of toxicity, mobility, or volume through treatment;
3. Short-term effectiveness;
4. Ability to implement; and
5. Cost.

RCRA requirements (as well as other relevant requirements) are often part of the ARARs allowing for the integration of the two regulatory frameworks.

The selected remedy is then summarized in the record of decision (ROD). The ROD documents all facts, analyses, and site-specific policy determinations considered in the course of selecting a remedial action. The ROD defines:

- Applicable federal and state requirements relevant and appropriate to the site.
- How the remedy is a cost-effective treatment that permanently and significantly reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants.

Details concerning the role of cost in the remedy selection process are established in existing law, regulation, and policy with regard to CERCLA) [36, 37].

In RCRA the analogous decision document to a ROD is the statement of basis or the permit modification.

Special Case: Removal Action

In CERCLA, after the site is characterized there are often needs for short-term actions to stop, avoid, minimize, stabilize, alleviate, or eliminate a release of contaminants. These are removal actions (known in RCRA as an interim measure [5]).

There are three types of removal actions:

1. Emergency, that respond to acute problems
2. Time-critical, that require onsite action within six months; and,
3. Non-time critical (NTC) that respond to releases where the need is less immediate

Effective use of removal actions for cleanups when the remedy is straightforward and does not require expensive and lengthy study can result in significant savings to the cost and schedule for cleanup projects [18]. Although removal actions are typically intended to reduce risk on short term timeframe; they can also provide complete permanent solution to a cleanup [36]. In particular, NTC removal actions provide an important method of moving sites more quickly through the Superfund process and are generally favored by stakeholders. This was formalized when the EPA and US Department of Energy (DOE) issued the 1995 Decommissioning Policy –endorsing the use of the NTC removal action process for decommissioning its surplus facilities. [23] Removal actions can occur any time throughout the Phase 1 or Phase 2 of the environmental cleanup process, as well as provide valuable information that can inform decisions affecting the overall site remediation.

In the case of removal actions, the engineering evaluation/cost analysis (EE/CA) is the analogous document to the RI/FS (discussed above), but it is less comprehensive. The EE/CA process is used by response personnel to develop, evaluate, and select a removal action. The goals of the EE/CA are:

1. Satisfy requirements for the review of NTC removal actions;
2. Satisfy requirements for administrative record for improved documentation of removal action selection; and
3. Provide a means for evaluating and selecting alternative technologies.

The EE/CA identifies the objectives of the removal action and provides a comparative analysis of removal action options for a Superfund hazardous waste site. This document serves as a record of the analytical process required for all non-time-critical removal actions. [19]

Another important advantage of using removal actions is that they can be approved at the owner-level (but only after circulation and presentation to the stakeholders and regulators who also comment on the related EE/CA documentation). This shortened process can save significant amounts of time and money.

PHASE 3: REMEDIAL DESIGN—ENGINEERING DESIGN AND PRE-CONSTRUCTION ACTIVITIES FOR TREATMENT OR REMEDIATION OF THE SELECTED ALTERNATIVE

The remedial design phase is used to develop detailed engineering documents for the selected remedy. Continuation of the characterization, modeling, analysis, and treatability studies to help refine the remedial design may also be a part of this phase.

In CERCLA remediation, the remedial action (RA) phase implements the selected remedy method. The RA undertaken is the one specified in the ROD or in the case of NTC removal actions the alternative proposed in the EE/CA.

In RCRA the selected measures are then implemented as the corrective measures design as part of the corrective measures implementation. [5]

PHASE 4: REMEDIAL ACTION – INITIATE SELECTED TREATMENT OR REMEDIATION ALTERNATIVES (INCLUDING CONSTRUCTION)

This phase includes start-up but excludes operations and maintenance. In CERCLA remediation, the remedial action (RA) phase implements the selected remedy method. The RA undertaken is the one specified in the ROD or in the case of interim actions the alternative proposed in the EE/CA.

In RCRA: The analogous situation is the corrective measures implementation phase.

PHASE 5: OPERATIONS AND MAINTENANCE (O&M)

This phase which uses the same terminology for both RCRA and CERCLA, includes all operations and maintenance for the selected treatment or remediation alternatives. It occurs in those cleanups where operations are required such as groundwater pumping and treatment. This phase ends when clean up or waste treatment goals are met.

