PARETO EFFICIENCY VS. IMPARTIALITY AND OBJECTIVITY IN CONSTRUCTION CONTRACTS FOR TUNNELS

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ABSTRACT: Most contracts are signed between parties with the intention of achieving specific targets. The client's objective is to obtain the planned product and/or service within the agreed requirements, budget, and timeline, while the contractor aims to deliver that product and/or service by effectively allocating resources, experience, and knowledge.

Theoretically, a Pareto Efficiency is established between the contracting parties at the time of signing. Pareto Efficiency is defined as a state in which resources are allocated in such a way that it is impossible to make one party better off without making another party worse off. This ideal scenario would exist only if no risks were involved and both parties possessed equal levels of experience, knowledge, and access to all essential data and information. However, this situation remains purely theoretical.

Many clients believe that by allocating a contingency budget based on perceived risk levels and transferring part of those risks to the contractor, they maintain coverage and achieve a near-Pareto-efficient position. Contractors, on the other hand, assume that by pricing risks into their bids and relying on contractual clauses and mechanisms for variations, they can also meet their commercial targets upon delivering the final product or service.

However, numerous uncertainties exist in construction—particularly in tunnelling—such as variable ground and physical conditions.

Aside from aleatoric uncertainties, all other uncertainties which lead to disputes, delays, and cost overruns can be minimized by providing impartial and objective data to contractors and by ensuring fair contractual clauses. For instance, in a tunnelling contract where excavation and support cycle times are linked to rock mass classifications, the mechanism may appear "fair" if schedule adjustments are allowed when classifications change. However, achieving near-Pareto efficiency in construction contracting requires more than "fair" clauses as explained in this paper.

1. INTRODUCTION

Do we have a problem of an increasing number of disputes in construction contracts?

In 97 Sextus Julius Frontinus was given responsibility for the water supply of Rome (cura aquarum) by the emperor. His first action on taking over was to make a detailed personal inspection of the entire aqueduct system. In Frontinus' own work De Aquis, particularly the Preface 1-2, he says "I have always made it my principle', considering it to be something of prime importance, to have a complete understanding of what I have taken on (nosse quod suscepi) (Landels, 1978). Frontinus made it clear that understanding the system, details, facts and responsibilities before starting the works and making decisions are essential.

Almost 1850 years of the Frontinus work of De Aquis, The Code of Hammurabi's code of law from ancient Babylon in Mesopotamia was written (1754 BCE), and it represents 282 laws to deal with the rights, obligations and punishments. The regulations between 228 and 233 is specifically for the construction represented in "building house" (Yale Law School, Lillian Goldman Law Library). Rule 232 states

232. If it ruins goods, he shall make compensation for all that has been ruined, and in as much as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.

The code regulates the builders that they are responsible for the quality, safety, soundness and stability of the structures that they build by ensuring that the builders have the sufficient and proper knowledge for materials, means and methods to deliver the result. Failing to deliver the requested product would be penalized. Rules provide details for professional activities and making sure that all professionals and merchants should provide the services and products in the best conditions that they were intended for.

However, due to the increases in both the spending on the construction and infrastructure projects from the 18th century onwards and expansion of international trade after the Second World War, construction projects have become more complex and geographically widespread. This expansion needed more engineers, architects, suppliers, designers, and contractors. The delivery methods and the contracts forms have been diversified vastly. They have all been tools created and developed to deal with funding, delivery cost, delivery time, insurance, quality, etc. Emergence of tunnelling as part of the expansion mainly in the water and transport sectors has caused (generally if not all) another layer of issues in disputes for the projects Build only, design and build, EPC, PPP, Alliance, BOT and carious other models have been tried and are still tried and will certainly be tried for the projects as actions to address the issues : a)deliver on time b) within budget and c) within requirements (administrative, quality, health and safety, compliance, etc.). While those three areas are the wish list of the governments, investors and lenders, the contractors have also sought for similar targets a) clear scope of works b) risk sharing c) stable funding and d) making profit (or at least no intended loss).

International Chamber of Commerce, 2025 reports that "Disputes arising from the construction/engineering and energy sectors, which traditionally generate the largest number of ICC cases, represented 44% of all new cases registered, or 193 (23.2%) and 170 (20.5%) new cases, respectively. The numbers are almost the same in 2023 statistics (ICC, 2024). Hence, every one of four of the arbitrations filed under ICC is construction and engineering cases. The same report also indicates that most requests filed under the Expert Rules originated from the construction and energy sectors and related to technical expertise. The disputes are arising from technical matters which require legal and financial resolutions. The costs of the disputes are high, and it could reach 4-5% of the claimed amount for each party which means 8-10% in total of the disputed amount in the range of 100M Euro or above. The arbitration would probably take longer than an average of 18 months and parties will dedicate not only the cost but also their own resources from the disputed project and their head offices. This would also cause the inefficient use of their skilled resources.

Based on a summary of facts above, it is reasonable to answer the starting question as: Yes, we, generally, have a problem of increasing number of disputes in construction contracts.

2. WHERE IS THE ISSUE?

There are many aspects and underlying causes that lead to disputes in the construction contracts. There are numerous surveys, papers, works on analysing the causes of the disputes.

HKA´s recent report (HKA, 2025) uses 2204 engineering and construction projects in 114 countries shows that the main reasons for the projects are the changes in scopes (leading cause) and design related issues.

