1 Introduction

Tunnelling and underground excavation involves handling of uncertainties. Risks associated with geological conditions are significant and 'unexpected geological conditions' are often claimed. This fact was realized long ago, and ITA (the International Tunnelling and Underground Space Association) published its 25 Recommendations on Contractual Sharing of Risks in 1988 (Ref. 1). This publication constitutes an important asset to the tunnelling industry as guideline for those working with contractual issues, even today almost 30 years after being published.

A more recent document is the ITIG code of practice for risk management of tunnel works from 2015 (Ref. 9). Various countries or geographical regions have their own view and tradition on risk sharing and tunnel contracts. In Scandinavia, unit rate contracts are most commonly used within a bid-build model. This approach shares the risk between owner and contractor. The owner retains the risk for geological conditions while contractor carries risk for efficiency of execution. Rock support is determined by assessing rock mass quality encountered at the tunnel face. Pre-excavation grouting (PEG) is applied to stem water. Actual quantities may and often do differ from the contract's BOQ, but contractual mechanisms enable adjustment of compensation based on actual quantities. Significant variation of quantities may even lead to adjustment of construction time based on contractual clauses.

Tunnelling contracts obviously represent a risk for both parties involved and this risk must be dealt with for each individual project. The frequently used model of an EPC contract with a fixed price for the project may seem favourable to the Client side, but will certainly raise the price of the project, especially if competition is limited, not causing bidders to gamble. On the other hand, if some bidders are gambling, the 'successful' bidder may go bankrupt if the gamble fails and a serious problem for the Client will be the result. The idea that all risk can be transferred to the contractor has been shown to be wishful thinking as demonstrated by a lot of failed contracts of the EPC type.

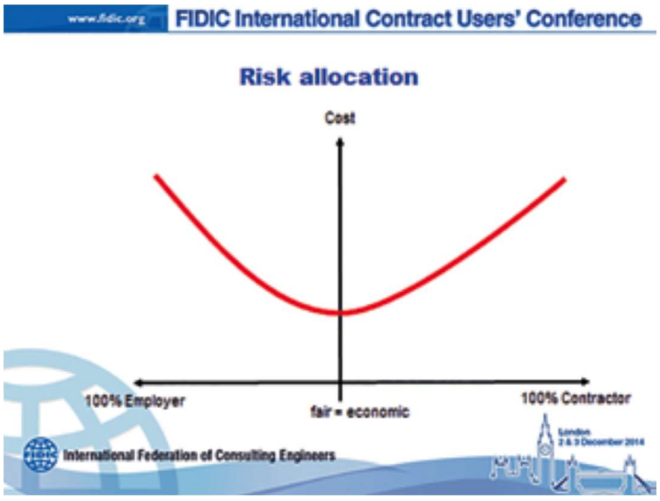

Figure 1. FIDIC-ITA Task Force 10 presentation of risk sharing to optimize the construction (FIDIC 2014) (Ref. 2)

Figure 1 shows a schematic way of illustrating the most economically favourable risk sharing between an Owner and a contractor. In Figure 2 below a more detailed picture is provided on the same principle as in Figure 1. This chapter aims at shedding light on the risk sharing principle being typically employed in Norway and Scandinavia, and it also describes the various elements of such a risk sharing principle.

2 Risk sharing, Norwegian style

By far, most underground projects in Norway during the last 50 years have been contracted as unit price contracts. During the hydropower boom in the 1960's through the 1980's, a contract concept was developed and applied that focused on risk sharing. During this period more than 150 mill m^3 of solid rock has been excavated, with an average output from the tunnelling industry at around 3.6 to 4 mill m^3 of solid rock. One of the first papers published on this issue was by Kleivan et. al in 1987. (Ref. 7). The risk sharing unit rate contracts address two main elements of risk:

- Ground conditions: The owner has selected the location and is responsible for the ground conditions. He 'provides the ground' and is also responsible for the accuracy of the site investigations executed. If these prove to be insufficient or inaccurate, it shall remain the Owner's uncertainty and risk.
- Performance: The contractor is responsible for the efficient execution of the works. He shall execute the works according to the technical specifications. He is reimbursed according to tendered unit prices for the work completed. The construction time using BOQ numbers may be adjusted based on pre-set 'standard capacities' ('time equivalents') for the different work activities.

