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Structure of price elements for construction works on water engineering systems

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Professional paper

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The construction of water engineering systems extends over several years. Prices of individual elements change over that period, which results in the calculation of price difference. The model for calculating difference in price of construction works on water engineering systems is presented in this paper through a selected structure of elements. The general conclusion is that the price element structure must be provided by contractors in their offers, based on the defined construction work organisation and technology and financial scheduling, while the Investor should take this into account when selecting the most favourable bidder.

Key words:
water engineering systems, prices, price elements, structure, construction works

Stručni rad

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Struktura elemenata cijena građevinskih radova na hidrotehničkim sustavima

Izgradnja hidrotehničkih sustava traje nekoliko godina. U tom razdoblju dolazi do promjene cijena pojedinih elemenata što rezultira izračunom razlike u cijeni. U ovom radu, odabranom strukturom elemenata, prikazan je model za izračun razlike u cijenama građevinskih radova na hidrotehničkim sustavima. Općeniti je zaključak da strukturu elemenata cijena treba dati izvođač u svojoj ponudi na temelju definirane organizacije i tehnologije izgradnje građevine i definirane financijske dinamike, a da investitor treba uzeti to u obzir pri odabiru najpovoljnijega ponuditelja.

Ključne riječi:
hidrotehnički sustavi, cijene, elementi cijena, struktura, građevinski radovi

Fachbericht

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Struktur von Preiselementen für Bauarbeiten an wasserwirtschaftlichen Systemen

Der Bau wasserwirtschaftlicher Systeme dauert mehrere Jahre. In diesem Zeitraum kommt es zu Preisänderungen einzelner Elemente und somit zu bedeutenden Preisunterschieden. In dieser Arbeit wird durch die Auswahl der Struktur einzelner Elemente ein Modell zur Berechnung der Preisveränderungen für Bauarbeiten an wasserwirtschaftlichen Systemen dargestellt. Allgemeine Schlussfolgerungen weisen darauf hin, dass die Struktur von Preiselementen im Angebot des Auftragnehmers, aufgrund der definierten Abwicklung, der Bautechnologie und der Finanzdynamik, gegeben sein sollte. Der Auftraggeber sollte diese Faktoren bei der Wahl des günstigsten Anbieters in Betracht ziehen.

Schlüsselwörter:
wasserwirtschaftliche Systeme, Preise, Preiselemente, Struktur, Bauarbeiten

1. Introduction

The construction of man-made facilities is a complex, long-lasting and risk-intensive process, which is why so many facilities fail to respect the planned/contracted deadlines and initial cost estimates. One of categories of causes, in the area of construction delays involving time and cost risks, is finance-related [1]. In the investment phase of construction of hydropower facilities, one of the economic risk factors is an increase in the price of human resources, energy, and material [2]. It is stated in paper [3], that the fluctuation of prices of materials, cash flow variations, financial difficulties faced by contractors, and shortages of materials, are significant factors affecting construction cost overruns.

According to paper [4], top ten factors affecting construction cost include: rise in price of construction materials, delay in construction, untimely supply of raw materials, other materials and equipment by contractors, fluctuations in the cost of building materials, limited funding for resources, and unprepared auxiliaries at temporary site. Three most significant cost overrun factors are: material price fluctuations, cash flow and financial difficulties faced by contractors, and poor site management and supervision [5].

Policies aimed at improving the price escalation system in construction contracts are suggested in paper [6]. It is stated that the bidding date can reasonably be adopted as the initial date for change in price. It is also suggested that losses caused by price changes should be shared between the contractor and the client, and that the corresponding clause should be introduced in the contract.

A methodological approach for determining the price change coefficient for construction work is described in paper [7]. The structure of construction works is presented based on the model of standard calculation of construction works. The equation for calculating this coefficient is presented and analysed in the scope of the method for determining the price change coefficient. The structure of elements for calculating price differences on water engineering systems is studied in this paper.

Investment costs for realization of water engineering systems can be divided into several cost groups, such as: construction costs, electrical equipment costs, mechanical equipment costs, hydromechanical equipment costs, and costs related to other works. This paper covers only the part relating to construction works, and does not include the cost of electrical, mechanical and hydromechanical equipment and other works.

Very often, the time for building big water engineering systems can be expressed in years, and such projects are very rarely completed within the scheduled time and budget. The construction of water engineering systems is always burdened with financial problems, oscillations in the price of materials, sudden and significant increases in the price of oil, metals, power sources, and other elements. Investment planning errors can bring clients into difficult situations especially when additional financing needs to be secured.

In some countries price changes are regulated by law. For instance, in the Republic of Macedonia the Civil Obligations Act allows price changes. The contractor has the right to change the price even in cases when the fixed price has been agreed upon by contract. This is permitted in cases when the price increase is greater than 10 %, and even then only for the price difference above 10 % as incurred within the agreed construction time, but also thereafter in case of delay if the contractor is not responsible for the delay [8]. However, an official methodology for calculating the price difference and the structure of elements is not defined by law.

