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Risk Evaluation and Control in Underground Construction

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ABSTRACT

Underground construction projects require different approach to risk evaluation. Conventional bidding and tendering is considered to be complicated for clients of major underground construction projects. It has shown that changed conditions leading to claims and disputes are increasing. Risk is the ultimate factor, deciding upon success or failure of a project. Risk needs to be covered and needs to be managed to finalize a project successfully. Risk needs to be shared between the parties involved and therefore needs to be identified, registered and controlled all along the development of a project. The governance of cost in design and construction of underground infrastructure projects are of paramount importance. To ensure cost and project delivery schedule requirements and to promote safety, quality and functionality of the underground facilities this risk to be continuously analyzed. Often it is not realized that underground construction project delivery even under the tested and proven conservative approach represents formidable challenges in terms of delivering the underground facility projects on time and within budget and in meeting all of the project requirements of safety and quality. A lot has been focused in the industry on the shifting of the risk to the contractor and on legalistic aspects of the contract documents. The physical nature of underground works, and the associated challenges with underground design and construction has not been fully appreciated. It is not sufficient only to extrapolate the above-ground infrastructure experience to underground construction. The features of underground design and construction procurement must be efficiently fused into the overall procurement.

1. INTRODUCTION

To enter as a contractor into construction industry is involved with little difficulties. If a contractor is awarded with a project, he mostly can act immediately at least until a project fails. Many governments are using construction industry appearance to show effectiveness. It can show an economic development in hausse and baise. If there is baise there is more competition at less profits. For this reasons there is no wonder that the construction industry is changing.

Conditions like described are neither for shareholders interesting nor for clients. It has lead to the fact that contractors are becoming rather service companies. It also shows that those contractors will win, who are able and willing to change. This is both in the interests of clients and markets, which are merging in requiring changes. Changes are not only driven by technology, nor by management systems, nor by mobile communication. Changes are driven by parameters of predictability and by limitation of risks.

How the underground infrastructure construction projects are procured is of paramount importance to ensure cost and project delivery schedule requirements and to reduce risk, to promote safety, quality and functionality of the underground facilities.

Much has focused on the shifting of the risk to the contractor and on legalistic aspects of the contract documents. Physical nature of the underground work, and the associated challenges with underground construction are not fully appreciated.

The paper elaborates to some extent in details criteria, whereas clients demand predictability under all circumstances during project execution. Such predictability is related to time, quality and cost. Furthermore the criteria of risk limitation is elaborated as well in explaining, why the construction industry is changing to a risk industry, whereas better risk management is demanded.

Underground projects and mostly public transportation projects require major financial investments. For reasons of successful investment construction costs estimates need to be combined with phased risk analysis. An unrealistic cost estimate can prepare the path for project failure in the early phase. The public sector faces major problems to finance such projects due to budget and time constraints.

In order to realize successful project implementation there is a need to carefully examine schedule prolongation. This risk can be reduced by reducing the time necessary for financing. Financial problems of schedule slippage can be controlled in such projects by using as a contract model "private-public-partnership (PPP)", whereas project financing comes from private financial institutes. Such institutes may be represented by individuals or by bank consortia who are interested to put funds on the market provided that a defined risk is covered by the public sector, and whereas other risks are covered by the private sector. This allows for the investment of capital over a longer period of time.

The prerequisite for successful investment is represented by reliable cost estimate for construction and related project costs. Underestimated construction costs principally do cause sincere problems such leading to the risk of project failure. There are mostly more than one reason for underestimating real project cost. The cost estimator may know constraint budget conditions, such trying to make his cost estimate fit into the public clients budget.

In order to reduce the risk of unrealistic cost estimate it is recommended to investigate both the overall cost of comparable projects and to examine the cost composition of such comparable data. The evaluation of other cost estimate and respective construction culture should result in reliable figures whereas it is recommended to use the dynamic risk analysis approach as a link between cost estimate and bid price from the beginning via bidding until the end of construction.