Activities for this phase vary widely depending on the nature of contamination at the site, as well as the selected remedy. Some remediation technologies do not require an operations phase. An example would be a soil excavation or D&D building demolition project that are completed at the "construction" phase. Also, for CERCLA sites, there is a prescribed 5-year review required for those sites where hazardous substances, at a significant level, remain on site and are usually performed after completion of a CERCLA response action and may continue into Phase 6. These 5-year reviews assess the following. [16]:

- Is the remedy functioning as intended?
- Are the exposure assumptions, toxicity data, cleanup levels and remedial action objectives still valid?
- Has any other information come to light that could call into question the protectiveness of the remedy?

It is important to note that the findings of 5-year reviews may result in requirements to perform follow-up actions needed to ensure the effective management of the remedy. This may result in additional work that must be included in a revised cost estimate. [11]

PHASE 6: SURVEILLANCE AND LONG-TERM MAINTENANCE (SLTM)

This phase, sometimes referred to as long term stewardship, is required once cleanup operations activities are completed or are no longer integral to the selected treatment. This involves long term site security and maintenance of installed protective measures, such as installed caps over buried waste sites as well as institutional controls (IC). Institutional controls are administrative and legal tools that do not involve construction which protect of human health and the environment at a site [22]. This includes long term site security and maintenance of installed protective measures such as annual inspection and maintenance of installed caps over buried waste sites, long term operations of treatment facilities, long term monitoring of sites, fencing, public communications, institutional (land use) controls and other installed environmental protective systems. For CERCLA sites, the prescribed 5-year review work, which may have initiated in Phase 5 (see above), is included as a part of Phase 6 long term surveillance and monitoring.

Measuring the Maturity of an Environmental Project

COMPLETED ENGINEERING AND TECHNICAL DELIVERABLES

Project maturity is measured by completion or the extent and types of input information available that include project scope definition, requirements documents, specifications, project plans, drawings, calculations, learnings from past projects, and other information that must be completed to define the project. The set of deliverables becomes more definitive and complete as the degree of project definition progresses and matures. A recent article provided a detailed discussion of the relationship of the status of the input data used for design, planning, and execution deliverables to the maturity of a project. [35]

Table 1 illustrates the six phases associated with environmental remediation projects (along with a brief description of work at each phase) and the documents typically produced for RCRA and CERCLA. This includes remediation of soil, groundwater, contaminated buildings, and structures. The completion of these (and related products) is key to the determination of project maturity.

It is important to note that, by definition, environmental restoration projects may require a combination of capital and operations activities. For those organizations where the funding/accounting source(s) for remediation work is differentiated, the project funding sources may contain both capital project expenditures (Capex), as well as corresponding operational project expenditures (Opex). [6, 17]

The documents listed in Table 1 (required deliverables for an environmental cleanup) are only a part of those required to gauge a project's maturity. In addition, there are documents that are required deliverables for general project management. Examples of these documents are:

- Project Scope Description;
- Project Master Schedule; and
- Work Breakdown Structure.

Many of the deliverables listed in Table 1, as well as the deliverables for general project management, are listed in the **Department of Energy Guide 413.3-8**, *"Environmental Management Cleanup Projects."* This guide was created to provide project management guidance for environmental cleanup projects across the DOE complex. [15] Although this guide was cancelled in 2008 and is no longer in active use, the specific CERCLA and RCRA framework has not changed. This guide still contains a great deal of currently useable information. In particular, it identifies the documents required for each phase of environmental remediation that can still be considered a resource for information on managing environmental projects.

