Risk Management to Make Informed, Contingency-Based CIP Decisions

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ABSTRACT: The City of Portland, Oregon's Bureau of Environmental Services (BES) initiated the use of risk registers and risk assessment practices early in the development of the $800 million (USD) Willamette River Combined Sewer Overflow (CSO) Program. As the program progressed into final design and construction, BES expanded the risk management process to include transfer of risk registries from design entities to a project team that included owner, construction contractor, construction manager, and design consultants. Qualitative and quantitative re-evaluation of the design phase risk registries by the project team lead to the development of project contingencies as well as advantageous procurement of Owner Controlled Insurance (OCIP) Coverage.

This paper will discuss the evolution of the risk management process utilized by BES throughout the CSO Program and explore the implementation of the bureau-wide systematic project risk management program to develop and manage BES-wide CIP contingencies.

INTRODUCTION

The City of Portland entered into an Amended Stipulation and Final Order (ASFO) agreement with the Oregon Department of Environmental Quality in August 1994. The agreement requires the City to control its 55 combined sewer overflows (CSOs) by 2011 with interim deadlines imposed to complete specific portions of the work prior to that date. The purpose of the Willamette River CSO Program (WRCSO) is to reduce the frequency and volume of combined sewer overflows from the drainage areas surrounding the Willamette River. The program, managed by the Bureau of Environmental Services (BES), commenced in 1991 with a set of initial cornerstone projects, including installation of stormwater sumps and sedimentation manholes in residential areas, building separate sewers for stormwater in some neighborhoods, downspout disconnection programs, and removal of certain streams from the combined sewer system. The program then continued with the development, design, and construction of two major capital improvement programs:

1. The Columbia Slough CSO Program included a 3.65-m (12-ft) diameter tunneled pipeline and open-cut section in addition to wastewater treatment plant improvements and was completed by its deadline of December 1, 2000.
2. The West Side Willamette River CSO Project (WSCSO) included a 5,633-m (18,481-ft) long, 4.3-m (14-ft) diameter conveyance tunnel and the 220 million gallons per day (MGD) Swan Island Pump Station and was completed ahead of its December 1, 2006 deadline.
3. The East Side Willamette River CSO Project (ESCSO) includes an 8900-m (29,200-ft) long, 6.7-m (22-ft) diameter storage and conveyance tunnel and is scheduled to be completed in 2011.

In addition to these three major projects, several appurtenant pumping and connection facilities are under construction.

In accordance with the ASFO, all facilities associated with the WRCSO Program must be constructed and operational by December 1, 2011. Otherwise, substantial fines may be imposed.

Historically within BES, inaccurate project schedules, cost projections, and unmitigated risk often negatively impacted fiscal year capital expenditure projections. Recognizing that a failure to properly manage risk and allocate realistic contingency budgets could jeopardize the program, BES adopted a risk recognition, assessment, and mitigation strategy in the design phase of the WRCSO program. As the program advanced into final design and construction, BES expanded the risk management process to include transfer of risk registries from design entities to a project team that included owner, construction contractor, construction manager, and design consultants. Subsequently, BES incorporated the risk program into all the WRCSO design and construction phases.

RISK MANAGEMENT PHILOSOPHY

Construction of any kind exposes the participants (i.e., owner, engineer, contractor, etc.) to some level of risk and liability. When risk is defined and managed ahead of time, projects are more likely to be delivered on schedule and budget.

A risk is an uncertain event or condition that, if it occurs, has a consequence. Risk can be considered a function of both frequency (probability or how often a particular risk may occur) and consequence (the impact or outcome of the risk). For example, a risk management process should identify the following types of risks on a project:

1. Risk to the health and safety of workers
2. Risk to the health, safety, and property of third-party people
3. Risk of schedule delay to completing the project
4. Risk of financial losses and unplanned costs
5. Risk to the environment
6. Risk associated with political and public issues
7. Risk of construction claims

A proper risk assessment should be conducted at defined milestones throughout the project and should generally include the following:

