Case Histories of contractual management of geological risks

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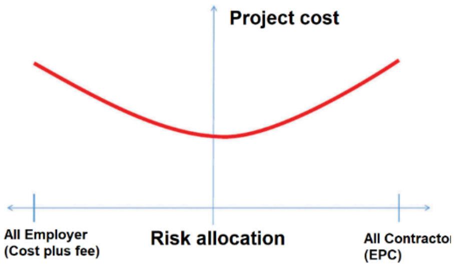
ABSTRACT: The geo-uncertainty of underground projects most often leads to differences between foreseen and encountered geo-conditions. Dealing with this uncertainty is a major challenge as it often raises claims and complex contractual problems mostly related to the construction programme. Over the last years, contract management tools have been developed in order to manage this risk. One of the key aspects for the successful delivery is the elaboration of a mechanism to adjust the time for completion. The clear allocation of duties and risks between the Employer and the Contractor, together with its proper integration in the contractual frame-work, play a crucial role. This paper presents cases of implementation of such a contractual mechanism in several Countries, standard forms and excavation methods together with the comparison with the FIDIC standard.

Keywords: Risk management, Forms of contract, Schedule of Baselines, FIDIC Standard.

1 INTRODUCTION

In order to control the costs and construction times for underground constructions, a risk management approach is considered a necessity (ITA/AITES, 2004; Marulanda and Neuenschwander, 2019). The difficulty of predicting ground behaviour and unforeseen conditions imply a degree of uncertainty for tunnelling projects, leading to particular and unique risks. A recent analysis of a database of 11,000 tunnel projects (W. Siganto, 2019) highlighted that underground projects are characterized by a 90% probability of a 33% project cost overrun and a 23% project time overrun regardless of the risk assessments made by the project protagonists. For a balanced contract it is important to clearly allocate risks to the parties, and for them to account for their liabilities. An unbalanced risk allocation can lead to litigation, escalation of project costs delays that are not contractually manageable. As it can be seen on Figure 1, unbalanced risk allocation, whether it is towards the Contractor or the Employer, will increase the cost of a project (Ertl, 2019). The specification and operation of risk management tools change for each project and country. The previously available FIDIC contract forms, in particular the Red, Yellow and Silver Books, do not include specific provisions related to underground conditions, other than the “Unforeseeable Physical Conditions” Sub-Clause. The recent FIDIC-Emerald-Book (FIDIC, 2019) was prepared to support such a balanced risk allocation approach, whereas the Employer retains the ground related risk and the Contractor is responsible for the performance related risk for defined ground conditions (Figure 1).



FIDIC Standard	Type of Contract	Risk allocation
Red Book	Construction (Design-Bid-Build)	• The Client engages a Consultant to develop the design and tender the works based on a BoQ (Bill of Quantities). • The Contractor executes the works as per the Client's design. Changing ground conditions can be dealt with by the BoQ (payment rates). Contractor entitled to compensation (Extension of Time and/or Cost) for "Unforeseeable Physical Conditions" (subject to the claim procedure).
Yellow Book	Design-build	• Design is Contractor's responsibility. • Contractor entitled to compensation (Extension of Time - EoT and/or Cost) for "Unforeseeable Physical Conditions" (subject to the claim procedure).
Silver Book	EPC/ turnkey	• Risks borne by the Contractor (no adjustment of the Contract Price for Unforeseeable or unforeseen difficulties or costs).
Emerald Book	Design-build	• The ground related risks are assigned to the Client, as the party who will most benefit from the completed project and as the party that can best control these risks. • The performance related risk arising from expected ground conditions are assigned to the Contractor.

Figure 1. Contract price in relation to risk allocation (left) and FIDIC forms of contract (right).