General Phases in the Environmental Cleanup Process and a description		CERCLA Documentation	RCRA Documentation
Phase 1	Conduct site surveys and investigations: • Assess conditions and identify contaminated areas that may require remedial actions	• Preliminary assessment/site inspection (PA/SI) report	• RCRA facility assessment (RFA) report
Phase 2	In depth investigations as well as development and selection of remedial alternatives: • Alternative analysis • Selection of preferred alternative • Summary schedule • Life cycle cost estimate ranges of alternatives • Identify the preferred alternative	• Remedial investigation (RI) report • Feasibility study (FS) report, including estimates associated with screening and detailed analysis of the alternatives • FS: treatability studies **Remedy Selection:** • Proposed plan • Draft record of decision	• RCRA facility investigation (RFI) report • Corrective measures study (CMS) report **Remedy Selection:** • Corrective action plan
Phase 3	• Detailed design, plans and specifications for the selected remedy • Detailed implementation plans for selected alternative • Detailed schedule	• Final record of decision (ROD) • Remedial design • Remedial action implementation plan • Waste management plan • Cost estimates and detailed schedules	• Final RCRA permit modification • RCRA corrective measure implementation plan • Associated detailed schedule and cost estimates
Phase 4	• Physical construction activities • Implementation of actual cleanup	• Execution of the remedial design – installation of equipment, excavation, etc. • Detailed execution schedules and cost estimates	• Corrective measures implementation • Detailed execution schedules and cost estimates
Phase 5	• Operations and maintenance (if any) associated with the cleanup • Decontamination and Decommissioning of facilities dedicated to the cleanup • The site is removed from the National Priority List	• Operations and maintenance plan and Manual (if needed) • Operations and maintenance (if any) reports associated with the remedial action e.g. operation of a pump and treat facility • CERCLA 5-year review report	• Operations and maintenance plan and Manual (if needed) • Operations and maintenance (if any) reports associated with the corrective measure
Phase 6	• Routine monitoring • Enforcing any long-term site restrictions	• Site surveillance and/or maintenance reports • CERCLA 5-year review report	• Site surveillance and/or maintenance reports

TABLE 1 Phases of Environmental Cleanup Relating to Specific Environmental Regulatory Framework, as Well as Required Documentation for Both RCRA and CERCLA [5, 13, 15,19]

A PROJECT DEFINITION RATING SYSTEM

Another method in documenting the maturity level of project definition is to establish a project definition rating system (PDRI). This type of tool measures the completeness of project scope definition through a checklist of scope definition elements and criteria, using a scoring rubric to measure maturity or completeness for each element. The higher the project definition rating score the better the probability of achieving project success. An example of a commonly used PDRI is one developed by the Construction Industries Institute (CII). [13] Although the project definition rating measures overall maturity across a broad set of project definition elements, it usually does not ensure completeness of the key project definition deliverables required to meet a specific class of estimate. For example, a good project definition rating can be achieved by progressing on certain project definition deliverables, but without completing that deliverable. Therefore, this tool should be used in conjunction with the AACE estimate classification system not as a replacement of the AACE estimate classification.

The DOE has developed a tool that is similar to the CII PDRI for environmental projects that measures their progress toward phase completions or decision points. This environmental PDRI tool has been periodically updated and revised and is now called the project critical decision assessment tool (CDAT) [38]. The authors believe that the CDAT can be tailored for general environmental projects (outside of DOE) with minor modifications to accommodate their specific requirements.

Cost and Risk of Environmental Projects as a Function of Maturity

Once the maturity of the deliverables for an environmental project has been determined, the classification range of the estimated cost can be established. Cost ranges for the various classes are summarized in Table 2. This table lists the five cost estimate classes related to the following factors:

	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%	(Phase 1) Early investigations and preliminary planning; preliminary assessment/site inspection (PA/SI); RCRA facility assessment (RFA) report and federal facility compliance agreement.	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +175%
Class 4	1% to 15%	(Phase 1 and/or 2) In depth investigations, evaluation of remedial alternatives and remedy selection; remedial investigation/feasibility study (RI/FS) facility investigation (RFI) and corrective measures study (CMS)	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	(Phase 2 and/or 3) Preliminary planning and design of selected remedy; record of decision; preliminary remedial design Initial estimates for O&M and LTM	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +45%
Class 2	30% to 75%	(Phase 3, 4, 5 and/or 6) Intermediate Remedial Design Refined estimates for O&M and LTM. Final remedial action/remedial action implementation plan (RA/RAIP); corrective measure implementation plan (CMP); construction and remedial action	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	(Phase 4, 5 and/or 6) Pre-Final/Final Remedial Design Detailed/remedial action, operations and maintenance and long-term monitoring plans and detailed cost estimates	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

TABLE 2 Cost Estimate Classification Matrix for the Environmental Remediation Industries [4]

- **The Maturity Level of Project Definition:** As discussed in the previous section, this parameter describes the completion (in percentage) of the project definition deliverables.
- **End Usage:** Identify the purpose of the estimate including a description of what the estimate should deliver for this phase. In this article (as in RP107R-19) these applications are specified for the environmental remediation industry.
- **The Methodology:** Identify the method(s) used to estimate the cost.
- **Expected Accuracy Range:** The degree to which the final cost outcome of a project varies from the single point value estimated.

