Probabilistic Analysis of the Delivery Models Unit Price and Alliance applied at the Project Gemeinschaftskraftwerk Inn with Focus on the Construction Time

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ABSTRACT: Innovative delivery models attempt to deliver major construction projects within budget and on time. However, proving their efficiency is difficult because of a missing base for comparing innovative and traditional delivery models. Therefore, a common ground is mandatory, as given in the "Gemeinschaftskraftwerk Inn" (GKI).
Part of the GKI is a 23.5 km long headrace tunnel. The excavations started in the design-bid-build model with a unit price contract, which was terminated during construction by mutual agreement. The alliance contract was chosen to continue the tunnel advance with a new contractor. Only key personnel was exchanged. That allows a unique direct comparison of both delivery models.
A probabilistic analysis was conducted. In principle, probabilistic models of the excavations were introduced to compare the construction time in the two different contract models.
The key finding is that the construction time is 15 % to 22 % faster using the alliance delivery model.

Keywords: alliance contract, Gemeinschaftskraftwerk Inn, innovative delivery models, probabilistic analysis, TIWAG alliancing contract.

1 INTRODUCTION

Traditional delivery models like unit price contracts often fail to fit the needs of major projects. These models exceed the budget, and projects are not finished on time. Therefore, innovative delivery models are commonly regarded as a solution and a better approach to project delivery (Sander et al. 2022). Even though these innovative models have been used more frequently in recent years, comparing both models is complicated: projects are only realized in either of these models.

During the construction of the "Gemeinschaftskraftwerk Inn" project, both models were applied. This research project aims to define a common basis for analyzing the different contract models and determine the main points of the contracts that cause delays. On this base, a comparison of the two contract models was conducted to evaluate the efficiency of the alliance contract.

2 PROJECT GKI – HEADRACE TUNNEL

The project “Gemeinschaftskraftwerk Inn” (GKI) is a hydroelectric power plant. Owners are the Tiroler Wasserkraft AG (TIWAG), with a share of 86 %, and the Engadinger Kraftwerke AG, with a share of 14 %. It is located at the Austrian and Swiss border and has been operating since the 4. November 2022. The yearly production is 440 GWh with a total capacity of 89 MW.

The construction was divided into several contract sections. This paper deals with the contract section Maria Stein, the power plant’s headrace tunnel advance. The advancement started at the window gallery Maria Stein. It was excavated with two drives in opposite directions by two dual-shield tunnel boring machines.

The excavations started in a design-bid-build model with a unit price contract. After approximately 16 % of the excavation, the unit price contract was terminated by mutual agreement. The owner TIWAG chose the delivery model alliance contract for the first time in Austria. Subsequently, the tunnel was finished within the owner’s expatiations (Herdina 2020).

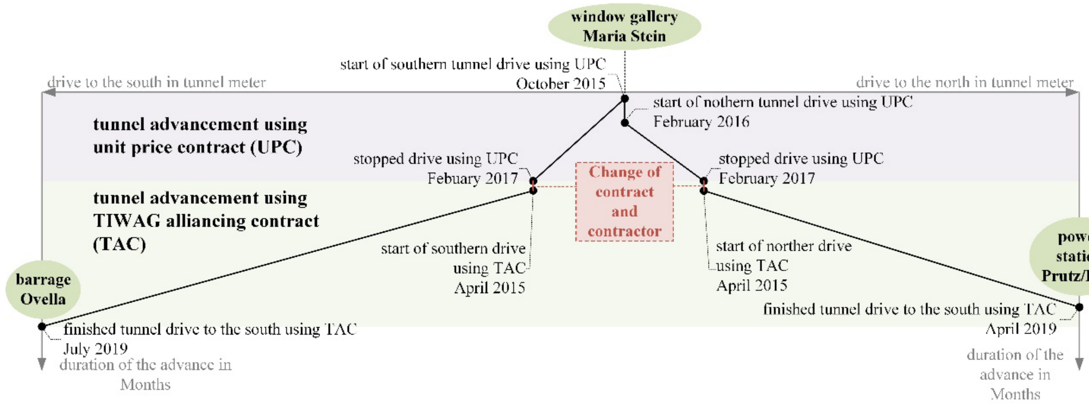

Figure 1. project timeline (Friedinger et al. 2023, p. 1).

The construction of the headrace tunnel was affected by delays right from the start. Delays occurred in the planning-, approval-, tendering-, contract- and execution phases, as well as during negotiations. The approval procedure took six years, and the construction started on the 30th of June 2014, conducted with a unit price contract. The planned start of the tunnel excavation towards the south in May 2015 had to be postponed. It was delayed until November 2015. Soon after, the delay in tunnel advance was already so significant that a dialogue took place in March 2016 to optimize the construction process (Herdina 2018). It proved to be complicated to reach an agreement. In October 2016, negotiations on the termination of the unit price contract took place. The principal and the first contractor terminated their contractual relationship by mutual agreement on the 15. February 2017 (Herdina 2019).