In this context, the paper analyses the participation of various elements in the structure of price changes for civil works conducted on water engineering systems [9].

2. Elements of change in the total cost of water engineering systems

Some changes in prices can reasonably be predicted, while some are utterly unpredictable. For predictable price changes, an index-based price adjustment mechanism is used. An index basket is used for long-term contracts. After analysis of price change in this index basket (e.g. oil, labour, and cement), it is determined whether an addition to the basic price should be made [10].

When determining elements to be included in the formula for calculating the price differences on water engineering systems, it is indispensable to take into account the organization and technology for the conduct of works, as well as the materials and machinery that will be applied in construction work. The structure of elements for calculating price differences should result from the calculations of prices for each individual item, and these documents should be used to determine in the end the cost of individual elements and their proportion in total price. It is also important to take into account the price index data from reports of the State Statistical Office in the country of domicile, the data from the stock exchange, and other official data. Elements significant for calculating price differences with regard to construction works on water engineering systems are presented in Figure 1. These elements are:

- life expenses,
- production of materials and elements for use in construction industry,
- production of refined petroleum products,
- production of metals,
- production of machinery and equipment, and
- production of motor vehicles.

Life expenses is one of the most important elements, because such costs are associated with the labour and must include direct employees on the project, administrative staff, machine operators, and support staff. This element is connected with the increase in the cost of living and salaries of the employees. In the current practice, these costs do not exhibit drastic changes and so they provide real data for a longer period.

Production of materials and elements for use in construction industry *(materials)*: the analysis of the cost of materials and elements for use in construction does not exhibit over a long term any sudden changes or unrealistic indicators that could result in a sudden increase in the price of the project.

Production of refined petroleum products *(oil)*: from the macroeconomic standpoint, the oil price changes are highly significant in the analysis of business environment. Crude oil is a precious commodity and is in high demend all over the world as it is closely related to transport [11]. The share of oil products in the construction of hydrotechnical systems is significant and can, unfortunately for investors, greatly boost the price of the facility.
Production of metals *(metal)* is an element presenting significant variations when analysed in the long term. It is significant to determine, as accurately as possible, the participation of this element; however, it should be left out altogether from formulas for calculating price differences on projects where the proportion of metal structures is not significant, in which case the reinforcement is regulated through materials and elements for use in construction industry.
Production of machinery and equipment *(machines)* ***and production of motor vehicles*** *(vehicles)* are elements from the methodology used for calculation of price differences. They cover changes in the costs of depreciation, insurance, capital and routine maintenance, and spare parts for machinery. In this case, we get real indicators for the calculation of price differences, and the level of participation of this element is determined through calculation of the machinery engaged and the anticipated scope of works.

Example: Annual averages of individual elements for calculation of price differences in the Republic of Macedonia are shown in Figure 1. Due to small changes, the indices for the machines and the cost of living almost coincide with the index of 100. The analysed elements are considered partially, which does not mean that they necessarily have to be in the structure of elements for the sliding scale calculation.

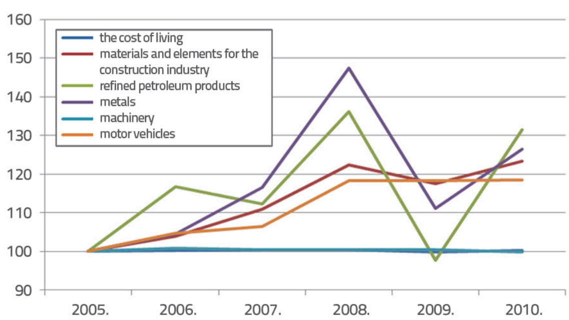

Figure 1. Diagram of annual averages of analyzed elements

3. Analysis of element structures for some water engineering systems

Elements structures for calculating price differences on several water engineering systems are presented below. The same investment values (40 million euros) and the same construction time (60 months) were adopted in calculations for different types of hydrotechnical systems, so as to be able to concentrate on other factors that are the subject/focus of this price difference analysis.

3.1. Structure of elements for Kozjak Earthfill Dam and associated facilities

The elements structure for calculating the sliding scale for the Kozjak Earthfill Dam is calculated in paper [9] based on the previously adopted organization and technology of works, and according to the detailed time schedule adopted for the project [12]. The most important elements, serving as basis for defining the element structure in the sliding scale calculation methodology for clay-core earthfill dams, are presented below (Figure 2).