Table 1: Top 12 Factors for the causes of claims and disputes (HKA, 2025)

Cause of claim or dispute	***Proportion affected, %***
Change in scope	*34.7*
Design was incorrect	*20.6*
Design information was issued late	*20.4*
Design was incomplete	*18.4*
Workmanship deficiencies	*17.5*
Contract management and / or administration failure	*16.7*
Poor management of subcontractor / supplier and/or their interfaces	*16.5*
Access to site/workface was restricted and / or late	*16.3*
Contract interpretation issues	*16.2*
Physical conditions were unforeseen	*15.5*
Cash flow and payment issues	*14.7*
Approvals were late	*14.3*

The causes shown in Table -1 is almost similar to many other studies conducted and / or reported by (Pang Hoi Yan, 2011) and (P.M. Silva, et al, 2024). Arcadis, 2022 report that over all dispute causes in the order are 1) 1 Poorly drafted or incomplete and unsubstantiated claims, 2) Errors and/or omissions in the contract document and 3) both Owner/Contractor/Subcontractor failing to understand and/or comply with its contractual obligations and Owner-directed changes The author in his own experience have observed through years that changes in scope and design delivery)late, missing, incorrect, etc) as well as site access and possession are the main causes of the disputes. Role of conflicting contract documents is also another major factor in creating disputes.

Disputing parties are looking for a relief either in the form of time extension or costs or more often both.

The causes are a bit diversified when it is a dispute for tunnelling projects. For many years unforeseeable ground conditions were the prime cause of the disputes related to the disputes. There have been many changes both technically and contractually to address the ground conditions issue and to make it more manageable contractually, if not turning the ground conditions as “foreseeable”. GBRs (Geotechnical Baseline Reports), risk allocations clauses in the contracts to deal with the time for changing ground conditions, etc. Have those measures addressed the issues and reduced the disputes between parties? The answer is no for the majority of the cases The issue is more exacerbated when the projects are complex, with multiple stake holders and with commercial operation timelines) such as hydropower and transport corridors).

3. ARE WE CERTAIN THAT WE CAN DELIVER THE PROJECT WITHIN TIME AND BUDGET?

The causes of disputes summarized in the preceding paragraphs are created using the contract documents. However, those causes are not the root causes of the issues faced in the industry. The root causes underlying the disputes mainly start to grow during the project development phase including initiation, feasibility, planning (assessments, scope, budgets, timelines, etc) and design (level of design depends on the contract type selected).

The developers have another stage to complete before posting the project to the next level: risk assessment. Risk assessment sessions are run and the contingencies for both time and cost are determined. They are added to the project timeline and the budget for the risks identified.

The essentials of the project are described at this stage, and the project is taken to the decision makers′’ table to choose any alternative or just to rubber stamp it to start the next stage of the project which is procurement.

The question is asked by the decision maker(s): Are we certain that we can deliver the project within time and budget? The reply would be along the lines that “yes, obviously we have a very good team and design, we benchmarked the project, we have allowed for risks and added in our budget for contingencies. There is a good response from the market during our initial talks. We do not see any issue”

When the decision makers approve the project, when contract is drafted with timelines, milestones, LDs , specifications, the procurement stage starts and the developer requests site visits, Q&A sessions. There may be hundreds of Tender Queries (TQ) from bidders, amendments, changes, etc. The author saw many tenders and contracts with TQs more than 500 and in one case around 800. Normally significant number of TQs and the amendments should ring the alarm bells for the project´s vulnerability for future disputes.

The developers do accept minor and trivial changes and apparent errors, but they generally do not accept major changes such as changes to the milestones, specifications and contract clauses. There are few reasons for this attitude and one of which is named as the Pareto Efficiency. Other reasons will be addressed in the paragraphs towards end of this paper in Section -5. It is defined by the Italian economist Vilfredo Pareto (1848-1923). The Pareto Efficiency occurs when resources are allocated so that no one can be made better off without making someone else worse off. It means that resources are allocated so that no further changes can improve anyone’s situation without harming someone else. However, it does not mean the allocation is perfect or fair only that it is efficient in this specific sense. The developer ´s Pareto Efficient budget model is generally look like the one in Table – 2. Table includes the main items only for the purpose of this Paper.

Table 2: Developer´s / Client´s Pareto Efficient Budget

No	Cost Item	Allocation
1	*Development costs including initiation and feasibility*	*Allocated in the total budget*
2	*Funding cost and financial advisors, if the fund is not from government resources*	*Allocated in the total budget*
3	*Environmental and Social Impact Assessment investigations and consultants*	*Allocated in the total budget*
4	*Permits*	*Allocated in the total budget*
5	*Expropriation / RoW costs*	*Allocated in the total budget*
6	*Design consultant and site investigations*	*Allocated in the total budget*
7	*Legal consultants*	*Allocated in the total budget*
8	*Project Management Consultant, if any*	*Allocated in the total budget, may include bonus / malus clauses*
9	*Consultants (quality, HSE, etc)*	*Allocated in the total budget, may include bonus / malus clauses*
10	*Construction cost*	*Allocated in the total budget, include LDs and may include incentives*
11	*Contingency*	*Allocated in the total budget based on risk management sessions such as QRA*
12	*Loss-triggering covered events*	*Under insurance policy coverage*
13	*Force majeure events*	*Under the contingency*
14	*Events that are not force majeure (escalation, supply chain issues, currency fluctuations, etc)*	*Covered partly under the Contingency and partly in the construction cost as part of contract clauses*
15	*TOTAL CAPEX cost*	*All from Items 1-11*
16	*TOTAL OPEX Costs*	*Based on the costs obtained from the operations*
17	*GRAND TOTAL of Project / Development Cost*	*Total of Items 15 and 16*

The developer has the opinion that it has all details sufficient to produce a Pareto Efficient budget and the numbers are cast in stone like the Codes of Hammurabi which were inscribed on a basalt column of 2.25 m high.

Interestingly the successful bidder for the project for the project / development has become the contractor and developed a similar balance sheet like the one in Table – 2 as shown in Table -3.