Simultaneously, a so-called TIWAG alliancing contract was negotiated with a new consortium, which turned out to be the second contractor. The tunnel excavation continued on the 16. February 2017 with the second contract. The second contractor adopted the entire construction site inventory, including the tunnel boring machines and miners. (Herdina 2019). The second contractor avoided further delays in the tunnel advancement by optimizing the construction site infrastructure and lifting the cutter head. The tunnel advance towards the north was completed on the 9. April 2019, and the one to the south on the 10. July 2019.

3 CONTRACT MODELS

3.1 GKI project specific

A special feature of the project GKI is the application of two different contract models, the unit price contract and the alliance contract.

During the unit price contract deployment, 1,899 m in the southern drive and 1,641 m in the northern drive were excavated. After the contractor and contract model change to the alliance contract, the second contractor drove the remaining 10,191 m to the south and 7,790 m to the north. The same labor force and equipment were used for the tunnel advance in both contract models. Due to the change of the contractor and contract model key personnel, like site managers and supervisors, were replaced to initiate a new contractual relationship between owner and contractor (Herdina und Mitteregger 2022). Thus, allowing a unique direct comparison of the performance of the two contract models.

3.2 Traditional delivery model – unite price contract

The deployed unit price contract is the standard construction contract in Austria. When procuring construction work in Austria, the ÖNORM B 2110 is regularly applied in general contractual terms. § 1151 Austrian Civil Code (ABGB) states that the contractor is obligated to "production of work for reimbursement" for the client. The contractor thus owes a product (to provide the building), while the client owes the reimbursement. In a unit price contract, reimbursement is an agreed-upon price for a specific product: the finished construction (Herdina 2019).

3.3 Innovative delivery model – TIWAG alliancing contract

Innovative delivery models aim to reduce conflicts, promote collaboration, and keep projects on time and within budget (Becker und Friedinger 2022, p. 10; Becker und Roman-Müller 2022, p. 5).

In Austria, the applied TIWAG alliancing contract is categorized as a contract for work and services. Thus, § 1151 Austrian Civil Code (ABGB) applies to the deployed alliance contract. Consequently, the second contractor must "produce a work for payment" for the client. However, the general contractual terms differ. The most critical applied terms are as follows (Deutschmann et al. 2012; Deutschmann 2019 and Herdina 2019):

- A cost-plus-fee reimbursement model with bonus-malus regulation,
- a joint organizational structure, which prescribes collaborative decision-making,
- a multi-stage, standardized conflict resolution process, and
- a collective responsibility when defined risks occur (risk sharing).

4 PROBABILISTIC ANALYSIS

4.1 General approach

A specific review was conducted to compare the construction time and the performance of both contract models. However, both contract models were applied in both drives, and there is no consistent data on the complete tunnel excavation for either model. To enable a comparison, models of an entire advance in either contract model are required. In order to develop them, two steps are mandatory. The first step is the analysis of the actual advance rates, and the second is forecasting delays (see Figure 2).

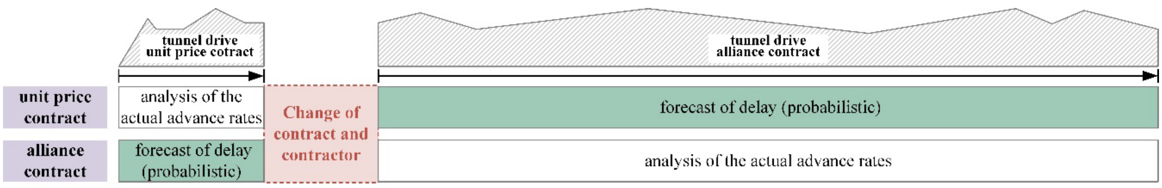

Figure 2. schematic model of general approach southern drive.

The determined data is subsequently validated in workshops by the project management of the GKI. Based on the obtained data, a digital model is generated for each contract model and tunnel drive. The simulation is carried out probabilistically in the software "Risk Administration and Analysis Tool" (RIAAT).

4.2 Advance rates

It was mandatory to review every daily report, and every drive log in a four-eye principle. Every day was categorized as either an excavation day or a delay day. A day would count as a delay day if no excavations were done on that particular day. Additionally, subcategories for the delay days were introduced, consisting of:

Logistical delays, major incidents, unplanned maintenance, scheduled maintenance, planned leaving, and assembly. Scheduled maintenance, planned leaving, and assembly are unrelated to the delivery and contract model. Therefore, they are negligible for comparison. The analysis results in the following input values:

- Basic advance duration: the time required for a complete tunnel excavation without delays. It can be transferred to the rate of advancement.
- Probabilistic estimate of the logistical delays: includes delays based on the logistics of the site. They reduce the rate of advancement.
- Major incidents: incurred risks, e.g., due to geological conditions. One part of the delay is based on conflicts influenced by the key personnel. The other part is the time needed for the technical solution.

