Risk Management: Introduction to the Principles and Practice of Risk Management for Underground Projects

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March 10, 2020
Major Tunnel Project? **DON’T TAKE THE BUS!**
CUT AND COVER IS LOW RISK ...
GEOTECHNICAL RISK MUST BE MANAGED
ALL PARTICIPANTS HAVE THEIR OWN ATTITUDE TO RISK
WHAT ARE WE TALKING ABOUT?

• Principles of risk management
• Risk registers and their use at all stages of a tunnel project
• Risk Allocation Report and its use in design, procurement and construction
• Quantitative risk analysis
PRINCIPLES OF RISK MANAGEMENT

1. AVOID
Change tunnel alignment to avoid structures

2. MITIGATE
Probe ahead and grout to mitigate risk from faults

3. ALLOCATE
Provide clear contractual baselines to allocate residual risk
DON’T WORRY, THERE IS GUIDANCE FOR THE UNDERGROUND INDUSTRY

• Code of practice exists for underground risk management

• Particulars include:
  Experience - most important aspect of project team
  Use risk registers to present and organize hazards
  Be open and transparent about awareness of project risks
TUNNEL PROJECT RISK MANAGEMENT

• US Practice established by this document
• Published – pdf available online
• Rigorous industry review
• Published by UCA of SME FREE!

• Guidelines emphasize:
  Importance of experience
  Collaboration
  The use of risk registers
  Appointment of Risk Manager
APPOINTMENT OF A RISK MANAGER

- Dedicated person in the project controls team of either Contractor or CM Team
- Can be fully committed to risk on sufficiently large or complex projects
- Could also have other project controls functions, including data management, schedule or cost control
- Serves as an advisor to project management team
  - Prompts team about upcoming risks
  - Facilitates decision-making
- Carries out quantitative analysis when required
- Leads risk workshops and meetings
- Presents project to auditors/insurers/owners/investors when necessary
- Updates risk register and reports on project risk profile
Risk Register Format
RISK MANAGEMENT IS A PROCESS

START

Identify Risks
What Could Go Wrong?

Assess Risks
Quantify / Rank

Identify Control Measures
Mitigation / Management / Control

Risk & Opportunity Register

Risk Eliminated

Implement Control Measures

Monitor

Risk Mitigated

Residual Risk Acceptable?

Update Risk Register

Risk Allocated

Acceptable?

Y

N
<table>
<thead>
<tr>
<th>Risk Description</th>
<th>Risk likelihood</th>
<th>Risk consequence</th>
<th>Control Measures Implemented (actually in place today)</th>
<th>Indicators or Metrics (Measuring the effect of Control Measures)</th>
<th>Residual Likelihood - After Mitigation (Blank = Risk Closed)</th>
<th>Residual Consequence - Once Controls in Place</th>
<th>Residual Risk Score - After Mitigation Action</th>
<th>Action Item for Risk Mitigation</th>
<th>Action Item Completion Date (Target Date)</th>
<th>Responsible Party or Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual ground conditions different to GBR baselines, due to unexpected changes in ground conditions, that leads to minor DSC claims, increased project costs, and/or project delays</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>16 Geotechnical investigation and laboratory testing</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>8 Create contractual baselines</td>
<td>see schedule</td>
<td>J. Doe</td>
</tr>
</tbody>
</table>
### Risk Description

Actual ground conditions different to GBR baselines, due to unexpected changes in ground conditions, that leads to minor DSC claims, increased project costs, and/or project delays

<table>
<thead>
<tr>
<th>Risk likelihood</th>
<th>Risk consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>4</td>
</tr>
<tr>
<td>Project Schedule</td>
<td>3</td>
</tr>
<tr>
<td>Social Environment</td>
<td>4</td>
</tr>
<tr>
<td>Regulatory/ Legal</td>
<td></td>
</tr>
<tr>
<td>Health and Safety</td>
<td></td>
</tr>
<tr>
<td>Operating &amp; Maintenance</td>
<td></td>
</tr>
<tr>
<td>Natural Environment</td>
<td></td>
</tr>
</tbody>
</table>

**Risk Score:** 16
## Likelihood Ratings and Risk Score Table

<table>
<thead>
<tr>
<th>Probability Rating</th>
<th>AKA</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Probable</td>
</tr>
<tr>
<td>4</td>
<td>Likely</td>
</tr>
<tr>
<td>3</td>
<td>Possible</td>
</tr>
<tr>
<td>2</td>
<td>Unlikely</td>
</tr>
<tr>
<td>1</td>
<td>Improbable</td>
</tr>
</tbody>
</table>

### Probability

- 5 (Probable)
- 4 (Likely)
- 3 (Possible)
- 2 (Unlikely)
- 1 (Improbable)