One important aspect of the geological risk is that at the time of preparing the geological summary report for the tender, and the project time schedule and BOQ of the contract, the Owner or the Owner's consultant shall provide the best estimate and judgement of the ground condition at the time this assessment is done. This was indeed an important message brought by Kleivan et. al in 1987. (Ref. 7). The owner keeps the risk of increased cost if the ground conditions prove to be worse than expected; after all he chose the site location and instructed the investigation program. He will also earn the savings if the conditions are better than expected. The contractor keeps the risk of performance. If he is less efficient than the norm set by the 'standard capacities', he may fall behind schedule and will have to catch up on his own expense to avoid penalties. If he is more efficient, he may finish earlier, save money and increase his profit, besides what he is hopefully earning within his unit prices.

This risk sharing principle ideally eliminates most discussions about 'changed conditions'. It becomes a matter of surveying the quantities performed, and the payment and construction time adjustment follow accordingly. The system is simply a balance sheet of time. This works well when the variations in ground conditions can be dealt with by just applying more or less of the work activities regulated by the tendered unit prices and the pre-set 'standard capacities'. This however assumes that all necessary work activities are included, which may not be the case if truly unforeseeable geological features occur. This system, its development and application was described by Kleivan et al. (Ref. 7) who coined the term NoTCoS – the Norwegian Tunnelling Contract System. In Figure 2 is illustrated

how this risk allocation produces the lowest average cost possible for tunnelling projects. Note that this illustration is about 30 years old and as valid today as it was then.

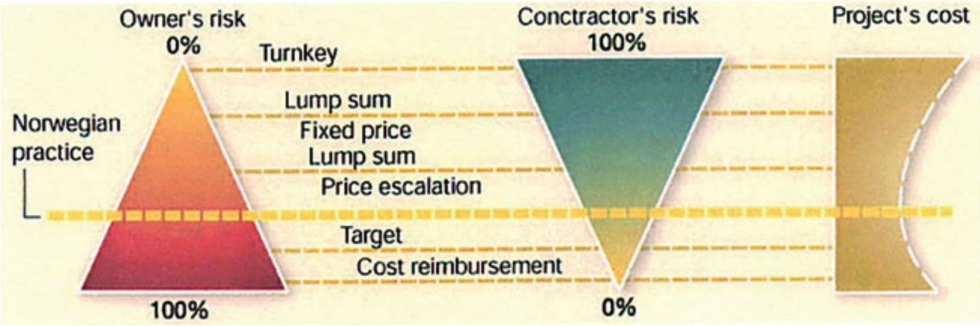

Figure 2. Risk allocation principles Kleivan et al. 1987 (Ref. 7)

2.1 Characteristics of unit price contracts

The typical unit price contract in Norway is characterized by the following (Ref. 8):

- Geological/geotechnical report: This report is prepared for the owner based on the performed site investigations. It shall give a full disclosure of the information available, as recommended by the 1992 document by ITA. Traditionally it also contained interpretations, not being limited to factual data, but this practice has unfortunately been compromised by some of the larger public owners. It is a pre-requisite that all important geological features have been identified. The tenderers shall anyway establish their own interpretation.
- Bill of Quantity (BOQ): The quantities for work activities with uncertain volume, such as excavation, rock support, grouting, lining etc., are specified according to the best estimate by the owner assisted by his advisors. Preferably, the owner shall refrain from tactical inflation of the quantities to get lower unit prices. Tactical pricing from the tenderers should also be avoided but can be discovered by analysis of the different bids.
- Variations in quantities: The actual quantities may vary due to variations in the ground conditions. The contractor is reimbursed as per finally executed quantity and his tendered unit prices. The unit price shall remain fixed within a pre-set range of variation, for some contracts this may be set as high as ± 100%.
- ‘Standard capacities’ (‘time equivalents’): Traditionally, the 'Standard capacities' have been set by negotiations between the contractors’ and owners’ organizations. They may be updated concurrently with technology developments but are usually kept from contract to contract over a period of a few years. Reasonably realistic capacities provide a fair tool for adjusting the construction time and completion date, if the time balance using ‘time equivalents’ shifts by more than a specified amount. Typically, the range which is included in the contract is ± 3 weeks, and all regulations of the construction time beyond this range shall lead to a prolonged or reduced construction time.

