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A New Approach for Setting a Tunnel Excavation Tender Price List

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Abstract

Egnatia Motorway is 680 km long and crosses Northern Greece from west to east; its budget is expected to reach € 6 billion. A 35 km long critical mountainous section has been tendered early this year with a budget of € 500 million. It includes, amongst other structures, thirteen twin tube tunnels totaling 22 km bore length. The predominant construction method to be applied is that of drill and blast, following the general principles of NATM. The Owner of the project has already the experience of 56 km constructed tunnel bores in various geological – geotechnical conditions. Based on this experience and taking into account the financial and time restrictions for the completion of the Motorway, an innovative strategy has been established for tendering tunnels in the above section. Tunnelling is a combination of expertise in several disciplines with the ability to fit different elements together. The emphasis of conventional approaches is on "quality production tunnelling", with exact contours and cost optimization. In the new approach both the Price List and the Technical Specifications have been thoroughly examined and modified, resulting in: first, premium price in the "lighter" excavation and support categories; second, rational handling of individual elements, i.e. forepoles, face bolts, micropiles, which are costly for the Owner and time consuming to install for the Contractor; and third, improved profit for quality contours. Operation analysis was used to estimate the cost per linear meter for each designed excavation and support category. The results triggered changes in the specifications. Clear guidelines for the construction works were defined as well as a set of parameters, which directly affect cost; these will be monitored during construction to enable early correction measures when needed.

Keywords

Tunnel, Cost, Excavation, Tender

1. Introduction

The most significant highway project in Greece is the Egnatia Odos Motorway, which is 680 km long and crosses, from west to east, the Regions of Epirus, Macedonia and Thrace. 400 km of motorway, more than

the half of the project, have already been given to traffic. Egnatia Odos SA, who is the Owner of the project, has obtained a wide knowledge of mountainous tunneling from the 40 twin tunnels already constructed, totaling more than 56 km in single bore length. The tunnels were excavated in various geological and geotechnical conditions (gneiss, limestone, flysch, peridotites, phyllite etc. of very poor to good quality rock-mass, according to the international geomechanical classification schemes). The conventional construction method of drill and blast and/or mechanical excavators was adopted within different contractual frameworks.

In the early stages of the project, tunnels were tendered under design and build contracts, dictating a lump sum price for the underground excavation and the primary support. The results of this period showed important contract deficiencies mainly because of the high price reductions that the Contractors offered and the unaccomplished and/or inadequate studies. In the next generation of contracts, the payment for the excavation and primary support of tunnels was accounted either by linear meter of constructed section or by price unit for all the works needed; according to the Greek Law Contactors offered a reduction to the Owner's Tender Price List. The definite design was conducted by the Owner.

Early this year, a 35 km long critical mountainous section, the so-called "brown bears' section", was tendered with a budget of € 500 million. It includes, amongst other structures, thirteen twin tube tunnels totaling 22 km in single-bored length; the longest bore is 2.6 km and the shortest 0.3 km. The tender budget for the fully constructed and equipped tunnels amounted to € 300 million. For the four tender lots reductions offered by contractors ranged from 24% to 31%. It is therefore obvious that tunneling works are predominant for the "on time delivery" and "within cost estimation" completion of this section.

Based on the experience of past underground projects of the Egnatia Motorway and taking into account the financial and time restrictions for the completion of this section, an innovative strategy has been established for tendering these tunnels; it is discussed in this paper.

2. Contractual Management of Tunnels

A literature review suggests that nine infrastructure projects out of ten fall victims to cost escalations, for motorways the average escalation amounts to 20% and for bridges and tunnels 34% (Flyvbjerg et al, 2002).

The analysis of 37 major contracts of the Egnatia Odos Motorway (with a budget over € 6 millions) shows that the average cost escalation amounts to 13% (Petroutsatou et al, 2004).

It is generally accepted that underground projects are difficult to manage mainly due to risks associated with ground conditions, which affect the final cost and delivery time (Rigby, 1999).

Given the fact that underground projects are perceived to be costly and difficult to manage, there is good potential for significant and consistent reductions in the total cost of tunnel construction. This can be achieved through more comprehensive and strategic management of the tendering procedures (Reilly, 2002).

Since the majority of underground projects contain high uncertainty, there is need to minimize this by incorporating experience and knowledge into the future contractual agreements (Kolic, 2001).

Bearing in mind that inappropriate risk management could lead to higher costs for the Owner, the selection of adequate contractual strategies, which fit Owner ambitions of the project, will lead invariably to the achievement of "value for money" (Langford et al, 2003).

A solution to the successful contractual management of tunnels is to acknowledge that substantial risk associated with underground conditions exists and cannot be completely eliminated; nevertheless, it can be successfully moderated if past examples are carefully analyzed. Egnatia Motorway offers a comprehensive and detailed range of data regarding tunnel construction and the associated risk of underground conditions.

3. The Rationale of the New Price List

Tunneling is a combination of expertise in several disciplines with the ability to fit different elements together. It was therefore decided to adopt in the tendering stage a value engineering approach, which is appropriate to complex projects involving several disciplines and experts. This approach required understanding and experience not only of the design and construction, but also of the legal, cultural and managerial environment (Muir Wood, 2000).

The Geology of the section in question includes mainly molasses (sandstones, siltstones and conglomerates of good to medium quality), which have not suffered heavy tectonic action. In the first third of the project gabbro and periodites of the ophiolithic complex are anticipated; their quality ranges from very poor (near to big thrust zones) to excellent quality. The excavation method to be applied is that of drill and blast, following the general principles of NATM. To expedite design, seven companies were hired following an international tender.