2. SHORT RISK EVALUATION OF TECHNOLOGY

There were essentially two, seemingly different tunnelling schools, which could be clearly distinguished from one another both in their application areas and in terms of cost. Alpine mountain tunnelling in rock was a domain of the "New Austrian Tunnelling Method" (NATM). By contrary, the construction of inner-urban traffic tunnels- where soft ground and ground water presents major influencing factors, as does the presence of surface structures, was essentially reserved for the shielded "Tunnel Boring Machines" (TBM), i.e. driving with precast tunnel lining systems.

NATM and TBM have been fundamentally differing competing technologies in the underground environment. NATM technology is coming from the geomechanic understanding of the interface condition & is aiming towards industrialized and thus highly mechanized tunnel production with less consideration of the interaction between excavation and geomechanical response. Experiences of the mining industry required preservation of three dimensional stress conditions in the underground to the maximum extend. The state of the art of mining technology, where all tunnel technology comes from, was waiting for new findings in regard to the interactive behaviour between soils, rock and water.

2.1 Conventional Tunnelling Technology

Conventional Tunnelling, widely named NATM started its development in hard rock. Economically it could compete later against TBM's in soft ground, because of its incorporation of geotechnique. TBM's became more and more mechanized, and even stronger with regard to their installed power. TBM manufacturers understood, that NATM construction time wise and tunnel lengthwise was not competitive with hard rock tunnelling machines, and therefore hard rock became the domain of TBM's. The need for mass transit, mostly in soft ground in densely populated urban areas - most of them located in alluvial deposits with rivers or near lakes-, created the need for public transportation. At least within the cities it was mostly impossible to avoid tunnelling underneath existing buildings. Requirements with regards to settlements became more and more strict.

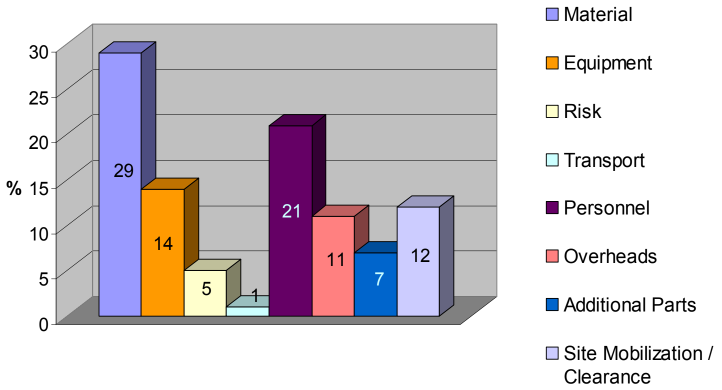

Figure 1. Typical Cost Distribution – Conventional Tunnelling (Metro tunnel in soft ground)

2.2 Mechanized Tunnelling Technology

Shield tunnelling technology started under soft ground conditions. The shield itself contains a cutter wheel at the face, and a segment erector in the rear. Soils typically moved onto the shield skin, thus giving close contact through its deformation behaviour between the underground and the temporary support, of the steel shield. The segments are erected in the shield tail area while the shield is pushed forward by hydraulic jacks resting on the segmented lining.

When rock tunnels have been excavated with tunnel boring machines in the past, such machines typically consisted of a cutter wheel with disk or teeth cutters, and with two pairs of grippers thursted against the rock, to move the machine forward.

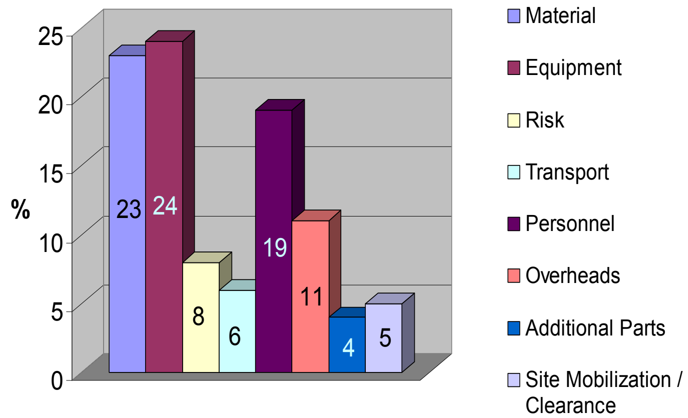

Figure 2. Typical Cost Distribution – Mechanized Tunnelling (Metro tunnel in soft ground)

