THE TIME RELATED COST INDEX
“TRCI”

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1.Introduction

The objective of this paper is the optimization of the management process control of the impact of a Variation Order/Change Order with respect to a great infrastructure Project. This document has been based on the study of a real case, during a six months stage that we have carried out with a primary Italian Construction Company. With this paper we intend to propose a new Formula, which will allow calculating a new Index, the TRCI (Time Related Cost Index) that will give to the Project Manager a realistic view of the impacts that a Variation Order can produce either from a delay point of view as well as from an economical point of view.

The “Time Related Costs” are those costs that the Contractor must incurs with the passage of the time and independently from the quantum of work performed. A typical example is the cost of the Workers. In fact, the Workers will be paid on hourly basis and not per quantity of work executed. Thus the longer the workers will remain on the job, the higher will be the cost to be paid to them.

Another example of the Time Related Cost is the depreciation of the machinery, such cost will have to be incurred by the Contractor, either if the machinery is working or not.

These two simple examples give an idea of the importance of that portion of the cost which is directly related to the time rather than to the quantum of work performed. In the overseas project these costs are even of greater importance as they are, in general, higher than the direct costs, from here the necessity to have an instrument that allows the immediate control of this variable, i.e. the **Time Related Costs Index**.

We have analyzed several Management’s control tools, which are normally implemented by the Construction Company and more specifically the Management control system adopted in the some overseas Projects.

The study of real cases has demonstrated that any Variation Order/Change Order is likely to generate delays to the completion of the Works as well as aditional costs.

The consequences of these Variations can turn out to be catastrophic if the Enterprise has not taken all the necessary precautions to prevent the occurrence of delay and additional costs by a detailed verification of the time impact and costs impact associated with the introduction of that specific instruction.

Moreover, it must be remembered that the great international Projects are generally executed within the ambit of International Standard form of Contract, which restrict the claim notification period, thus demanding a remarkable effort to the Contractor for presenting his request of Extension of Time and related compensation, which should be accompanied by a detailed and demonstrable costs analysis and Time Impact Analysis.

Therefore our job has been concentrated to find a method capable to synthesize in a mathematical formula the influence of Variation Order/Change Order with respect to the Time Related Costs in comparison with the Time Related Costs indicated in the Tender Documents.

The Formula that we have worked out shows the Index of variation between the Time Related Cost considered at the time of the Tender and those introduced by the Variation Order is named **TRCI**, or the **Time Related Cost Index Formula**.

This Formula shows the percentage ratio between the Time Related Costs recovered through the Variation Order minus the Time Related Costs recovered through the original work, dived by the Time Related Costs recovered through the original works and multiplies by 100. The Formula is as follows:

$$TRCI = [(TRC_V - TRC_O)/TRC_O]*100$$

Where:
TRCv indicates the Time Related Costs recovered through the execution of the Variation Order
TRCo indicates the Time Related Costs that were foreseen to be recovered as per Tender.

In the next pages we will explicate how we have analyzed an important Variation Order which has been implemented during the construction of an important hydroelectric project in India.

The quantities and values of money are not the real one for commercial reason, but they are reflecting the right proportions.

2. Analysis of the Variation Order

2.1 Introduction

We have used a real case in order to study the problematic faced by the site Management when in presence of an important Variation Order, that it might affect the economical result of a complex Project.

From the analysis of the Case Study and from the thematic dealt by the international literature, is emerged that between the more significant events that often determine an increment in the times of execution of a Project, with a consequent increase of costs, there is the notification and the performance of a Variation Order.

The Variation Order is often under evaluated by the site Management, or not considered in its full aspects, such as: contractual, time, technical, economical, and operative. Unfortunately this is the most common way to approach the Variation Order as the operative people are always more interested in doing the work rather than doing the money. "…*Some body else shall be looking into this problem, we must go on…*" this is the classical approach of the production people. Regrettably this behaviour is the one that will generate considerable loss of time and money, which losses can be detected only after months, and some time many months or even years.

The case under analysis is a Variation Order which had affected the original design of the primary rock supports during the construction of a Head Race Tunnel pertaining to an important Hydroelectric Project in the Himalayan Mountains.

