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U.S. Army Corps of Engineers
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USACE Recommended Best Practices

Cost & Schedule Risk Analysis (CSRA)

March 2024

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1. Purpose

Cost and Schedule Risk Analysis (CSRA) requirements within the U.S. Army Corps of Engineers (USACE) originated with the Water Resources Development Act (WRDA) of 2007, Section 203 Planning, which requires risk analyses (RA) of water resource projects during the planning phase. This document provides the recommended processes for performing acceptable RA that meet USACE regulation requirements and represents the lessons learned and best practices developed since 2006. The process was developed to be scalable and adaptable for all construction projects within the Department of Defense (DoD) and associated business lines.

The WRDA 2007 requirement does not specify estimated project cost value, implying all must receive an RA. USACE Headquarters (HQUSACE) mandates the RA requirements to address the WRDA 2007 and enforce improvements in identifying the cost and schedule risks and resulting contingencies that are used within the calculation of the Total Project Cost (TPC). These requirements are also emphasized within the USACE cost community under Engineer Regulation (ER) 1110-1-1300, Cost Engineering Policy and General Requirements and ER 1110-2-1302, Civil Works Cost Engineering, which require risk-based contingencies. The use of this process in Civil Works has resulted in a significant reduction in requests for additional funding and maximum project cost exceedance requests to Congress. The process, as developed, is applicable to all projects and it has been utilized successfully on Military and Civil Works, as well as in the Support For Others program, on numerous projects.

For Military Construction (MILCON), the CSRA process is a tool that supports the risk management process and is a key portion of a risk-management strategy. The CSRA process, results, and report are not meant to serve as the risk-management process and should not be mistaken as the process or the risk-management plan (RMP). During the course of project execution, the prudent Project Manager (PM) may choose to monitor and update the CSRA as the project evolves and risks change, regardless of the mandated requirements. Annual updates of larger projects should include design, acquisition, and construction phases.

Many informational sources are available and recommended for the PM and the Project Delivery Team (PDT). Among these sources is the Project Management Body of Knowledge (PMBoK) published by the Project Management Institute (PMI).

Key products of the CSRA process identify date of development, PDT members, risk register, respective contingencies, and a risk report. Major categories to be studied include funding availability, potential project scope change, acquisition strategy, design and construction elements, quantity confidence, special fabrications or equipment, cost estimate assumptions, and external project and public risks.

2. Applicability

This guidance is mandatory for both Civil Works and MILCON projects and applies to all HQUSACE decision documents prepared for receipt of Congressional authorization and/or appropriations. For Civil Works projects, a CSRA process distinction is made between projects where TPC is less than $40 million (M) and those where TPC is more than $40M. It also applies to any funding document prepared where HQUSACE, Division offices, or upper management has made a request for a CSRA to support the project. For MILCON projects, the CSRA process will be required on all projects by fiscal year (FY) 2024. For all other projects and/or business lines this is recommend best practice.

2.1. Civil Works

For Civil Works Projects with a TPC less than $40M, the abbreviated risk analysis (ARA) method may be used. Since these smaller projects can be successfully completed in a shorter timeframe, schedule risks are considered low and typically are not addressed. It is generally not recommended for use other than in the Civil Works Program, as the experience curves utilized are based on that specific business line.

For Civil Works Projects with a TPC greater than $40M, the Monte Carlo process is required using Oracle Crystal Ball software, a plug-in to Microsoft (MS) Excel. This process addresses cost and schedule risks because of the larger costs and longer durations.

2.2. MILCON

For MILCON projects authorized in FY24 and later, a formal CSRA is required.

Refer to the “New Military Construction Budget Estimate Requirements” memorandum from the Under Secretary of Defense, dated 17 Mar 2020 for additional details.

3. Distribution Statement

Approved for public release; distribution is unlimited.

4. References

- Water Resources Development Act of 2007
- Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works Projects
- ER 1110-1-1300, Cost Engineering Policy and General Requirements
- ER 1110-2-1302, Civil Works Cost Engineering
- ER 1165-2-217, Civil Works Review Policy
- UFC 3-740-05, Construction Cost Estimating 09 December 2022
- Engineering and Construction Bulletin (ECB) Number (No.) 2007-17, Application of Cost Risk Analysis Methods to Develop Contingencies for Civil Works Total Project Costs
- CECW-CE Memorandum, dated 3 Jul 2007 by Major General Riley, Application of Cost Risk Analysis Methods to Develop Contingencies for Civil Works Total Project Costs

- CECW-CP Memorandum, dated 19 Sep 2007, Initiatives to Improve Accuracy of Total Project Costs in Civil Works Feasibility Studies Requiring Congressional Authorization
- PMBoK Guide, published by Project Management Institute
- Joint Agency Cost Schedule Risk and Uncertainty Handbook 12 March 2014
- GAO, Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs, GAO-20-195G, March 2020
- Under Secretary of Defense Memorandum, dated 17 Mar 2020 by Ellen Lord, New Military Construction Budget Estimate Requirements

5. Policy

5.1. Civil Works

In accordance with ECB No. 2007-17, dated 10 Sep 2007, *"Cost risk analysis methods will be used for the development of contingency for the Civil Works Total Project Cost estimate. It is the process of identifying and measuring the cost and schedule impact of project uncertainties on the estimated total project cost. When considerable uncertainties are identified, cost risk analysis can establish the areas of high cost uncertainty and the probability that the estimated project cost will or will not be exceeded. This gives the management team an effective additional tool to assist in the decision making process associated with project planning and design."*

The ECB further states, *"A formal cost risk analysis shall be prepared for all decision documents requiring congressional authorization for projects exceeding forty million dollars. This applies to USACE commands having design and/or construction responsibilities for Civil Works."*

The ECB continues by assigning the cost engineer the responsibility for conducting the CSRA for development of project contingencies. The PDT shall assist the cost engineer in establishing project contingencies by identifying risks and their potential impacts to cost and schedule. Oracle Crystal Ball software will be used to conduct a statistically based Monte Carlo CSRA.

Memorandum CECW-CE (1110), dated 3 July 2007, from Major General Don T. Riley *"...directs the use of specific cost risk analysis methods for the development of contingency on Civil Works Total Project Cost. This is applicable for all decision documents requiring Congressional authorization for projects exceeding $40 million."*

Generally, decision documents are formal requests for funds that are presented to the vertical team. Decision documents can also be project and cost information requested by HQUSACE or Congress in support of decision making. Per Civil Works Review Policy, a decision document is defined as: *"Any product that provides analysis and recommendations for an Agency decision to obtain project authorization to commit Federal funds for project implementation or project modification."* These documents serve as the basis for approval to receive/spend funds as a result of entering into agreements with other agencies or organizations, including those to obtain Congressional authorization.

As mentioned before, CSRA is required for all planning projects, regardless of estimated project size or cost. To satisfy the various references and regulatory requirements, any document going

forward for funding requires a formal CSRA. Within the USACE community, for consistency in approach and software usage, HQUSACE mandates the use of Oracle Crystal Ball software to perform CSRAs for TPC greater than $40M. For projects valued at less than $40M, a risk-based approach is still required. The process for TPC less than $40M is commonly referred to as the abbreviated method; however, critical, high-risk projects should still undergo a Monte Carlo study when warranted, regardless of TPC value. The abbreviated method employs similar practices relative to PDT identification, risk discussions, risk register development identification, Work Breakdown Structure (WBS) study, resulting contingencies, and a report. It stops short by not utilizing Monte Carlo-type analysis using Oracle Crystal Ball modeling; rather, its results are based upon Civil Works experience curves of cost growth. This process focuses on the cost risk only. Final products are sufficient to support a CSRA report, potential project scope change, acquisition strategy, design and construction elements, quantity confidence, special fabrications or equipment, cost estimate assumptions, and external project and public risks.

The formal process of applying the Oracle Crystal Ball software is more labor intensive, but also yields confidence levels relative to risk identification and contingencies of a more detailed cost and schedule nature.

If you are using a Monte Carlo analysis on a project where a formal analysis is not required, it is recommended that the risk analyst write a 1 to 2 page summary of the overall project risks. This may provide more clarity and show overlapping ranges of risks that may be beneficial when comparing alternatives.

While HQUSACE requires a CSRA for decision documents, the initial risk discussions can begin much earlier. As project scope and estimates are updated, the RAs and TPC must also be updated. This process will carry through the project life as a prudent project risk-management tool. This is especially important on large projects that span over extended years, where project scope, costs, schedules, and risks have a greater chance of changing. Regardless of project size and complexity, all funding requests must be accompanied by a current, risk-based contingency, and the accompanying analysis.

5.2. MILCON

Per the 17 Mar 2020 memorandum from Ellen Lord, Under Secretary of Defense, *“The military construction program depends upon adequate project budget estimates to enable timely delivery of full project scope that satisfies warfighter and installation requirements. To reduce the risk of underfunded projects and the resulting detriment to scope and schedule, I am establishing Department-wide requirements for military construction projects submitted to Congress for authorization in FY 2022 and beyond.”*

6. Risk Analysis Overview

The goal of risk management is to identify project risks and develop strategies to manage them, which is a critical part of the RMP. In that process of managing and mitigating risks, there are project opportunities and benefits that can likely be realized.

Four main building blocks of the risk-management process are:

1. PDT identification
2. Assessment
3. Response
4. Documentation

The CSRA process addresses the Risk Identification and Assessment portions of the risk-management process. The activities of Response and Documentation are PM and PDT management efforts to mitigate, monitor, and manage the risks throughout the life of the project. On larger projects over extended years, industry chooses to continue the CSRA process, recognizing that, as the project evolves, and risks are mitigated, new risks may become apparent. The CSRA process is a tool used to study, quantify, and communicate the new risk potentials throughout the project life.

The Risk Identification and Assessment portions focus on the entire project. The outcome identifies the greater impact risks to the project cost and schedule and assists in establishing contingencies to manage the project to completion. In Figure 1, note the point estimate change and growth over time and the scope development. The figure illustrates a common project evolution, whereby the final cost is beyond the originally developed scope and the budgeted TPC estimates. For this reason, it is important to begin this process early in project development, so that the risks determined over time can be managed, planned for, and mitigated, as much as is practical, to remain within the appropriated budget. It is critical that the CSRA be performed on the latest project information—the best-known project scope should be included in the base cost estimate and schedule; otherwise, the contingencies developed from the CSRA may be too low and unable to capture the funding needed as the project scope is further developed.