Table 3: Contractor´s Pareto Efficient Budget or balance sheet

No	Cost Item	Allocation
1	*Bidding costs*	*Allocated in the total budget*
2	*Cost of working capital: Compensation by the advance payment*	*Allocated in the total budget (probably the learning curve in an international project where the contractor has limited experience has been kept short…)*
3	*Consultants (HSE, temporary design, survey, etc).*	*Allocated in the total budget*
4	*Design consultant and site investigations (if under the contractor based on the contract type)*	*Allocated in the total budget*
5	*Permits for the contractor (employment, environmental, blasting, etc)*	*Allocated in the total budget*
6	*Legal consultants*	*Allocated in the total budget*
7	*Resources (management, labour, equipment, plant, materials, methods, logistics, etc)*	*Allocated in the total budget*
8	*Contingency and risk*	*Allocated in the total budget based on risk management and experiences with the client, consultants and the designer and the country where the project will be executed.*
9	*Loss-triggering covered events*	*Under insurance policy coverage*
10	*Force majeure events*	*Under the contingency*
11	*Events that are not force majeure (inflation and escalation, supply chain, currency fluctuations, etc)*	*Covered partly under the Contingency and partly in the construction cost.*
12	*Profit*	*Allocated in the total budget*
13	*TOTAL cost*	*All from Items 1-12*

The contractor can only assess and price the risks that are either provided to it in the bidding documents openly (such as GBR, client / developer´s risk register-if provided-, contract clauses) or its own assessment of the conditions including the ground and experiences from similar projects and the experiences with the country, client, consultant, designer, etc. It is important to know that a greater amount of information will help to reduce epistemic uncertainty as pointed out by (Kahyaoglu, 2012).

However, the risks have not been eliminated for the contractor (for the project as well) just by pricing them based on what have been provided. The bidding document and the contract is probably providing the visible portion of likely issues. There may be other issues which may have not been provided to the bidders / contractors such as stakeholder issues / disagreements, permitting issues, limitations and assumptions used in setting the milestones, financial issues, etc. They are part of the epistemic uncertainties for the bidders / contractor.

Grolier Webster dictionary defines impartial as "not favouring one party more than another" and objective as "belonging to the object of thought rather than to the thinking subject" (i.e. independent of personal opinions, feelings, or perspectives). The contracts are generally drafted with an intent of "being watertight" from the party who drafts it and, in this case, mainly the developers / clients. However, branding the contracts as impartial and objective with fair risk sharing clauses do not automatically make them such.

4. IMPARTIAL AND OBJECTIVE CONTRACT FOR RISK SHARING?

The examples below may provide some insights. Due to the commercial reasons, name and features of the projects were not provided and, in some cases, details are changed for that purpose. However, the changes do not affect the opinion provided.

4.1 PROJECT T1N1

This is a transportation project with multiple long headings and complex lining works. The excavation is carried out by drill and blast and supported with shotcrete, rock bolts, lattice girders, etc. The rocks masses are volcanic, sedimentary and metamorphic with negligible or no water ingress. The rock mass classification is done empirically, and the support is selected based on designed support sections corresponding to the assigned number for the rock mass. There are various complex and large geometrical excavations within the tunnels. The tunnel contract has milestones for major events: Starting the excavation, underground excavation and support, concrete lining, other structural concrete works (such as ventilation, escape gallery, firefighting and cables). The section is around 150 m^2.

During the tender stage the milestones were provided to the bidders who were requested to mobilize all resources and services to execute the works in line with the milestones. The contract was drafted in a similar manner to FIDIC "Emerald Book" which is officially known as "Conditions of Contract for Underground Works". A Geotechnical Baseline Report was provided as to set the foreseeable conditions (i.e. the distribution of rock mass classes). The contract conditions provide that the Time for Completion directly related to ground conditions shall be adjusted accordingly. Where physical conditions encountered are more onerous than those described in the Geotechnical Baseline Report (GBR), the Time for Completion shall be extended. Conversely, where the physical conditions encountered are less onerous than those described in the GBR, the Time for Completion shall be reduced. The tenderer also submits excavation and support cycle times for each rock mass as defined in the GBR, which are converted into daily production rates to determine the excavation and support durations for each tunnel drive.

The contract clauses seem to provide the impartial and objective time adjustment factor for the potential (and highly likely) changes in GBR assessments. This is a perfect approach for the contractor to know that it will not be penalized for the likely changes in the ground conditions, which in most times, is beyond its control. The contractor should enter the production rates and shows that it complies with the client´s / developer´s initial framework milestones. Entering the production rates for excavation and lining would not be sufficient to follow a logical sequence to achieve the milestones. The example below explains.

If no works are executed behind the tunnel excavation face (Figure-1), then there is no issue to comply with the excavation cycle times (i.e. the production rates) that the contractor has proposed if the cycle times are correctly calculated and the methodology is implemented. The tunnel length will not be an issue to comply with the cycle times (the tunnel diameter is more than 12.5 m and there is enough room for the construction traffic).