### Consequence

- 5
- 4
- 3
- 2
- 1

### Color Coding
- Red: High Risk
- Yellow: Moderate Risk
- White: Low Risk

### Diagram

The diagram visualizes the likelihood ratings and consequences, with high-risk areas in red, moderate-risk areas in yellow, and low-risk areas in white.
## CONSEQUENCE SCORING CATEGORIES

<table>
<thead>
<tr>
<th>Risk Consequence Criterion</th>
<th>Consequence Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low 1</td>
</tr>
<tr>
<td><strong>Financial</strong></td>
<td>Less than $100k</td>
</tr>
<tr>
<td><strong>Project Schedule Impacts</strong></td>
<td>1 to 7 days</td>
</tr>
<tr>
<td><strong>Social environment</strong></td>
<td>Complaints from local public</td>
</tr>
<tr>
<td><strong>Regulatory / Legal</strong></td>
<td>Isolated non-compliance</td>
</tr>
<tr>
<td><strong>Health &amp; Safety</strong></td>
<td>Minor injury or near-miss (non-reportable)</td>
</tr>
<tr>
<td><strong>Operating and Maintenance</strong></td>
<td>Minor increase in expected O&amp;M activity (barely measurable)</td>
</tr>
<tr>
<td><strong>Natural Environment</strong></td>
<td>Minor short term local impact</td>
</tr>
</tbody>
</table>
## RISK REGISTERS – RISK MANAGEMENT AND ALLOCATION

<table>
<thead>
<tr>
<th>Control Measures Implemented (actually in place today)</th>
<th>Indicators or Metrics (Measuring the effect of Control Measures)</th>
<th>Residual Likelihood - After Mitigation (Blank = Risk Closed)</th>
<th>Residual Consequence - Once Controls in Place</th>
<th>Action Item for Risk Mitigation</th>
<th>Action Item Completion Date (Target Date)</th>
<th>Responsible Party or Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geotechnical investigation and laboratory testing</td>
<td>Distribution of lab test results</td>
<td>2 3 4</td>
<td></td>
<td>Create contractual baselines</td>
<td>see schedule</td>
<td>J. Doe</td>
</tr>
</tbody>
</table>
CORRECTLY ASSESSING YOUR PROJECT RISKS IS IMPORTANT
SOMETIMES THE RISKS ARE OBVIOUS TO ANYBODY
CHANGES TO RISK REGISTER THAT OCCUR DURING THE PROJECT

• Risks change during the project
• Format of the risk register can change
• Audience for the risk register through project
  Planning – upper management and politicians
  Design team
  Contractor and construction team
  Risk auditors
  Operations staff
USE OF THE RISK REGISTER AS A PROJECT MANAGEMENT TOOL

• Action Items become a consolidated “to do” list for the project.
• Presentation tool for risk/hazard mitigation
• Easily understood by non-technical staff and decision-makers
• Easily reviewed by project management staff
• Once set up – easy to modify
USING THE RISK REGISTER TO MANAGE RISK

• Should be a single location for all foreseeable project risk

• Owner, designer, contractor must use the same risk register

• Forward-looking document to consider upcoming hazards

• NOT a checklist of all the bad things that have happened!
COMMITMENT TO THE PROCESS LEADS TO SUCCESS

• Comparison between risk register and schedule
• Schedule is on the wall – does not mean the job will be completed on time!
• Having a risk register is not enough
• Must have a sound process
• Must execute that process
• Must constantly check and validate the process
What Did We Learn So Far?
ANYTHING CAN BE DANGEROUS
IF YOU HAVE THE WRONG PEOPLE INVOLVED
WHAT WILL WE LEARN THIS WEEK?

• We must learn lessons from our projects.
• Under no circumstances - learn lessons during a project.
• Involve your attorneys in every meeting – just in case you want to make materials non-discussable later.
• Share the risk register.
• Do not share the risk register.
• Project owner sets the tone for risk management process.
• Project owner is sometimes the biggest risk on the project.
• Risk management is a critically important process.
• Why bother!
PRUDENT RISK MANAGEMENT CAN HELP PREVENT FORESEEABLE PROBLEMS

DIG THREE GRAVES UP THERE.

I'LL EXPLAIN IT TO YOU LATER.
Moving the Risk Register Through Design Build Procurement
RISK REGISTER DURING DESIGN BUILD PROCUREMENT

- Risk register should be a contract document
- Well established process
  - Risk register requested as part of the bid
  - Used during one-on-one meetings
- Best value selection
  - Allows the risk mitigation strategy to be used as part of selection
- Process can be molded to suit agency
Moving the Risk Register Through Design Bid Build Procurement
• Risk register could be a contract document – but better issued “for information only”
• Remove fully mitigated risks
  Issues such as obtained permits, finance, design process risks etc.
• Be clear on contractual allocation of residual risk
  Location in contract where risk considered
• Use a Risk Allocation Report
WHAT IS A RISK ALLOCATION REPORT?