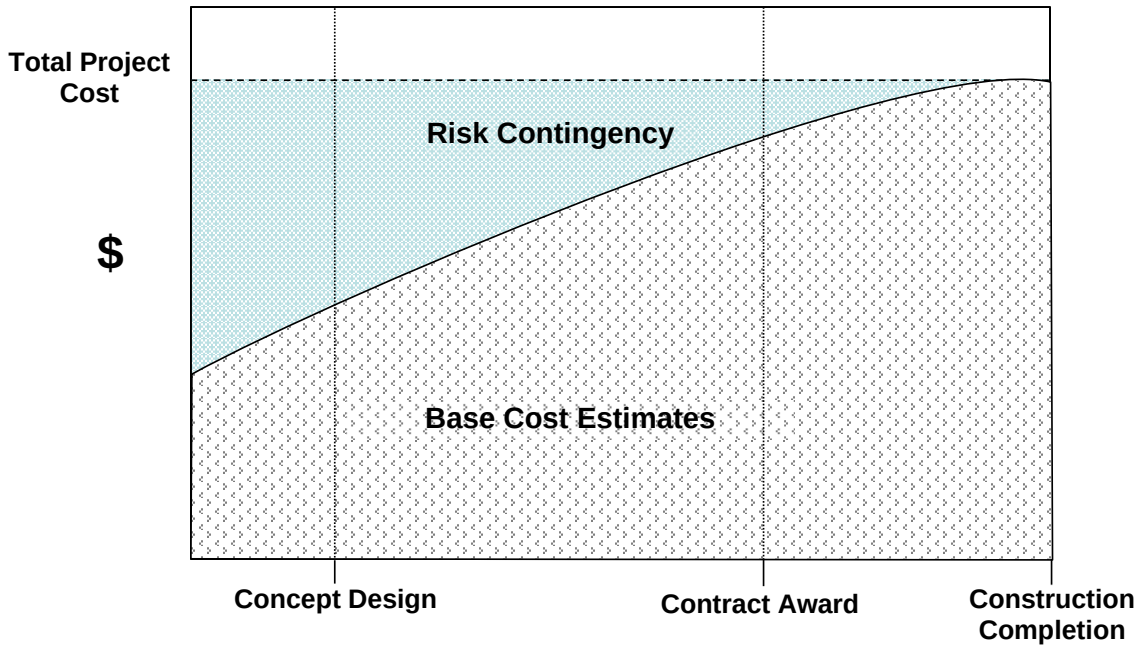

Figure 1. Project Evolution Over Time

The CSRA process qualitatively identifies risks, then quantifies the potential cost and schedule variances of the risks related to the project cost and schedule. The results are expressed in terms of cost and schedule contingency amounts, in the form of dollars and time, by the confidence levels for successful execution. It is a formally documented process of the PDT efforts, considerations, and concerns, utilizing risk-based identification processes that are used in standard industry.

It is recommended to perform the RA on the TPC, including all features of the project. When considering total project features, it is recommended to utilize a WBS representative of the project's business line. For Civil Works, refer to the USACE Civil Works Work Breakdown Structure (CWWBS). For MILCON and/or Sustainment, Restoration, and Maintenance (SRM) projects, refer to the appropriate MILCON WBS. Experience indicates that all too often, risk studies focus on just the construction activities within the cost estimate, which can result in critical risk elements remaining unidentified and unmanaged. Main categories of project development include budget development, program maturity, receipt of project funds, study and design, acquisition strategies, construction execution, and possibly operation and maintenance. Through early determination of potential project risks, management can then focus efforts to mitigate those risks and realize opportunities for cost and schedule savings.

A formal CSRA must be accomplished as a joint analysis between the PM, the cost engineer, and the PDT members that have specific knowledge and expertise on all possible project risks for all features, internal risks, and external risks. Internal risks are those related specifically to the project, many within the control of the PDT. External risks are those outside forces that can impact the project with little PDT control.

The advantages to performing CSRAs on projects include:

- Involving PDT to communicate as a team regarding project scope, status, cost, and risk concerns.
- Better understanding the potential risks and opportunities that could impact the project.
- Establishing contingencies supported by PDT involvement and studies.
- Defining and targeting high-risk areas for management and risk reduction.
- Possibly realizing cost and schedule opportunities, similar to value engineering processes.
- Improving the odds of successful completion of the project.

7. Responsibilities

The CSRA requires the active participation of the entire PDT. As members of the PDT, the Cost Engineer and/or Risk Analyst play key roles in facilitating the process, and in preparing the risk register, developing and running the risk models, and analyzing the results. However, the necessary familiarity with, and detailed knowledge of, the project resides with the PM and other members of the project team. Additionally, the PM, and other members of the project team, are in the best position to identify and qualitatively assess the risks, and to provide potential risk-mitigation measures.

7.1. Project Manager and/or Lead Planner

The responsibility to adhere to the CSRA process lies predominantly with the PM or Planner that leads the project and manages project funds. Since CSRA is instrumental for successful project completion, their engagement is critical for the following tasks:

- Determining the need for a CSRA based on regulation/agency requirements and/or what is reasonable for a healthy project execution.
- Developing and updating a project management plan (PMP) that addresses risk management, the CSRA requirements, and its execution.
- Developing and updating the RMP and ensuring it correlates with the CSRA.
- Supporting the CSRA process related to budgeting, scheduling, and team formulation to accomplish the CSRA.
- Participating in the identification of risk-reduction measures.
- Establishing and communicating the contingency level based on the CSRA confidence curves.
- Monitoring and managing recognized risk items and mitigation efforts that may impact successful execution of the budget and schedule.
- Evaluating the need for follow-on CSRAs.
- Ensuring CSRA results are appropriately captured in the project estimate and schedule.

7.2. Cost Engineer/Risk Analyst

An experienced Cost Engineer and/or seasoned Risk Analyst will perform key roles in the CSRA process; one individual may be responsible for both functions. In USACE, the cost engineering office is often tasked to perform the CSRA, as well as present the final report within the cost engineering appendix. In support of the CSRA, the cost engineer will likely lead the market research that supports the study. Often, the cost engineer will develop the draft documents used to support the PDT risk discussions. Their knowledge of the project and estimate assumptions helps when initiating these draft documents.

It is highly recommended that an experienced CSRA facilitator/Risk Analyst perform this function—one who is accustomed to risk processes and estimate/schedule assumptions identification.

A senior Cost Engineer is typically assigned the role of Risk Analyst, and many times, serves as a meeting facilitator to lead the PDT through the CSRA process (i.e., PDT discussions to develop the initial risk register and establish the resulting CSRA conclusions). A confident facilitator, knowledgeable with the type of project work, is needed to actively engage and encourage communication amongst the project team.

Cost engineering personnel should be trained in the CSRA process and have Oracle Crystal Ball licensed software. USACE offers a PROSPECT class, which is developed and managed by the USACE Cost Engineering Center of Expertise (Cost MCX), and that teaches the overall process, with a focus on Civil Works. The Cost MCX has also developed training and recommendations for other agencies, based on their specific business rules and practices. The

physical process of risk identification and risk modeling is the same, regardless of agency and/or business line.

The Cost Engineer/Risk Analyst is tasked to lead the CSRA and report the results. Typically, a Risk Analyst is responsible for developing and running the CSRA models to develop project contingencies. Additional responsibilities include:

- Sharing the contents and assumptions of the estimate and schedule.
- Updating the cost estimate and schedule as information is gathered from the project team.
- Recording/documenting team comments and determinations in the risk register meeting.
- Leading the market analysis to quantitatively bracket the variances with regards to cost and schedule.
- Facilitating the identification of risk items.
- Facilitating the qualitative assessment of risk levels.
- Creating, running, documenting, and summarizing cost and schedule risk models.
- Coordinating with the PM/PDT on documenting risk-reduction measures for high-risk/medium-risk items.
- Communicating and collaborating with the PM on the results of the CSRA.
- Incorporating the contingency results from the CSRA model into the TPC and schedule.

7.3. Project Delivery Team

The PDT, in support of the CSRA process, should involve all major members that have knowledge of the specific project and critical responsibility for development and management of the total project and project features. The CSRA is to be performed on TPCs, not just construction costs. The project team shall assist in identifying risk likelihoods and their potential impacts to cost and schedule. PDT representatives typically include the following (among others):

- Project/Program Management
- Planning
- Contracting and Acquisition
- Real Estate/Relocations
- Environmental/Regulatory
- Technical Design
- Estimators and Schedulers
- Risk Analysts/Facilitators
- Construction
- Operations
- Sponsors/Stakeholders
- Others with critical input

8. Documents Required for a Risk Analysis

Before beginning the process, the PDT should understand the processes identified within this document. The documents and software recommended for a CSRA include:

- Current, well-developed, and understood project scope
- Quality base estimate, excluding contingency
- Quality schedule correlating with the project scope and estimate
- Expended project costs and durations
- MS Excel with Oracle Crystal Ball software installed (needed to run a CSRA)
- Risk presentation to educate the PDT *
- Risk checklist presenting typical risks considered *
- Risk register *
- Cost and schedule risk templates/models *
- Report template of the process, outcome, and recommendations *

*These documents are maintained by the USACE Cost MCX at the Walla Walla District. Note that this is the same MCX charged with maintaining the Construction Equipment Ownership and Operating Expense Schedule (Engineer Pamphlet (EP) 1110-1-8) and Civil Works Construction Cost Index System (Engineer Manual (EM) 1110-2-1304) and is the USACE coordination center for Agency Technical Reviews (ATRs) of Cost Engineering products.

The Cost MCX maintains a website where these documents and sample products can be obtained by USACE and contractors.
http://www.nww.usace.army.mil/Missions/CostEngineering.aspx

9. Risk Analysis Methods

The PM or Planner initiates the RA process by determining the need for abbreviated or Oracle Crystal Ball RA. Method selection should be based on project size, complexity, and potential risks. Projects that are valued at less than $40M can still benefit from the Oracle Crystal Ball method, especially if risks are considered great enough to warrant scrutiny by the agency's leadership.

Regardless of estimated project costs and with growing emphasis at feasibility stage of planning studies, the abbreviated process is often utilized for establishing rudimentary contingency values for the array of alternatives that are under study to establish the recommended plan. It is recognized that differing alternatives carry differing risks and that the contingencies are part of the economic study to confidently justify that the correct plan is recommended.

