FUSRAP Cost and Schedule Risk Analysis

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ABSTRACT

As with other types of projects, accurate budget planning for investigations and in particular site cleanups of hazardous, toxic and radiological waste (HTRW) sites is important. However, accurately budgeting for HTRW projects presents some unique problems, due to the inherent uncertainty in estimating the total scope of a cleanup project based on limited, discrete sampling data collected during the site investigation phases. Discovery of additional contamination and other project risks encountered during site remediation can cause unexpected and large increases in project cost and duration. This paper discusses an approach to address project risks during the cost estimation process. Discussions include identification of project risks, development of contaminated soil volumes, selection of cost confidence levels for budgeting, and updating of the risk-based cost estimates. Overall, the paper presents a method for incorporating project risks into developing cost and schedule estimates for budgeting purposes on HTRW sites.

BACKGROUND

The Great Lakes and Ohio River Division (LRD) of the US Army Corps of Engineers (USACE) has completed remedial activities at three Formerly Utilized Sites Remedial Action Program (FUSRAP) sites and continues remediation at two sites; the Linde Site in Tonawanda, New York, and the Painesville Site in Painesville, Ohio. Two additional sites have signed Records of Decision and will begin remediation as program funding allows. These are the Luckey site in Luckey, OH and the Seaway site in Tonawanda, NY. Due to the complexity of these sites, unforeseen difficulties sometimes result in significant increases in cost and schedule during remediation. To improve the ability to accurately forecast project budget and schedule over the years it takes to clean up these sites, the Corps' LRD adopted a method of identifying, analyzing, and accounting for a wide range of uncertainties that can affect a project's cost and schedule.

Buffalo District project teams reached out to subject matter experts from Corps' offices nation-wide, including Corps' contractors, to help develop a Cost and Schedule Risk Analysis (CSRA) process specific to FUSRAP projects. This risk analysis focuses only on cost and schedule uncertainties. Human health and ecological risks are addressed with a separate comprehensive Site Safety and Health Plan. Team members for this effort included experts from the following:

- USACE Headquarters
- USACE Great Lakes and Ohio River Division
- USACE Buffalo District
- USACE Environmental and Munitions Center of Expertise Omaha District
- USACE Cost Engineering Directory of Expertise for Civil Works, Walla Walla District
- Argonne National Laboratory

PROCESS

The CSRA process includes several steps that allow the project team to build on site-specific information and develop a complete understanding of potential cost and schedule risks and how to manage them. These steps begin during the Feasibility Study (FS) phase, when the nature and extent of, and human health and ecological risk associated with FUSRAP-related site contamination is known.

Step 1: Estimate Contaminated Material Volume

The cost of cleaning up a contaminated site is primarily driven by the volume of FUSRAP-related contaminated material that requires remedial action. Estimating this volume accurately requires a thorough understanding of how the materials got to the site; where they are; and if, where, and how fast they are moving. As more is learned about the site during Remedial Action, the actual volume of FUSRAP-related material often exceeds the original volume estimate. This increases cost and causes schedule delays. With the help of Argonne National Laboratory, the Corps has incorporated the use of a geostatistical method of estimating how much material is contaminated and will require remedial action. This method uses not only laboratory data from samples taken from the site, but also incorporates data from historical aerial photos and information learned from community members and others who have specific site knowledge. This estimating method gives a range of potential volumes and a percent confidence level associated with values in the range. The higher the confidence level associated with a certain contaminated soil volume, the more likely the actual volume found will be below the volume estimate.

Step 2: Base Cost and Schedule Estimate

During the Feasibility Study (FS), a base estimate of the cost and duration required to clean up the site will be developed for each of the remedial alternatives undergoing detailed analysis, using software and techniques accepted as the industry standard.

Step 3: Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The project risk register is a table of all known and suspected uncertainties related to cost and schedule for cleaning up a site. Human health and ecological risks, identified during Remedial Investigation, are addressed with a separate comprehensive Site Safety and Health Plan. This register is compiled by the project team and each risk is discussed and assigned a qualitative likelihood and cost and schedule impact (high, medium, or low). Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire PDT must be obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the PDT and empirical data from similar projects is desirable and must be considered. Current risk registers include thirteen risk categories and between 60 and 90 individual cost and schedule risks. The risk categories include:

- Program Management
- Project Management
- Contract Acquisition
- Real Estate/site Access
- Document Preparation and Review
- Design Activities
- Resource Availability
- Regulatory or Environmental

- Construction Operations
- Waste Disposal
- PRP Interface
- Community or Stakeholder Interface
- Closure

Each risk is evaluated by the project team to determine the probability of the project being affected by that risk, and how much project cost and schedule will be impacted. Once input from the team has been included, the risk register goes through a second team review to ensure that each risk has been fully considered. For the sites listed below, the project uncertainty causing the greatest impact to cost and schedule has been the increase in volume of FUSRAP-related contaminated material.

Step 4: Cost and Schedule Risk Analysis

The results of steps one through three then serve as the basis of a statistical analysis that incorporates all of the risks. This mathematical evaluation determines how individual risks, and combinations of risks, can change the project cost and schedule. The risk analysis process used for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve any desired level of cost confidence. A parallel process was also used to determined the probability of various project schedule duration outcomes and quantify the required schedule contingency (float) needed in the schedule to achieve any desired level of schedule confidence.