A more detailed description of the specific information for each cost class is provided after Table 2. The following information is supported whenever possible in the available referenced literature.

CLASS 5

This cost class is at the beginning of an environmental project. As described in the other cost classification RPs, the end use for projects in this class is for feasibility studies [1, 3, 35, 38]. In the environmental remediation industry, the end use is described in Phase 1 where the initial characterization determines whether the possible or actual release of hazardous substances, pollutants, or contaminants on the property results in potential contamination.

The initial cost estimate range listed in the table is based upon studies of completed hazardous waste sites. This resulted in a cost range between +175% to -50%. [9, 21, 32] Compared to most other cost estimate classification systems [1] for other industries the class 5 for the environmental remediation industry is unique insofar that there are greater uncertainties. [25,34,39] Therefore, the range of estimates within this AACE cost class is not unexpected when compared to those of other projects.

CLASS 4

After it is determined that an environmental project is necessary there is a need for initial planning and further characterization. For RP-17R-19 (as well most of the other cost classification RPs) the end use for this class is developing estimates for each of the alternatives in order to select the preferred project options. [35, 38] In the environmental remediation industry, the end use is very similar, as described in Phase 2, where the feasibility of various remedial alternatives as well as the risk assessment for each of the alternatives is evaluated.

As is the case with Class 5, the initial cost estimate range listed for Class 4 is also based upon studies of completed hazardous waste sites. Accounting for the increased project maturity, the resultant in a cost range is between 50% to -30%. [9, 21, 32]

CLASS 3

As an environmental project matures further, the remediation approach is selected and the design develops to the "conceptual" stage. At this point, sufficient information about initial construction of the selected remediation remedy is available to support an AACE Class 3 estimate. For RP-17R-19 (as well as most of the other cost classification RP's), the end use for this estimate class is for obtaining project funding and developing project baseline cost/schedule controls used during its execution phase. [38] In the environmental remediation industry, the end use is as described in Phase 3 and 4 where the technology (or technologies) for the remediation have been selected, followed by preliminary designs and planned life-cycle estimates for operations and long-term stewardship phases.

In an earlier historical cost analysis of completed environmental remediation projects, over 66 percent of projects at this phase (with a completed ROD) had a baseline cost range between 125% above and 25% below their baseline estimate. [32]

A more moderate cost range for this class of estimates is supported by more recent detailed case studies of two site cleanups:

- Rocky Flats Environmental Technology Site (RFETS) and
- The East Tennessee Technology Park (ETTP) Three Building Project

Case Study 1
Rocky Flats Environmental Technology Site (RFETS) [27]
The Rocky Flats Site played a key role in the production of nuclear weapons, by refining and machining special nuclear material, plutonium and enriched uranium. These activities left behind a legacy of contaminated buildings, soils, and groundwater.

A direct comparison of the baseline estimates with actual costs through closure resulted in a range of costs for the projects that comprise the RFETS cleanup program with a range between 20% greater than the baseline cost to 46.8% less than the baseline cost.

Case Study 2
The East Tennessee Technology Park (ETTP) Three Building Project [10]
Three buildings, K-33, K-31, and K-29, were constructed in the early 1950's. at the ETTP in Oak Ridge, Tennessee, that produced low enriched uranium to fuel nuclear power plants. In December 1987, the three buildings were permanently shut down. These three buildings were part of a non-time-critical removal action under CERCLA. [23, 31]

The accuracy of the EE/CA (baseline) cost estimate of $253 million, when compared to the actual project cost of $356 million yields a 40.7% difference greater than the baseline.