9.1. CIVIL WORKS ONLY – ABBREVIATED RISK ANALYSIS < $40M and Alternative Studies

The abbreviated process was developed by the MCX as an acceptable risk tool that addresses the WRDA 2007 requirements for use of risk in determination of contingency and copies of the most recent can be obtained there. It focuses on cost, neglecting schedule based on the

assumption that the smaller projects have less schedule risks. The abbreviated process is more qualitative than quantitative. It requires less labor and can be completed by key PDT members often within a single day. The abbreviated process requires PDT inclusion and the creation of a risk register. It identifies key risks and can establish approximate contingencies at various WBS levels of differing risks. Its risk categories reflect the results of many Oracle Crystal Ball studies: potential scope growth, acquisition strategy, construction elements, design quantities, special fabrication and equipment, cost estimate assumptions, and external risks. These seven categories, assigned within a matrix measured with a risk variable WBS structure, can result in reasonable risk identification and contingency output.

9.2. Abbreviated Risk Analysis Process

The abbreviated process is an acceptable tool for Civil Works in establishing the contingencies for measures or alternatives, recommended plans at feasibility, and smaller cost projects. To minimize labor impacts, it is recommended that the Cost Engineer prepare the initial CSRA based on his/her knowledge of scope, estimate assumptions, and development.

Preparation includes establishing a reasonable WBS level where construction risks differ from one activity to another. An example might be an earthwork project where mobilization, clear and grubbing, excavation, earthwork haul, earthwork placement, concrete structures, and pump plant carry different costs and risk assumptions. The study input and risk register would consider the WBS elements and associated risks separately.

Upon development of the initial model, the Cost Engineer then meets with the major PDT members that play a role in defining the project scope and risks. The PDT members are listed by name and position, the risk register is completed, and risk levels are established with a resulting contingency value per WBS element addressed. Since the risk register can be reviewed by the MSC, HQ or the public, it must be of an acceptable quality and completeness.

Upon completion of the PDT draft CSRA, the resulting risk discussions and respective contingencies per WBS element are studied for reasonable value. If certain contingencies for the WBS elements appear unreasonably high or low, further study may be warranted, and possible risk-reduction measures taken prior to final product submittal. The process should address present project state and present risks. It cannot be assumed that since a risk will be mitigated in the future, it is no longer a risk.

9.3. FORMAL RISK ANALYSIS CSRA PROCESS > Oracle Crystal Ball

The USACE CSRA process relies on the Pareto Principal, which states that in construction projects, 20 percent of the risks will cause 80 percent of the impacts. This is akin to the “Few Risk Items” approach outlined in the DoD Joint Cost Schedule Risk and Uncertainty Handbook.

It is important to note that we do not recommend the use of “expected value” type modeling for construction risks but recommend focusing on the moderate-risk and high-risk items identified through qualitative assessment, and modeling only the moderate-risk and high-risk items with their potential ranges of impact. The process was developed in 2007, with the help of Dr. Humphries from Association for the Advancement of Cost Engineering (AACE), and follows

the best practices, from range-estimating techniques with adaptation, to general DoD principles of DoD Construction cost estimating. This process can generally be applied to any type of project where the “Few Risk Items” approach is warranted.

The CSRA can be considered synonymous with the Monte Carlo statistical-based method, a method used by the USACE-mandated Oracle Crystal Ball software. This method and software address both cost and schedule risks. The main building blocks of the CSRA can be seen in Figure 2, following. Note the separation of the cost and schedule processes, as each requires a separate analysis, though the results of each may impact the other.

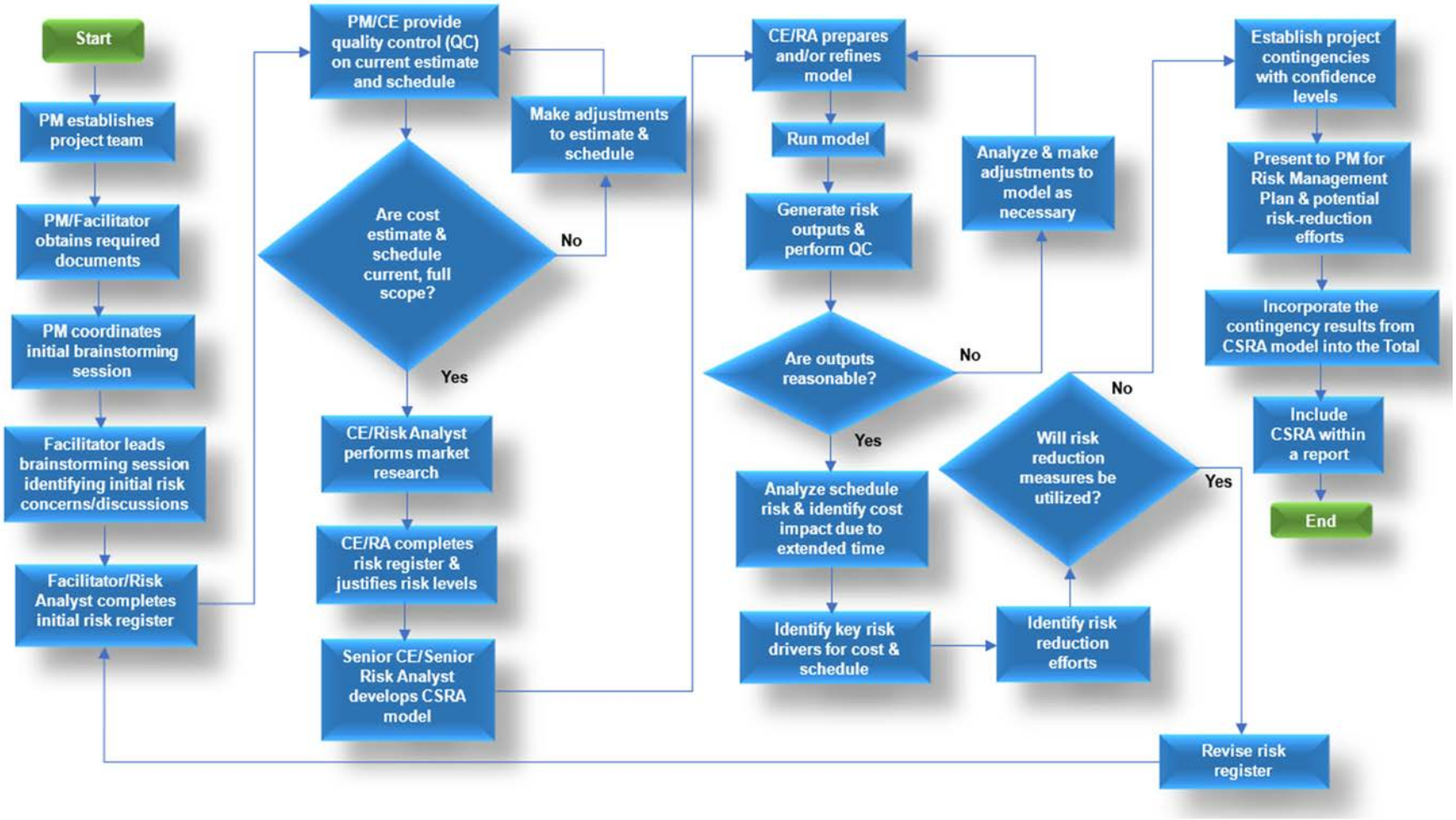

Figure 2. CSRA Flow Chart

9.3.1. CSRA Determination

The Monte Carlo CSRA is recommended for all projects that are large and/or complex, of long duration, and have high federal visibility or critical funding constraints. HQ regulations, policy, and guidance play a large role in establishing mandatory CSRAs. The PM must follow their agency requirements, but also consider whether other project milestones warrant a CSRA update based on scope, cost, schedule, and risk changes. This is a critical step in quality project management processes. The PM may directly consult leadership, but generally the regulations and intent are fairly clear. As a rule, well-defined scope is the critical element that then establishes the current cost estimates and schedules. The lower the quality of these products, the greater become the risks and resulting contingencies. As scope is improved and more confident designs are developed, contingencies normally decrease.

The risk-management process should be incorporated as an RMP and included within the PMP. The RMP should include the four main risk-management building blocks: identification, assessment, response, and documentation.

9.3.2. Initial CSRA Preparations

The PM should ensure an adequate TPC estimate and reflective schedule have been prepared to support the CSRA process as the base case estimate. The total project scope must be reflected within the two products. (ER 1110-2-1150, Engineering and Design for Civil Works Projects, and ER 1110-2-1302, Civil Works Cost Engineering, provide further guidance related to the expected quality levels for Civil Works projects.)

The PM must establish the PDT. The PDT is comprised of senior staff members with knowledge of the project scope and criteria, as well as the associated potential risks, opportunities, and unknowns.

The PM must determine what project costs and durations have already been expended, as they should not be part of the CSRA. Obligated, but unfinished contracts still carry risks in the form of modifications and claims.

In preparation for the initial PDT risk discussions that prepare the first risk register (the document used to support the CSRA), it is recommended that the PM distribute to the PDT a list of potential risks that are commonly encountered for the specific business line. A PDT sample risk checklist is available on the Cost MCX website and included here in Appendix A. The checklist is a compilation of common risks encountered by USACE, the U.S. Navy, Department of Energy, and state Departments of Transportation.

It is encouraged to examine lessons learned from previous, similar projects to develop custom checklists for the project's business line. **These risk checklists are not intended to be all-inclusive, but to serve to stimulate the team in the brainstorming of each project's specific applicable risks.** After reviewing the checklist, the PDT members will be better prepared to present their risk concerns at the PDT brainstorming meeting where the risks are discussed and captured within the initial risk register (the document used to support the CSRA).

9.3.3. Initial Risk Discussions

The PDT brainstorming session is the initial attempt to develop the risk register that serves as the basis for and supports the CSRA. To prepare the initial risk register, certain coordination steps are recommended. These recommendations are based on experience in performing CSRAs since 2006.

9.3.3.1. PDT Coordination and Assembly

The PM will coordinate an initial risk discussion meeting with the PDT members, also referred to as a brainstorming session. This is the first meeting where the PDT attempts to collectively capture the total project risks and place them into the risk register. It is recommended that the designated facilitator begin the PDT brainstorming session with a CSRA presentation. (The Cost MCX provides a CSRA slide show presentation on its website.) A confident facilitator, knowledgeable with the type of work, is needed to actively engage and encourage discussion and communication amongst the PDT.

9.3.3.2. Project Scope and Cost Presentation

Following the CSRA presentation, it is highly recommended that the PM and the lead Cost Engineer for the project present the project scope and related costs. The presentation should include the major construction features and assumptions in the base case estimate. Often, it is discovered that the estimate assumptions do not match current understood scoping and construction elements. This presentation will lead the PDT into risk discussions, and possibly an adjustment to the estimate(s) and schedule(s).

If scope is not well-defined, it may be necessary to have a scope review meeting with the PDT prior to the risk discussion meeting to avoid the risk meeting turning into a scoping session.