For this system to work properly, some conditions are important to pay attention to:

- Owners and contractors: Both parties will benefit from being experienced in underground works and the site management teams from both sides must have the necessary authority to make decisions, allowing technical and contractual issues to be solved on site as they occur. This requires respect for each other's tasks. It needs to be said that owners like the Norwegian Public Road Authority, the National Railway Administration and the hydro power development companies are multiple time builders of underground facilities. 'One-time' clients may have a different perspective and approach to risks associated with tunnelling works.
- Decision making: Of critical importance is the ability and authority of the representatives of both parties to take decisions at the tunnel face, especially with respect to primary rock support and ground treatment like pre-excavation grouting. Again, experienced, educated people through-out the project organizations of all parties involved is a requirement.
- Contract knowledge: If both parties are acquainted with the principles and details of the contract, discussions and agreements can be made expediently and with confidence as the need arises. This is typically the situation when both parties have experience from a number of similar projects.

One main advantage of this system is that the contractor’s incentive to meet the penalty deadline will be maintained, even if ground conditions get worse than expected. Contractors have recently voiced as a disadvantage that their role is limited to performing the specified work for the owner without incentives to introduce innovative solutions by which the contractor could better utilize his special skills. Some owners do not ask for, or even allow, alternative solutions to be introduced. However, this is not a result of the type of contract being employed, but only reflecting how individual owners may choose to act.

2.2 Contract clauses for rock support measures

In Norwegian tunnelling practice, important decisions are taken at the tunnel face, both related to necessary measures ahead of the tunnel face and support at the face. A possible consequence is that over time, a considerable difference may build between the stipulated quantities in the contract and the executed quantities. This is well taken care of in the typical contract formats, such as 'Prosesskoden' developed by the Norwegian Public Roads Administration, also used by the Railway Administration, whilst the standardization bureau Standard Norge has its own 'Construction Contract'. To tackle this, the contract defines “the 100 % rule” describing support:

- The unit prices apply even if the sum of actual quantities differ from the BOQ by up to ± 100 %.
- If the owner or the contractor wishes unit prices to be adjusted, prices are set by negotiation.
- The adjusted unit prices shall not differ from the contract’s unit prices by more than 20 %. Adjusted price shall be determined according to documented expenses.

These regulations take care of quantity changes due to changes in the encountered geological conditions compared to those anticipated, but not the fact that varying quantities also have an impact on the contractor’s available time towards the date of completion. To handle also the aspect of construction time, a contract clause has been introduced that is called “the equivalent time principle” for adjusting the total construction time depending on the applied support methods and quantities. This is particularly important for support works that are needed to secure safe tunnelling but are slowing down the tunnel advance:

- If the actual quantities for tunnel support vary in comparison with the contract's estimated quantities, the completion time is adjusted according to predefined standard capacities for the different operations, for example:
  - Manual scaling: 1 hour/h
  - Bolts up to 5 m length: 12 bolts/h
  - Sprayed concrete (shotcrete): 6 m^3/h
  - In-situ concrete lining: 0,1 m/h
  - Exploratory drilling and pre- excavation grouting: 60 m/h
- The total time for support measures is summed up in hours, both performed and described amounts from the bill of quantities
- The difference (between accumulated values) is calculated
- The contractor normally has a tolerance for added support measures (typically a week per year of construction time)
- When this tolerance level is exceeded, the exceeded time value is calculated as shifts and days, which are added to the project completion time

These standard capacities were negotiated between the contractor's organizations and representatives from the owners. The standard capacities reflect the average outputs in Norway, based on equipment and methods being standard at a given point in time, and may not unconditionally be transferred to other countries. However, the equivalent time principle has proven to be a useful tool for sharing the risk for both owner and contractor. In combination these two clauses are useful tools to distribute risk in tunnelling contracts, meaning that the risk that the contractor must carry is considered fair.