Figure 2. Kozjak Earthfill Dam

Preliminary works - The value of preliminary works is determined based on the predefined type and volume of preliminary work through the analysis of their cost, time of use, and maintenance.
Structure of machinery costs - This group of costs for the light and heavy machinery and transport includes depreciation, interests on loans for the purchase of machinery, insurance, capital and routine maintenance costs, spare parts, fuel and energy, and the cost of machine operators.
Cost of materials, labour and machinery – Based on calculations according to individual items, the cost summary is made for materials, labour and machinery, which is later used to determine the participation of individual elements in the sliding scale structure.
The cost of metal is included in the costs for production of materials and elements.

The above analysis is used to calculate the proportion of individual elements in the sliding scale structure. The amounts are adopted based on individual elements, as shown in Figure 3.

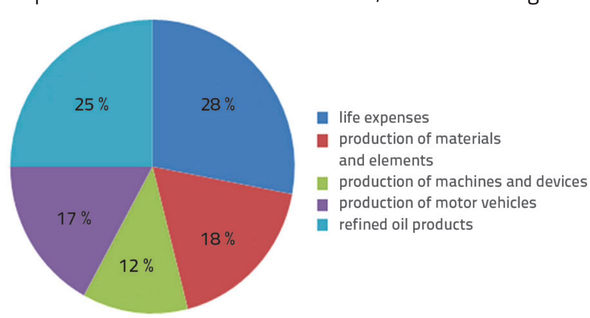

Figure 3. Sliding scale structure adopted according to calculations for Kozjak Earthfill Dam

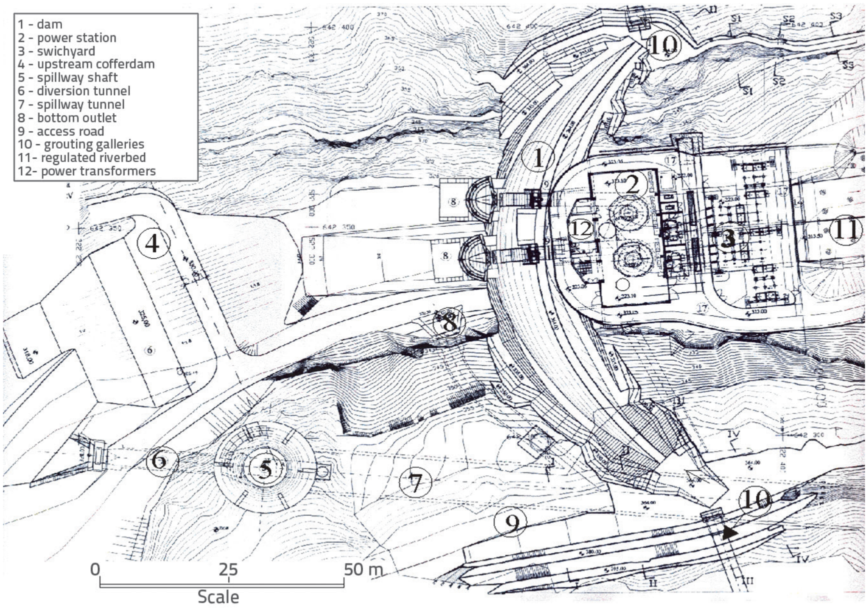

Figure 4. St. Petka Hydropower Plant – General layout

3.2. Structure of elements for water engineering systems comprising concrete arch dam, hydropower plant and associated facilities - St. Petka HPP

The structure of elements for calculating price difference for the St. Petka HPP (Figure 4) was adopted pursuant to contract documentation for the construction of the St.Petka HPP [13]. This structure is shown in Figure 5.

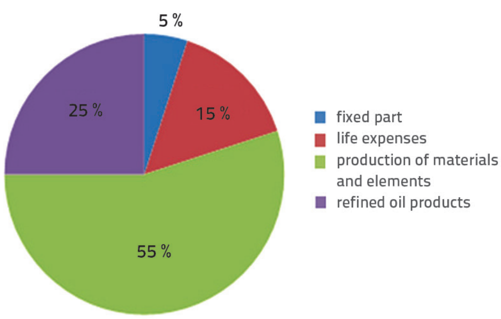

Figure 5. Sliding scale structure adopted according to contract documents for St. Petka HPP (HPP - Hydropower plant)

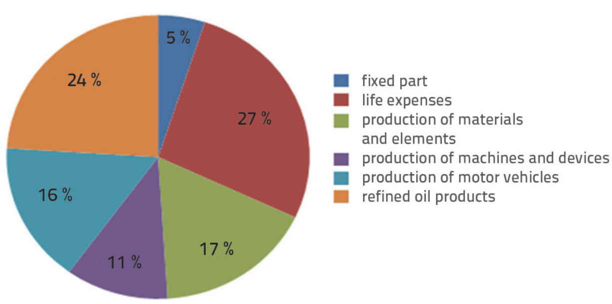

Figure 6. Sliding scale structure based on contract documents for the Lisiče Water System

3.3. Structure of elements for water engineering systems comprising earthfill dam and associated facilities – Lisiče Water System

The sliding scale structure adopted according to contract documents for the Lisiče Water System, which is used for the water supply and irrigation purposes, is given in Figure 6. The sliding scale structure for this facility is based on contract documents for the construction of the Lisiče Water System [14].