9.3.3.3. PDT Brainstorming Session

The PDT brainstorming session is the opportunity to bring the PDT together to gain a better common understanding of the project, discuss the basis of design/scope and how that translates to the cost estimate and schedule, discuss constructability concerns, and qualitatively define the risk concerns, as well as potential opportunities.

The potential variances to the base estimate that are identified in the Brainstorming session are the basis for further study and modeling in the analysis. This stage is considered the qualitative stage that lacks the studies to establish cost and schedule impacts or variances. This period is more speculative, pre-study.

It is highly recommended that the brainstorming session include the major PDT members because the dialogue between the members typically results in scope clarification or change, identification of new risks, even possible revision of the estimates and the schedules. It is also the best opportunity to address all features of the project. To lead the PDT through the discussions, an effective approach is to simply work down the PDT risk checklist (see Appendix A). This ensures that each major PDT member is given equal opportunity to address their concerns. As the concerns are discussed, the facilitator or Risk Analyst begins developing the initial risk register that supports the CSRA, capturing the PDT's concerns and discussions. Like in a value engineering study, all concerns are valid, considered, and captured within the

risk register—even lower risks, because they serve as a record of the discussion. This session can, and often will, result in revised estimates and schedules.

Generally, there are key risks that the PDT must address: Potential scope growth, acquisition strategy, construction elements, design quantities, special fabrication and equipment, cost estimate and schedule assumptions, and external risks. Similar to the abbreviated process, those factors would consider major contracts and major construction elements, including durations. There are other items that also must be addressed:

- Assumed funding timeline, structure, federal and non-federal contribution limits, etc.
- Design confidence, major assumptions, and current knowns/unknowns
- PMP (pre & post design)
- Potential for unknown-unknown risks
- Change management approach of agency

9.3.3.4. Completing Initial Risk Register

A risk register is a tool commonly used in project planning and RA. The complete risk register includes low-level risks, as well as additional information regarding the nature and impacts of each risk.

A risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register include:

- Documenting risk-mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk-management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of RMPs.

The recommended software for risk registers is MS Excel (a sample risk register in MS Excel is available on the Cost MCX website). The risk register will serve as the basis for the CSRA model, which is run in Oracle Crystal Ball. This software utilizes MS Excel in its CSRA application. When referring to the risk register, the PDT should simply focus on the following columns:

- Risk Type – Project Management, Contract Acquisition, Construction, etc.
- Risk/Opportunity Event – simple, clear title
- Risk Event Description – clearly written specific concerns
- PDT Discussion on Impact & Likelihood – expand on base scope, estimate, schedule assumptions, and associated risk ranges
- Project Cost: Likelihood, Impact, and Risk Level as a result

- Project Schedule: Likelihood, Impact, and Risk Level as a result
- Responsibility/Point of contact (POC)
- Suggested Risk-Reduction Measures – Avoid, Escalate, Exploit, Transfer/Share, Mitigate/Enhance, or Accept (reference PMBoK)

The Risk Analyst will complete the remaining risk register columns during the market research and the CSRA model development during the quantitative phase. A PDT risk register is provided in Appendix A and sample risk registers are provided in Appendix B.

The PDT should capture all concerns for all project features, even if the risk level is considered low. The register serves as an archive of discussions, and there is potential for those low-level risks to become higher-level risks following market studies, or with more information being made available, or through time during the risk-management and risk-reduction processes.

The PDT concerns and discussions must be adequately and clearly captured within the risk register because the logic presented in those discussions must support the “likelihood” and “impact” decisions reflected within the risk register. While this product is the initial risk register, it has already captured the PDT’s greater concerns. The PDT can begin using this data to prepare for project risk management.

10. Estimate & Schedule Independent Review

If necessary, the CSRA can begin before the estimate and schedule have received an adequate review, whether that review is by quality control check, agency technical review, or by external agencies. This may be a reasonable approach if the PM is keenly interested in quantifying the potential impacts from the established risk events. However, if later reviews determine that sufficient changes in the estimate and schedule are needed, the CSRA may have to be adjusted prior to finalization of the analysis.

Once the initial risk register is complete, the PM and Cost Engineer, responsible for the estimate and schedule, must consider whether the current estimate and schedule truly represent the most likely case. Often, PDT discussions will present scope changes or processes that may impact the current estimate and schedule. There could be a different construction approach. There could be items such as revised productivity or crew makeup. Important assumptions and quantities may not yet be considered confident.

Other PDT members may choose to revise their portions of the feature costs and schedules that reside within their area of responsibility. In USACE, the Cost Engineer is responsible for the construction costs and schedules. Other PDT members are responsible for the estimate of their project areas/efforts, such as project management, relocations, contract acquisition, design studies, construction management, etc. The PM must obtain confirmation from the PDT whether these areas must be further developed or improved to reflect the most likely case estimate and schedule that serve as the basis for the market studies and the CSRA product. Those estimates should exclude contingency, because the CSRA process will establish the contingency values.

For Civil Works Real Estate costs, the District’s Real Estate section chief is responsible for developing the Real Estate estimate and contingency. In this case, the PDT needs to evaluate

the adequacy of the real estate contingency with regard to the project scope and risk and add any additional identified risks to the risk register for items such as a project footprint expansion.

Expended costs do not generally carry risk, though obligated contracts that are not yet closed still carry risks in the form of potential contract modifications and claims.

11. Market Research

Once the initial risk register is completed, and the PDT is confident that the total project estimate and schedule reflect the base case conditions, it is time for the Risk Analyst to begin the market research. Risks qualitatively determined to be medium to high will be moved forward for qualitative analysis. This classification is made using a standard likelihood vs. impact matrix. It is recommended to carefully review the qualitative assessment of each risk to ensure that it is accurately characterized, as only the moderate and high risks will move forward for analysis. Any misclassified risks should be corrected in the risk register.

The market research supports the quantitative portion of the CSRA, establishing actual values or ranges in cost and schedule impacts. It is intended to validate the presumed risk levels within the initial risk register for both cost and schedule. The market analysis will help establish the “most optimistic” (or “low value”), and the “worst case” (also referred to as the “high value”). These two data points or values will be used within the Oracle Crystal Ball risk model to evaluate the range of costs from the base case cost estimate and schedule. A key concept is that we are studying the potential variances to this base case cost estimate and assumptions within.

The study and quantification of risks may require PDT interviews, historical data research, internet searches, etc. Issues may include items such as real estate fluctuations, land acquisition and easements, construction productivity concerns, significant weather impacts, fuel pricing, construction modifications, specialized equipment and material availability, local labor resources and rates, potential scope growth, bidding competition, effects resulting from the acquisition strategy, economic trends, etc.

12. Risk Register Completion

This section describes the completion of the risk register. A logical flow must occur between the risk event, concerns, and discussions, and reasoning for the chosen likelihood and impact values that result in the risk level of low, moderate, or high. Oracle Crystal Ball model preparation is described separately for cost and schedule in subsequent sections of this document.

To finalize the risk register, market research may result in the Risk Analyst revising the risk register as he/she prepares the final risk register for the CSRA models. Refinement may reveal similar risk events that could be duplicates or double-counted as a risk impact. It may result in adding risk/opportunity events not previously captured. It may result in revising the “likelihood” and “impact” values to support a revised risk level that reflects the research findings. Should the

likelihood and impact values be revised, the PDT concerns and discussions may have to be reevaluated to ensure that they logically support the revised risk register.

The market research will enable the Risk Analyst to complete the risk model columns, which include:

- Cost Impacts
- Cost Variations (best and worst case)
- Schedule Impacts
- Schedule Variations (best and worst case)
- Correlation of Risks to One Another
- Cost Impacts due to Schedule Variations.

12.1.Cost Impacts and Distribution

The market analysis will help establish the most optimistic (also referred to as the best case or low value), the base case (the existing estimate/schedule), and the worst case (also referred to as the high value). These three points or values will be used within the Oracle Crystal Ball risk model and serve as the bases for the modeling of risks. The best-case and worst-case impacts can be indicated in dollars or percent. The Cost MCX recommends the use of minimum, likely, and 80 percent for risks modeled with a triangular distribution. As noted in the 2016 DoD Joint Risk handbook, *"…the best subject matter experts usually fail to capture even the 70% confidence interval of risk magnitudes that occur."*

12.2.Schedule Impacts and Distribution

The market analysis will help establish the best-case, the most-likely case, and the worst-case values. These three points or values will be used within the Oracle Crystal Ball risk model and serve as the variance curves. The impacts can be indicated in months or percent. Additionally, in investigating the schedule risks, the risks will often imply that an additional cost may be incurred. In the recommended standard template, there is a separate column to include/model any specific risks due to schedule. This technique provides visibility to the impacts schedule has on the project. These risks sum into the overall cost risk forecast in the template. In general, nearly all schedule risks will have some cost risk. Often, this cost risk is below the threshold of modeling and should be evaluated case by case.

12.3.Correlations

Many times, risk events have a correlation or relationship to one another. A positive correlation occurs when one risk goes higher and the other must also go higher. A negative or adverse correlation occurs when one risk increases and the other risk must decrease. To complete the risk register, note the assumed correlations and include them in the model development. When preparing the model, it is highly recommended to review correlations before running the risk model, because they can significantly alter the output. Frequently, assumed correlations are actually restatements of the same risk, and should be combined into one variable. In developing correlation factors, if no specific data exists to accurately determine the factor, it is recommended to use 85 percent as a value.

12.4. Risk Register Quality Control Check

Upon completion of the market research, the Risk Analyst should complete the risk register, confident that the:

- PDT risk/opportunity events are adequately captured/conveyed.
- PDT discussions support the “likelihood” and “impact” decisions.
- Market research supports the risk level assigned.
- Current estimate and schedule serve as the most likely case for the CSRA.
- Correlations and event duplication are minimized and addressed.
- Market research adequately defines the cost and schedule variations.

13. Cost & Schedule Risk Model Development

The cost risk model development and resulting CSRA are most commonly performed by a trained senior Cost Engineer and/or a senior Risk Analyst. On larger projects, this may require several members to study the initial risk register, evaluate the concerns captured within the brainstorming session(s), perform market studies of those risk events, and validate whether the PDT’s risk-level assignments are accurate.