The Change in Design occurred in this project was not immediately recognized as a critical change, but rather a beneficial change as the increment of rock supports quantities induced the people to believe that they will improve the revenue and in turn the profit.

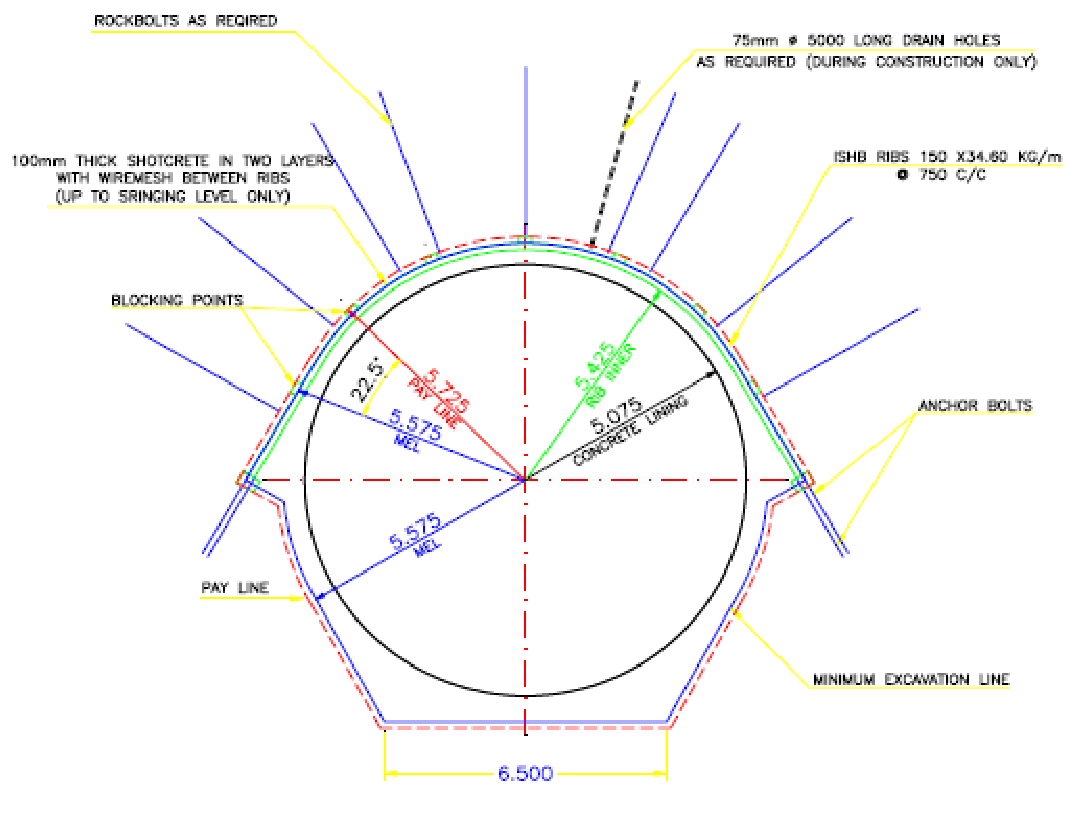
2.2 Variation Order regarding the Change in Design of the Primary Rock Supports.

As already pointed out the case related to the excavation of a portion of 11.25 km. in length of a Head Race Tunnel (HRT) measuring a total length of 27.5 km. The tunnel was excavated by drilling and blast method all along.

In the Tender documents were foreseen to excavate 6 different classes of rock, i.e. form class I until class VI. The prevailing Rock Classes were class I, II, III and class IV, as class V and VI were only 5 and 60 meter in length.