1. **Risk Management Objectives/Planning:** Determine how to implement the risk assessment process to best suit your project.
2. **Risk Identification:** Identify potential risks on your project and describe them. This involves the creation of a Risk Register.
3. **Risk Qualitative Analysis:** Assess the probability and consequence of the risks.
4. **Risk Quantitative Analysis:** Complete a numerical analysis of risk probabilities and their consequence on project objectives.
5. **Risk Mitigation:** Develop, quantify and implement plans to reduce either the probabilities or the consequences of identified risks. The cost-benefit of mitigation measures should be analyzed if they are not considered to be mandatory.
6. **Risk Management and Monitoring:** Track identified risks and mitigate for them. This involves monitoring risk, identifying new risks, requantifying existing risks, and evaluating the effectiveness of actions taken.

In general, a typical risk assessment involves assigning numerical values to both the probability of a risk occurring and to the severity of the consequences of the risk item in order to obtain a risk rating. When analyzing risk on a project, several risks may have a low or high probability of occurring along with a minor consequence, making them an acceptable risk to the project. Unacceptable risks will also be encountered, which may have a high likelihood of occurring with a major consequence to the project. The overall project risk management philosophy is to minimize and ultimately eliminate "unacceptable" risks by reducing the likelihood of occurrence of an event with large consequences.

RISK ASSESSMENT PROCESS

Risk Management Objectives/Planning

As the program headed into the design phase of its first major project, the West Side CSO Tunnel Project, BES set forth the objective to recognize and reduce all risks to their lowest possible level while properly allocating risk contingency monies for recognized risks. The cornerstone to achieving this objective was to formalize the risk assessment process into the future projects from early design through construction, including contractor participation.

Risk Identification

Brainstorming workshops were used to identify project risks. Typical risks include major unforeseen geologic conditions, equipment failure or malfunction, and the occurrence of extreme events (or hazards) not considered or remediated in the design/planning stages of the project. The purpose of the brainstorming is to identify and develop a registry of risk events that have the potential to cause undesirable impacts.

Risk Qualitative Analysis

Once the working list of identified risks/events was compiled, an analysis was performed to determine the likelihood of each risk occurring and the possible consequence if the risk actually did occur. Values for likelihood and consequence were assigned to each risk in accordance with those summarized in Tables 1 and 2. To the extent possible, historical information and experience with similar projects was relied upon to help in assigning the values.

Risk Quantitative Analysis

The overall significance of a risk is defined as the likelihood value multiplied by the consequence value. The significance of a risk is defined as substantial if its numerical designation is greater than 12 (shaded areas in Table 3). For significance values of 8 to 12, the risk is considered moderate. Acceptable risks are those for which the numerical designation for significance is less than 8.

In addition to the social analysis discussed above, a quantitative risk model was used to quantify the uncertainties in capital cost and schedule associated with risks with a significance of 8 or higher following the development of the risk registry. The risks were input into a risk model that uses a mathematical approach to assess the likelihood of the occurrence of a certain risk (event), and the cost (in time and money) to the project if such an event occurs. The model was run for each phase of review. The mathematical model (Monte-Carlo simulation) ran 10,000 iterations with events occurring at random according to the assigned probability. The result of the analysis was a probability distribution indicating contingency amount confidence levels based on the input risk probability and impact. The results of the model were used to provide additional calibration of the social model and to develop a confidence level for the appropriation of financial contingency for risks that could not be mitigated to the acceptable level. Examples of the model runs are presented in Figure 1.

Table 1. Likelihood categories

Value	Likelihood	Probability (%)
5	Very Likely	>70
4	Likely	50–70
3	Possible	30–50
2	Unlikely	10–30
1	Very Unlikely	<10

Table 2. Consequence categories

Value	Consequence	Increase of Cost or Time (% of cost or time)
5	Catastrophic	>20
4	Severe	10–20
3	Substantial	2.5–10
2	Moderate	0.5 –2.5
1	Minor Impact	<0.5

Risk Mitigation

The mitigation process involves identifying measures that can be taken to reduce the probability or consequence of the risk/event. These measures fall into one of four categories:

- **Mitigate:** Implement an action to reduce the probability and severity of the risk. For example, additional data from a geotechnical investigation can reduce uncertainty about subsurface conditions, thus reducing the probability that a hazard will occur.
- **Transfer:** Direct the consequence of risk by allocating the risk contractually either to the contractor or to another party such as an insurance carrier.
- **Avoid:** Change the project plan to eliminate the risk.
- **Accept***:* Accept the risk and do not assign a risk control measure, but monitor it in case it changes and a risk control measure becomes necessary.

