Risk Management in Underground Construction Through Good Contractual Practices

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Content

1. Importance of risk management in underground works
2. Risk handling alternatives.
3. The contract as main regulator and allocator of risk.
4. Precedent on contractual practices in tunnels.
5. Procurement alternatives.
6. Shortcomings of existing standard form of contracts
7. Required elements in underground construction contracts.
8. Recent developments in the area.
• Before the Renaissance: 
  Future = luck, random,  
dependent on the god’s wishes.

• Great strides in knowledge and  
  science were only possible when  
  humanity took charge of its future.

• Acknowledged that despite the  
  uncertainties that the future holds it  
  was in its power to manage and  
  mitigate these risks.

• "Riscare" Italian for to dare.
Until recently risks were managed implicitly, rather than explicitly in regular engineering practice. Engineers have started to recognize the shortcomings of this practice.

In particular, geotechnical and tunneling engineering benefit greatly from formal, rigorous risk management.

Risk management lies at the heart of tunnel engineering.
The Observational Method: A different Design Philosophy.

- Terzaghi & Peck promoters of this method.
- Important in the success of the Chicago (USA) Subway.
- Role of Engineer

- Identify Risks
- Probable Unfavorable Circumstances
- Devices Remedial Measures
- Deploys them if unfavorable Conditions Encountered
Subsurface Risks (geotechnical risks) are amplified.

- Differing Site conditions, main source of risk.
- Geotechnical uncertainty stems from:
  - Inadequate knowledge of geological conditions.
  - Ground response often difficult to predict.
  - Complex ground-structure interaction.

- Most structures foundation often main source of uncertainty. In tunnels the ground is the main construction material.
- Lineal nature and extent of tunnels makes characterizing the ground costly and difficult.
- Most activities in the critical path. Difficult to introduce additional excavation fronts.
IMPLICATIONS OF VARIABILITY AND UNCERTAINTY?

Variability and Indefinition of Scope of Work for Contractor.
1. **Major Cost Overruns and Delays**

- **Central Artery Tunnel -“Big Dig” in Boston**.
- **Originally to be completed in 1998.**
- **Estimated cost of $2.8 billion (in 1982 dollars.**
- **Completed only in December 2007, 9 years later.**
- **Cost of over $14.6 billion ($8.08 billion in 1982 dollars,**
- **Cost overrun of about 190%.**
- **Most expensive infrastructure project ever undertaken in US.**
- **Extensive leaks and fatal collapse**
Euro Tunnel - "Chunnel"

- Construction of the tunnel started in 1988.
- The project took approximately 20% longer than planned (at 6 years vs. 5 years)
- 80% overbudget (at 4.6 billion pounds vs. a 2.6 billion pound forecast).
- Owner bankrupted twice.
Jubilee Line Extension

- **Original Budget:** $4,884,225,500
- **Final Cost:** $8,997,257,500%
- **Over Budget:** 84%
- **Start Year:** 1993
- **Deadline:** 1997
- **Completion Year:** 1999
- **Years Past Deadline:** 2
Increasing Difficulty Insuring Tunneling Projects

- List of subways with largest insurance losses since 1994.

<table>
<thead>
<tr>
<th>Project</th>
<th>Type of Loss</th>
<th>Cause of Loss</th>
<th>Loss (£m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heathrow Express, 1994</td>
<td>Tunnel Collapse</td>
<td>Faulty workmanship</td>
<td>150</td>
</tr>
<tr>
<td>Munich metro, Germany, 1994</td>
<td>Tunnel Collapse</td>
<td>Faulty design</td>
<td>2</td>
</tr>
<tr>
<td>Metro Taipei, Taiwan, 1994</td>
<td>Ingress of water</td>
<td>Faulty workmanship</td>
<td>12</td>
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<td>Metro Los Angeles, USA, 1995</td>
<td>Tunnel Collapse</td>
<td>Faulty workmanship</td>
<td>16</td>
</tr>
<tr>
<td>Metro Taipei, Taiwan, 1995</td>
<td>Ingress of water</td>
<td>Faulty workmanship</td>
<td>30</td>
</tr>
<tr>
<td>Metro Taegu, Korea, 2000</td>
<td>Tunnel Collapse</td>
<td>Faulty design/workmanship</td>
<td>13</td>
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<td>Shanghai Metro, PRC, 2003</td>
<td>Tunnel Collapse</td>
<td>Faulty workmanship</td>
<td>69</td>
</tr>
<tr>
<td>Singapore Metro, Singapore, 2004</td>
<td>Tunnel Collapse</td>
<td>Faulty design/workmanship</td>
<td>180+</td>
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<tr>
<td>Barcelona Metro, Spain, 2005</td>
<td>Tunnel Collapse</td>
<td>Geotechnical problems</td>
<td>t.b.a</td>
</tr>
<tr>
<td>Lausanne Metro, Switzerland, 2005</td>
<td>Ingress of water</td>
<td>Geotechnical problems</td>
<td>t.b.a</td>
</tr>
<tr>
<td>Kaohsiung Metro, Taiwan, 2005</td>
<td>Ingress of water</td>
<td>Faulty workmanship</td>
<td>t.b.a</td>
</tr>
<tr>
<td>Sao Paolo Subway, Brazil, 2007</td>
<td>Tunnel Collapse</td>
<td>Faulty design/workmanship</td>
<td>t.b.a</td>
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<tr>
<td>Beijing Subway, PRC, 2007</td>
<td>Tunnel Collapse</td>
<td>Faulty design/workmanship</td>
<td>t.b.a</td>
</tr>
<tr>
<td>Cologne Metro, Germany, 2009</td>
<td>Tunnel Collapse</td>
<td>Geotechnical problems</td>
<td>t.b.a</td>
</tr>
</tbody>
</table>
• Projects with long tunnels experienced cost overruns of over 60% due to geologic adversity
Differing Site Conditions