In simple terms, contingency is an amount added to an estimate (cost or schedule) to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

These contingency amounts are added to the base cost and schedule estimates and are each associated with a confidence level. The higher the estimated cost and duration, the less likely the actual cost and schedule duration will exceed the estimate.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) which is an add-in to Microsoft Excel.

Step 5: Annual Updates

This process is refined each year to account for the greater knowledge obtained about the sites. The cost estimate, schedule, and risk register are revised with new and current information, and the cost and schedule risk analysis is re-run to provide the most current range of contingencies for each project. As our site knowledge increases, this annual analysis will progressively decrease the range of cost uncertainty.

CSRA PROJECTS AND RESULTS

The process described above was applied to the FUSRAP sites listed in the tables below and resulted in the ranges of cost-to-complete estimates shown on the next page. Cost-to-complete estimates include all costs associated with the management and implementation of the project. The low cost represents the 5% confidence level in the cost-to-complete estimate and the high cost represents the 99% confidence level in the cost-to-complete estimate. The chosen cost contingency was quantified at the 80 percent level of confidence (P80). The P80 level is the contingency value most commonly reported for programming and management purposes within USACE. These results reflect contingencies based on both the cost and schedule risk analyses.

It should be noted that use of P80 as a decision criteria is a risk adverse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level. Results for confidence levels below P05 and above P99 are not considered meaningful for the purposes of this CSRA.

Table I: Painesville Cost to Complete Contingency Summary

Confidence Level	Remaining Cost to Complete	Contingency ($)	Contingency (%)
P05	$22,013,000	$1,578,000	8%
P10	$22,848,000	$2,413,000	12%
P20	$24,051,000	$3,616,000	18%
P30	$25,104,000	$4,669,000	23%
P40	$26,188,000	$5,753,000	28%
P50	$27,395,000	$6,960,000	34%
P60	$28,784,000	$8,349,000	41%
P70	$30,463,000	$10,028,000	49%
P80	$32,590,000	$12,155,000	59%
P90	$35,624,000	$15,189,000	74%
P99	$42,358,000	$21,923,000	107%

Table II: Linde Cost to Complete Contingency Summary

Confidence Level	Remaining Cost to Complete	Contingency ($)	Contingency (%)
P05	$54,500,000	$2,670,000	5%
P10	$56,235,000	$4,405,000	8%
P20	$58,676,000	$6,846,000	13%
P30	$60,782,000	$8,952,000	17%
P40	$63,007,000	$11,177,000	22%
P50	$65,896,000	$14,066,000	27%
P60	$71,618,000	$19,788,000	38%
P70	$86,012,000	$34,182,000	66%
P80	$106,339,000	$54,509,000	105%
P90	$135,762,000	$83,932,000	162%
P99	$193,253,000	$141,423,000	273%

Table III: Luckey Cost to Complete Contingency Summary

Confidence Level	Remaining Cost to Complete	Contingency ($)	Contingency (%)
P5	$86,765,000	$2,453,000	3%
P10	$90,648,000	$6,336,000	8%
P20	$96,442,000	$12,130,000	14%
P30	$102,186,000	$17,874,000	21%
P40	$111,946,000	$27,634,000	33%
P50	$142,482,000	$58,170,000	69%
P60	$185,297,000	$100,985,000	120%
P70	$238,955,000	$154,643,000	183%
P80	$308,744,000	$224,432,000	266%
P90	$406,986,000	$322,674,000	383%
P99	$596,260,000	$511,948,000	607%

Table IV: Seaway Cost to Complete Contingency Summary

Confidence Level	Remaining Cost to Complete ($)	Contingency ($)	Contingency (%)
P5	$80,296,000	($4,679,000)	-6%
P10	$84,023,000	($952,000)	-1%
P20	$88,956,000	$3,981,000	5%
P30	$92,856,000	$7,881,000	9%
P40	$96,410,000	$11,435,000	13%
P50	$99,969,000	$14,993,000	18%
P60	$103,645,000	$18,670,000	22%
P70	$107,678,000	$22,703,000	27%
P80	$112,562,000	$27,587,000	32%
P90	$119,489,000	$34,514,000	41%
P99	$182,961,000	$97,986,000	115%

Note: Values presented are the current cost (the amount that would be paid in the current period) and do not reflect the Net Present Value of future outlays. Contingency was calculated as the difference between the cost forecast at various confidence level intervals and the base cost estimate.

CONCLUSIONS

The Great Lakes and Ohio River Division (LRD) of the US Army Corps of Engineers (USACE) has developed a process to improve the ability to accurately forecast project budget and schedule over the years it takes to clean up hazardous, toxic, and radiological waste sites. This process outlines a method of identifying, analyzing, and accounting for a wide range of uncertainties that can affect a project's cost and schedule. The process includes the sequential steps of estimating the contaminated material volumes, developing a base cost and schedule estimate, compilation of a risk register, and the actual cost and schedule risk analysis using a statistical analysis tool (Crystal Ball). This process will be updated annually based on new and current information. As site knowledge increases, the annual updates will progressively decrease the range of cost uncertainty. This process will result in much less disruption to program and project management due to cost and schedule overruns.