Risk And It Sources

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Risk and its Sources

Project risk is an uncertain event or condition that potentially impacts the project objectives for cost, schedule, and quality. Impacts may be both positive and negative. A risk has a cause and, if it occurs, a consequence. Risk is the combination of the likelihood of the uncertain event times its consequence. A likely event with moderate consequences may expose the project to more risk than an unlikely event with high consequences.

Risk management is a systematic process of planning for, identifying, analyzing, monitoring and responding to project risk. It involves processes, tools, and techniques that help the project team minimize the probability and consequences of adverse events and maximize the probability and consequences of positive events. Project risk management is most effective when started early in the life of the project and continued throughout the project. Geocomp Corporation has developed the concept of Active Risk Management™ to describe an organized risk management strategy that transcends the entire project.

Risk can be managed by (1) adopting "conservative" approaches and praying for a good outcome with the hopes of getting lucky, (2) transferring it to another party via a contract, (3) purchasing insurance to cover the risk, (4) using management tools to identify sources of risk and minimize their consequence, and (5) using a combination of these approaches. The first approach was predominating in heavy civil construction until the mid-1900's. The second and third approaches evolved in the last half of the 1900's. Today, the second and third approaches represent what many people refer to as "risk management" in underground construction. However, transferring risk to another party and covering risk with insurance are not very effective at dealing with some of the substantial risks encountered in underground construction.

Active Risk Management provides the project team with more complete information on the risks they face in an understandable format – cost and schedule at risk. This not only helps team members to make informed decisions, but also to monitor the progress of risk management efforts over the duration of the project.

Risk assessment is the first part of a risk management program. It is a systematic process of identifying and analyzing risk. It applies methods of uncertainty analysis with project management tools to consider all potential risks and find those with the highest potential impact on the project objectives.

Construction in, on, or around soil and rock inherently involves substantial uncertainty that creates risk to the owner, contractor, and engineer. These risks are in addition to the conventional risks - those from injury, contract, regulatory, legal, financial, and other risks - associated with the project. No amount of planning and engineering can predict with 100-percent certainty how the ground will actually behave during construction. Among the unknowns are: the geologic profile; the engineering properties of each component of the geologic profile; the groundwater conditions; the in situ stresses; the effects of environmental conditions, construction activities, and time on the underground conditions; limitations of analysis and design methodologies; unknown obstructions; location, condition and performance during construction of existing utilities and other structures; and interactions between the ground and structures. There may also be uncertainty in the forces from extreme events that the project will experience. On top of these are the uncertainties that derive from the mistakes, poor judgment, and improper actions of the work force. These types of risk are referred to as "operational risks". Operational risks are often ignored in the contract, financial, and legal discussions of risk management; yet they may jeopardize the entire project.

One approach to managing risks is to develop a conservative design based on what the project team considers a worst-case scenario, and hope for the best. But unexpected factors, such as excessive ground movements or unexpected groundwater flow can damage completed work or adjacent facilities. These, in turn, can cause project delays, add substantial costs, degrade quality and risk the health and safety of workers and the public.

A more cost-effective way to mitigate risks is to design for the most likely scenario based on an investigation of the underground conditions and potential hazards. The design would include a risk assessment to determine which sources of uncertainty dominate the operational risks, which risks can be reduced with design modifications, and which risks can be avoided with observation and remedial work during construction, i.e. monitoring how the site actually performs as construction begins with adjustments to the design and/or construction methodology as required by the observed performance. This approach uses tools from decision theory, probability theory, and quantification of expert judgment to make numerical assessments of each component of operational risk for underground construction. Information from complex analyses is integrated with opinions from lay experts to produce a balanced assessment of all sources of operational risk. This approach has helped owners and contractors make informed decisions regarding design and construction of underground facilities – decisions that have saved hundreds of millions of dollars by avoiding overly conservative approaches and focusing resources on the most beneficial actions.

Quantitative risk assessment provides a way of numerically estimating the probability that a project will meet its cost and time objectives. Quantitative analysis is based on a simultaneous evaluation of the impact of all identified and quantified risks. The result is the probability that the project will meet its objectives for cost, time, quality and scope, and the effects of the factors that may influence these objectives.

Effective risk management consists of several steps that can be visualized as a continuous circle of improvement shown in Figure 1. Effective risk management requires the process of risk amelioration to be completed and repeated throughout the project duration as new information becomes available. Past risk management practice on many projects has typically been to prepare a risk assessment during the planning phase of a project, then to ignore it for the remainder of the project. This practice does not provide the substantial benefits of a complete risk management program. Effective risk management of project construction starts in the planning phase and continues until after the facility is placed into service.