3. RISK ANALYSIS VS. COST OVERRUN

It is necessary to address the risk factors which will give best value. The three most important risk factors are:

⇒ The "Retained Risk" which, by its nature, always rest by the public sector. An example is the London Underground PPP where the risk of fare revenue falling below its expected level.

⇒ The "Base Cost" of providing services required by the public sector. For LU this is principally the public's sector estimate of what it will spend to enhance, maintain and manage the infrastructure over 30 years in accordance with the performance. The "Base Cost " projections have been prepared in four categories : major investment costs, steady-state investment costs, maintenance costs and other infrastructure company costs as e.g. management and overhead costs of the new businesses.

⇒ The "Risk Adjustment" of the base cost figures, to reflect the probability that service will not be delivered at the cost shown in the base cost projection because of events like cost overruns or technical problems, or that the budgets may be maintained but at the expense of reductions in service quality.

Special attention has been paid on procedures of risk analysis regarding financial aspects of the project. Following the procedures for risk analysis identification and categorisation of risks have been stated: risk register has been prepared to identify and categorise the main project risks according to their allocation.

⇒ Design and construction risks (principally failure to deliver enhanced assets as required by the performance specification due to : poor or inadequate design, design errors, late changes to design or the late delivery of completed design, implementation risks such as site access problems, unforeseen ground conditions, weather, or archaeological discoveries, interferences from other parties, cost overruns)

⇒ Demand and revenue risks (as e.g. availability of services and related assets, failure to meet required "scheduled-journey-time-capability", poor ambience of trains and stations)

⇒ Operating and maintenance risks (as e.g.: cost of operations, availability of staff, spares and consumables, fire, theft accidental damage and vandalism to the extent that these cannot be covered by insurance)

⇒ Other risks (such as: availability and cost of finance, changes in law, taxation, general inflation etc.).

Quantification of risk needs to be cross-checked from independent interdisciplinary experienced estimators, financial experts have to question the management to test whether the financial risk quantification can be regarded as financially sound for this purpose. Where risks could be mitigated by insurance (for example the risk of fire) the insurance premium which could be obtained form the market needs to be considered.

The risk analysis has taken measures to avoid double counting of risks and took into account any correlation between them. For example:

⇒ If the quantification of potential cost overruns partly reflects the possibility of increased staff costs then there should be no separate allowances for differential wage increases over and above inflation.

⇒ It will be estimated that there is a correlation between unforeseen ground condition costs and the risk of contractual claims etc.

The allocation of risks between the parties is fundamental to making sure that only bankable projects are brought to the market. Prior to introduction to the market the project has to be subjected to rigorous risk assessments within own risk profile. One risk management methodology needs to be established consisting of following:

- Establish objectives and risk appetite
- Risk identification, classification and allocation
- Assessment, impact and quantification
- Identify mitigation procedures
- Prepare or update risk register

The purpose of this approach is to ensure that no risks are overlooked, and that all identified risks are monitored and managed in order to minimize potential adverse impacts. Identification of risk will be continuous activity throughout the development of a project. A starting point is to establish the broad categories within which risks will be analysed and to define their allocations as shown in Tab.1.