Also significant is that there were lessons learned from these projects that served the remaining ETTP cleanup effort. Most significantly, the EE/CA estimated significant cost savings due to recycling that could not be realized due to the moratorium on recycling across the DOE Complex. [26]

CLASS 2

As an environmental project continues to mature, the remedial design is nearing completion. At this phase, enough design is completed and site information is known to permit the preparation of an AACE Class 2 estimate. This includes estimates for the construction of the remediation technology, as well as operations and maintenance (if applicable). As with RP 17R-97 and other cost classification RPs, the end use for this estimate is continued cost/schedule controls providing the project team with information to make well informed project decisions. [34]. In the environmental remediation industry, the end use is similar, as described in Phases 4 and 5, where cost/schedule controls are used to monitor the project as construction is completed and operations (as needed) begins.

As is the case with Class 3, the initial cost estimate range listed is based upon studies of completed hazardous waste sites, resulting in a cost range accuracy between +20% to -15%. [9,21, 32]

CLASS 1

As an environmental project continues to mature, final remedial design is completed, and confidence in the level of knowledge of scope, site conditions, and the technology is high. At the end of the remedial design phase the required "construction-ready" estimate is based on highly detailed design and site knowledge and it will generally qualify as an AACE Class 1 (or possibly class 2 estimate classification - if there is remaining uncertainty in certain project aspects).

Similarly, when the remedial action phase is completed, and if operations will be involved, all of the necessary equipment is installed and operating supplies are made available, the estimator will have sufficient detailed knowledge to prepare an AACE Class 1 (or 2) estimate for the next phase, which is operations.

The end use for the Class 1 estimate is the final comparison of the original project goals and objectives to actual results [38]:

- As construction is completed the Class 1 estimate for operations (as needed) can be prepared; and
- As the environmental remediation completes the Class 1 estimate for long term stewardship can be prepared.

As is the case with Class 2, the initial cost estimate range listed is based upon studies of completed hazardous waste sites. This resulted in a cost range between 15% to -10%. [9, 21, 32] Although long term monitoring cost can be estimated with high accuracy at the end of phase 4, the specific number of years required to support cleanup is highly variable and difficult to predict. Therefore, although the annual costs may be estimated precisely it is difficult to do the same for the life cycle of a specific project. It is important to note that the costs for many SLTM activities are relatively low cost (e.g., the cost to conduct a five-year review have recently been reported to range from $30,000 to $150,000). [22] Therefore, variation in the number of five-year reviews has a minimal effect on the life cycle cost of most specific project.

As a general observation, it is acknowledged that the cost estimates listed here are somewhat limited. The quality of the cost data listed in Table 2 will improve over time with more extensive analyses of a greater number of cost estimates compared with the actual costs of those completed projects.

The summary of the relationship between the cost classes is illustrated in Figure 4 and Figure 5. Figure 4 shows CERCLA environmental restoration phases related to the environmental cleanup phase, as well as their cost classification. Figure 5 shows RCRA environmental restoration phases related to the environmental cleanup phase, as well as their cost classification. These illustrations show the connection between the activities required to perform an environmental cleanup as the project matures across each phase. In addition, as the project matures so does the cost classification.