2 THE EXAMPLE OF CENERI BASE TUNNEL

The CBT is the southernmost portion of the New Railway Link through the Alps (NLRA) crossing the Swiss Alps. The CBT is a twin tube single track railway tunnel of 15.4 km in length connected by 47 cross-passages (Figure 2). The entire CBT is situated in the crystalline bedrock of the Southern Alps. Based on the detailed geological and geotechnical surveys executed during the period 1991–2008, it was possible to draft documents similar to the GBR (Geotechnical Baseline Report) and the GDR (Geotechnical Data Report) provided by the latest FIDIC Emerald Book. 47 homogeneous sections were identified and for each sections the risk scenarios were assessed. In 2008, within the Lot 851, an intermediate adit (2.3 km) was excavated using a gripper-TBM. The excavation of the main tunnels started in 2010 from the intermediate heading of Sigirino. The north (approx. 8.3 km) and south (approx. 6.3 km) tunnels were excavated simultaneously using D&B (Lot 852, about 90% of the total excavation). The remainder portion of the tunnel was completed by opposed tunnelling. The commonly used process in Switzerland, is the Design-Bid-Build approach, meaning that the Client's is responsible for the tender design and the detailed design, similar to the approach in the FIDIC-Red-Book (FIDIC, 1999). The Client ATG, together with his Design engineer, carries out the tender phase. According to the Swiss Code SIA 118/198 (SIA, 2007), the design engineer gives his estimate of the length of each excavation class. The Contractor offers his daily advance rates with his bid for each excavation class (Figure 3). Additional days for interruptions are considered in the calculation of the working phase and are added for the calculation of the total construction-time. The bidding documents were built according to the Swiss standard code catalogue. This ensured a fair distribution of risk between the tendering partners and a clear cost accounting system. The support and the excavation are paid on the base of the remeasured quantities. Lump sum items are provided for site equipment. After the contract is awarded, the Client's engineer prepares the construction documents. The design engineer acts also as the Client's site supervision, reviews the progress of the works, and issues site instructions. The Client is responsible for the design of the project and for the coordination of all parties involved. During construction the risk management system was reviewed in detail on a quarterly basis. The accounts were updated on a monthly basis, so that the estimate at completion was known at any time until the end of construction. The excavation of the CBT finished in March 2015 and January 2016 with a breakthrough at the south and north portals, respectively (Figure 4).

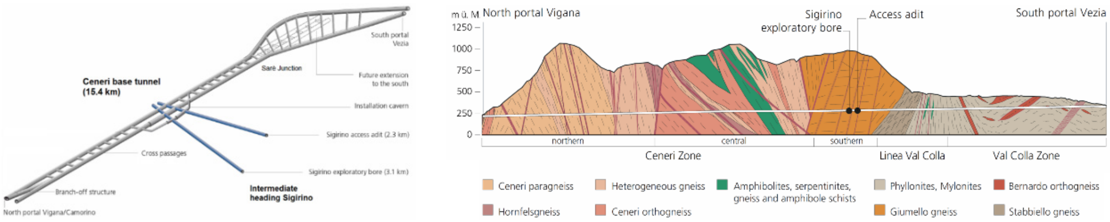
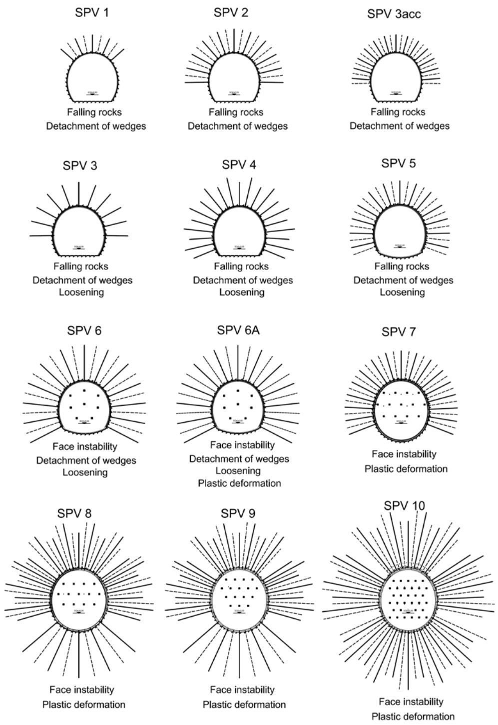