• Purpose: clarify how risks are considered in contract document
• Assists contractor with familiarization of contract documents
• Narrative support to risk register
  References contract clauses
  Explains how risks are allocated
  States mitigation action necessary
  Considers all sources of potential conflict
DO YOU KNOW THE RISKS YOU ARE TAKING?
WRITING A RISK ALLOCATION REPORT?

• Written at 90% design stage
• Should contain no new information
• Most risks require a single simple reference to the contract
• Some risks need a more detailed narrative to describe fully
• Writing report is similar to claim analysis
  In depth analysis of each major risk issue
  Narrative description of that issue
USING A RISK ALLOCATION REPORT

- Does not supersede any contract document
- Helps to promote a well thought out design
  Aids in producing more consistent documents – help avoid disputes
- Subject of discussion during procurement
  Pre-advertisement workshop
  Pre-bid meeting
- Assists with administration of contract during construction
Quantitative Risk Analysis
COMPLEX MATH CAN LEAD TO AMBIGUITY

3. Find x.

Here it is
BE CAREFUL WITH STATISTICS

Critical factors in this process include:

- Experience important in obtaining correct input
- Strict mathematical discipline with analysis and model

There is a right answer – but you must be ready to defend your method

Useful analysis at milestone points of design and construction

- Assessing budget contingency required during design
- Assessing when to release contingency during construction

Not as effective in managing day-to-day project risk as qualitative methods
### Quantification of Risk Rating Scale [Mega Project]

<table>
<thead>
<tr>
<th>Rating Scale</th>
<th>Rating Description</th>
<th>Evaluated Probability</th>
<th>Percentage (Single occurrence = mean)</th>
<th>Poisson (Reoccurrence Possible)</th>
<th>Minimum Cost</th>
<th>Most Likely Cost</th>
<th>Maximum Cost</th>
<th>Minimum Delay (mo)</th>
<th>Most Likely Delay (mo)</th>
<th>Maximum Delay (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Probable</td>
<td>&gt;50%</td>
<td>75.0%</td>
<td>1.37</td>
<td>$500,000,000</td>
<td>$750,000,000</td>
<td>$1,000,000,000</td>
<td>12</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Likely</td>
<td>25-50%</td>
<td>37.5%</td>
<td>0.45</td>
<td>$100,000,000</td>
<td>$300,000,000</td>
<td>$500,000,000</td>
<td>6</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Possible</td>
<td>25-50%</td>
<td>17.5%</td>
<td>0.20</td>
<td>$50,000,000</td>
<td>$75,000,000</td>
<td>$100,000,000</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Unlikely</td>
<td>5-10%</td>
<td>7.5%</td>
<td>0.09</td>
<td>$5,000,000</td>
<td>$27,500,000</td>
<td>$50,000,000</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Improbable</td>
<td>&lt;5%</td>
<td>2.5%</td>
<td>0.03</td>
<td>$ -</td>
<td>$2,500,000</td>
<td>$5,000,000</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>
USE WBS TO DISTRIBUTE BASE COST IN TIME
ADD RISK TO WBS ITEMS - DISTRIBUTE RISK AND ESCALATION

Color Key:
- Escalation – Purple
- Risk Cost – Red
- Base cost – Blue
QRA OUTPUT—PROBABILITY CURVES OF COST/CONTINGENCY

Base Cost = Blue Line
Base+Risk = Red Lines
Base+Risk+Escalation= Green Lines
Post-Risk Mitigation = Dashed Lines
CONCLUSIONS

- Design risk register should be scrubbed thoroughly before being used during procurement
- Procurement risk register in bid package for information only
- Procurement risk register supported by Risk Allocation Report
- Risk register should have contractor-identified risks added in a workshop held before NTP
- All contractual parties must be incentivized to respond positively for full benefits to be recognized
ACKNOWLEDGE THE POTENTIAL HAZARDS AROUND YOU
BE JUDICIOUS ABOUT YOUR RISK ASSESSMENT
AVOID THE BAD GUYS
RISK MANAGEMENT – BRINGS GOOD RESULTS FROM DIFFICULT PROJECTS!
QUESTIONS?

- **The Documents**
  - Codes of Practice – BTS (2003) and ITIG (2012)

- **The Tools**
  - The contract
  - Risk register
  - Risk allocation report
  - Qualitative management of risk
  - QRA for budget and contingency control