Several workshops were held to identify appropriate risk mitigation strategies. The risk registry was updated, revised cost and schedule impacts for each of the risk mitigation measures were developed, and the numerical models rerun.

Table 3. Risk matrix for evaluating significance of a risk

	Consequence (Severity) of a Risk Event				
Likelihood of Risk Event	**Catastrophic**	**Severe**	**Substantial**	**Moderate**	**Minor**
Very Unlikely	5	4	3	2	1
Unlikely	10	8	6	4	2
Possible	15	12	9	6	3
Likely	20	16	12	8	4
Very Likely	25	20	15	10	5

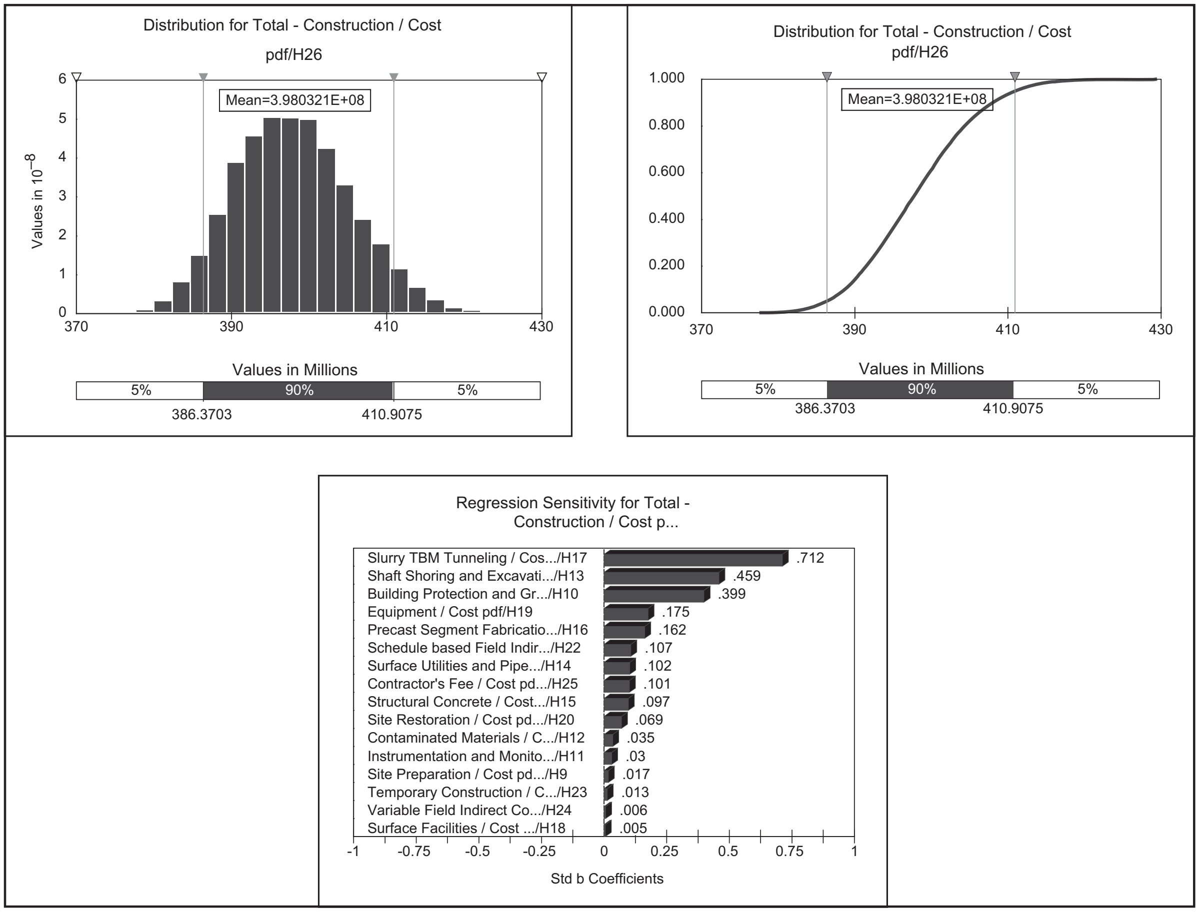

Figure 1. ESCO risk simulation examples

CASE STUDIES

West Side Willamette River CSO Project

Early in the design process of the WSCSO project, BES had concerns that the existing contracting practices commonly implemented by the City of Portland may be unsuitable for the WSCSO. The City of Portland standard practice is to use the design-bid-build approach to contracting, as required by Oregon Revised Statutes (ORS) Section 279. The design-bid-build projects constructed under the City's previous CSO milestone were done utilizing partnering, escrowing bid documents, geotechnical baseline reports, differing site condition clauses and, in some cases, dispute review boards. However, unresolved disputes still led to claims for additional compensation as a result of a number of differing site condition claims. Consequently, with the higher level of construction risk and complexity of the West Side CSO project, BES chose to utilize an alternate contracting structure, modeled after but with significant differences from a construction manager/ general contractor (CM/GC) approach. The contract approach was to procure a prime contractor using a qualifications-based process, and establish a contract as cost reimbursable with a fixed fee. The significant differences with CM/GC contracts researched by BES is that the prime contractor would not be limited in the amount of work to be self-performed (on the contrary, BES wanted to know who would be doing the tunnel and shaft work), and there would be an estimated reimbursable cost developed rather than a guaranteed maximum price (GMP).

Oregon Revised Statutes (ORS) 279 allows public agencies to utilize alternate procurement methods for public contracts, provided they offer the best value to the public. Subsequently, BES evaluated several alternate delivery methods for applicability to the WSCSO project. The Bureau chose to utilize a cost reimbursable fixed fee (CRFF) contract for the WSCSO project. The selected contractor, Impregilo-S.A. Healy Joint Venture, entered into a two-phase contract that included a preconstruction services phase and construction phase. The preconstruction services phase scope of work included the following to be performed by the contractor: design review, cost saving suggestions, project planning, schedule development, risk assessment, reimbursable cost estimate, safety plans, and subcontracting procurement plans.