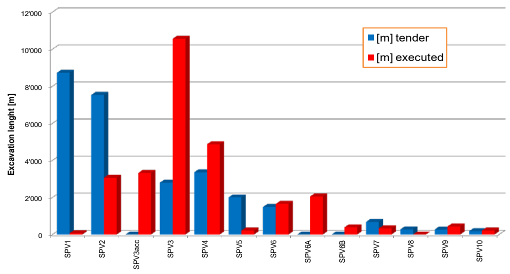
Figure 2. Ceneri base tunnel layout (left) and geological longitudinal profile (right).

The northward advance rates had to go through a contractual redefinition process with the addition of specific contractual appendices due to more complex geomechanical conditions than expected. To meet the new completion deadline, in addition to the new rock support classes SPV3acc and SPV6A, it was necessary to schedule the inner lining in parallel with the excavation. Compared to the base contractual solution 16 months of delay were recorded for the northward excavations and about 14 months of time saving for the southward excavations thanks to better geomechanical conditions. Compared with the forecasts, the medium classes SPV 3 to 6 were increasingly used instead of the light classes SPV 1/2 (Figure 4). Thanks to the contractual system adopted, all underground construction lots were delivered within the respective contract amounts. Despite the magnitude of the project, all project claims have been resolved at project level or through a Dispute Review Board; no claim has escalated to a public court except the claim inherent to the contract for the railway system, which led to a delay in the commissioning of the CBT by 1 year.



Support class	Bolts [m/m']	Shotcrete [m3/m']	Steel ribs – distance [m]	Daily advance rate tender [m/day]	Costs [€/m]
SPV 1	≤ 25	> 1 ≤ 3	-	11.94	4480
SPV 2	> 25 ≤ 50	> 1 ≤ 3	-	10.00	4925
SPV 3	> 25 ≤ 50	> 3 ≤ 5.5	-	7.00	6900
SPV 3acc	> 25 ≤ 50	> 3 ≤ 5.5	-	5.59	7385
SPV 4	> 50 ≤ 80	> 3 ≤ 5.5	-	5.10	7840
SPV 5	≥ 30 ≤ 70	> 3 ≤ 5.5	1 – 1.5	3.94	11935
SPV 6	> 70 ≤ 110	> 4 ≤ 9	1 – 1.5	3.61	13040
SPV 6A	> 70 ≤ 110	> 4 ≤ 9	1 – 1.5	3.18	14995
SPV 7	> 60 ≤ 140	> 8 ≤ 13	0.8 – 1.2	3.02	17560
SPV 8	> 130 ≤ 200	> 10 ≤ 15	-	2.74	19210
SPV 9	> 130 ≤ 220	> 10 ≤ 16	≤ 1	2.14	25080
SPV 10	> 220 ≤ 360	> 10 ≤ 22	≤ 1	1.89	29870

Figure 3. Standard cross-sections used for the CBT excavation and related risk scenarios (left); main supports quantities, daily advance rate and costs for each contractual excavation class for D&B excavation (right).



Lot	Contractual amount	Difference between contract and delivered
851	90 Mio €	-10 %
852	1'060 Mio €	-11 %
853	92 Mio €	-2%
854	52 Mio €	-7%

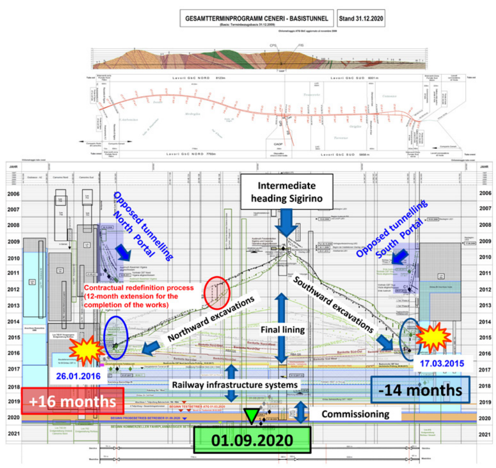


Figure 4. Comparison between SPV forecast and executed (left above); difference between contract and delivered amounts for the main CBT lots (left above); Baseline schedule for the CBT (right).