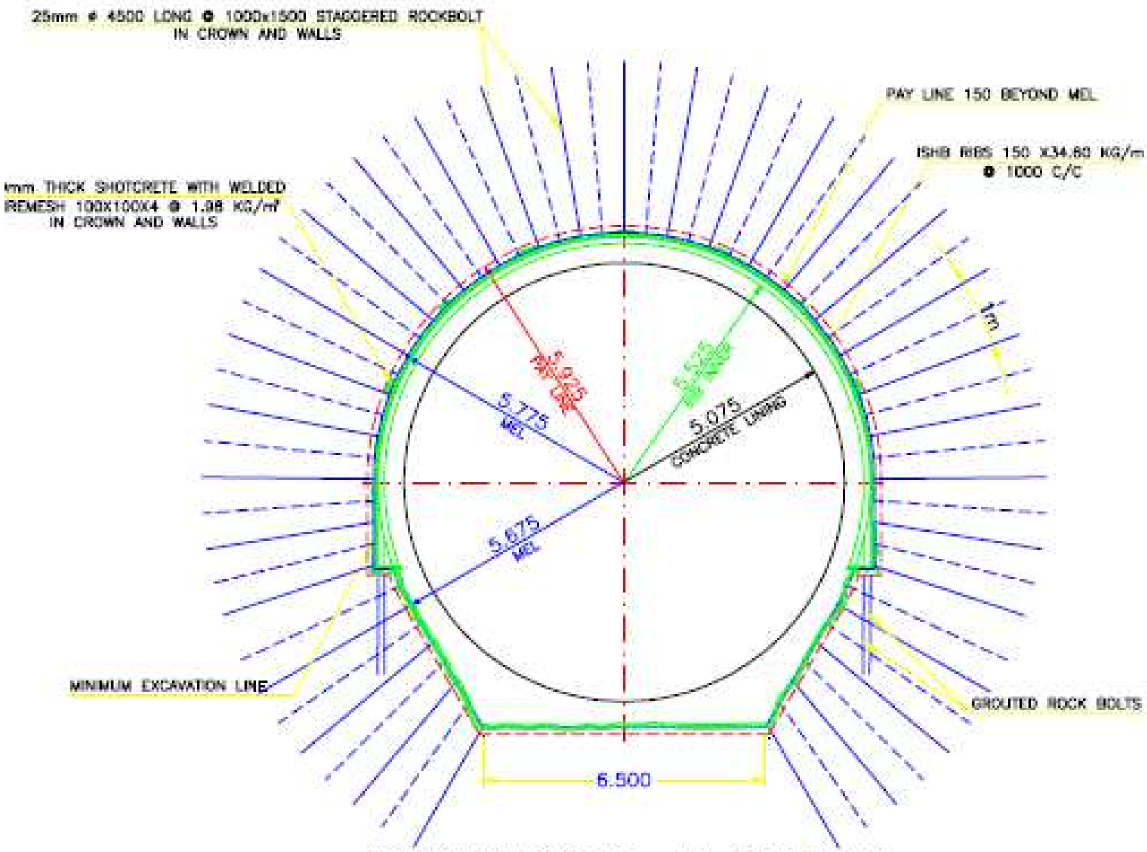
In order to define the price per cubic meter excavated the Contractor submitted at the time of the Tender the cycle time necessary for each type of rock classes.

The typical Tender sections of Class IV forwarded to the Contractors ad the Tender stage was as here below:



TENDER X–SECTION
ROCK CLASS IV
SCALE 1:150

With the Change Order the design of the typical section of Class IV rock was changed as here below:



CONSTRUCTION X-SECTION
ROCK CLASS IV
SCALE 1:150

The differences between the two drawings are evident, but in order to appreciate the amount of changes introduced, and to understand how the TRCI will work, we have worked out the following **Table 1** which compares the relevant quantities of Tender versus Variation Order.

Comparison Table between class IV Tender and Class IV Variation:

AS PER TENDER METHOD STATEMENT AND DRAWINGS

	ROCK	**CLASS IV**				
	LENGTH	2,5 m (per Round)				
NOTE	**HEADING**	**QUANTITY** (Excavation up to Springing level)			**TIME**	
					min	**min per m HRT**
1	TOTAL DRILLING TIME					104
2	TOTAL LOADING TIME					40
	TOTAL ROCK SUPPORTS TIME					144
3	BOLTS as required	4,50 No./round	4,50 m/bolt	8,1 m/m HRT	1,5	12,15
4	RIBS	17,71 m/rib	0,0346 MT/m	0,820 MT/m HRT	92	75,44
5	WIREMESH			0,039 MT/m HRT	1100	38,5
6	SHOTCRETE			19,50 m^2/m HRT	1	17,81
NOTE	**BENCHING**					
7	TOTAL DRILLING TIME					62
8	TOTAL LOADING TIME					40
	TOTAL ROCK SUPPORT TIME					0
	BOLTS					0
	RIBS					0
	WIREMESH					0
	SHOTCRETE					0
	FULL FACE					
	TOTAL DRILLING TIME					166
	TOTAL LOADING TIME					80
	TOTAL ROCK SUPPORT TIME					**144**
9	THEORETICAL RATE OF PROGRESS CLASS IV				m/day	5
	EFFICIENCY FACTOR CLASS IV				%	84
	ESTIMATED ACTUAL RATE OF PROGRESS CLASS IV				m/day	**4,2**