Rival Relationships

Claims and Disputes

Constly Litigation

Cost increases
MEGAPROJECTS AND RISK

• Highly Complex
• Multiple restrictions
• Large CAPEX
• Long duration
• Affected by socio-economic changes
• Interference with other projects and existing infrastructure (i.e. utilities).
• Multiple Stakeholders often with conflicting interest
• Budgets are undervalued.
• Initial design stage budgets are taken as the comparison basis.
• Estimates do not take uncertainty into account.
• Changes in external conditions.
• Contigencies estimated with no rigor.
• Deterministic vs. probabilist budgets.
• Differing Site Conditions.
• Unforeseen Conditions.
• Lack of contractual flexibility.
• Inappropriate risk allocation.
• Deficient project implementation and management.
Influence over Project Costs vs Percentage Completion
Uncertainty in the Cost Estimate

- Budget contingencies should be adjusted to the level of risk.
- More advanced designs indicate less contingency.
Comparison of tender price vs Final price for different levels of geotechnical investigation

UTRC, 1984
• **Projects should comply with the triple restriction**

• **Good PM proactive not reactive.**

- PM keep triangle balanced.
- Risks: Impact one of the sides of the triangle.
- Good risk management contributes to equilibrium.
RISK MANAGEMENT IS NOT OPTIONAL

O s t r i c h Strategy

RISK

• Stressing
• Intimidating
• Generates Anxiety.

Manage risk
(Face when making decisions)

Vs.

Dissapear

Risks don’t dissaperar if ignored
¿What is risk?

\[ \text{RISK} = p(i) \cdot I \]
• **Nature of uncertainty determines how the probability of occurrence of a risk is estimated**

• **Uncertainty:**
  • Random
  • Epistemic: Lack of knowledge

• **Probability estimate:**
  - Relative frequency  \( \text{Probabilidad} = \text{frecuencia durante varias pruebas} \)
  - Degree of belief.

• **In tunnels uncertainty is mostly epistemic**
GENERAL RM FRAMEWORK

RISK IDENTIFICATION

RISK MONITORING

Periodic Update

Risk Assessment

RISK HANDLING

Assume Mitigate Transfer Avoid

Prioritized List
RISK HANDLING ALTERNATIVES

- Avoid
- Assume
- Mitigate
- Transfer

Selection should be based on cost/benefit analysis.

- Avoiding often most effective.
- Assigned risks to the natural owner. Who can control it?
- Transferred risks could still come back to the original owner.
- Assign to party with capacity to understand and handle risk

Proper risk Management = Competitive Advantage
CONTRACTS REGULATE RISK IN PROJECTS

- Procurement strategy and type of contract fundamental to identify, assess, regulate, and allocate risk in construction projects.
- Regulate risk ownership=> responsibility to manage it.
- By determining who is liable for a risk, it determines who has the motivation to avoid it.

Contractual risk allocation defines fundamental issues:
- Contractors Contigency.
  Greater risk, greater contigency and higher tenders.
- Contractual behavior and attitudes.
  Unbalanced Contracts=> disputes.
• Exhibit unique characteristics
• Demand special contractual considerations
• Contractual practices key => efficacy and efficiency of design and construction methods
“Good contract” (Edgerton, 2008):

1. Unambiguously define scope.
2. Allocate risks fairly.
3. Define procedural protocols.
4. Clearly define roles and responsibilities.