3 THE EXAMPLE OF CERN HL-LHC

This section presents an example of contract and risk allocation based on the FIDIC Red-Book (FIDIC, 1999), amended with the addition of specific provisions and mechanisms for the underground works such as the SoB and the GBR, to deal with geological risks during construction. This Contract is a kind of prototype of the recent FIDIC Emerald-Book. The Large Hadron Collider (LHC) is the most recent and powerful accelerator constructed on CERN site. The LHC consists of a 27 km circular tunnel, about 100 m underground, with 8 sites around the circumference (Figure 5). High-Luminosity LHC (HL-LHC) is a new project aiming to upgrade the LHC, at Point 1 (ATLAS in Switzerland) and Point 5 (CMS in France). The design schedule and construction schedule of the civil works are very constrained by the general timeline of the HL-LHC project, and by the high vibration sensitivity of the LHC-Machine. The main design and construction phases are shown in Figure 6. The contracts were elaborated by CERN and the Consultant. In particular, a specific time-adjustment mechanism was defined in relation to the underground excavation (Figure 6). As per this mechanism the Time for Completion is adjusted based on the difference between the encountered and the expected subsurface conditions. The expected subsurface conditions are described in the GBR in terms of definition of support class and geotechnical baseline conditions. The quantities forecast by the Engineer and the performance rates proposed by the Contractor are part of the Baseline Schedule, based on the principles defined in the SIA Standard 118/198. This tool allows the time for completion to be managed and is periodically updated with the quantities remeasured during excavation. To this purpose, three different Bills of Quantities (Underground Works, Surface Works and Common Items) were prepared, based on the CESMM4 (ICE, 2012). Lump sum items are considered for site equipment. One of the main challenges of the project is related to the limitation of the vibrations induced from excavation, which may affect the operation of the LHC machine and its experiment detectors. The excavation of the shaft in rock takes place during the operation of the LHC Machine, before the Long Shutdown Period 2 (LS2), whereas the excavation of the cavern and the galleries is foreseen during the LS2. In order to manage the vibration risk, the Consultant defined several excavation methods: A) Mechanically assisted tunnelling in rock with electrical roadheader, B) Mechanically assisted tunnelling in rock with rock breaker; C) Excavation with hydraulic rock splitter inside drilled holes; D) Bucket excavator. During the excavation of the shaft, the vibrations are monitored by the Employer by means of seismometers and accelerometers. The Employer may stop the excavation works at any time and require a change of excavation method if the project requirements are not complied with. In this case, the Contractor shall quickly dispose of the ongoing excavation installation and set up the new one. In the event that all methods generate vibrations above the acceptable level for the LHC machine, the Contractor shall stop the works until the LHC shutdown. The consequence, in terms of time and costs, of the change of excavation method and interruption are ruled, respectively, by the SoB and the BoQ. The excavations were completed in 2022. All technical risks such as vibrations and geotechnical uncertainties were kept under control. Contractor had some problems in understanding and accepting the mechanism during the execution phase. In particular, for the Point 5, the legitimacy of the contractual mechanism Adjustment of time was confirmed by the Panel of Adjudicators (POA) following disputes with the Contractor. The main subjects of claims included EoT related costs were: 1) presence of hydrocarbons 2) the impact of COVID-19, 3) the hardness of Molasse. However, all claims were closed with a global settlement that remains in the contract amount.