The work proposed herein covers the first two steps of the circle of risk improvement – identify and assess the potential risks that may impact project cost and completion date and find those with the highest potential impact on the project objectives. Numerous sources of risk exist on a complex project. Some examples of possible risks compiled from various sources are listed in Table 1. The list is not complete and may contain items not applicable to this project. However it illustrates the point that a large underground project may face many sources of risk. It becomes easy to overlook or forget a significant source of risk that later threatens the project objectives.

Using established methods and tools, qualitative risk analysis assesses the probability and the consequences of each identified risk to determine its overall importance. These tools help to correct biases that often creep into the project plan. In particular, careful and objective definitions of different levels of probability and impact of risk events are the keys to the credibility of the results.

IDENTIFY -	Establish the components of risk
ACCESS -	Determine the likelihood of each risk element and the consequences
PLAN -	Define strategies to minimize likelihood and control consequences
MONITOR -	Measure anything that can indicate risk, evaluate the results and update the risk assessment
CONTROL -	Take action to reduce risk at every opportunity.

Figure 1: Circle of Risk Improvement

Another source of project risk comes from uncertainties associated with how well the completed system works, i.e. meets the intended functional requirements. These "efficacy risks" depend greatly on the detailed design. They will not be considered in this work.

Table 1: Sources of Risk in Underground Construction

Table 2: Some Risks in Underground Construction External Risks

- Priorities change on existing program
- Inconsistent cost, time, scope, and quality objectives
- Local communities pose objections
- Funding changes for fiscal year
- Political factors change
- Stakeholders request late changes
- New stakeholders emerge and demand new work
- Influential stakeholders request additional needs to serve their own commercial purposes
- Threat of lawsuits
- Stakeholders choose time and/or cost over quality

Environmental Risks

- Permits or agency actions delayed or take longer than expected
- New information required for permits
- Environmental regulations change
- Water quality regulation changes
- Reviewing agency requires higher-level review than assumed
- Lack of specialized staff (biology, anthropology, archeology, etc.)
- Historic site, endangered species, wetlands present
- EIS required
- Controversy on environmental grounds expected
- Environmental analysis on new alignments is required
- Project in an area of high sensitivity for paleontology
- Project on a Scenic Highway
- Project near a Wild and Scenic River
- Project in a floodplain or a regulatory floodway
- Project does not conform to the state plan for air quality at the program and plan level
- Water quality issues
- Negative community impacts expected
- Hazardous waste preliminary site investigation required
- Growth inducement issues
- Cumulative impact issues
- Pressure to compress the environmental schedule

Right of Way Risks

- Landowners unwilling to sell
- Utility relocation may not happen in time
- Freeway agreements
- Railroad involvement
- Objections to Right of Way appraisal takes more time and/or money

Regulatory Risks

- Water quality regulations change
- New permits or new information required
- Reviewing agency requires higher-level review than assumed
- Different agency claims unexpected authority

Organizational Risks

- Inexperienced staff assigned
- Losing critical staff at crucial point of the project
- Insufficient time to plan
- Unanticipated project manger workload
- Internal "red tape" causes delay getting approvals, decisions
- Functional units not available, overloaded
- Lack of understanding of internal funding procedures
- Priorities change on existing program
- Inconsistent cost, time, scope and quality objectives

Technical Risks

- Design incomplete or in error
- Right of Way analysis in error
- Environmental analysis incomplete or in error
- Inaccurate assumptions on technical issues in planning
- Surveys late and/or surveys in error
- Materials/geotechnical/foundation in error
- Structural designs incomplete or in error
- Hazardous waste site analysis incomplete or in error
- Need for design exceptions
- Consultant design not up to MTA standards
- Context sensitive solutions

Project Management Risks

- Project purpose and need is poorly defined
- Project scope definition is poor or incomplete
- Project scope, schedule, objectives, cost, and deliverables are not clearly defined or understood
- No control over staff priorities
- Too many projects
- Consultant or contractor delays
- Estimating and/or scheduling errors
- Unplanned work that must be accommodated
- Communication breakdown with project team
- Pressure to deliver project on an accelerated schedule
- Lack of coordination/communication
- Lack of upper management support
- Change in key staffing throughout the project
- Inexperienced workforce/inadequate staff
- Resource availability
- Local agency issues
- Public awareness/support
- Failed agreements