Table 1. Risk Allocation Matrix

Risk category	Procurement Agency	Private Partners	Shared Risks
Land acquisition	*		
Railway order			*
Utilities			*
Design, Construction, Supply		*	
Commissioning, Operating, Mainten.		*	
Demand			*
Residual value		*	
Technology and obsolence		*	
Regulatory, Legislative		*	
Environment		*	
Financial		*	
Safety		*	

While the risk allocation outlined in table 1 is recommended, it is sure that the finding of final risk allocations is an iterative process through which initial positions will change as a result of actual experience and interaction with the partners throughout the tendering and/or negotiating processes on specific projects. The structuring of infrastructure transactions will be heavily influenced by models which have been adopted for large scale project financing transactions. The primary commercial and financial objectives will relate to:

- clear responsibility for the ownership and management of risks
- no preference on funding structure, the exact nature of funding will depend on specific project risks
- to transfer revenue risk where it is appropriate and provides value for money
- payment mechanism and performance should complement each other
- preferred position on risk allocation as shown in Table 1

4. BALANCING OF COST

In order to balance cost in underground design and construction critical contracting issues have to be identified. In this context various construction methods and contract models need to be examined and potential approaches have to be proposed. It is especially necessary to identify issues of risk sharing, quality, design and construction cost and schedule.

4.1 Construction Issues

Issues of construction are related to subsurface and geotechnical issues, utilities and buried structures, third party approvals and permits, differing site conditions, contractors contingencies and risk sharing and risk management.

4.2 Geotechnical Risks

Balancing of cost will specifically be influenced by geotechnical risks related to difficult ground conditions, contaminated soil and ground water, boulders and buried objects, extent of geotechnical investigation, as well as interpretation of geotechnical data and ground behaviour.

4.3 Geotechnical Disclosure

Geotechnical issues are of paramount importance in regard to cost balancing. There are numerous standard reports which should be fully disclosed to the parties interested in the project. Such reports are Geotechnical Data Report, Geotechnical Baseline Report, Geotechnical Summary Report and Geotechnical Interpretive Report.

4.4 Risk Management / Sharing

It has shown that underground infrastructure design and construction needs not only risk management but also fair risk sharing. Therefore it has proven in many countries that a dispute review board is giving benefit to all parties involved in the project. Escrow bid documents did show to be useful as well. In the project differing site conditions should be addressed in a different site condition clause. Value Engineering should be useful in order to allow the contractor to offer his experiences and new technologies to the client on the basis of acceptable partnering conditions.

An owner controlled insurance program will be helpful in this context. Unit prices in a fair combination of lump sum costs will help to avoid disputes. Contingence bid items are generally used as part of the contract as well as owner directed works. It has shown to be beneficial if incentives for early completion of the project, achieved high safety standards and good quality have been included in the contract.

5. RISK REDUCING MEASURES

The Basis is formed by project descriptions, drawings, technical specifications, etc. The main layout needs to be evaluated e.g. a protective dike on both river banks. The construction of emergency lanes or emergency gates should be considered. The further reduce the risk, design accident loads, e.g. design fire load, design accident load, design ship impact load should be defined. Changes in traffic and infrastructures, e.g. restriction on ship traffic may additionally be helpful. Requirements for operational procedures, e.g. restrictions on road traffic in adverse weather conditions should be anticipated. In case of accidents, tunnel traffic should be closed. Sufficient safety measures, e.g. fire protection, emergency escape routes have to be foreseen.

6. CONCLUSIONS

In summary a new contract model for financing of underground projects is recommended based on the following reasons.

- A project development is recommended transferring risk from the public to the private sector in order to provide appropriate project financing
- It is further recommended to analyse comparable projects as adapted to local circumstances and to link it with respective risk analysis in order to provide appropriate cost estimate.
- It is recommended to implement a dynamic risk and cost management throughout the life time of the project in order to provide appropriate reliability of project cost and schedule.
- The cost governing experience with design / build tunneling projects is encouraging for the future. It has been observed that European functional tendering has been useful. It remains intended for use on future high-speed railway projects, e.g. in southern Germany. The critical examination of geotechnical risks well in advance of project activity is advocated. It has been further asserted that the European practice of requiring the contractor to perform his own exploratory work during the bid may result in poor quality or disparities in information, leading to high claims during construction. It has to be concluded that there have been positive experiences and lessons learned in design and construction of tunneling for better cost governance experiences in the future.

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