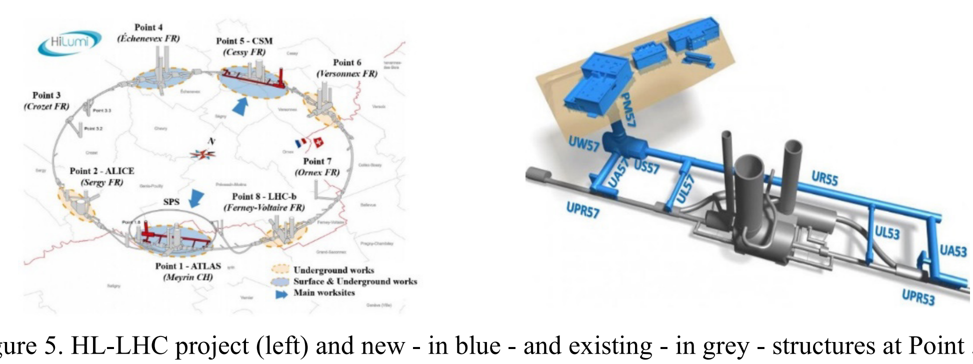


Figure 5. HL-LHC project (left) and new - in blue - and existing - in grey - structures at Point 5 (right).

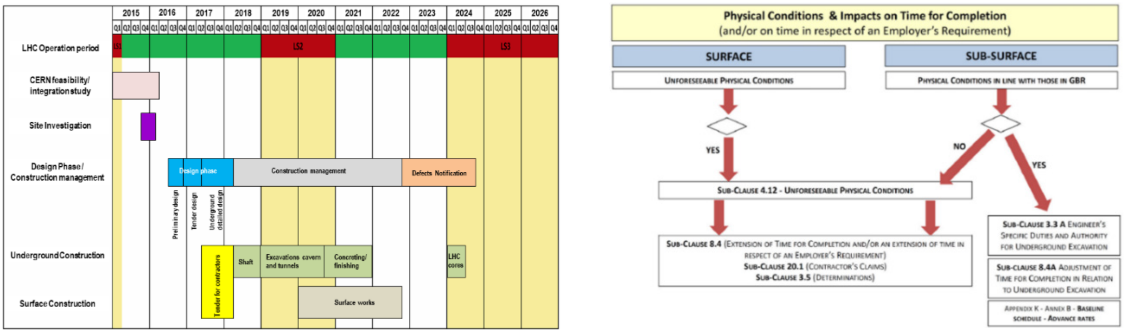


Figure 6. General schedule for HL-LHC project (left) and contractual principles for dealing with Unforeseeable physical conditions (right).

4 THE EXAMPLE OF TUNNEL EURALPIN LYION TURIN (TELT)

This example presents an application of risk allocation following the principles set out in the recent FIDIC-Emerald-Book. As part of the TEN-T transport network, the Mont-Cenis base tunnel is the most important element of the cross-border section linking France to Italy via a 57.5 km rail tunnel (Stocker and Humbert, 2019). The base tunnel consists of two single-track tubes connected every 333 metres by crossing passages (Figure 7). The total excavation length for the construction of the structure is approximately 160 km, of which 19% completed. 75% of the total length of the base tunnels were excavated with TBMs. High overburden up to 2200 m and complex geological conditions are two key factors for the design and construction. The work has been divided into 12 main lots in order to limit the interfaces between the sites and to take account of the approval deadlines. TELT's contracts are of the Design-Build type. The Tender design is developed by the Client together with his Design engineer and completed by technical reports on the construction methods, phases and technologies proposed by the Bidder. Documents similar to the GDR, based on extensive geological investigations and detailed risk analysis techniques, are developed by the Client’s Designer. The Contractor Designer is in charge of the detailed design (DD) and for construction design (FCD), implementing the proposed construction methods, phases and technologies from the tender phase onwards. The site supervision and detail design check is carried out by the Client together with his nominated Designer. The contract system is mainly based on: 1) the Risk allocation define the risk type and the owner of the risks; 2) a reference Baseline Schedules which is defined in the tender, with contractual unit rates and items/quantities on the basis of the expected geology; 3) the time adjustment is recalculated on these bases, according to the effective condition encountered 4) some items (installations and equipment) are defined in terms of duration and are therefore activated in case of EoT. The flowchart in Figure 8 summarizes the management procedures for normal and exceptional conditions. Since the main lots are recently awarded or currently under awarded, there is no direct experience of claims but this possibility seems to be limited only to cases concerning situations not foreseen, and not foreseeable, given the responsibility of the Contractor and its Designer in the development of the DD and FCD.