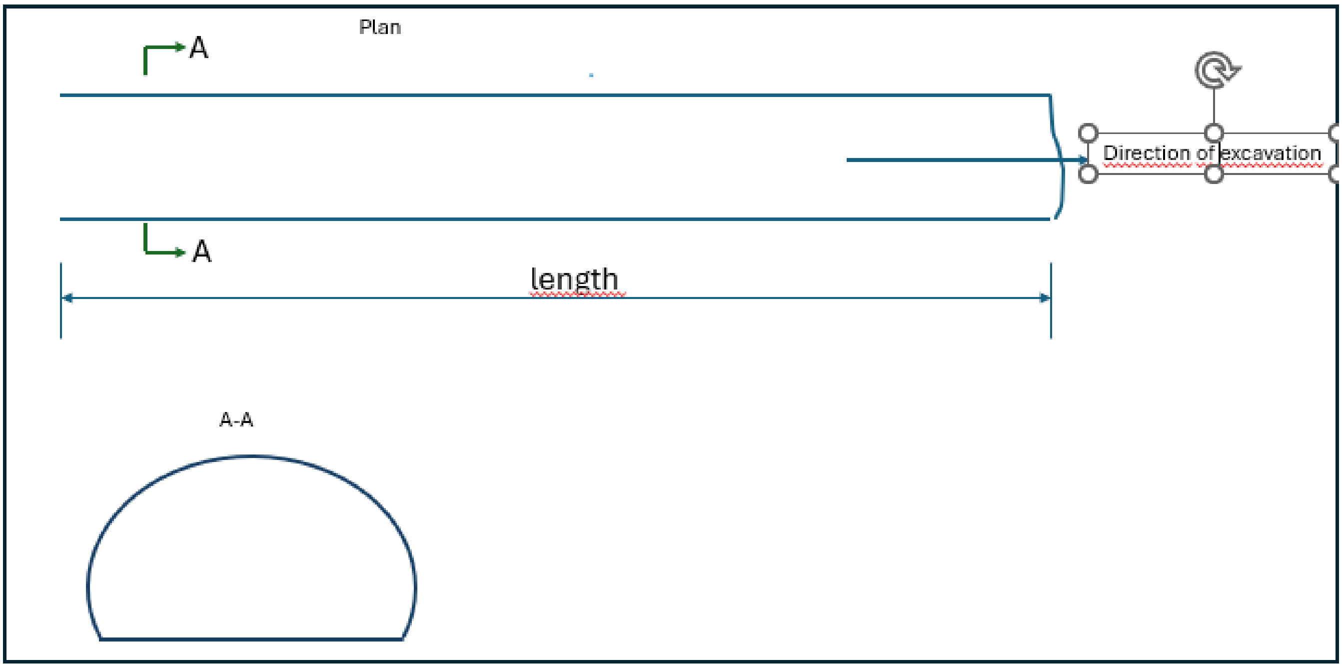
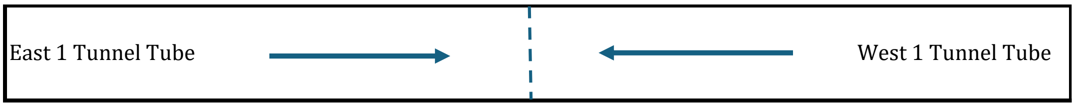


Figure 1: No other works (lining, invert, etc) behind the excavation face

However, Case-1 is usually not the case and there are other activities behind the excavation face (water proofing, concrete lining, invert, etc)

The milestones as provided in the tender and the contract are tabulated below for a single tunnel tube excavated and supported from both ends meeting almost in the middle.



				1999				2000				2001			
Tunnel	Work Area	Start	Finish	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
East 1	Exavation and support	24/07/1999	2/08/2000												
	Inner concrete lining	16/12/1999	5/01/2001												
	Partition wall	4/01/2000	14/02/2001												
West 1	Exavation and support	24/07/1999	3/10/2000												
	Inner concrete lining	29/02/2000	22/02/2001												
	Partition wall	18/03/2000	6/04/2001												

Figure 2: Summary milestones for the main works

Figure -1 shows that while the excavation is in progress at the tunnel faces, all other works such as abutments for lining, waterproofing, invert, reinforcement for partition wall, partition wall formwork and concrete and various other fitout works are ongoing. All other works are creating hindrances to achieve the planned cycle times of excavation and support. The average cycle time for excavation and support for 4.5-6.0 m daily advance is 18 hours (4.5 m long round lengths). Mucking out approximately 900 m³ material (including bulking) would require 50-60 trips of trucks. Additionally, truck mixers for shotcrete supply and supply of all other materials should be considered in the logistics of the excavation and support works. However, Figure-3 and Figure-4 show that the available areas at each zone of works creates barriers for the logistics flow in the tunnel tube. Crossing the partition wall reinforcement fixing area and formwork and concrete cast area are not possible due to the fact that the spaces are used by the scaffoldings and multiple shutters as well as the trucks supplying to those works (steel, concrete, etc).