13.1. Risk Model Template

The risk model utilizes the risk register as its basis within the MS Excel format. The Risk Analyst and the PDT must determine the best modeling method that provides adequate model output for the project. The result is a customized model specifically related to the project. The final product must present contingencies in the desired format for the TPC estimate. For example, CSRAs can be performed on each contract (assuming several contracts), on assumed funding cycles, on each project feature, or on the TPC. The use of the standard risk model template is recommended for all agencies, projects, and business lines, as it provides a common platform for development, review, analysis, and future data collection efforts. The Cost MCX coordinates each year with other DoD agencies and releases an updated template for the coming calendar year in January. It is recommended to use the latest template.

13.1.1. Methods

In general, our modeling approach assumes that the few moderate-risk and high-risk items in the model will drive the overall cost risk. We do not use expected value modeling (probability of occurrence times the cost impact), as doing so does not capture sufficient funds to pay for the event should it occur yet allocates unnecessary funds to the project if the event does not occur. The qualitative assessment of the likelihood and potential impact of the risk determines if the item is referred for further quantitative assessment and inclusion within the risk model. Items that are categorized as moderate risk or high risk are included in the risk model and low-risk items are not included.

In general, we do not consider uncontrollable events that can impact the cost of the program. Acts of God, industry collapse, and mission-changing events, are generally excluded from modeling; however, in some cases, discrete events, such as hurricanes and floods, could

impact a project's construction, and the risk and uncertainty of these should be studied and included in the risk model, generally as a two-step-type risk with an annual probability of occurrence and a range of cost/schedule impacts.

When developing the risk models, the final use of the resultant cost and schedule should be considered. Contingencies may be desired for total baseline cost as a whole, or as subsets of the larger overall project. Other considerations could be given based on construction features or number of planned contracts that span a longer period of time. The simplest, and also more common, approach is based on total baseline cost estimate with a single contingency outcome.

A more complicated approach would be to separate costs and risks based on WBS features, construction features, or contract. Modeling can become more cumbersome but may be a better approach if the project is large, complex, and includes various construction features and a number of contracts that span over multiple years. It is also noted that more detailed modeling and summing of individual contingency calculations by lower-level features can overstate the overall contingency if these are simply summed together. Caution must be exercised to avoid overstating the overall contingency.

Table 1 is a sample of the cost risk model. Note that the model focuses on certain risk register categories and the market research values related to best case, most likely, and worst case. The entire risk register can be included; however, it can be cumbersome when producing paper documents and reports. The key risk register columns are:

- Risk Number
- Risk/Opportunity Event Title
- Concerns
- PDT Discussions and Conclusions
- Likelihood-Impact-Risk Level
- Variance Distribution/Correlation to Others

Table 1. Sample Cost Risk Model

REF	Risk Type	Risk/Opportunity Event	Project Cost			Other Information		COST		
			Likelihood (C)	Impact (C)	Risk Level (C)	Cost Variance Distribution	Correlation to Other(s)	Low Variance (Min)	Likely (C)	High Variance (80%H)
1	1 - Project & Program Management (PM)	Efficient Fed Funding	Likely	Significant	High	Uniform		$0	$0	$8,300,000
2	1 - Project & Program Management (PM)	Stakeholder Funding	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
3	1 - Project & Program Management (PM)	Adequate PDT Resources	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
4	1 - Project & Program Management (PM)	Sponsor Support	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
5	1 - Project & Program Management (PM)	Schedule Quality	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
6	1 - Project & Program Management (PM)	Construction Schedule - 2 years	Likely	Marginal	Medium	Triangular		-$451,000	$0	$0
7	1 - Project & Program Management (PM)	Public Access Requirements	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
8	5 - Contract Acquisition Risks (CA)	Contract Acquisition Strategy	Unlikely	Negligible	Low	N/A - Not Modeled	PR1	$0	$0	$0
9	5 - Contract Acquisition Risks (CA)	Number of Contracts	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
10	7 - General Technical Risk (TR)	Dredged Material Quantities	Likely	Marginal	Medium	Triangular		-$253,000	$0	$253,000
11	7 - General Technical Risk (TR)	Beach Fill Volumes	Likely	Marginal	Medium	Triangular		-$805,523	$0	$2,416,569
12	7 - General Technical Risk (TR)	Non-Compatible Sediment	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
13	7 - General Technical Risk (TR)	Bedrock Encounter	Likely	Marginal	Medium	Triangular		$0	$0	$465,000
14	7 - General Technical Risk (TR)	Sea Level Rise	Unlikely	Marginal	Low	N/A - Not Modeled		N/A	$0	N/A
15	9 - Lands and Damages Risk (RE)	Acquire Real Estate	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
16	9 - Lands and Damages Risk (RE)	Real Estate Estimate	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0
17	33 - Regulatory & Environmental (ENV)	Encountering Small Arms	Unlikely	Negligible	Low	N/A - Not Modeled		$0	$0	$0

REF	Risk Type	Risk/Opportunity Event	Project Cost			Other Information		COST		
			Likelihood (C)	Impact (C)	Risk Level (C)	Cost Variance Distribution	Correlation to Other(s)	Low Variance (Min)	Likely (C)	High Variance (80%H)
18	33 - Regulatory & Environmental (ENV)	Sea Turtle Site Take	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
19	33 - Regulatory & Environmental (ENV)	Bird Nesting	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
20	33 - Regulatory & Environmental (ENV)	Right Whale Restrictions	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
21	33 - Regulatory & Environmental (ENV)	Dune Revegetation	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
22	33 - Regulatory & Environmental (ENV)	Archeological	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
23	13 - Construction (CO)	Contract Modifications	Likely	Marginal	Medium	Triangular	PR3	$0	$350,000	$1,275,000
24	13 - Construction (CO)	Pipeline Dredge	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
25	14 - Estimate and Schedule Risks (ES)	Dredges, number & size	Likely	Marginal	Medium	Triangular		-$367,000	$0	$284,500
26	14 - Estimate and Schedule Risks (ES)	Pipeline dredge	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
27	14 - Estimate and Schedule Risks (ES)	Mobilization Costs	Unlikely	Significant	Medium	Triangular		-$150,000	$0	$450,000
28	14 - Estimate and Schedule Risks (ES)	Fuel	Likely	Significant	High	Triangular		-$5,200,650	$0	$751,205
29	14 - Estimate and Schedule Risks (ES)	Dredge Productivity	Likely	Marginal	Medium	Triangular		-$375,000	$0	$125,000
30	14 - Estimate and Schedule Risks (ES)	Borrow Location Assumptions	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
31	4 - External Risks (EX)	Market Conditions	Likely	Significant	High	Triangular	CA1	$0	$0	$12,402,645
32	4 - External Risks (EX)	External Opposition	Unlikely	Marginal	Low	N/A - Not Modeled		$0	$0	$0
33	4 - External Risks (EX)	Acts of God	Likely	Marginal	Medium	Uniform	CO1	$0	$0	$450,000
34	4 - External Risks (EX)	Borrow Competition	Likely	Marginal	Medium	N/A - Not Modeled		$0	$0	$0
35	4 - External Risks (EX)	Esc exceeds OMB rates	Likely	Marginal	Medium	N/A - Not Modeled		$0	$0	$0

13.1.2. Establishing the Risk Events for Study

We recommend that all moderate-risk and high-risk items be further studied and included in the model. Typically, 10 to 15 of the identified risks will meet this threshold and should be included in the final model with Oracle Crystal Ball assumptions created for them. All identified risks should be examined to make certain of their overall risk rating. Items can often be qualitatively assessed in error by the team, and further study may indicate it is overall a low risk (not modeled), or a moderate to high risk (included in the model). If the risk analysis later determines a risk was either not identified, and/or was not qualitatively assessed correctly by the team, it should be added/noted in the risk register and the proper classification entered to ensure the model and the risk register match.

Table 1 depicts only the risk events under study; however, the Risk Analyst could still include all risk events within the model, simply indicating that the risk is not modeled and not assigning a variance distribution.

13.1.3. Incorporating Market Research into Model

Once it has been established which risk events will be incorporated into the model, the market research findings can be added. For traceability purposes, the recommended approach is to create MS Excel tabs next to the risk model dedicated specifically for each risk event. The tabs will present the market findings and the logic used to determine the best-case and worst-case values for each risk event. Those values are then placed into the model input to support the variance distribution. When assigning the distributions, the likely case must be a hard value with no equations or links to other data. Remember that the likely case should generally be $0 indicating that the base estimate value is the likeliest value for this model. If the likely value is nonzero this can indicate that the base estimate/schedule may be deficient in the costing/duration of this variable. It is recommended to fix deficiencies in the estimate/schedule correct the deficiencies prior to modeling the project.

13.1.4. Establishing Variance Distribution

The variance distribution within Oracle Crystal Ball is assigned to address only those risk events under study. By definition, the base case value in the estimate has established what is most likely to occur and our risk study is based on how the costs within the estimate can vary. Generally, most risks in the model should have “zero” for the likely value.

Within the Oracle Crystal Ball software, the distribution gallery provides more than 20 diagram or curve choices that can represent the market research data related to “best case,” “most likely,” and “worst case.” The two most used and recommended for first consideration are the triangular and the uniform distribution curves. Other curves may better address certain risks where better data exists and should be considered when more appropriate. This is very rarely the case in construction.

When modeling assumptions (risks) within the Oracle Crystal Ball model, for each assumption (risk event), the Risk Analyst must properly name the risk event title, enter the best-case, most likely (usually zero), and worst-case values, and address any correlations (both positive and negative) between the respective risk events.

The triangular distribution (Figure 3) is commonly used for construction. Our estimate generally will reflect the likely value and the ranges of low and high variance can be determined by market research. Typically, the range can be expressed in dollars or percent. This distribution is recommended for the risk events that impact discrete areas or details of the estimate. It is recommended to set the default parameters to Minimum, Likely, and 80 Percent when utilizing the triangular distribution. Lessons learned indicate that often the teams are too optimistic in the high variance value and understate the maximum potential value of the risk. Research shows that even the most experienced subject matter experts' opinion on the impact rarely, if ever, exceeds 70 percent confidence. If there is little to no known data available to assess the risk, a lower confidence for the high value should be considered.