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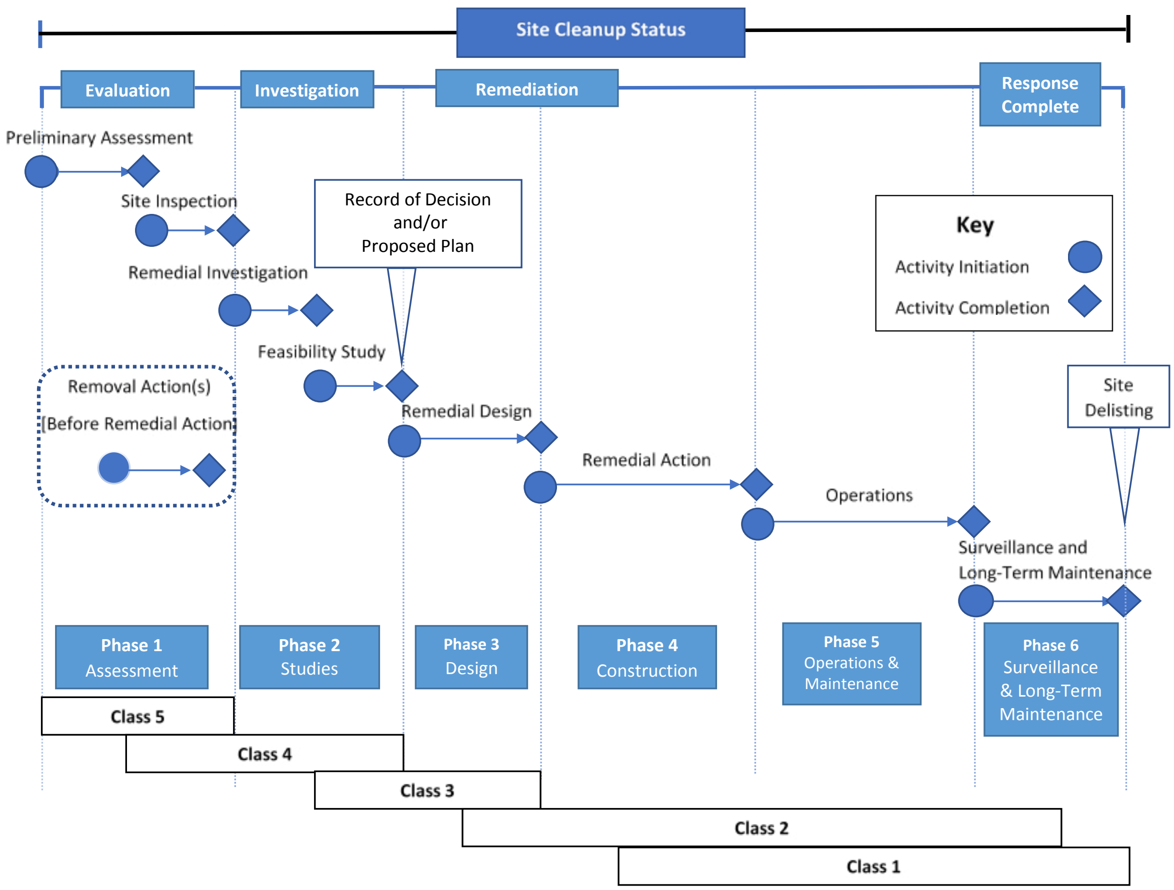

FIGURE 4 The Major Activities of a CERCLA Environmental Restoration Related to Its Life Cycle Phases and to Their Cost Classification