The shared risk assessment during the preconstruction services phase turned out to be a significant and critical activity. In the normal course of design development, the design engineer had performed a risk assessment prior to selection of the contractor. Some 41 risk items were identified and quantified. Upon mobilization, the contractor was tasked to facilitate a formal risk assessment workshop for the end of the first month of the preconstruction phase. As the development of the design continued during the contractor procurement period, this month allowed the contractor to get familiar with the current stage of the design and with other members of the project team. A professional facilitator was engaged, and team members from the owner, design engineer, contractor, construction manager, and the City's advisory board were included in the workshop. During the workshop, a total of 251 risks were identified for the various categories of work, as shown in Table 4.

Each of the identified risk items was evaluated following the risk assessment process described above. Upon rating the various identified risks, a series of risk mitigation proposals was developed with the intent of reducing risk to the project during the preconstruction phase. Methods of mitigation included revisions to the design and the contract documents, additional geotechnical investigation or instrumentation, and development of a subcontracting plan that addressed packaging of subcontracts and management of subcontractor claims and disputes. In addition, the access/permit and financial/other risks were to be managed by including the costs thereof in the estimated reimbursable cost (project construction budget).

This risk assessment was then used by the contractor and BES to independently develop proposed contingencies to be applied to the budget. BES elected to assign costs to items that had a risk condition of 8 or more. Each party provided more detailed cost range estimates for each risk. The risk-estimating exercise resulted in a total estimated risk impact amount of $34 million. The total amount was then evaluated. BES assigned a contingency value of $17 million based upon the assumption that 50% of the items could be expected to occur.