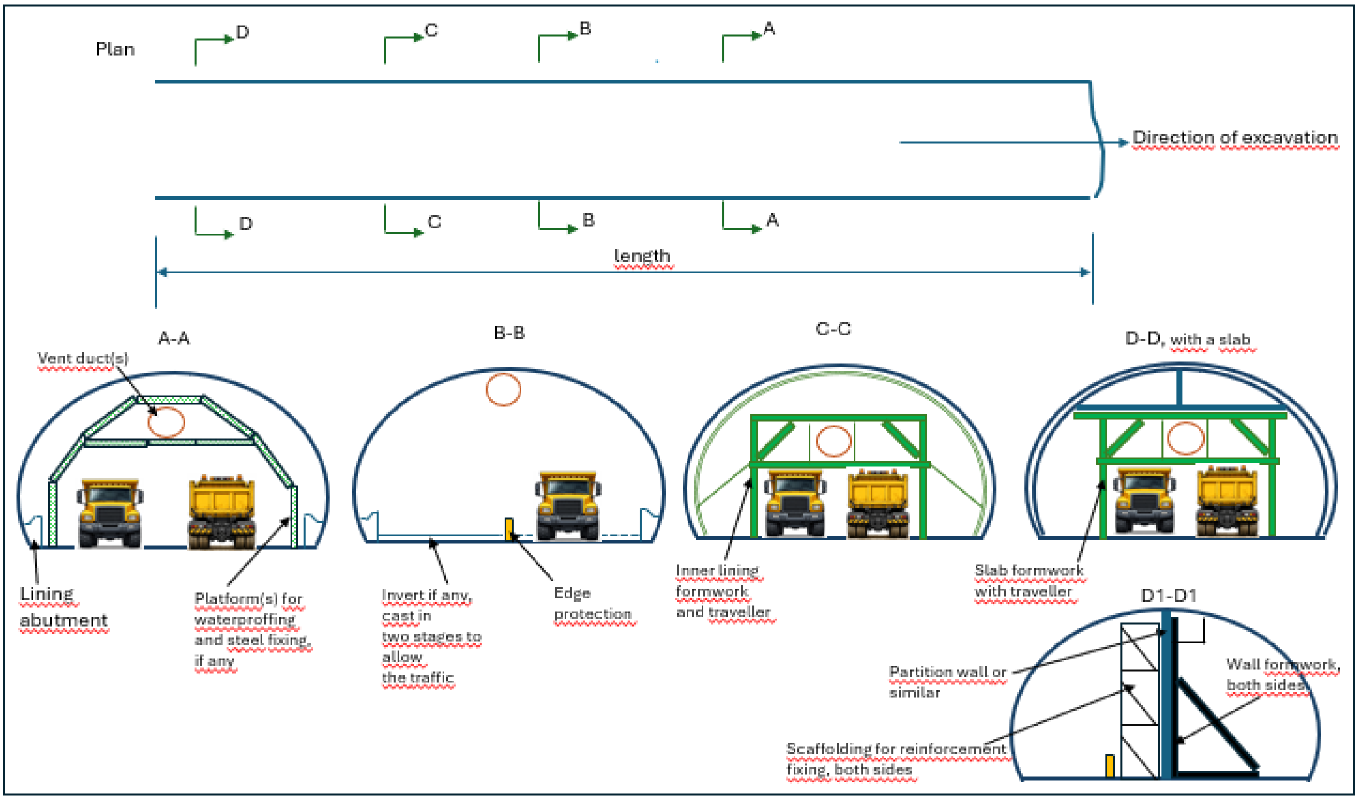


Figure 3: Plan and sections depicting the main works

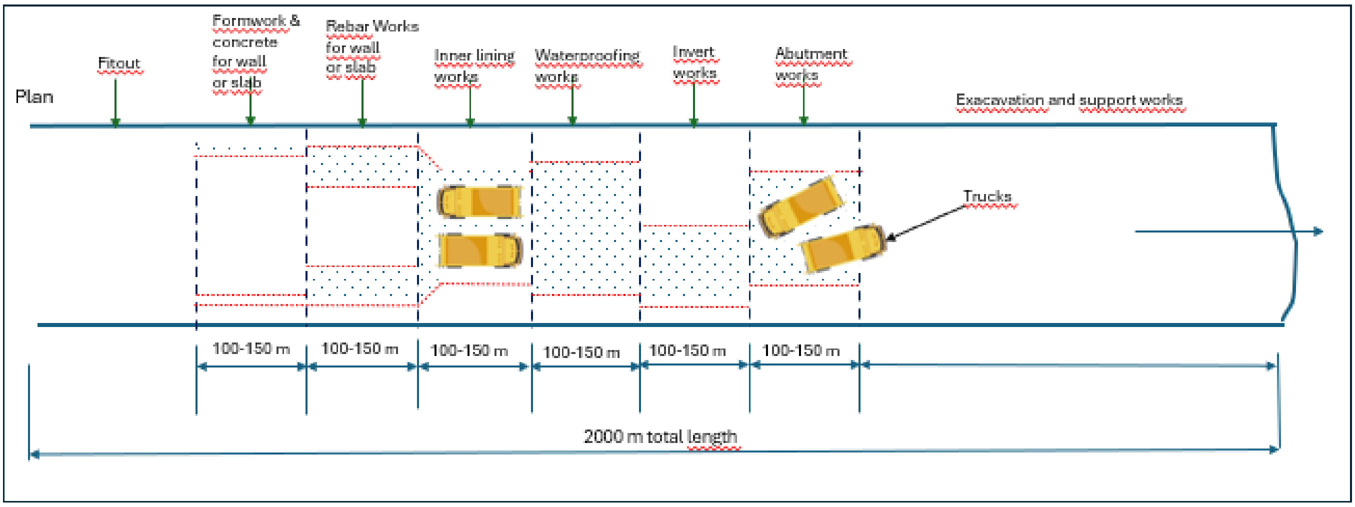


Figure 4: Available spaces (dotted areas) for logistics flow on a plan (tunnel dia. approx. 12.5 m)

Importantly such a traffic flow and available spaces will not be sufficient to allow for pedestrian access and emergency egress in line with international norms such as OSHA 1926.800 (Safety and Health Regulations for Construction, Underground Construction, Caissons, Cofferdams, and Compressed Air), BS6164 (Health and safety in tunnelling in the construction industry – Code of practice) and Safe Work Australia (Guide for Tunnelling Work). The norms specify that there shall be access and egress in such a manner that employees are protected from being struck by excavators, haulage machines, trains and other mobile equipment. The refuge chambers shall be located 150-300 m from the face (clause 19.3 of ITA Report no 14, 2014) would not be suitable for the workers away from the chamber.

It is evident that the milestones shown in Figure – 2 are not only realistic but impossible to execute a proper and safe construction. Then the question is: What is the use of impartial and objective contract clauses for time adjustment where to achieve the cycle times is highly likely impossible_

The answer is that if the portion of the work that is a hindrance to allow for traffic flow and the safe access and egress is executed after the completion of the excavation and support the minimum delay to the original milestones will be approximately 400 days (see Partition Wall dates in Figure -2). There will be more delay due to other hindrances such as invert, etc. Partition Wall works would be better to be executed from one end to the other end following the inner concrete lining works.

The milestones were determined by the client and provided to the bidders and the successful bidder adopted them in the contract. Reason for such an approach of the parties is explained in Section – 5.

Solution: Although the compensation mechanism in the FIDIC Emerald Book is a big step forward instead of asking the contractors to "fill in the blanks" of the ground investigation points, the mechanism is still not objective as explained above.