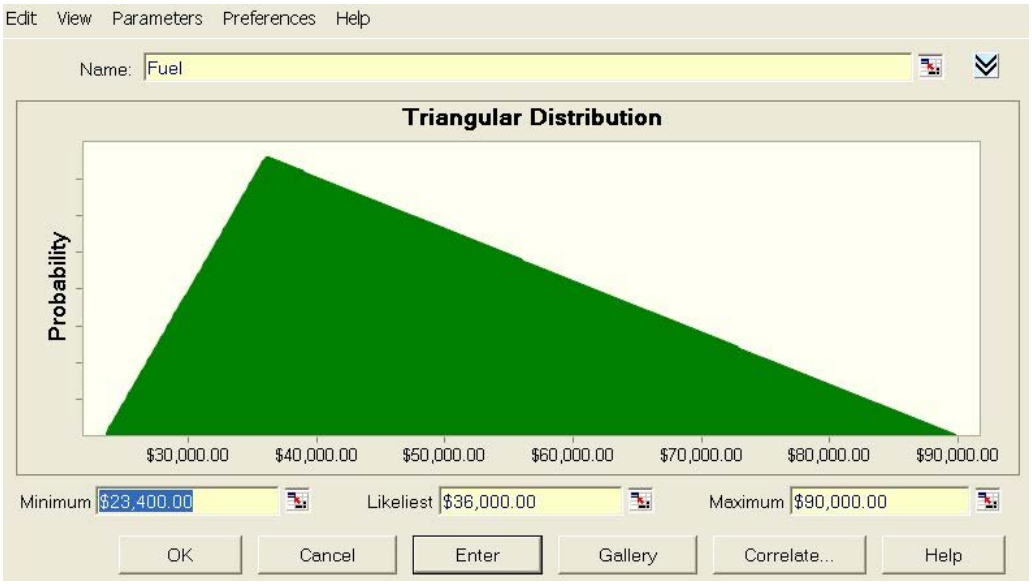

Figure 3. Example of Triangular Distribution

The uniform distribution (Figure 4) is used when any value between the best case and worst case is equally likely to occur. In these instances, only two points are needed: the best and the worst case. A second variable of Probability of Occurrence could be added to the equation for items with discrete causal effect, such as a storm or overtopping event. Caution must be exercised to use this approach to ensure the modeling is correct. Often, a triangular distribution may be more appropriate.

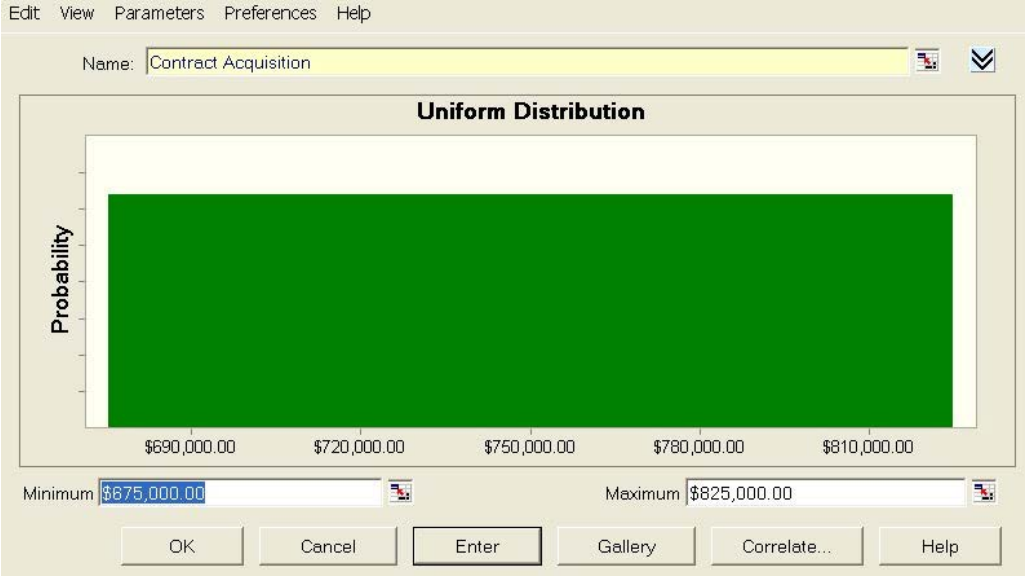

Figure 4. Example of Uniform Distribution

13.1.5. Forecast

Oracle Crystal Ball software models each of the assumptions. A cell that mathematically sums each assumption is used to calculate the output using a Forecast. The Risk Analyst needs to understand what the summation of the assumption represents.

- Simply summing the assumption cells and creating a Forecast on the formula cell will yield the variance of the model.
- Summing the base case cost and the assumption cells will show the variance of the TPC of the model.
- The creation of confidence tables and charts showing the probability of expedience is not an automatic Oracle Crystal Ball function, but instead, they are created using the outputs of the Forecast cell.

Within Oracle Crystal Ball, the Risk Analyst must set the model related to desired reports and decision variables, defining the forecast, establishing precisions, etc. Once the model includes the risk events under study, all distribution variances have been assigned, duplications and correlations have been addressed, and the most likely estimate captured, the Risk Analyst is ready for the initial model run.

13.1.6. Initial Model Run

By this time, the Cost Engineer and Risk Analyst should have a feel for the scope, the estimate, and the market research quality. This will be valuable when reviewing the initial output data. The Risk Analyst evaluates the initial reports, reviewing areas of potential conflict or inaccuracy. Even if the contingency values appear reasonable, a quality control (QC) check should still be performed.

Generally, several iterations will be performed as the model is studied for logic, assumptions, and values. Through several iterations, the model is corrected and improved; however, care must be taken to ensure the model is not arbitrarily adjusted to present preferred results.

Ultimately, the final product and report must reflect logic and pass the scrutiny of independent review.

13.1.7. Model Results Quality Check

After the initial model or first trial is run, a QC check is required for reasonableness. The contingency calculations may seem too low or too high, based on the Risk Analyst's knowledge of the scope and estimate quality. If the contingency data falls significantly outside the anticipated range, there may be errors within the model development, the base case estimate, or market research. Within the sensitivity chart (Figure 5), the order of high-risk events may seem unlikely or out of expected order.

Common mistakes include:

- **Poor project scoping.** RA cannot overcome significant omissions or errors in the scope of the project. If something significant is missing, no amount of contingency will be enough.
- **Base case estimate is too optimistic or too conservative.** A conservative estimate could result in the outcome of negative contingency, or an optimistic estimate could result in the base case estimate falling below zero percentage of occurrence.
- **Double counting of risks.** There may be similar risk events that are listed separately within the risk register, thereby measuring the risk twice.
- **Modeling of all risks with the inclusion of a probability of occurrence variable.** In Oracle Crystal Ball software, the probability of occurrence is handled within the shape of the variable used. For a triangle distribution, the extreme ends have the lowest probability of occurrence and the "likely" has the highest probability of occurrence. Probability of occurrence variables should generally only be used for high impact discrete events, such as significant weather, or project decision points.
- **Omission of risks.** There may be critical risks absent from the modeling, especially external risks.
- **Risk mitigation measures assumed to be 100 percent effective prior to execution and/or no consideration for second- and third-order effects of mitigation.** Often PDT will assume they can mitigate the risk and it will not affect the project and omit or understate the risk severity. The second- and even third-level effects of risk mitigation could be more severe than the original perceived risk.
- **Failure to adjust the risk likelihood and impacts based on quantitative analysis.** Quantitatively assessing the risk often results in changes to the likelihood and impact of the risk.

13.2. Risk Model Output

Numerous Oracle Crystal Ball outputs are helpful in presenting the data, as well as supporting the CSRA report. While not all are portrayed in this document, the more common figures used to support the final report are presented in the following paragraphs. This data is obtained from the Oracle Crystal Ball report output after the risk simulation is run.

13.2.1. Model Analysis

In examining the model output, various techniques can be used to analyze the root drivers of the uncertainty. The following three charts are of value in analyzing the results. (Oracle Crystal Ball will generate both Sensitivity and Tornado charts; however, a Pareto chart must be developed by the user.) The standard USACE risk template for 2024 and beyond will develop a Pareto analysis for the user utilizing MS Excel formulas embedded in the template.

Sensitivity chart: Identifies the elements with the largest range of uncertainty.

Tornado chart: Identifies the uncertain variables that most influence the target contingency total value.

Pareto chart: Identifies the elements that contribute the most to the target contingency.

The sensitivity chart (Figure 5) reflects the risk register areas of greatest range of variability as modeled, rated in order of magnitude. It is similar to a Tornado chart, which does not include any effects of modeling and simply shows the absolute value of the ranges of the modeled variables from highest to lowest. These charts can be very misleading as to the true contribution of contingency to the project. Generally, the risks with the largest ranges of cost will show up at the top of the chart. This may or may not indicate their actual contribution to project contingency. High cost or time impacts with small ranges of variance can contribute substantially to the overall contingency and may not show up on the sensitivity chart at all.

For example, consider the following two items:

- Risk 1 is a risk with a low of -$4M (savings), a likely of 0, and a high of $4M (cost increase has a variance of $8M).
- For Risk 2, it is determined that most likely an item of $5M is missing from the base project estimate and it is added to the RA, with a low of $5M, a likely of $5M, and a high value of $6M.

From a sensitivity analysis point, Risk 1 has an $8M range and will show higher than Risk 2 ($1M range) on the sensitivity chart. Understanding and analysis of the model is required to determine the truly critical risk drivers that should be addressed. It is recommended to compare the sensitivity results to a sorting of the risks based on the likely and high-risk values for comparison to identify additional critical risks beyond the sensitivity analysis. This is often referred to as a “Pareto ranking.” Sensitively analysis alone is not adequate for ranking of risks in priority and the Risk Analyst must examine the risks, and the effects of modeling, and communicate the key risk drivers within the analysis.

As noted, in 2024 and beyond, the USACE standard CSRA template will generate a Pareto ranking of risks by confidence level. The ranking is automatically generated in Tab “J- Sensitivity charts” for both Cost and Schedule. The user will need to manually open the Oracle Crystal Ball-generated cost and schedule sensitivity charts and paste them in the assigned area on the tab in the area below row 105.

The top cost-risk drivers by confidence level should be compared with the sensitivity chart data and evaluated. It is very common for the two analyses to show different risks as being the

highest ranked. The risks ranked highest by “confidence level” are contributing the most to the contingency value and the highest by “sensitivity” have the largest range of potential impacts. Generally, a risk ranked higher by “confidence level” should focus more on mitigation efforts applied than should those that have large ranges in sensitivity.