Construction Risks

- Inaccurate contract time estimates
- Permit work windows
- Design incomplete or in error
- Right of Way issues
- Environmental issues
- Contract dispute
- Error in quantities
- Material shortages
- Unexpected geotechnical issues
- Change requests because of errors
- Surveys late and/or surveys in error
- Materials/geotechnical/foundation in error
- Unexpected hazardous waste conditions
- Disposal of spoils
- Need for design exceptions
- Unexpected Utilities
- Surveys
- Buried man-made objects/unidentified hazardous waste
- Fire
- Theft and vandalism
- Equipment failure
- Injuries and fatalities
- Disputes
- Quality issues
- Performance issues
- Sabotage
- Power shortage or loss
- Damaged utilities
- Damage to neighboring facilities
- Complaints from neighbors
- Errors and Omissions
- Readiness for execution

Ten Step Approach

Geocomp Consulting's approach to risk assessment involves close teamwork among the Owner, the Engineer, the Contractor (if contract has been awarded) and our team of specialists. The Owner provides information on the project scope and objectives and supplies other resources necessary to conduct the risk assessment. The Engineer provides information on possible risk events, their likelihood of occurrence and their consequences. The Contractor (if under contract) also provides information on possible risk events - especially those tied to the Contractor's means and methods, their likelihood of occurrence, and their consequences.

The Geocomp Risk Team provides the framework for a systematic examination of risk by the team; facilitates the definition of risk events, their likelihood of occurrence, and their consequences; tests the information for completeness and consistency with scientific requirements; develops and applies a mathematical model of risk; and interprets and reports the results to the project team. The Geocomp Risk Team is comprised of professionals experienced in all aspects of planning, design, and construction of underground facilities. We include independent consultants whose expertise closely aligns with unique aspects of the project combined with an understanding of the essential elements of risk analysis.

Figure 2 illustrates the sequence of tasks we use to complete a risk assessment. The process runs in a linear sequence in which the specific work in each task depends on the results of previous tasks.

<u>Step 1: Understand Project Purpose and Scope</u>

All members of our team participate in a briefing by the project team to provide us with an overview of the purpose and scope of the project objectives and constraints. The project team will also describe their prior approaches to risk management and allocation, including insurance and contract provisions for the project. Results of the briefing are intended to orient our team with significant project components and requirements so they can identify the specific activities required to assess risk and the people available to provide information. We present our proposed approach for this risk assessment, identify the types of information that we will require, and describe the methods and tools we will use to obtain information and test its validity.

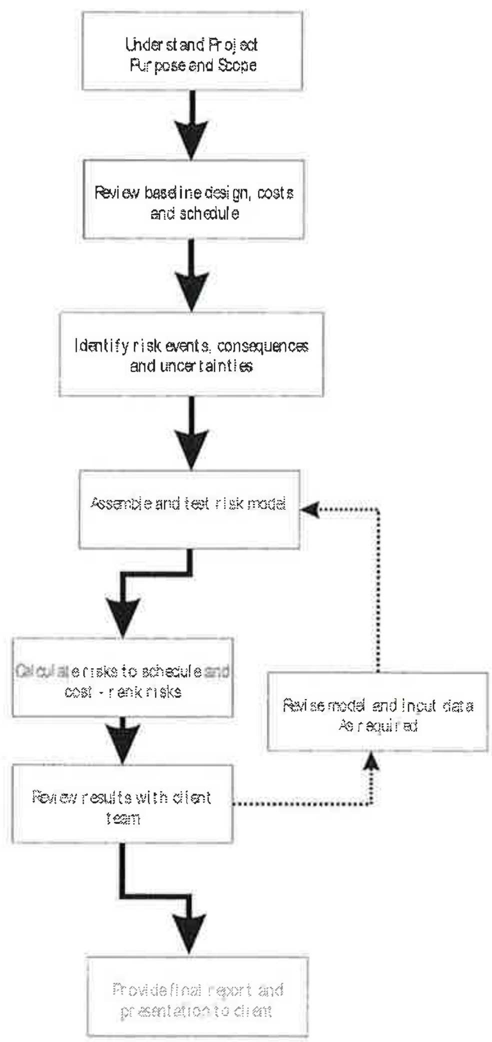


Figure 2: Work Tasks for Risk Assessment

Step 2: Review Baseline Design, Costs, and Schedule

All members of our team will participate in a briefing by the project team to describe the principal elements of the design, the Engineer's cost estimate, the detailed project schedule as planned, the principal assumptions used to produce this information, and the known sources of uncertainty. Results of this briefing provides our team with the baseline conditions and components for cost and schedule that we can examine for elements of risk.