Additionally, the risk data were statistically modeled by Jacobs Associates. This was done to provide an independent secondary check of the contingency amount. The estimated construction amounts along with the lowest cost and higher cost percentages were evaluated by the model. The model calculated the ranges and ran through a number of iterations on a Monte Carlo simulation of probability of increased or decreased costs. This resulted in a median cost, lowest cost, highest cost, standard deviation, confidence level, and required contingency based upon the confidence level. This check confirmed the assumptions made by the project team, estimating a contingency value of $17 million at the 99 percent confidence level.

Table 4. WSCSO risk categories

Risk Category	No.
Access/Permit Risks	35
Tunnel Construction Risks	47
Ground Improvement Construction Risks	58
Shaft Construction Risks	25
Pump Station Construction Risks	20
Microtunneling Construction Risks	33
Completion/Startup/Operation/Maintenance Risks	10
Financial/Other Risks	23
Total Identified Risks	**251**

Subsequently, the contingency amount of $17 million, representing approximately 6% of the construction contract value, was approved by the City Council along with the construction contract. During construction, risk mitigation was a continuing process through value engineering, regular and detailed schedule management, and aggressive cost management. The risk registers and corresponding contingency budgets were reviewed on a quarterly basis and at each new major construction activity or phase. During construction, a few of the funded risks did occur and remedial actions were successful. Additionally, a couple of identified risks that scored in the acceptable range occurred with a greater consequence than initially anticipated. For example, the subcontractor "low bid" for the slurry walls and ground improvement exceeded the project budget by $20 million and consumed the contingency budget prior to commencement of any construction work. This event, coupled with delays caused by difficulties in achieving groundwater cut-off for the pump station excavation, could have had a devastating impact on the contingency budget and the overall project cost. However, the contract method allowed for continual value engineering, and as a result of several collaborative efforts to implement innovative solutions coupled with good contractor performance, the project team recovered the majority of the contingency budget and lost schedule. At project completion, the majority of the remaining contingency budget was then utilized to refund $14 million to the Bureau's CIP budget for escalation associated with the WSCSO project.

It is clear that the contractor's input into risk assessment and constructability reviews in the midst of the design process provided a fresh outlook. The pre-construction services agreement of the type used here provided a timely opportunity for this activity.

East Side Willamette River CSO Project

Similar to its requirements for the WSCSO project, BES required a rigid risk assessment and mitigation program to be carried forth, beginning with the design of the ESCSO project. Once again the CRFF contracting method was utilized to procure the ESCSO contractor. The joint venture of Kiewit Bilfinger-Berger (KBB) was selected, based on qualifications, as the construction contractor for the ESCSO Project. Springboarding off the success of the WSCSO risk assessment program, BES made some refinements and continued the process with KBB. The approach utilized to assess risk and develop contingency budgets for the ESCSO included:

- Design stage risk assessment
- BES budget risk calculation
- KBB budget risk calculation
- Statistical modeling

Risk Assessment

The design-stage risk assessment was performed by the design team based upon risks that could be foreseen at the time. Two additional risk calculations were performed during the preconstruction stage of the project. These calculations were based upon a risk assessment developed jointly by BES, designers, construction managers, and the contractor. The list of items to be considered were derived from the West Side CSO project risk register and supplemented by the designer's risk assessment listing and additional items brought up by the contractor. Two hundred and eighty items were identified during this phase. Each item derived from this assessment was then evaluated following the previously discussed process.

Contingency Development

This risk assessment was then used by the contractor and BES to independently develop proposed contingencies to be applied to the budget. BES elected to assign costs to items that had a risk condition of 8 or more. The total BES contingency amount developed was $33.5 million. The KBB risk assessment resulted in a total contingency amount of $39.7 million.

Additionally, a statistical method of analyzing the risk was prepared by Jacobs Associates. The information was provided by BES and included a probable, low, and a high estimate of the costs for the major construction portions of the project. The simulation model estimated a value of $31 million of contingency at a 95 percentile level of confidence. An example of the risk simulation is shown in Figure 1.

Follow-on Review of Risk and Contingency

The project risk register, project budgets, and contingency budgets are reviewed on a quarterly basis, and risk contingencies are adjusted to release contingency as risk contingency items are completed or are not realized. Contingency monies are often redistributed to other items or new risk items based upon project experience. Every six months a comprehensive cost to complete forecast is conducted by both KBB and BES. To date, the ESCSO project is approximately 80% complete, the contingency budget is relatively untouched, and the project has been able to release a portion of the contingency budget back to the Bureau CIP budget.