When parties believe that relationship is regulated by fair contract and reward for the known risk is within control:

=> Increases the likelihood of project success.
=> Inappropriate risk allocation leads to claims and disputes.
Traditionally built using LUMP SUM contracts

All the geotechnical or ground risk was shifted to the contractors

“Lowest bidder”. Contractors try to recover through claims arguing differing site conditions

Costly litigation, more costly projects and even uncompleted projects

• **Current contractual approach to tunneling projects promotes an equitable allocation of risks.**
• **Fosters a collaborative atmosphere between owner and contractor, and stimulates the use of advanced construction techniques and technologies.**
1. It is the owner who will benefit from the completed project. Thus, the ground belongs to the project owner.
2. The owner has the responsibility to pay reasonable costs required to handle ground conditions.
3. Risk should be allocated to the party that can best control it.
4. Transferring the geological or geotechnical risk completely to the contractor gives the owner a false sense of security.
5. Balanced and equitable allocation of ground related risks leads to lower cost of the works and more competitive bids.
6. A changed conditions clause should be included in underground construction contracts. Disclaimers and exculpatory language should be eliminated.
7. All available data and interpretations should be disclosed to bidders.
8. Alternative dispute mechanisms implemented.
• **Procurement strategy selection decision** with greatest overall effect on overall risk management of a project.
• **Choice should involve identifying risks and ad/disadvantages from owner’s perspective.**
• **No scheme is adequate in all cases.**
• **Depends on owner's capabilities, sophistication, financial capacity, project complexity, schedule restrictions, and scope.**
• **Should be left to solely to the legal area.**
Ø New Joint Code of Practice for Risk Management of Tunnel Works
Ø ITA guidelines for risk assessment
Ø Formulate owner’s risk policy
Ø Contractor contractually required to perform RM

Ø Five Step Process:

1. Identify Risks- Brainstorming by experienced team
2. Quantifying impacts of risks (costs, schedule, safety)
3. Identify proactive actions to eliminate or mitigate them
4. Identify methods for control of risk
5. Contractually allocate risks (Who owns them?)
### Risk Registers

<table>
<thead>
<tr>
<th>Probability (P)</th>
<th>Impact/Consequence (P)</th>
<th>Time and Cost Impact (US$)</th>
<th>Risk Rating</th>
<th>Risk=PxI</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Likely</td>
<td>5</td>
<td>&gt; 10 weeks on completion</td>
<td>&gt;1 million</td>
<td>Intolerable</td>
<td>17 to 25</td>
</tr>
<tr>
<td>Probable</td>
<td>4</td>
<td>&gt; 1 week on completion</td>
<td>&gt;10^5 to 1 million</td>
<td>Intolerable</td>
<td>13 to 16</td>
</tr>
<tr>
<td>Likely</td>
<td>3</td>
<td>&gt; 4 weeks&lt;1 week on comp.</td>
<td>&gt;10^5 to 10^6</td>
<td>Substantial</td>
<td>9 to 12</td>
</tr>
<tr>
<td>Unlikely</td>
<td>2</td>
<td>1 to 4 weeks on activity</td>
<td>&gt;10^3 to 10^4</td>
<td>Tolerable</td>
<td>5 to 8</td>
</tr>
<tr>
<td>Negligible</td>
<td>1</td>
<td>&lt;1 week on activity</td>
<td>&lt;10^3</td>
<td>Trivial</td>
<td>1 to 4</td>
</tr>
</tbody>
</table>

### Risk Cause

<table>
<thead>
<tr>
<th>Risk</th>
<th>Cause</th>
<th>Before Control</th>
<th>After Control</th>
<th>Response/Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>P</td>
<td>Impact</td>
<td>Risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost</td>
<td>Schedule</td>
<td>Safety</td>
</tr>
<tr>
<td>Explosive Gases</td>
<td>Methane</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

(After Clayton, 2001)
ITA has recommended application of certain principles and practices into tunneling contracts.

Avoided prescriptive and specific recommendations.

WG-3 Contractual Practices

• “ITA Recommendations and Contractual Sharing of Risks”
• “ITA Position Paper on Types of Contract”
• “The ITA Contractual Framework Checklist for Subsurface Construction Contracts”.
• Some of recommendations and best practices have permeated industry.
• No international standard is currently accepted nor recognized.

• Standard form of contracts, exhibit shortcomings for implementing them in tunneling projects, and require considerable adjustments for UP.

• Legal (common law vs. civil law), regulatory and local practices around the world are so varied that make the standardization impractical and perhaps impossible???