Step 3: Identify Risk Events, Consequences, and Uncertainties

Our teams leads a workshop with selected members of the project team to discuss the purpose of the risk assessment; provide background information on the meaning of risk, consequences and uncertainties; and describe methodologies used to determine probability of a risk event occurring. We divide the participants into specialty working

Project:

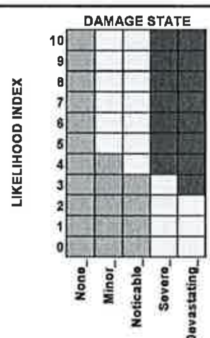
Risk Event:

Description of Potential Loss:

Likelihood of Potential Loss:

Consequences of Potential Loss:

Possible Mitigation Measures:



			Examples
>0.99	≤1	Virtually certain	sun rising tomorrow; telephone will work
>0.8	≤0.99	Almost certain, very likely	you rising tomorrow
>0.6	≤0.8	Likely, probable	
>0.4	≤0.6	Fifty-fifty, neutral	coin toss gives heads
>0.2	≤0.4	Moderate, considerable	
>0.1	≤0.2	Occasional	rolling a six with a single die
>0.01	≤0.1	Unlikely, low	
$>10^{-3}$	$\leq 10^{-2}$	Very unlikely, very low	
$>10^{-4}$	$\leq 10^{-3}$	Improbable, rare	you will die in car accident
$>10^{-5}$	$\leq 10^{-4}$	Very rare, extremely low	single large dam will fail in any year
	$\leq 10^{-5}$	Virtually impossible	1 km diameter object strikes earth next year

Place symbols in appropriate box using
- C for cost
- T for time/schedule
- Q for quality
- S for scope

None
- no identifiable losses

Minor, insignificant
- no injuries
- no loss of use
- repairs done by maintenance
- no impact on Critical Path
- very minor impact on quality
- scope change is barely noticeable

Noticable
- minor injuries
- some loss of use
- requires some reconstruction
- recoverable impact on Critical Path
- cost impacts <10% increase
- scope changes <10% of contract
- extra QA work required

Severe (requires detailed assessment)
- loss of life
- loss of use
- requires major reconstruction
- significant delay to project, penalties incurred
- 10-30% increase in cost
- scope does not meet purpose and need
- quality severely degraded

Devastating (requires detailed assessment)
- substantial loss of life
- >30% increase in cost
- collapse
- must demolish and replace
- scope does not meet purpose and need
- poor quality prevents occupany

Comments:

Figure 3: Risk Event Worksheet

groups to examine specific groups of risk, including Contractual, Financial, Regulatory, External, and Operational Risks. During Step 3 we will make extensive use of a tool shown in Figure 3 that we have developed to help us make preliminary risk assessments. Figure 3 is completed for each potential source of risk by knowledgeable project staff and members of our risk team. Potential effects on project objectives for cost, time, quality, and scope are considered. Results of this effort help us to identify and focus our efforts on the significant risks to the project without overlooking any known element. All risks that are classified as yellow or red are subject to refinements for the estimates of likelihood and damage state. Probability of each risk event is determined from historical data, expert opinion, and subjective estimates from project staff. Some values of probability and consequence may themselves be uncertain, but this can be considered as well. Results of this step are crucial to the adequacy and validity of the risk assessment. We employ risk assessment techniques to capture subjective estimates of risk, identify internal biases, and reveal hidden risks.

<u>Step 4: Assemble and Test the Risk Model</u>

Each project faces a unique set of risks with complex mathematical interactions between events, and their likelihoods and consequences. These interactions can be estimated by a numerical simulation model. This numerical model determines how the risks propagate through the project model to affect the estimated cost and completion time. Numerous simulations are completed to obtain a distribution of possible costs and schedules. The numerical model must be calibrated by testing it with repeated runs of known scenarios to remove any errors produced while assembling the model. The model must also be kept as simple as possible while still capturing the components of all components of risk that can potentially impact the project objectives.