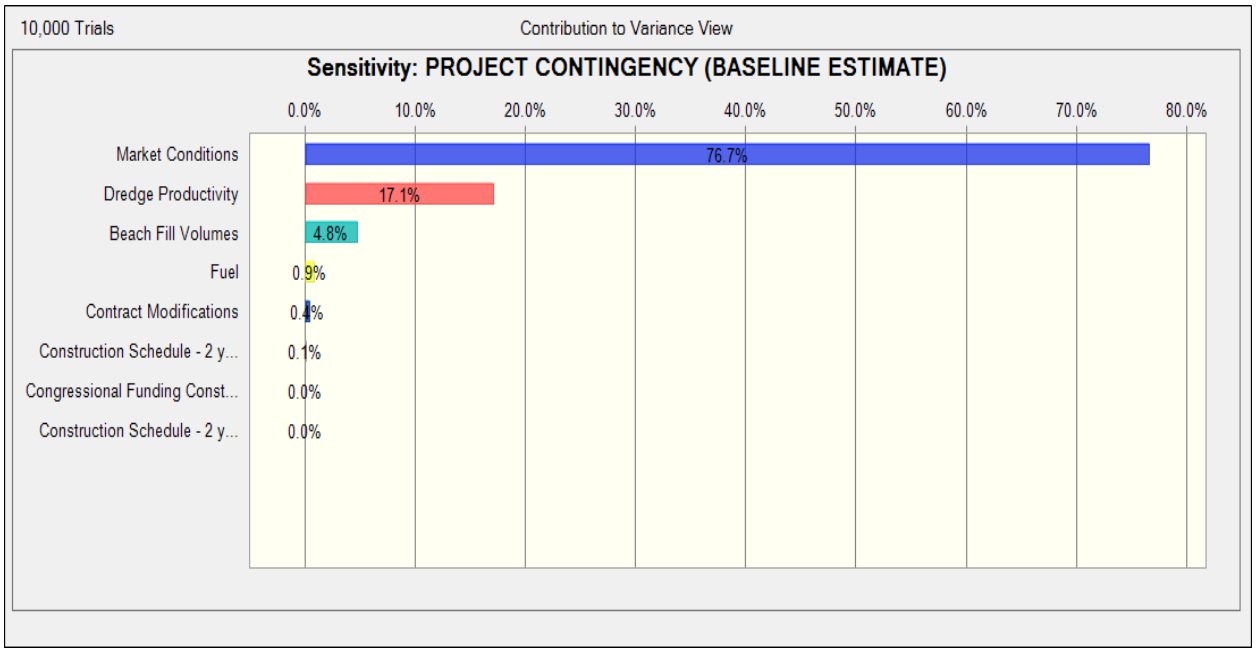

Figure 5. Sensitivity Chart for Cost

13.2.2. Total Project Contingency Analysis

The contingency analysis is measured against the most likely estimate in dollars. The output (Table 2) presents the cost values based on the confidence levels for successful project execution and completion, but we have not yet included the schedule growth impacts to the cost. It can be presented in tabular form and also represented graphically and termed as the confidence curve. The PM and management are left to decide what confidence level they prefer to present to Congress for authorization. Historically, Congress and the Assistant Secretary of the Army are accustomed to a contingency value with an 80 percent confidence of successful execution and completion.

It is recommended that the project contingencies should be presented with confidence levels and associated contingencies in 5 to 10 percent confidence increments from 0 to 100 percent. Management will then choose the confidence levels and associated contingencies for both funding requests and application in calculating the benefit cost ratio.

Items to consider in the confidence level chosen could be life safety, project complexity, national priority, project status, and likelihood of mitigating risks. In any case, the chosen value should be justified within the CSRA and main reports. For MILCON, current policy is to present costs at the 50 percent confidence interval.

An example is presented in Figure 6.

Table 2. Contingency Analysis Output for Cost

Base Estimate w/o Real Estate->	$164,220,233	
Confidence Level	**Contingency Value**	**Contingency**
0%	-6,568,809	-4%
10%	18,064,226	11%
20%	22,990,833	14%
30%	26,275,237	16%
40%	29,559,642	18%
50%	31,201,844	19%
60%	34,486,249	21%
70%	36,128,451	22%
80%	**39,412,856**	**24%**
90%	44,339,463	27%
100%	68,972,498	42%

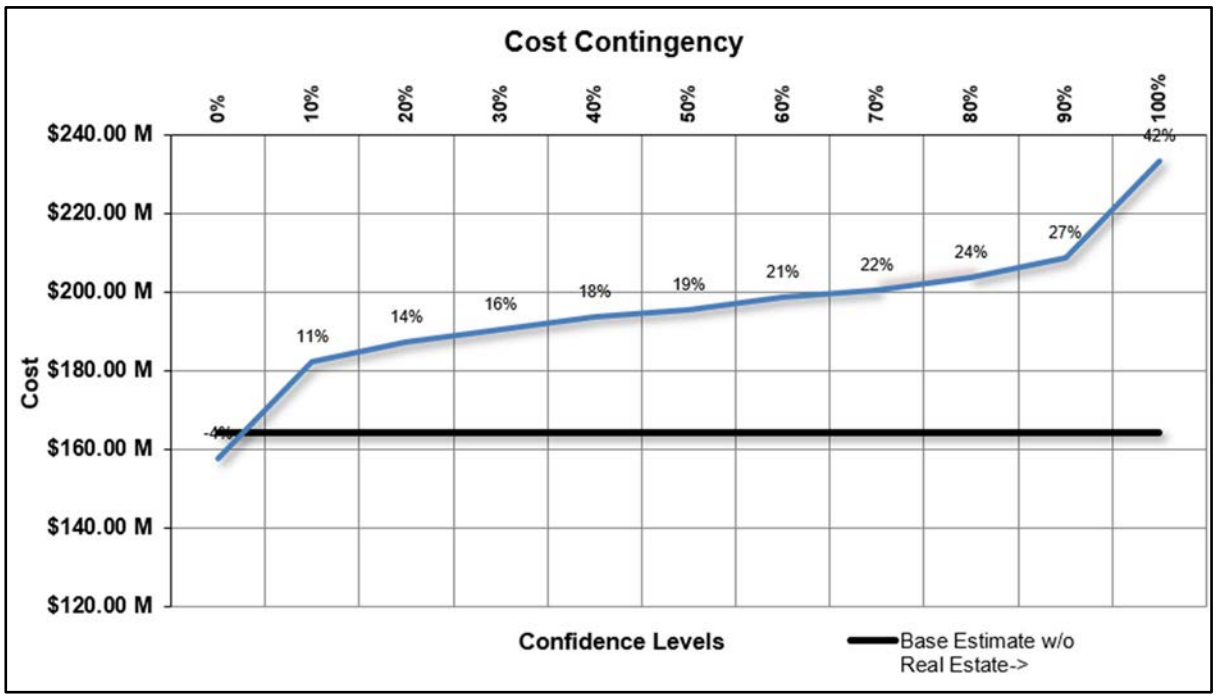

Figure 6. Cost Contingency Analysis

14. Schedule Risk Model Development

The guidance prescribed for the schedule risk analysis (SRA) is nearly the same for input and results; however, time variances are portrayed in months, resulting in a contingency growth in months. The schedule growth in time should also be converted to added dollars, depending upon what costs could be affected by the time growth (time is money). Added time can increase costs related to added administrative overheads, contractor overheads, and greater risk in escalations to labor, equipment, and materials. In general, most schedule risks will have a cost associated with them and often cost risks may not have an associated schedule risk. The preferred method to measure schedule impacts in cost is to add the cost impact to the cost risk model variances.

The schedule risk model development and the resulting SRA are most commonly performed by a trained senior Cost Engineer and/or a senior Risk Analyst. On larger projects, this may require several members to study the initial risk register, evaluate the concerns captured within the brainstorming session(s), perform market studies of those risk events, and validate whether the PDT's risk level assignments are accurate.

To perform a reasonable SRA, an adequate schedule must be developed that reflects all project features, including the critical and near critical paths and any work windows of those features. If the project is large and more complex, the construction schedule requires further development so that the Risk Analyst can determine how the schedule impacts would affect those durations. The key consideration in evaluating schedule risk is, will that risk item affect the Critical Path of the project if it occurs? The analysis does not use program evaluation and review technique (PERT) method to examine the tasks in a schedule but instead relies on the team's judgement that the risk would alter the critical path.

The construction schedule should reflect most likely estimate durations and how the PDT expects the construction to occur. Items such as site access and easements, long lead items, parallel or concurrent activities, and phasing and sequencing for the major construction and equipment items for the critical and near critical paths, are critical for a confident result. Often, the construction representatives are included in these discussions and are considered a valuable asset for consultation.

14.1. Schedule Risk Modeling

The risk model utilizes the risk register as its basis within the MS Excel format. The Risk Analyst and the PM must determine the best approach to use that provides adequate SRA model output for the project. The final product must present schedule growth contingencies in the desired format for the TPC estimate. For example, risk analyses can be performed on each contract (assuming several contracts), intermittent funding, on each project feature, or on the total project base cost.

14.1.1. Methods

In developing the schedule risk model, the approach should consider what contingency output is preferred by the project manager. For example, if just a single project or contract is planned, the

PM may desire a single contingency value. The PM may prefer a contingency developed for each project feature or major construction elements. If several projects, contracts, or funding streams are planned, the PM may desire a separate contingency for each period of performance. These issues should be resolved before preparation of the risk model. The typical approach recommended is to develop the model to reflect the completed risk register. In a sense, the risk register becomes the model, but a more detailed risk register better supports the outcome or findings. In that way, the Oracle Crystal Ball outputs directly reflect the risk register's risk event established by the PDT. This output well supports the PDT when related to document traceability, risk management, and follow-on risk studies. The SRA output is risk based and typically presents the contingency for the project.

14.1.2. Sensitivity Chart

Following the processes used within the cost RA, including market research and quality checks, the sensitivity chart (Figure 7) reflects the risk register items with the largest potential range of outcomes (risk-event based), rated in order of greatest variance. The current 2024 and beyond USACE CSRA template will also generate a Pareto-ranked priority list showing the risks that contribute the most to the overall schedule contingency.

The top schedule risk drivers, by confidence level, should be compared with the sensitivity chart data and evaluated. It is very common for the two different analyses to show different risks as being the highest ranked. The risks ranked highest by "confidence level" are contributing the most to the contingency value and the highest by "sensitivity" have the largest range of potential impacts. Generally, a risk ranked higher by "confidence level" should focus more on mitigation efforts applied than should those that have large ranges in sensitivity.