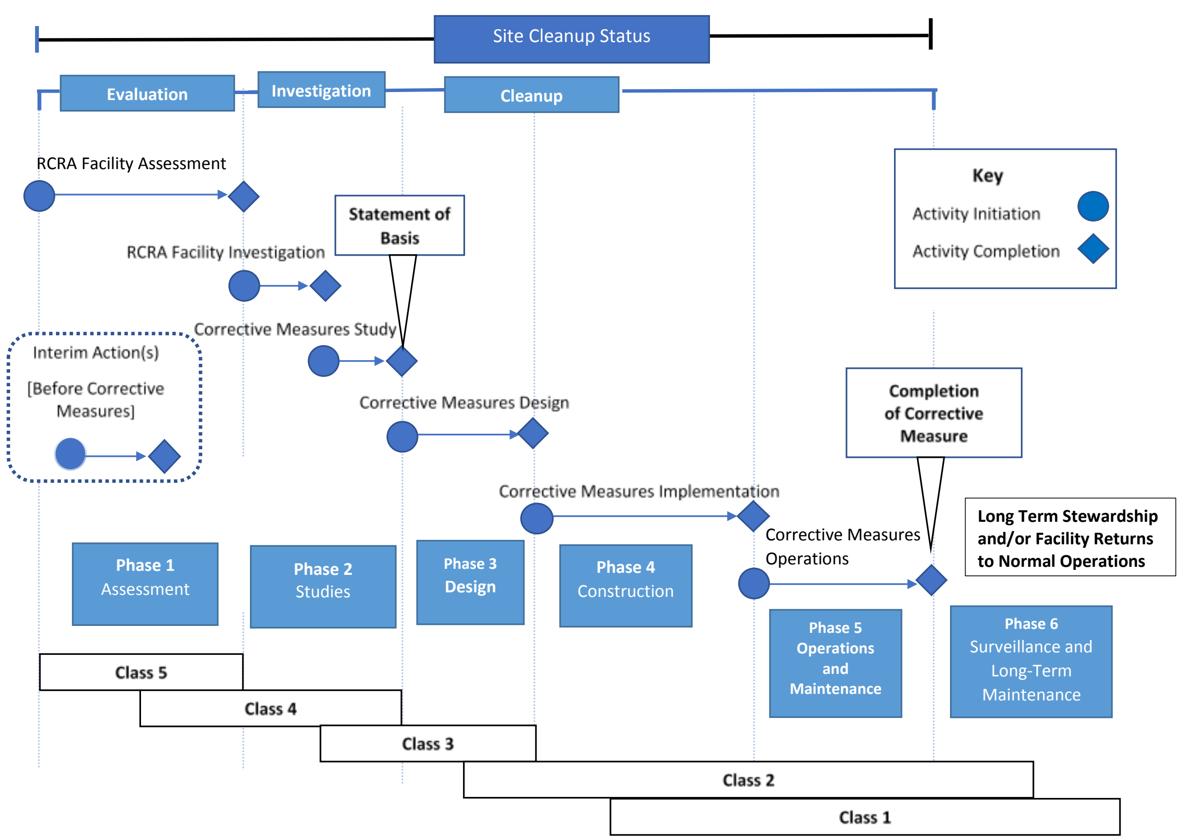

FIGURE 5 The Major Activities of a RCRA Environmental Restoration Related to Its Life Cycle Phases and to Their Cost Classification

RISK AND ITS ROLE IN THE COST ESTIMATE

Table 2 illustrates typical accuracy ranges that are associated with environmental remediation industries. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically to achieve a 50% probability of project overrun versus underrun) for given scope.

The accuracy range for any particular estimate is expected to fall into the ranges identified in Table 2 - depending on the technical and project deliverables (and other variables), as well as the risks associated with each estimate. The inclusion of project-specific risks can result in far wider ranges. However, this does not preclude a specific actual project result from falling outside of the indicated range of ranges identified in Table 2. This is because environmental remediation projects are known for a high level of uncertainty due in part to the limitations of site characterization and cleanup technology effectiveness in different situations. [34] In addition, these projects are under the scrutiny of a wide variety of stakeholders, including state and federal regulatory agencies, the environmental consultant, the construction manager (if needed), and the local citizen action groups that review and approve the activities and oversee the work. This results in either delays in the approval of the submittals or work restrictions at the site. [26, 36]