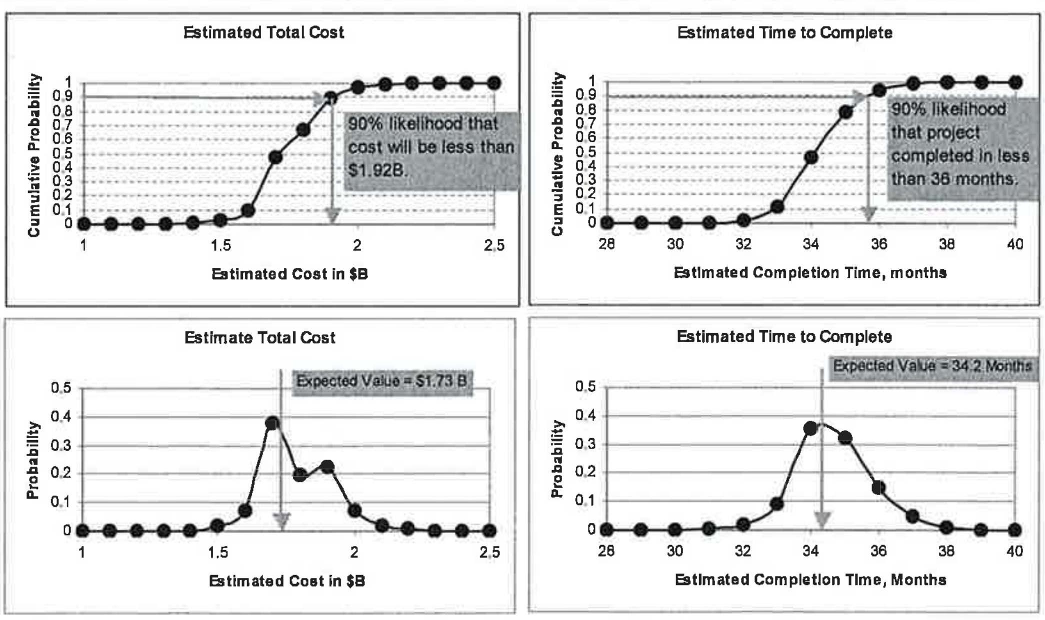


Figure 4: Uncertainty in Project Cost and Schedule

Step 5: Calculate Risks to Schedule and Cost

The numerical model of risk is run through numerous simulations using the likelihoods and consequences obtained from our work with the project staff. Figure 4 illustrates a typical result. In addition to the expected cost and completion time that comes from conventional estimating procedures, the risk assessment indicates how the uncertainties that may affect the estimated cost and completion time. One of the most useful results from the risk assessment is the information to examine the likelihood that the cost will exceed a certain amount or that the schedule will overrun a certain date. Figure 4 illustrates how this is done. The example shows a 90% chance that the cost will not exceed $1.92B and a 90% chance that the schedule will not exceed 36 months.

The simulations are repeated with probabilities for each major risk set to zero to determine the relative contributions of each major source of risk to uncertainty in estimated total cost and estimated time to complete.

Step 6: Review Results with Client Team

Results from Step 5 are presented to and reviewed with the Client Team. Results include the contribution of each risk event to the uncertainty in estimated project cost and completion time. The purpose of this review is to reconsider the risk assessment components on the computed results to ensure that the information being used is complete, consistent, and meaningful. This activity also helps us to develop the most effective ways to summarize and present the results of our risk assessment in ways that are most useful to the Project team and MTA management. This review will also identify any changes required to the risk model and the risk information.

Step 7: Revise Risk Model and Input Data as Required and Prepare Draft Report

We revise the risk model based on the outcome of Step 6 and rerun it to prepare the revised risk assessment. We draft a written report that documents the procedures we used, the data we obtained, and the results of the risk analysis. We will provide recommendations for future actions to incorporate this risk assessment into an overall risk management plan for the project.

Step 8. Identify Key Risk Indicators

Which key components of risk can be measured in real time to provide early warning of unexpected behavior so consequences can be mitigated.

Step 9: Prepare Final Report and Present to Client

We will revise the final report based on comments received from the Client's representatives. We also propose to present the results obtained from this risk assessment to an audience selected by the MTA and encourage the Project Team to implement a strategy to manage risk for the duration of the project.

Step 10. Implement Active Risk Management Program

KRIs are monitored and assessed as often as necessary to maximize benefits of active risk management. Periodic updates of the risk assessment are prepared and reviewed with the project risk management team. (risk update should be an item on the project meeting agenda just like safety, schedule, budget, etc.) All results of ARM to be documented so effectiveness and benefits for the project can be assessed at the end of the project and reviewed with the risk management team and the key project players.

Client Benefits

Active Risk Management provides the project team with more complete information on the risks they face in an understandable format – cost and schedule at risk. This not only helps team members to make informed decisions, but also to monitor the progress of risk management efforts over the duration of the project.

Active Risk Management provides clients with a continual assessment of their risk profile and how it is changing as the project progresses. Active Risk Management identifies specific actions that can be used to alter events and reduce consequences; thereby preventing unexpected and costly events. Active Risk Management seeks to contain and control the many costs that result from unexpected and uncontrolled events, resulting in savings that are many times the cost of the risk management effort.