The author proposes the following controls for compensation of ground changes to make it real impartial and real objective.

a) If possible, the best way is to use collaborative contract approach or at least Early Contractor Involvement (ECI). Although ECI has also limitations and certain drawbacks such as conflicts of interest, reluctance of accepting solutions / innovations due to financial concerns, lack of specialist subcontractors which may impact the solutions. A good framework agreement at the beginning between parties along with set performance milestones may address some issues.

b) If point (a) above is not possible, the developer / client will add a framework method statement of all works in the biding documents along with equipment, tools, formworks, shutters, scaffoldings, methods, sequences, logistics, traffic control and health and safety considerations of the proposed methods. The equipment, plant, shutters, formworks, etc should have the basic dimensions that are enough to design the construction. The method statement will also include the proposed production rates used in the establishment of the milestones.

c) The bidders should provide method statement and should have two options:

d)
   i) accept the developer / client framework method statement and then develop, submit, and obtain approval for a fully detailed Method Statement following Contract award (in any case the contractor cannot claim the unsuitability of the developer´s method statement as it will sign it as its own one) or,
   ii) each bidders proposes its own method statement with complete details as in Point (i) above. The Contractor should then develop, submit, and obtain approval for a fully detailed Method Statement following Contract award.

e) The method statement in Point (c) will become the inseparable part of the baseline schedule.

f) As part of the work on the method statement, if the bidder finds out that the developer´s milestones are not achievable based on the developer´s method statement, the bidder will propose changes to the milestones.

g) The developer must check the proposed milestones based on proposed method statement and will have two options:
   i) Accept the milestones and change the contract (which could be problematical because of the developer´s governance)
   ii) Thoroughly review the bidder´s proposed milestones a along with the proposed method statement) and if those proposed milestones dates are later than the developer´s the duration between official milestone dates and the bidder's milestone dates would be declared as no LD period (i.e. developer's original milestone dates will remain). In this case the contractor will be sure that it would not be penalized for unrealistic milestones of the developer while it can apply its own

methods to achieve its reviewed and accepter completion dates. The Contractor will not raise any claim to the execution of its own method statement unless the project details remain the same.

iii) The developer may develop an incentive scheme to close the gap between the completion dates proposed by the contractor and its own milestones (if achievable at all).

4.2 PROJECT W1A1

This is a headrace tunnel of a hydropower project. The excavation was executed partially by TBM and partially by using conventional drill and blast methods. TBM part was lined with segments whereas the conventional part was lined with shotcrete. Tunnel diameter is 11 m. Tunnel was excavated in agglomerates, tuff, pyroclastic rock masses with various levels of weathering and presence of faults, dikes, etc.

Within less than a year after the start of the commercial operation the observations at the tailgate channel (muddy water, presence of rock fragments) had initiated a search in the tunnel using underwater Remotely Operated Vehicle (ROV) with 3D scanning capabilities. ROV investigation revealed collapses at various locations in the conventional trunnel section (Figure-5)

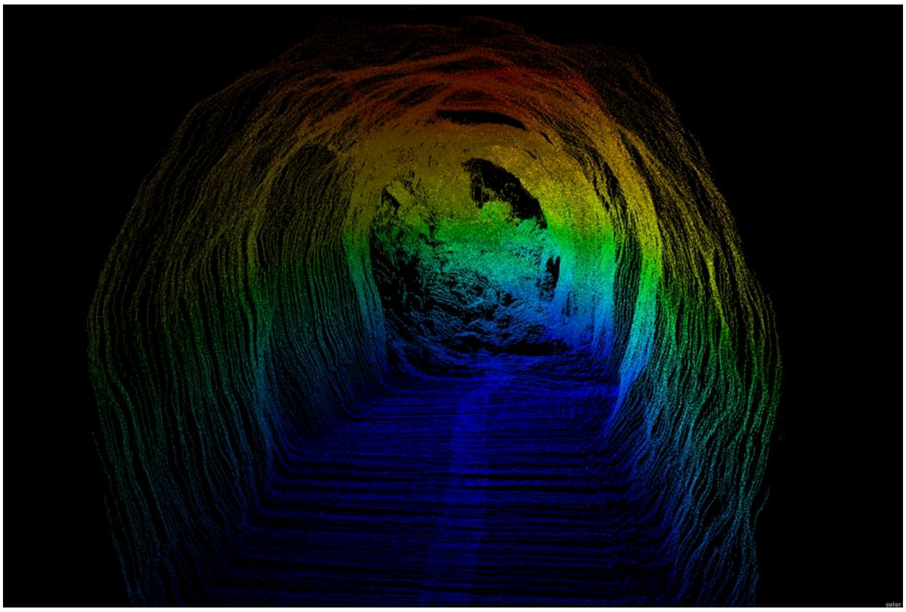


Figure 5: ROV – 3D scan showing a collapsed section

Figure 6: Same section of the collapse in Figure-5 after dewatering

Water at the intake was discharged as well as in the headrace tunnel was discharged slowly with waiting periods in between each discharge step. Access was reestablished and the teams started to investigate the damages and collapses. Apart from very significant size of collapses, substantial number of defects were identified in the shotcrete lining sections. It was then decided to rectify the critical defects by re-supporting those sections (approximately 2 km long tunnel section). All works were completed less than a year and the power plant was put into operation.

Apart from the sharp engineering solutions for very specific problems and careful construction planning and execution, the issue was the defects. This paper will not deal with all technical causes of the collapses and defects as they were classified as latent defects.

The contract is partly modified FIDIC Red Book. The defects are addressed under clause 11. There is a defects notification period (DNP) which then can be extended another two years due to a defect or damage that prevent the intended use of a work or section. Any defect afterwards is dealt with the local laws under clause 11.10 (Unfulfilled Obligations).