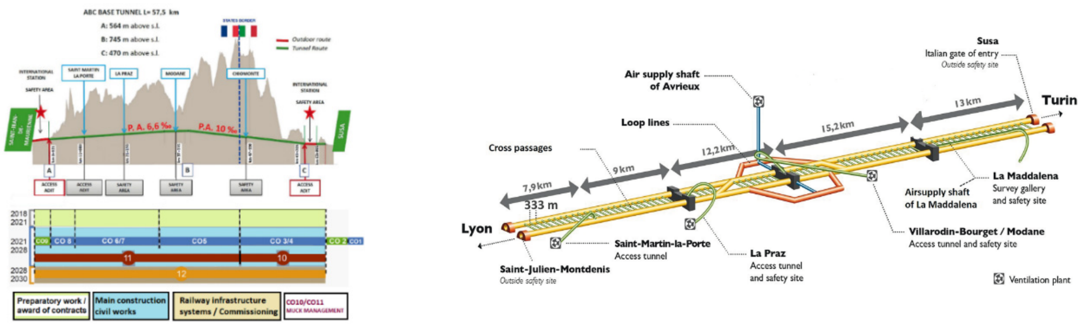


Figure 7. The longitudinal profile of TELT, subdivision of the main lots and general schedule (left) and the layout of TELT project (courtesy TELT-sas).

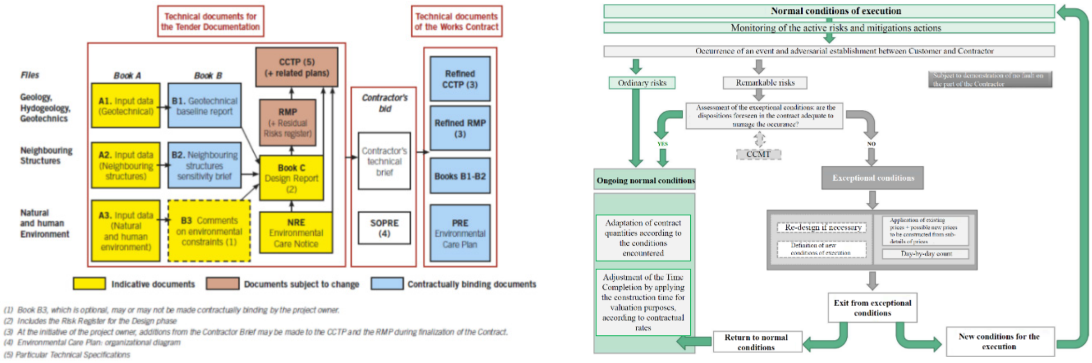


Figure 8. Organization of technical documents for the tender phase according with AFTES GT32.R3A2 (AFTES, 2020) (left) and contractual risk management under normal and exceptional conditions (right).

5 CONCLUSIONS

The following recommendations can be given by the Authors based on the experience of design and construction of important underground project:

- Applying a fair risk allocation, which means that the Employer has to bear part of the risk of divergent ground conditions, reduces the dispute potential.
- Time dependent costs must be clearly defined in the bill of quantities. The Employer's risk analysis has to show the expected variation of the construction time.
- Tender documents must be prepared with a high level of detail and must be consistent: Contract, Specifications, BS, Rules of measurement/BOQ, GBR, risk allocation, etc.
- A fair risk sharing helps to find fast solutions in the case of change of conditions and helps to reduce the total project costs.
- A fair Contract increases the cooperation among the parties, also in critical conditions.
- Involving the Contractor in the detailed design and having it validated by Engineer can simplify interfaces and support design optimization.

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