According to the existing price list, the “heavier” excavation and primary support categories per linear meter tunnel excavation were more costly for the Client and more profitable for the Contractor. The experience of past projects has shown that the Contractor in order to increase its profit used to claim more “heavy” excavation and support categories. The reasoning behind these claims was that the risk involved in poor rock masses could be dealt more safely by using “heavier” support. When the on site classification team (consisting of representatives of the Client, the Construction Manager and the Designer) adopted a different resolution, it was almost certain to initiate a dispute on who would take the underground risk.

Taking into account the aforementioned claims and the technical experience gained out of the 56km of tunnels already constructed, the need to develop a new price list was apparent. The subsequent steps were followed.

A team was nominated to analyze each critical element of the project, namely the underground excavation and the primary support. The emphasis in value management was on specifying functional requirements as the project definition developed, since the definition itself brings in to focus the choices available (Muir Wood, 2000). Each element was identified and ranked using its cost/value ratio (explained below), highlighting areas of potential improvement. Experience was examined critically in the light of the changed requirements of the new project.

The next step involved the standardization and grouping of excavation and primary support sections, given the fact that seven designers were involved. This was done by estimating the specific characteristics of each tunnel without changing both the design basis and the respective analytical simulation followed by each designer. All the proposed excavation and primary support characteristics were grouped into five categories (A to E). The criteria used were the geotechnical conditions (Geological Strength Index, Unconfined Strength of the intact rock, etc), the height of the overburden, the excavation step, the thickness of shotcrete and the steel sets.

The following step involved operation analysis and cost estimation of each element for the timely tunnel completion, as proposed in the design phase. All necessary resources (manpower and machinery) were analyzed on the basis of the work breakdown structure (WBS); current market prices were applied. To

calculate each element's cost/value ratio, the "cost" derived from the above analysis was used. The respective "value" was determined taking into consideration:

- The difference between the "price" of each element in the previous Client's contracts and the above "cost".
- The impact of each element on the work cycle and the project's time schedule.
- The effectiveness of the primary support elements.

This procedure revealed the items whose existing prices needed "adjustment".

Last but not least, the analysis of the claims raised by Contractors in the past contracts revealed elements where adjustment was necessary. Conclusively, the new strategy aims at triggering the Contractor to use more "light" support categories with positive results for both parties. With this approach, it is incumbent on the Contractor to request the use of "lighter" support categories and undertake the additional underground risk; the on site experts team will evaluate the proposal and decide accordingly.

4. The Formulation of the New Price List

Based on the above, the following decisions were taken regarding the formulation of the New Price List for tunnel tendering:

- Application of a combined Price List including:
  - Prices per tunnel linear meter T_i for each excavation and primary support category:

$$T_i = \Pi_i + K$$

where: Π_i is the "core" cost per linear meter for each excavation and primary support category. It refers to the basic geometrical features, i.e. it corresponds to the maximum excavation volume, the maximum volume of shotcrete applied and all defined elements of the primary support (steel sets and anchors – rockbolts). In a few cases only ("high risk" conditions) it refers also to the pre-reinforcement elements above and ahead of the excavation face (forepoles, spiles, face anchors, face shotcrete) as well as to the works for foundation improvement of the primary support shell (e.g. micropiles). Π_i is the "inelastic" part of every excavation and primary support category cost.

K is the Contractor's profit for all excavation and primary support categories. The Client accepts the Contractor to profit a reasonable percentage of the total "core" cost ($\Sigma\Pi_i$) of every tunnel. K is the quotient of the division of this total profit for each tunnel by its length. Therefore, the Contractor is indifferent in terms of direct profit regarding the excavation and primary support category, whereas the total cost for the Owner is minimized.

Furthermore, when "lighter" excavation and primary support categories from those of the design are used, the time schedule of the project is shortened, resulting in increased indirect profit for both parties involved. Additional "potential" profit for the Contractor can be also derived from the accuracy achieved regarding the excavation lines, since T_i includes a certain accepted "over excavation" and respective shotcrete.

  - Unit prices E_i for all elements used for:

- Prereinforcing above and ahead of the excavation face (forepoles, spiles, face anchors, face shotcrete),
- Improving the foundation of the primary support shell (micropiles),
- Dewatering (drainage holes).

The real need (number, arrangement) for these elements can be specified only on site by evaluating the real geological – geotechnical conditions of the exposed excavation face in relation to the monitored behavior of the underground rock mass. Their use delays production and results in cost and time increases. Therefore, they have been strategically characterized as "not attractive" with the scope to use only the "necessary" quantities and no profit was assigned to them.

- Modification of the existing Technical Specifications for Tunnel Construction involving:
  - Clarification of processes (e.g. detailed description for the designation of the applied excavation and primary support category on the basis of NATM principles and for the claim procedure in case of disagreement)
  - Control of works and practices (e.g. blasting control by an expert, monitoring of steel sets foundation, etc).

5. Conclusions

The innovative Price List and accompanying Technical Specifications, set on the occasion of a Egnatia Motorway section tendering, was the result of application of "value management" based on the experience gained in previously constructed underground projects. Its primary target is the orientation of the Contractor towards the adoption of productive excavation and primary support categories, with lucid and austere criteria that assure the quality of works; thus having as a final result the maximum profit for the both parties involved, the Contractor and the Owner.

For the success of this strategy a set of actions is required during the construction phase to assure: the immediate and smooth communication lines among all the parties involved; the rapid reaction in case of problems; the continual supervision of the construction; the control of the basic geometrical features (excavation line, shotcrete line); the monitoring and systematic evaluation of the rock mass behavior.

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