AS PER CONSTRUCTION DRAWINGS

	ROCK	**CLASS IV**				
	LENGTH	2,5 m (per Round)				
NOTE	**HEADING**	**QUANTITY** (Excavation up to 2m below Springing level)			**TIME**	
					min	**min per m HRT**
	TOTAL DRILLING TIME					104
	TOTAL LOADING TIME					40
	TOTAL ROCK SUPPORTS TIME					255
10	BOLTS	22,00 No./row	4,50 m/bolt	66 m/m HRT	1,5	99
11	RIBS	25,91 m/rib	0,0346 MT/m	0,900 MT/m HRT	92	82,8
12	WIREMESH			0,039 MT/m HRT	1100	49,94
13	SHOTCRETE			19,50 m^2/m HRT	1	22,94
NOTE	**BENCHING**					
	TOTAL DRILLING TIME					62
	TOTAL LOADING TIME					40
	TOTAL ROCK SUPPORT TIME					63
14	BOLTS	8,00 No./row	4,50 m/bolt	24 m/m HRT	1,5	36
	RIBS					0
15	WIREMESH			0,0454 MT/m HRT	1100	18,7
16	SHOTCRETE			22,94 m2/m HRT	1	8,44
	FULL FACE					
	TOTAL DRILLING TIME					166
	TOTAL LOADING TIME					80
	TOTAL ROCK SUPPORT TIME					**318**
	THEORETICAL RATE OF PROGRESS CLASS IV				m/day	2,55
17	EFFICIENCY FACTOR CLASS IV				%	90
	ESTIMATED ACTUAL RATE OF PROGRESS CLASS IV				m/day	**2,3**

Table 1. Difference between the excavation cycle time of Tender and that of the Variation

The above table shows that the rock supports time had increased dramatically, i.e. 318 minutes against 144 minutes.

Therefore against a considerable increment of the quantities of rock supports the time for achieving the excavation of a round had increased more than double.

The mayor consequence of such increased cycle of excavation was the drastic reduction of the daily advance. In other words, at the time of Tender the Contractor estimated to advance with the excavation of the full face of the tunnel, at a rate of 4.2 meter per day trough rock Class IV, while with the new rock supports this progress has been reduced to 2.3 meter per day.

However, the increased number of supports and the consequent mayor revenue per day induced the Management to wrongly assume that the increased revenue will in fact counterbalance the extra time needed to achieve the same advance.

The contract foresees two main documents that are explaining how the Contractor worked out his prices, i.e. the **Method Statement** and the **Sealed Envelope.**

The Method Statement is the document detailing how the Contractor will carry out his work and how the time ahs been calculated, the Sealed Envelope is a Contractor's document that clarify how the Contractor worked out his prices and how the Mark Up was constituted.

The Sealed Envelope, as the name is saying, was a Sealed Document which would had be open in presence of both Parties and only in case of disputes.

As we have said the TRCI is calculated by comparing the recovered Time Related Costs (TRC) generated by the Change Order against those foreseen at the Time of Tender.

For Recovered Time Related Costs we intend the portion of TRC that are included in each item price. In other words we can said that the price per cubic meter of excavated material or per linear meter of rock bolt installed, etc. contain a portion of costs, which are directly linked with the passage of time and can be recovered only if the work is performed. In case of suspension, or stoppage of Work, or delay, the Contractor cannot recover the TRC, while he is always incurring them.

It is worth noting that the TRC portion is quite heavy and is normally ranging from 30 to 45% of the item price. (in order to consider only the pure costs the "Profit and Taxes" should be removed, but for the purpose of this exercise this consideration is irrelevant).

The TRC includes, but are not limited to:

Labour Cost, Staff Cost, Management Cost, Head Office Cost, Financial Cost, Bonds Cost, Machinery Depreciation Cost, Camp and Facilities running Costs, General Expenses, Insurance Costs, Site Office Running Costs, etc.