The collapses might have happened during filling of the tunnel with water or during the operation. There are few methods to identify the collapses and the damages in a headrace tunnel such as hydraulic data to calculate the head loss fluctuations during operation, visual observations (as explained above for this example), use of ROV. The first hydraulic data available would be during the wet testing of the system (turbines). Then the next data would be at the time of the start of the commercial operation. Filling stage of the tunnel with water is extremely important as it causes internal water pressure to act the shotcrete lining, saturation of the shotcrete lining and opening of joints, etc. There is a list of such hydropower tunnel failures in Brox,2022 along with the causes and recommendations. There is always a common conception that the tunnel as constructed could be stable for many years for the people involved in as there is no water in it yet. The tunnel in this example could probably stay many years without failure if it was intended for dry environment such as transportation. Shotcrete linings may also have many quality issues and jointing. Hence a rigorous construction control and quality control should be implemented.

The question is why such extensive defects were not identified during the construction or at least before the taking over and filling the tunnel with water? There may be many reasons such as management system failure, quality control and assurance systems failure, lack of design – construction interface failure, lack of skilled personnel. The main reasons is generally sum of many reasons. Extensive investigation programme revealed extensive nature of defects. If the damages were confined to three main collapse zones, this example could, probably, be classified as design failure and construction failure. However, issue is more complex than that. However, one of the main reasons is the lack of controls in the contract.

Hydropower tunnels cannot be left to usual DNP and latent defect clauses. The consequences are significant. Visual inspections in hydropower tunnels for DNP are not only practical but also harmful as such depressurizing and repressurizing cycles exerts stresses on the linings.

Solution: The author proposes the following controls for hydropower tunnels lined with shotcrete:

a) The contract model is ideally Early Contractor Involvement (ECI). ECI facilitates the solutions between the clients, contractor and designer subject to notes under the Section 4.1, Point a.
b) The design including geological predictions subjected to independent third-party verification and checks.
c) The parties will set up a committee with a representative from the client, designer, contractor and third-party quality control / shotcrete expert. The committee may be headed by a tunnel expert assigned by the insurance company. This committee will carry out inspections at the tunnel when every 10% of the length of the tunnel is completed and prepare a report highlighting issues, if any. Inspections will be made visually, coring, testing, NDT (such as GPR, etc). This should not be seen as "just another committee" or as "just another report" as the committee reports will be binding on the parties in the contract.
d) Any shear zone, weak zone, faults, etc in the tunnel where the stability cannot be attained in the long term by assigning the support in line with standard support drawings should be checked and verified

by the designer. Designer should provide a solution under an official submission. The same applies to large overbreak areas where the risk having a void behind the support is greater than other parts. However, the GBR should have a general assessment of such zones, and the contractor should have an information on potential solutions in order not to trigger lengthy variations discussions.

e) During the first filling operation of the tunnel, robotic inspection of the tunnel behind the water level should be implemented. The robots can be equipped with LIDAR scanner for scanning risk areas.

f) ROV inspection should be carried out after 6 months of the commercial operation date (COD), another inspection should be carried out after 23 months of COD to check if there is any need to trigger extension of DNP under clause 11.3. Last ROV inspection can be carried out after 58 months of COD.

g) If any defect is found later than that this should be dealt with under clause 11.10 observing statutory limitation periods.

h) The above should be in the particular conditions of contract regardless of the client has a latent defects insurance and business interruption insurance policy. Implementation of the above measures would reduce the insurance premiums and protect the reputation and business continuity.

Why do I address this example under the title of this paper? The answer is that the budgets for both the developer/ client and the contractor has no allocation for such latent defects as the inclusion of such would be accepting the failure even before starting the work. All in the process would probably say that we have the best design considering all factors, we would support the tunnel in the best way, spray the best shotcrete, have the best QA/QC practices as we have done numerous times and there will be no issues. However, the history repeats and the failures occur. Impartial and objective contract should accept and then address the historical trends and failures in a way to take measures to minimize them as much as possible. All parties should not treat such risks and occurrences as to penalize the other party but assess measures and treatments objectively (i.e. independent of personal opinions, feelings, or perspectives) to precent occurrences.

5. IT WILL NOT HAPPEN IN OUR PROJECT.

In Figure 7, the Author proposes an analysis in graphical format to show how the confidence of the parties (i.e. developer / client and the contractor) changes by time. This is essential since the conflicts in the execution stage after the contract award are significantly rooted in pre-award stages.