The owner must always bear in mind that risk has a price. To reduce the total construction cost, the contractor's risk must be reduced as well. No matter the type of contract chosen for a project, if the contractor is forced out of the contract, by termination, bankruptcy or something similar, the ultimate risk taker would be the owner. In figure 2 above this classical risk principle is illustrated. In the long run it shows that the Norwegian contract practice based on unit rate contracts would in average produce the lowest construction cost.

2.3 Frequency of court cases

Despite the advantages and good track record of the typical unit price contracts in Norway, an increasing number of projects still may end up in litigation. This appears often to be due to:

- Inexperienced owners. The owner may be lacking experience with underground projects. Deviations from the expectations may put him 'off his feet' and the cooperation with the contractor deteriorates into contractual confrontations, instead of solving the problems as they arise.
- Insufficient funding for contingencies. The project may be based on too optimistic cost estimates. This could be to get project approval from the authorities or by sheer lack of respect for the potential variations of nature.
- Public scrutiny. Public projects may be subject to criticism for any decision made during construction that deviates from the expected. The project management may prefer to stick to the letter of the contract in order not to be criticized, which may cause disagreements to accumulate and to be dealt with in court instead of using common sense.
- Tougher profit requirements. The contractors, to survive in an increasingly competitive climate, focus on the economical result of their contracts. If a contract does not bring the planned profit

by just performing the contracted work, it may be tempting to seek additional compensation in court.

2.4 Dispute settlements

During the recent years, basically all Norwegian contracts contain a clause stating that disputes that are not resolved at the construction site through ordinary meetings, must be raised to a dispute resolution forum on a higher level. This forum includes representatives from the company management of both the owner and the contractor. The representatives from both owner and contractor may agree to invite experts who may advise a solution. There is currently again a drive in the tunnelling industry in Norway towards obtaining solutions at the construction site to avoid disputes being brought to arbitration and court. Such solutions may involve both technical as well as commercial and contractual aspects.

In a couple of large projects, for instance the Bjørvika immersed tunnel in Oslo, dispute review boards have been appointed. Feedback so far suggests that the DRB's are playing an important role in resolving disputes. An additional effect is that the DRB's mere existence seems to have increased the willingness to reach a solution through the site meetings. If the dispute is not resolved by any of the chosen means, the ultimate solution still will be to forward the case to the court.

2.5 Lessons learned

In the articles by Blindheim and Grøv (Refs. 3 and 4) the authors conclude that the following lessons have been learned by experienced construction project parties. Obviously, these lessons should provide good input to all owners:

- Independent of the type of contract, it is important not to become too confident about the results and interpretations from the site investigations prior to construction. It is necessary to rely on relevant and sufficient site investigations, still maintaining the respect for the potential variations of nature, both regarding variations of foreseen features, but also regarding the unforeseeable, the features that nobody expects. The systematic use of an independent project review, by a party not identifying itself with the project, is advisable.
- In unit price contracts, which normally allocate all or most of the risk for the ground conditions to the owner, it is easy to deal with large variations of quantities in a fair manner, as regulation mechanisms are built into the contract. If unforeseen features occur, for which there are no methods and quantities available in the contract, separate agreements need to be established, and cost reimbursement may be a suitable way to solve an intricate and difficult situation.
- Fixed price contracts, with all risk for ground conditions allocated to the contractor, may have an apparent predictability of cost, which may be attractive to the owner. However, this type of contract imposes risks on the contractor that may at best be difficult to quantify, at worst disastrous if the unforeseen or unforeseeable occurs. Such risks may become the owner's problem, no matter the contract text, e.g. if the contractor is not able to bear the loss and complete the project.

2.6 Conclusions

To achieve success according to the above, the following contract requirements may apply:

- Incentives: By including incentives for the contractor, not only penalties, it is possible to stimulate focus on productivity, while maintaining quality and safety. Experience shows that in standard unit price contracts it may be tempting for the contractor to increase his production volume by applying more rock support than strictly necessary, especially if some support

measures are tactically priced. If he instead gets a bonus for early completion, and possibly also a compensation for saved rock support ('lost production'), this may turn around. The owner will then have to follow-up to ensure the sufficiency of the rock support for permanent use. The maintenance of safety during construction under such circumstances may be challenging and requires experienced personnel for follow-up.