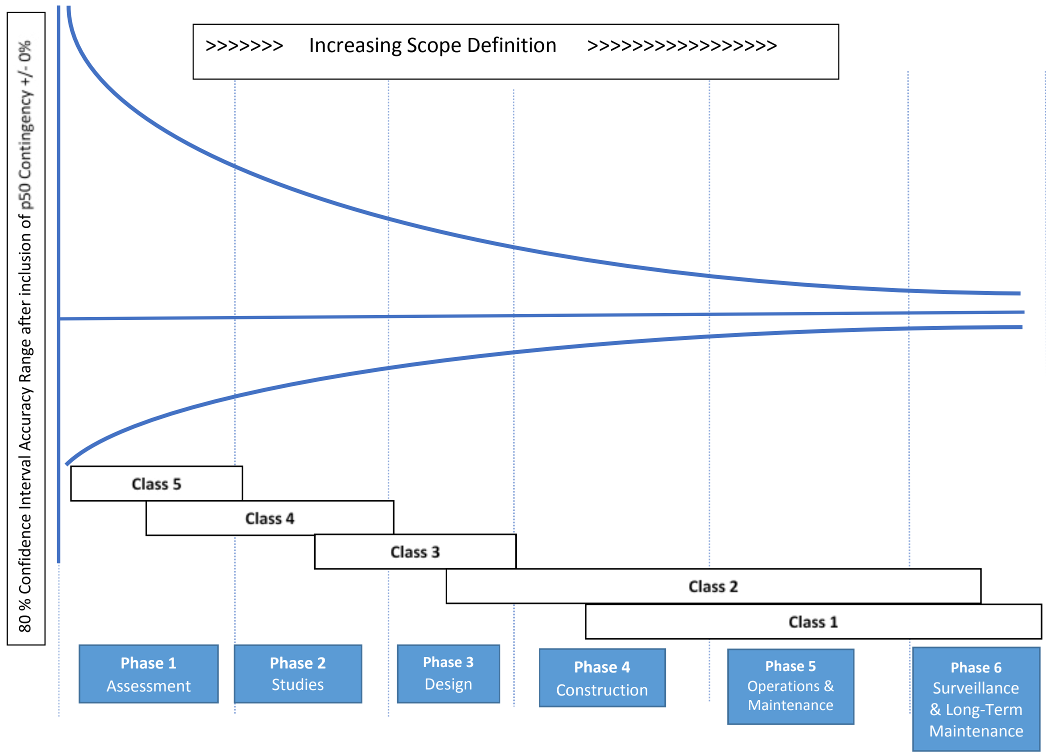

FIGURE 6 The Variability in Accuracy Ranges for Environmental Remediation Industry Estimates in Relation to Increasing Project Maturity, Across the Six Phases of An Environmental Cleanup Project

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

- Estimator's level of non-familiar technology in the project.
- General complexity of the environmental project.
- Quality of reference cost estimating data.
- Quality of assumptions used in preparing the estimate.
- Estimating techniques employed.
- Time and effort budgeted to prepare the estimate.
- Unique/remote nature of project location(s) and the lack of reference data for these locations.
- Limitations in site characterization technology.
- Heterogeneity and wide variability in subsurface conditions (e.g., hydraulic conductivity).
- Extent of regulatory engagement.
- Accuracy of records concerning site process history.

The systemic risks (listed above) are often the primary driver of accuracy, especially during the early stages of project definition. It should be noted that many of these systemic risks can and should be adjusted to reflect the specific qualities of the projects and programs at a given cleanup site. As project definition progresses, project-specific risks (e.g., risk events and conditions) become more prevalent and drive the accuracy range.

As a project progresses and matures the estimate accuracy increases. This is illustrated in Figure 6 that shows a general (non-representative) relationship trend between estimate accuracy and the estimate classes (corresponding with the maturity level of project definition). This figure also shows that the estimating accuracy ranges overlap with the estimate classes that are unique for a specific project. For example, if the Class 5 estimate of a project is a repeat project with parallel scope (i.e., very similar to an existing completed project) good cost history and performance data can be comparable to the Class 3 estimate for another unique project which lacks the previous project's advantageous cost history but is reliant on a new technology.

Table 2 indicates the typical ranges of accuracy values for each class of estimate. However, as shown in the End Usage column, the specific phase associated with that class estimate can apply to a variety of phases for the environmental cleanup. This allows for consideration of the specific circumstances inherent in a project in an industry sector to provide realistic estimate class accuracy range percentages. While a target range may be expected for 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. [2]

If contingency has been addressed appropriately approximately 80% of projects should fall within the ranges shown in Figure 4. However, this does not preclude a specific actual project result from falling inside or outside of the indicated accuracy ranges identified in Table 2.

Lastly, cost estimates for the O&M and SLTM stages are initially and importantly defined during the feasibility study and refined sequentially during the Remediation Design (RD) phase. Typically, cost estimates for O&M and monitoring at the Pre-Final or Final RD stages are Class 3 or Class 2. During the remedial action construction phase, the contractor finalizes the O&M plan/manual and then updates the O&M estimate (typically to a more accurate Class 2 or Class 1 estimate).

Conclusion

This article provides a clear description of the environmental cleanup projects within the CERCLA and RCRA framework. Both environmental cleanup processes are described using the environmental cost element structure (ECES) using a six-phase system that provided a general description of the requisite steps for an environmental remediation project framework.

The authors have outlined the general process of determining the maturity of an environmental cleanup project. In addition, we have provided the cost ranges for these projects as a function of its project maturity that is also related through the ECES six phase system.

Lastly, the role of risk in the cost and schedule for environmental remediation projects has been provided.

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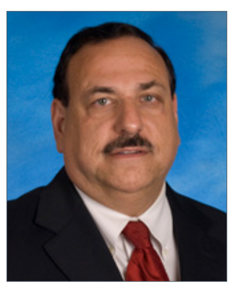

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