• Certain principles and considerations are universally applicable and valid in different jurisdictions, and we should thus aim to promote them globally.
• **During implementation phase the original intend of some of principles is sometimes misunderstood or modified due to inexperience from individuals drafting particular provisions.**

• **Potential for standard form of contract for the tunneling industry valid across the world.**

• **Aid in the standardization, predictability and globalization of tunneling industry.**

• **WG3 - Evaluated Existing Standard Form of Contracts.**
Adapting the FIDIC Standard Forms of Contract for Underground Construction Projects
FIDIC Standard Forms of Contracts

- **FIDIC=International Federation of Consulting Engineers**
- **Most widely used contract conditions for construction industry worldwide. Especially for large international projects.**
- **Multilateral development banks also endorse them.**
- **Popularity and acceptance due to: applicability in different legal systems, clear and coherent language and perceived equitable distribution of risks.**
- **Satisfy conditions of a “good contract”.**
- **Require substantial modifications and complements to properly allocate and manage subsurface risk in UCP.**
SELECTING THE PROCUREMENT STRATEGY

**FIDIC suit of contracts for procurement alternatives**

**Traditional**  
*(Design-Bid-Build, DBB)*

**Design-Build**  
*(Engineer-Procure-Construction EPC)*

**Turnkey Contract:** Not suitable for tunneling projects => risk shifted completely to contractor
Representatives from FIDIC-ITA.

Started work in September 2014 in Geneva.

Switzerland, Austria, France, Korea, England, Sweden and Colombia.

Friendly review Phase.
Traditional Scheme (Design-Bid-Build, D/B/B)

- Separate contracts for design and construction.
- Owners first contracts designer.
- Contractor builds project in accordance with design and specifications.
- Typically in public projects contractors are selected based on the lowest price.
- Lump sums, unit prices or combination of both.
- Owner retains most of the project risks, including varying subsurface conditions.
Traditional Scheme (Design-Bid-Build, DBB)

1. The designer has more time to carry out designs and studies.
2. Uncertainty in the variation of construction costs tends to be smaller when project is bid for construction.
3. Greater owner control, focused responsibility, construction pricing based on a final and complete design, and better quality control.

1. Longer project development times.
2. Limited value engineering and constructability feedback from the contractor.
3. When designs are delayed and the contractor is affected, claims often result from schedule impacts.
Design-Build (Engineer-Procure-Construction EPC)

- A sole entity in charge of design, and construction of the whole project or a portion.
- Single line of communication and responsibility between the owner and the Designer-Builder.
- Appropriate if owner wants to delegate majority of project responsibilities to a third party or has little managerial capacity or experience.
1. Reduced project schedule.

2. Single point of responsibility.

3. Constructor participation in design, constructability and value engineering reviews.

1. Quality control. Long term incentives not aligned. Possible incentive on the contractor to reduce the quality and durability of the project works.

2. Owners has less control on performance specifications.

3. Potential to use poor and basic designs to bid the construction. This leads to cost and schedule overruns when the detail designs are developed.

4. Risks shifted to contractor become a reality through contingency.
1. The owner bears the risk of physical conditions which could not have been reasonably foreseeable by an experienced contractor at the date of tender. (see clause 4.12).

2. Owner required to provide all relevant data it has on subsurface conditions.

3. Contractor obliged to inspect site and procure necessary info that might affect works (clause 4.10).

4. Allow for time extension and additional costs if physical conditions are not reasonably foreseeable.

5. Risk distribution philosophy=> employer owns ground risk.

6. Practical difficulty interpreting boundary of ground risk allocation and establishing what is “reasonably foreseeable”.

This often leads to claims and disputes, and unclear risk allocation.
Proposed Changes to Improve Ground Risk Handling - FIDIC

- Include a more specific **differing site conditions clause**.
- Incorporate a **Geotechnical Baseline Report (GBR)** as part of the contract documents.
- Use a **unit price contract payment system** for items that affected by differing site conditions.
- Implement a **ground classification system** that properly reflects the cost of excavating and supporting particular conditions.
- Implement **adjustment procedures** to adjust **time and contract value** according to actually encountered conditions.
1. GBR set contractual conditions anticipated to be encountered during construction.
2. Sets ground risk allocation.
3. Provide clear indications in the contract documents for resolution of disputes concerning subsurface conditions.
4. Must be part of contract documents, not just a reference.
5. A contractual baseline, not necessarily geotechnical fact. Developed partly from factual data derived from subsurface investigations, but also incorporate interpolations and extrapolations of data, precedent, and engineering judgment.
6. Facilitates contractor understand complexities and restrictions of project.
7. Alerts bidders of project risks.
8. Employer should avoid establishing an overly conservative GBR, because it would render it ineffective.
More Specific Differing Site Conditions Clause (DSC)

Unforeseen Physical Conditions Clause

- Use of Site Data
- Foreseen Defined in GBR
- Adjustment of Time for Completion
- Adjustment of Contract Price
Contractual Ground Classification not based solely on geological parameters.