- Conflict solving: It is important to keep, or get back to, the problem solving at site instead of in the courtrooms. A tool to achieve this may be the use of advisory 'reference groups'. A key point is that such groups meet on a regular and frequent basis to monitor the works, before small problems develop into conflicts. In this respect a 'reference group' may have a different function than 'dispute resolution boards' dealing with already materialized disagreements. The responsibility of such 'reference groups' should be defined in the contract. The personnel should be nominated by the parties and include professionals with practical tunnelling experience.
- Co-operation: Although it is frequently expressed in contracts that the parties have a duty to cooperate, as is the case with Norwegian contracts, this may not always come easy. It may be effective to stimulate this by focusing on the strong common interest in completion on time. However, other tools may also be used, e.g. 'geotechnical teams' to which coordination of geotechnical issues can be referred and disagreements about e.g. choice of rock support measures can be solved.
- Functional requirements: The use of functional requirements, rather than detailed technical specifications and work instructions, may stimulate innovation and development by the contractor. However, functional requirements are not easy to apply for rock works, and the result of many of the work processes does not lend itself to quality checking afterwards (e.g. grouted rock bolts).
- Regulations for 'changed conditions': As the inclusion of all uncertainties in a fixed price may result in a very high price, it may be beneficial overall to be specific about the risk allocation. A suitable balance may be found by identifying which features shall be included in the fixed price and which are kept as a risk of the owner, to be reimbursed by specified regulations. To include risk sharing clauses would be fully in agreement with the recommendations by the International Tunnelling Association (Ref. 1).

Experience shows that unit price contracts are suitable to deal with 'unexpected geological conditions', as long as the 'unexpected' element results only in variations in the *quantities* of work activities. This means that all necessary work activities must have quantities and preferably also 'standard capacities' for regulation of the construction time. In fact, variations in quantities must be expected in any underground project, and such variations therefore hardly deserve the term 'unexpected'. If truly unforeseen geological features necessitating work activities not included in the Bill of Quantity, the unit price contract must be supplemented by special agreement, usually some form of cost reimbursement. Fixed price contracts for underground projects, may not provide the intended predictable cost. Modified or 'adjustable fixed price' contracts, combining elements from unit price and fixed price contracts, may prove to be more suitable than fully fixed price contracts, and easier to handle than unit rate contracts.

Norwegian Tunnelling Network

August 2018

3 References

1. International Tunnelling Association (Working Group on Contractual Sharing of Risks): "ITA Recommendations on Contractual Sharing of Risks", Tunnelling and Underground Space Technology, Vol. 3, No. 2, pp. 103-104, 1988.

2. FIDIC – ITA Task Group 10. Presentation of Task group 10, Contract Form for Tunnelling and Underground Works. London 2014.

3. E. Grøv & O. T. Blindheim: "Risk allocation in 'adjustable fixed price contracts", Tunnels & Tunnelling International, June 2003.

4. Blindheim, O. T. & Grøv, E. Contract suitability – unit or fixed price. Tunnels & Tunnelling International, December 2003.

5. Grøv, E., Hansen, D.R., (2009). 30 m Rock Pillar to the Atlantic Ocean, Sub sea tunnelling in the Faroe Islands. 5th Symposium on Strait Crossings in Trondheim, Norway

6. Tattesrall, J. W., Grøv, E. (2009) Rock Mass
Groutability – Application of Norwegian Experience to Hong Kong. Hong Kong Tunnelling Conference 2009

7. E. Kleivan: "notcos – Norwegian Tunnelling Contract System", in Norwegian Tunnelling Today, Publication No. 5, Norwegian Soil and Rock Engineering Association, 4p, 1987.

8. Grøv, E. "Norwegian contract practice Suitable also for dealing with unexpected geological conditions." NFF Publication no. 23 on Tunnel Contracts, 2014

9. The International Tunnelling Insurance Group. A code of practice for risk management of tunnel works. 2015