Owner Controlled Insurance (OCIP) Coverage

Concurrent with the ESCSO Project preconstruction phase, BES was in the process of marketing the OCIP coverage for the remainder of the WRCSO Program. Initial carrier quotations were significantly higher than estimated. BES and its broker agreed that more favorable terms and conditions and cost savings could be realized if BES marketed the program directly to the London Underwriters Market. This action required BES to demonstrate proof of compliance with the ITIG Code of Practice for Risk Management of Tunnels. The strong risk management approach implemented by BES coupled with the methods to select and utilize the contractor for preconstruction input were looked upon favorably by insurers and delivered favorable results. As part of the process, the underwriters required that an independent engineering group evaluate the program on a quarterly basis. Part of this review includes review and updating of the project risk register.

MOVING FORWARD

Based upon the success of the risk assessment process utilized on the WSCSO and ESCSO projects, BES expanded the process to include additional projects, for example, the Portsmouth Force Main Project Segments 1 and 2 and the Balch Consolidation Conduit contracts. To date, the use of this process has generally been limited to projects with tunnel or microtunnel construction elements. However, the favorable experience has BES exploring the implementation of a formalized risk assessment process for all projects in the Bureau's Capital Improvement Program (CIP). To this extent, BES has developed a risk assessment manual and is preparing to add the process into the CIP Implementation Plan.

CONCLUSION

By implementing a risk assessment program, BES found it possible to more accurately identify and quantify project risks and their impacts to cost and schedule in advance, and to account for this as the project contingency in schedule and cost projections. In addition, implementation of a risk assessment program brings together design and construction staff to identify and manage potential project issues ahead of time, prior to their occurring during construction.

However, in our experience, risk management processes are also fraught with their own set of risks. For example, as discussed above, the WSCSO encountered risks that were evaluated as "acceptable" individually but, when coupled together, the "consequence" pushed the risk value to the unacceptable range. If this had occurred on a low bid contract, both of these together would have severely hindered the project from a schedule/cost standpoint and would not have been covered by a risk contingency.

Additionally, the ESCSO Project may be impacted by the acceleration of the proposed streetcar and light rail expansion construction running through the middle of the project's main staging area. This event was never considered as a possibility during the risk assessment process. Hopefully, these impacts will be manageable, but the project won't have the ability to have control over the direct costs and impacts, and this certainly was not included in the risk contingency.

The point that it is impossible to predict and analyze the unknown is emphasized in the book *The Black Swan, the Impact of the Highly Improbable* (Taleb 2007). In some instances, this can be a role for insurance, but since there are numerous exclusions in most insurance policies and it is equally as difficult to buy insurance for something that cannot be described or statistically presented, it should be understood that the process remains "risk management" not "risk elimination."

REFERENCES

Actuarial Profession and Institute of Civil Engineers. 2002. *Risk Analysis and Management for Projects (RAMP).*

Bureau of Environmental Services, City of Portland, Oregon. 2009. *Risk Assessment Manual—Draft* (Internal Correspondence).

Gribbon, P., Irwin, G., Colzani, G., Boyce, G., and McDonald, J. 2003. Portland, Oregon's alternative contract approach to tackle a complex underground project. *RETC Proceedings.*

Gribbon, P., Colzani, G., McDonald, J., 2005. Portland, Oregon's alternative contract approach—A work in progress. *RETC Proceedings.*

Eskesen, S.D., Tengborg, P., Kampmann, J., Veicherts, T.H. 2004. Guidelines for tunnelling risk management. *International Tunnelling Association, Working Group* No. 2 q, Research, ITA-AITES, c/o EPFL, Bat GC, CH 1015 Lausanne, Switzerland.

Taleb, N.N. 2007. *The Black Swan: The Impact of the Highly Improbable.* Random House.

ITIG, February 2005. *A Code of Practice for Risk Management of Tunnel Works—Final Draft*

State of Oregon, 2001. *Oregon Revised Statutes (ORS) Section 279.*