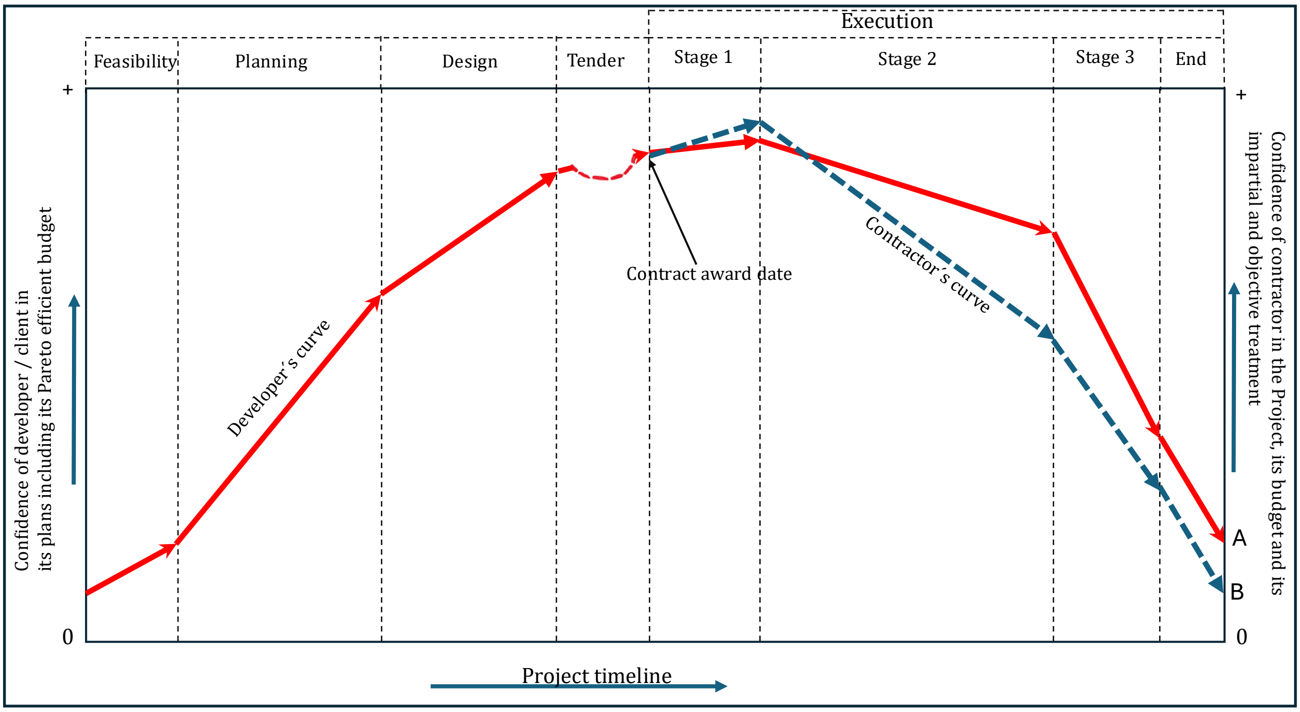


Figure 7: Model of a project timeline from initiation to completion

As explained in Section 3, the developer´s / client´s confidence increases at every stage and reaching to its near peak at the beginning of the tender stage when the developer observes the market reaction and number of interested bidders. The confidence may be dented a bit (broken line of the curve) due to number of tender queries that spark kind of "doubts". But the confidence is always in place, and the contract is awarded without any significant changes to the contract documents, and the price is negotiated and ended up within the budget that may include part of the contingency. The Contractor starts the project with high confidence as they think that they have investigated the project well and allowed all in the budget and in the end the contract has fair compensation clauses. Majority of the time the contractor site teams and management are not the same which had managed the bidding stage. Stage 1 is representing approximately 20% of the project duration. I call this stage" lovely days, we are altogether in the same boat". Both parties have high confidence in the project and their budgets, but the things start to change in the second stage of execution which is approximately 50% of the project duration. More progress causes more issues, and it is almost clear that the contract particulars (design, classification, methods, etc) are becoming questionable. Stage 3 is where the relationships are almost broken, top managements start to intervene, but the positions remain almost unchanged, and the lawyers are on the stage. Last part is where the project teams of both sides hear a story and timelines from the lawyers as if it was a different project that they have worked and everyone wants to rewrite the history. Right side of the graph in Figure 7 shows that both confidence of both parts never reach zero (points A and B) as the developer believes that its contingency in Pareto efficient budget will save it while the contractor believes that the changes are high in the dispute resolution.

What are the reasons under this scenario:

1) Confidence becomes a strength only when grounded in knowledge, experience, and learning from past decisions. When these elements are absent, overconfidence often leads to failure. Every project is unique on its own considering the ground where the tunnel will be excavated. Nobody has seen the ground before. It is an issue of classification of the ground. However, the past experience is full of learnings (including successes and failures) of rock mass behaviours, methodologies implemented in such grounds, tools and equipment, designs, etc.

2) Endowment effect leading to epistemic uncertainties to remain as such for the bidders. Endowment effect is defined by Thaler, 2015: The stuff you own is part of your endowment and the people vale things that are in their endowment more highly than things that are available but not yet owned. In many cases the developers / clients have more in-depth knowledge about the project particulars. The developer / client is aware of potential future changes in design, permits, other projects in the same area or country which may influence its own project (logistics, resources,), land disputes, etc. Viewing internal or other information as too valuable to share and therefore withholding it from bidders to gain an advantage in potential negotiations, is an example of the endowment effect. This effect is increasing the epistemic uncertainty and provides a clear path for future issues and under performance.

3) Generalization, oversimplification and framing of risks are the major factors that will lead to erroneous planning (scope, budget, contract). Generalization of the risks by ignoring the site and project specific conditions to the current project in hand will cause misestimating the consequences. Similarly reducing complex risks to a single factor or ignoring interactions between multiple factors will yield in oversimplification. The consequence is underestimations. The same is applicable for the framing of the risks. The following could be an example.

   - Statement-1: On average, 3 m^2 out of every 2,000 m^2 of sprayed concrete lining may have a significant jointing issue.
   - Statement-2: The risk of significant jointing in shotcrete is extremely low (0.15%)

   Both cases have the same probability. If the risk has a large consequence regardless of numbers, then it should be framed as such to reflect its importance.

6. CONCLUSIONS, TAKEAWAYS

There are many successful projects around the world where the parties complete the works without significant disputes, and those projects do not become part of the statistics such as those under Section 2. Purpose of this paper is to offer solutions, where applicable, to contribute for the minimization of the conflicts and disputes.

The conclusions and recommendations are provided in the paragraphs above. Hence no need to repeat the same under these sections. Closure statements if this paper will be two:

1) This paper starts in Section -1 with a reference to Frontinus' own work De Aquis: he says, “I have always made it my principle, considering it to be something of prime importance, to have a complete understanding of what I have taken on”. The most important is to know what we do. Hence skilled people are always above all factors as they are the ones to produce qualified solutions for a successful project.

2) Richard E. Goodman in the very last sentence of the Preface of his book Introduction to Rock Mechanics, 1989, stated that “….it is to help you see the simple truths before trying to take hold of the big numerical tools.”. This is a very fundamental approach to understand the simple truths before complicating the matters for others.

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