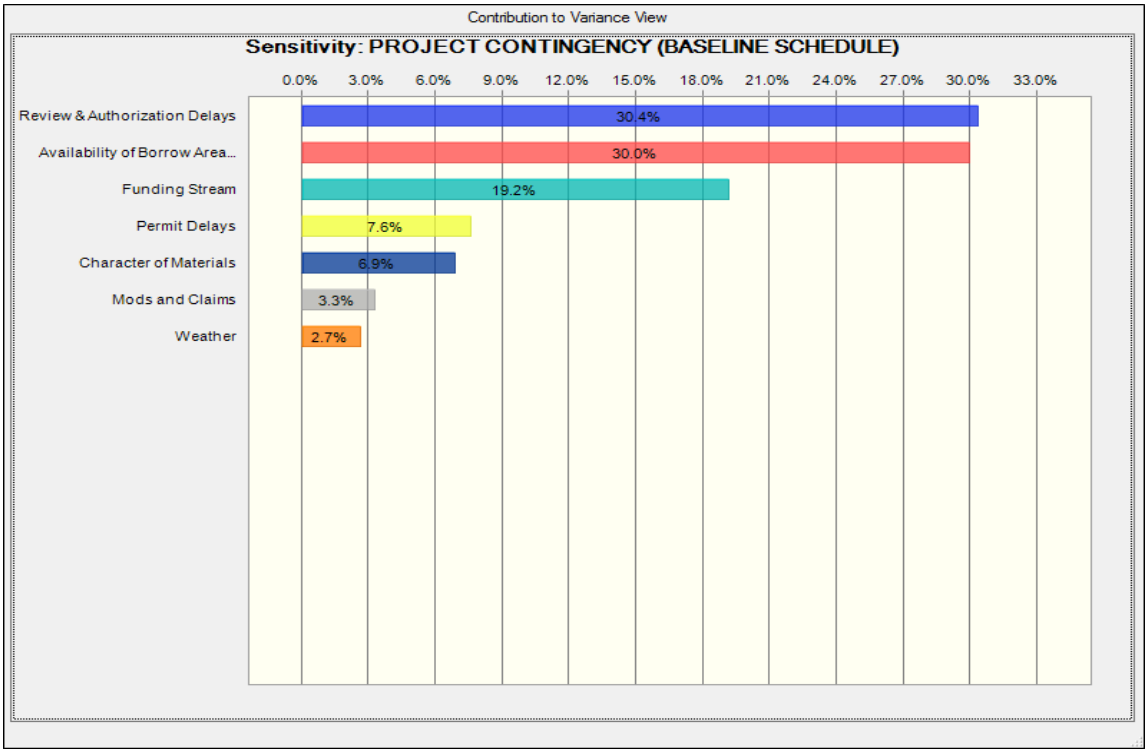

Figure 7. Sensitivity Chart for Schedule

14.1.3. Total Project Contingency Analysis

The contingency analysis is measured against the most likely schedule. The output (Table 3) presents the duration values based on the confidence levels for successful project execution and completion. It can be in tabular form, and also represented graphically, and termed as the confidence curve. The PM and management are left to decide what confidence level they prefer to present to Congress for authorization. Historically, Congress and the Assistant Secretary of the Army are accustomed to a contingency value with an 80 percent confidence of successful execution and completion. Any other chosen confidence levels must be justified. For MILCON, current policy is to present the schedule at 50 percent confidence.

An example is presented in Figure 8.

Table 3. Contingency Analysis Output for Total Project Schedule

Base Schedule Duration ->	**79.1 Months**	
Confidence Level	**Contingency Value**	**Contingency**
0%	-0.8 Months	-1%
10%	6.3 Months	8%
20%	7.9 Months	10%
30%	9.5 Months	12%
40%	11.1 Months	14%
50%	13.4 Months	17%
60%	15.0 Months	19%
70%	17.4 Months	22%
80%	**19.0 Months**	**24%**
90%	20.6 Months	26%
100%	30.1 Months	38%

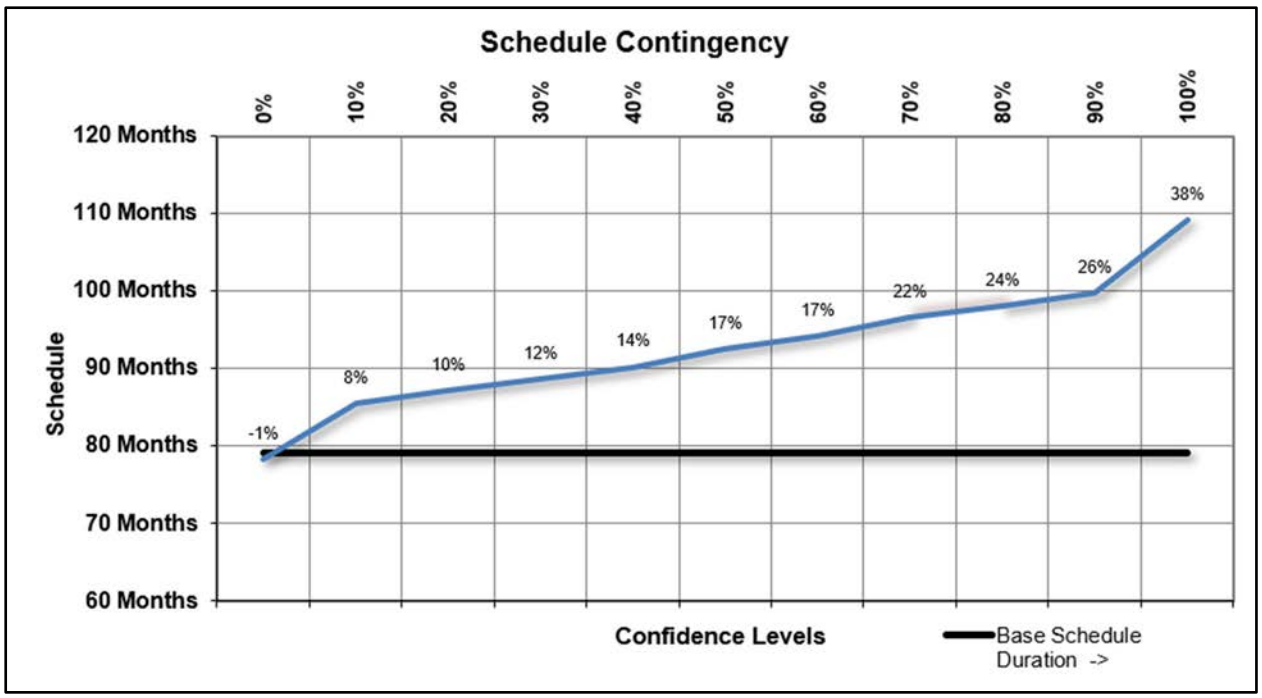

Figure 8. Schedule Contingency Analysis

14.1.4. Schedule Risk Conversion to Contingency

The risk model output presents the schedule risk in months. It should demonstrate where those schedule risks are and by what monthly value. Realistically, the schedule duration also represents a cost to the project that the CSRA did not capture. Schedule risk should be presented in both schedule growth and cost growth potential. When evaluating the schedule growth, consider what costs may be related to those risk events.

Once determined, the schedule duration must be evaluated to determine if the added time results in added costs specifically related to the project and its stage in the design and construction process. Such cost impacts would be added onto the cost contingency calculations, generally in the “cost due to schedule” risk column with the risk item. Evaluation should consider how the time risks relate to items such as:

- Any current authorizations, appropriations, and Section 902 limits
- Anticipated funding profiles
- Pre-construction engineering and design risks
- Construction risks
- Local markets exceeding the established Office of Management and Budget (OMB) escalation
- Market risks impacting contractor bids related to market variability on lengthy construction activities

15. CSRA Report

Finally, the CSRA results are included within a report (a sample report is available on the Cost MCX website at https://www.nww.usace.army.mil/Missions/Cost-Engineering/, as well as https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05. The CSRA report can be added to the cost engineering appendix, or it can remain a standalone report or appendix. The report should be a result-focused document and not include common methodology/process-related discussion on CSRA. These deliverables are to be updated at each submittal, as required by the inclusion of CSRA. The report should include the following:

- Title page with project name, date, and author
- Table of contents
- Report purpose, background, and project scope, including key assumptions, and listing concerns, inclusions, exclusions, etc.
- Summary of the base estimate from which the CSRA was conducted
- Summary of the base schedule from which the CSRA was conducted
- Presentation of the base cost estimate and schedule with contingencies
- Summary of CSRA results, including contingency tables (confidence levels), top risks, sensitivity charts, major findings, and observations, etc.
- CSRA details, such as risk dashboard, risk register, risk-reduction measures, assumptions, risk register attendance, and risk details (if applicable)

16. Conclusion

The CSRA report and output (risk identification, risk-reduction measures, and resulting report contingencies) serve as a management tool in establishing or updating the RMP and the TPC. It serves as a risk baseline for PM risk management, risk reduction, and further CSRAs as the project moves forward and updates are deemed necessary.

17. Project Assumptions

The following data sources and assumptions should be used in quantifying the costs associated with the project.

a. The cost estimate files. The files transmitted, final estimate, and resulting independent review, should serve as the basis for the final cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within the report should be based on design scope and estimates that are at least to the feasibility level of design.

c. Schedules are analyzed for impact to the project cost in terms of delayed funding, uncaptured escalation (variance from OMB factors and the local market) and unavoidable fixed contract costs, and/or languishing federal administration costs incurred throughout delay.

d. The Cost MCX guidance generally focuses on the 80 percent level of confidence (P80) for contingency calculation. For this RA, the 80 percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criterion is a moderately risk-averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

e. Only high-risk and moderate-risk level impacts, as identified in the risk register, should be considered for the purposes of calculating cost contingency. Low-level risk impacts should be maintained in project management documentation and reviewed at each project milestone to determine if they should be placed on the risk "watch list."

f. Second- and third-order effects of risks should be identified and evaluated for inclusion in the model as separate risks or included within the first-order risks modeled impacts.

17.1. Recommendations, Risk Management, and Updates

17.1.1. Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *7th edition*, states that *"…project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project."* Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (RA model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation), risk monitoring, and control. In short, the effectiveness of the project risk management effort requires that the proactive management of risks not conclude with the study completed in this report.

The CSRA produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute for a formal risk management and response plan.

The CSRA study serves as a road map towards project improvements and reduced risks over time. The PDT should include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the RA throughout the project life cycle is important in support of remaining within an approved budget and appropriation.

17.1.2. Risk Management

Project leadership should use the outputs created during the RA effort as tools in future risk-management processes. The risk register should be updated at each major project milestone or every 1 to 2 years. The results of the sensitivity analysis may also be used for response-

planning strategy and development. These tools should be used in conjunction with regular risk review meetings to manage identified risks.

17.1.3. Risk Analysis Updates

Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk-management watch lists if any risk's likelihood or impact significantly increases. Subsequent CSRAs serve to recalibrate, and identify new risks, as well as to exclude mitigated or unrealized risks. The resulting CSRAs can also be used as a comparison to the funded amount and forecast whether the project is on target with the available appropriated funding. Project leadership should also be mindful of the potential for secondary risks (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).