Ground conditions should be classified based on what it costs the contractor to excavate and support the ground.

Description should include:
• Quality and structure of the rock in relationship to the tunnel
• Influence of water on the excavation
• Methods of excavation
• Average types and quantities of support
• Excavation and support installation sequence
• Expected deformations
• Ancillary construction methods
Use of geomechanical classification systems (RMR, GSI, Q) for the contractual classification of the ground is discouraged:

- Different combinations of classification parameters can lead to the same rock mass rating.
- Support “recipes” recommended by some GMS do not incorporate excavation or support excavation sequence.
- GM are based on empirical methods, relying on a large degree on subjectivity. Two different experienced geologists apply them to a specific tunnel sector. Often results are quite dissimilar.
- Simple number does not describe ground characteristics for complex geologies, such as anisotropic RM or exhibiting time dependent behavior.
- RMCs cannot replace more elaborate tunneling design systems that combine numerical and geologic models, engineering judgment, and precedent.
• Simplified assumptions of these systems do not account for failure mechanisms, deformations or rock-support interaction.
• Variables such as relationship between the maximum and minimum in-situ stresses, type of rock, and geometry of the excavation, are not considered either.
• Some parameters required for CS are not available when the heading is excavated. Some parameters require lab tests, the individuals in charge of classifying the ground have to estimate them to keep up with rapid excavation and support of the tunnel. This leads to significant differences between the estimated and actual values encountered.
• GMS were developed based on limited number of case studies with specific ground conditions. When geotechnical conditions of tunnel vary significantly from conditions used to derive the CS, it is extrapolated beyond its proven validity.
Given difficulty in predicting ground conditions very important to have flexible contractual framework for tunneling contract.

Items that may be potentially affected by differing site conditions (mainly excavation and primary support) should be handled with a unit price contract system.

Unit price structure organized to facilitate the distinction between:

- Fixed costs
- Time-related costs
- Quantity-related costs

Owner retains geologic risk. Contractor retains performance and efficiency risk.
Encountering unanticipated conditions can translate into time delays.

Contractors should also include construction times for each ground class in proposal.

Initial contractual time (GB)

\[ \text{Vs.} \]

Time resulting from the actual encountered ground

Determine if a contractor is entitled to additional time and its related costs.

Clause 8.4- Extension of Time for Completion of the FIDIC standard forms of contracts should also be modified.
• Disputes still arise, even if projects are structured with an equitable risk distribution and balanced unit price contract that incorporates a differing site condition clause.

• Need to complement with dispute resolution mechanisms that promote an equitable, prompt, and cost-effective resolution of claims and disputes. Without them, benefits and flexibility of contract hindered.

• Issues at hand in differing site condition claim typically complex, require deep understanding of underground design and construction.

• Typical drawbacks of litigation include lengthy and costly processes that in case of large projects can take several years and large amounts of money in legal fees.

• Judges and juries typically do not possess the knowledge to understand technical subtleties behind a differing site conditions claim.

• Often public servants and supervisors do not accept claims at a project level, because of fear being investigated for wrongful doing or corruption.
DISPUTE REVIEW BOARD’S (DRB)

- Usually conformed by three members.
- Involved from the beginning of the works.
- Regular project visits.
- Experts from the industry.
- Often convenient to involve one lawyer.
- Binding vs. non-binding.
- Serves as basis for later litigation or arbitration.
- Cost around 0.2%.
- Potential conflicts of interest.
- Endorsed by multilateral agencies such BID, WB.
CONCLUSIONS

• Due to risky nature of UW special contractual considerations are required.
• Contractual practices key to achieve efficacy and efficiency of design and construction methods.
• Include a specific differing site conditions clause defining what is foreseeable and providing adjustment mechanisms for variations.
• Incorporate a Geotechnical Baseline Report (GBR) as part of the contract documents.
• Implement a ground classification system that properly reflects the cost of excavating and supporting particular conditions.
• Items that may be potentially affected by differing site conditions should be handled with a unit price contract system to determine cost and time implications based on prices negotiated in the contract.
• Need adjustable provisions for time and cost.
• Require an alternative dispute mechanism. DRBs a good alternative
• New FIDIC standard form of contract for UW should be ready for friendly review by end of the year.