4.3 Forecast of delay

Probabilistic estimations and forecasts were then used to model excavations that were not performed in the respective contracts. The data obtained from the preliminary analysis provides information on the probability of the occurrence of risks and shortfall of the advances in both contract models. Thus, the analyzed advancement rates can be provided with a range. Furthermore, the data of the respective other contract model's major incidents build the forecast's foundation. The time of the technical solution is adopted. In contrast, the delay based on conflicts and unplanned maintenance is adjusted accordingly to the considered contract model. This allows probabilistic schedule forecasts of the driving durations in either contract model and drive.

4.4 Modeling technique

The developed model should be as realistic as possible. A representation of delays using deterministic point estimates reduces them to a specific value. This reduction makes little sense from a practical point of view, as it produces an unrealistic prediction of construction times without any consideration of existing uncertainties (Schneider et al. 2010). Since ranges represent predictions more realistically, distribution densities are the right model choice (Sander 2012, p. 19; Gürtler 2007, p. 183f). The distribution density Beta-PERT has been chosen to generate the model in this analysis. Accordingly, the deterministic values cannot be used to compound the model since they are not considering uncertainties. The software RIAAT simulates the tunnel drives using Monte-Carlo-Simulation.

The generated models are used as a baseline for comparing the driving durations of both contract models. The model contains the data of the analysis of advancement rates as well as the probabilistic estimated forecast of delays. In summary, four models were introduced: tunnel advances in either contract model and direction were simulated separately in the software RIAAT. The input data is described in 4.2 and 4.3.

5 FINDINGS

The developed models enable the comparison of alliance contracts and unit price contracts. The comparison predicts a reduction in construction time in the range of 15 % to 22 % when using the applied TIWAG alliancing contract compared to the deployment of the unit price contract (reference Figure 3). The figure shows the overlapped results of both drives. Percentile 5 (P5) shows that the construction time is reduced by 15 %, and P95 shows that the reduction can be up to 22%. However, with the highest probability, the reduction will be about 18 % (P50).

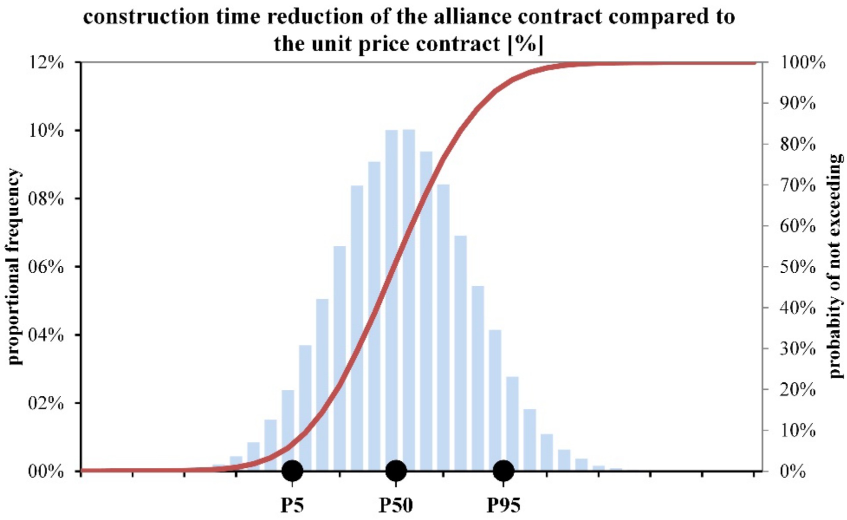

Figure 3. construction time reduction in [%].

The leading cause of delays is the handling of risks and logistics. The more efficient logistics prepared on the construction site during the deployment of the alliance contract led to fewer risks incurred. The following results represent the most important findings (Friedinger et al. 2023, p. 4):

- 0.1 % contractual share of delays, due to major events in the alliancing contract, compared to 20.5 % in the unit price (models of the southern drive). The difference is due to more efficient conflict management and better collaboration in the alliancing contract.
- The major incidents which occurred during the use of unit price contract are handled on average 14 % faster in the estimated delay forecast in the alliance contract. The improved performance of key personnel triggers this effect. The improved performance is based on the incentive in the alliance contract.
- In unit price contracts, failure in site logistics (logistical delays) is responsible for 28.5 % of all modeled delays. The delay in logistics accounts for 13.4 % of the total driving time (unit price model - southern drive). The poor logistics result from the lowest bidder principle and the cheap construction methods.

6 CONCLUSION & OUTLOOK

By the time the alliance contract was initiated in the GKI, it was the first usage of an alliance contract in Austria. The research of this new model and the conducted comparison was a great experience and an important step to prove the advantages of alliance contracts in Europe. The implemented incentive in the alliance contract avoids problems based on the lowest bidder principle, promotes collaboration, and results in “best for project thinking” on-site. However, even though incentive mechanisms work, further studies and development are required. More projects using that innovative delivery model in Austria, e.g., Kühtai, Asfinag, and Gallery Angard, are executed, and many more will follow, and project-specific incentive is the key to successful project delivery (Sander et al. 2022).

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