In the case under examination the overall total percentage of the TRC was 43.67%, which means that for each 1,000 $ of revenue the Contractor was able to recover 436.7 $ to cover is costs that are incurred independently from the amount of work done.

In this regards we should clarified that the Contractor is able to recover the TRC only if he is working and producing at a rate capable to recovers the costs that he is incurring with the passage of the time.

We can now examine how the TRCI will apply.

According to the above description we can tabulate the revenues per round foreseen at the time of Tender against the revenues per round modified by the Variation Order.

CLASS IV TENDER – REVENUE AND TRC PER ROUND (i.e. 2.5 meter)

	Excavation	Steel Ribs	Rock Bolts	Wiremesh	Shotcrete
Revenue per Round (INR)	358,758.9266	73,971.8515	9,577.0350	4,361.3778	28,883.4000
TRC per Round (INR)	156,670.02	32,303.51	4,182.29	1,904.61	12,613.38

Table 2. Revenue per round and recovered TRC per round

Thus the total revenue per round was **475.552,59 (INR Indian Rupees), i.e. 190,221.036 per meter**

The total TRC recovered was **207.673,82 (INR Indian Rupees), i.e. 83,069.528 per meter**

CLASS IV VARIATION ORDER – REVENUE AND TRC PER ROUND

	Excavation	Steel Ribs	Rock Bolts	Wiremesh	Shotcrete
Revenue per Round (INR)	358,758.9266	81,188.6200	106,411.50	9,438.4700	62,862.1300
TRC recovered per Round (INR)	156,670.02	35,455.07	46,469.90	4,121.78	27,451.89

Table 3. Revenue per round and recovered TRC per round

Thus the total revenue per round was **618,659.65 (INR Indian Rupees), i.e. 247,463.86 per meter**

The total TRC recovered was **270,168.67 (INR Indian Rupees), i.e. 108,067.47 per meter**

As can be seen the revenue per meter has increase considerably with the Variation Order and the TRC recovered are also increased with the same ratio.

Unfortunately this simple comparison did not give the right picture, as does not show and does not compare the daily advance rate of excavation between the Tender Drawings and the Changed Drawing.

Let us do such comparison and see the results.

As we have seen in **Table 1** the foreseen daily advance rate at the time of Tender was 4.2 meter while with the Variation drawing the daily advance rate drop down to 2.3 meter.

Therefore by applying the Revenue and TRC per meter we will be able to compare the amount of TRC recovered with the two different designs.

CLASS IV TENDER

Revenue per day 4.2 * 190,221.036 = **798,928.35**

TRC recovered per day 798,928.35*0,4367 = **348,892.01** !!!

CLASS IV VARIATION ORDER

Revenue per day 2.3 * 247,463.86 = **569,166.88**

TRC recovered per day 569,166.88*0,4367 = **248,555.18** !!!

Now we have all the necessary data to apply the TRCI Formula

$$\mathrm{TRCI} = [(\mathrm{TRC}_V - \mathrm{TRC}_O)/\mathrm{TRC}_O]*100$$

((248,555.18–348,892.01)/348,892.01)*100 = **–28.75%**

The result is self explanatory; with the Variation Order the Contractor is loosing 28.75% of the Time Related Costs.

In other words, notwithstanding a greater income at the end of the work the Contractor will be unable to recover more than 65% of his Time Related Costs, i.e. (28.75/43.67).

This example shows that a timely application of this Formula can really give to the Site Management a quick and important tool to unveil the trap behind a Variation Order or a Change in Design.

Off course the same strategy can also be applied for checking the Direct Costs implication and variations with respect of the Tender stage.

In addition to the above the TRCI can also be used to check and evaluate the cost of an Extension of Time Claim.

The detailed computation of the TRC can be considered as the evolution of the Emden Formula, Hudson Formula and Eichleay Formula. In fact the breakdown of TRC cost can be established at the Tender stage and used in case of dispute during the course of the Project. Moreover, the TRC can also be used for determining the Loss of Productivity claims.

We believe that the TRCI could improve and help both parties to a contract to find a quicker, cheaper and equitable response to the Construction Disputes Resolution.