3.4. Structure of elements for water engineering systems due to major changes during construction work

The structure of elements for water engineering systems comprising a concrete arch dam, hydropower plant and associated structures, with elements presenting major changes during construction work, is shown in Figure 7. It is marked as type G in Figure 8. This element structure for calculating price differences is an example of an improperly defined structure as proposed by the contractor. In case it is used for calculating price differences, it results in major price variations that are not realistic.

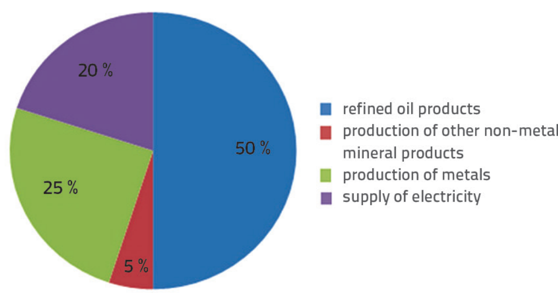

Figure 7. Elements structure for water system with concrete dam and elements presenting major changes during construction - example of an improper structure

3.5. Comparison of price differences for water systems under study

A chart showing price differences for the previously studied water engineering systems is presented in Figure 8. It shows:
- uneven time schedule (with monthly implementation depending on work conditions during the year), and
- even time schedule (with the same monthly implementation throughout the construction time).

The sliding scale was not calculated for the Lisiče HPP because its construction started in 1990 when no adequate statistical data were collected.

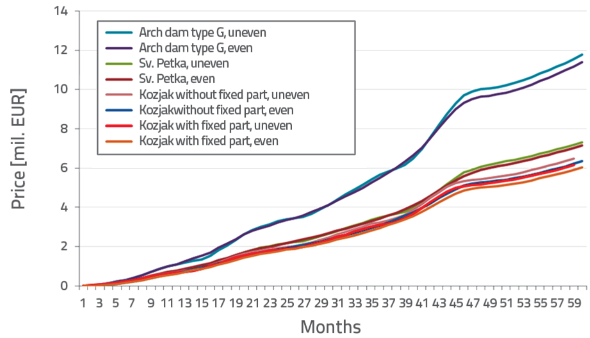

Figure 8. Chart with sliding scales for water engineering systems: Kozjak, St.Petka, and type G arch dam

3.6. Practical example

The following calculations show the influence of "turnkey" provisions and financial scheduling, based on price differences for water engineering systems with arch dam, hydropower plant, and associated structures, with the construction cost amounting to € 17,598,163. The financial scheduling is based on the time schedule proposed by the contractor in its offer, and on the prices based on the turnkey arrangement. Coefficients were calculated for the completed arch dam structure:

- Fixed part: 5 %
- Cost of living: 15 %
- Production of materials and elements in construction industry: 55 %
- Refined petroleum products: 25 %

The coefficients are calculated until June 2005 = 100, which is the base month indicated in the offer. These coefficients were then weighted until July 2006, which month corresponds to the scheduled start of the contract. The construction time amounted to 34 months. The monthly output was calculated based on the prices offered for each type of work and the time needed for its completion. The following was calculated:

- Price differences with the turnkey provision and financial scheduling based on the offered item rates and time schedule, taking into account the legally imposed fixed price percentage, amount to € 398,167.
- Price differences, not taking into account the turnkey provision, with the financial scheduling based on the offered item rates, amount to € 1,968,425.
- Price differences, with equal monthly output (without financial scheduling) and without the turnkey provision, amount to € 2,071,614.

The calculated differences are only related to construction works amounting to € 17,597,784, while the agreed construction time is 34 months. The above conclusions are practical examples of the impact of the type of contract on price differences, and they remind us of the seriousness of the decision to be made by investor/client when selecting the type of contract for a capital project.

3.7. Example of price differences according to type of project

When negotiating capital investment projects, it is possible to define a methodology for calculating price differences for specific facilities/projects and their particularities, which enables a more realistic calculation of an expected price increase. Two similar facilities were analysed to determine whether special formulas are needed to calculate price differences depending on the type of structure ant type of work, rather than to use the same methodology for the entire project.

The following structure of elements was used for the water engineering system involving construction of the Prvonek Earthfill Dam in the Republic of Serbia [15], for the bottom outlet, outlet gate, grouting works, and connecting pipelines, for which the contract was awarded in November 1990:

- fixed part: 4 %
- price index for production of construction materials: 50 %
- cost of living: 35 %
- index of transport services: 11 %

This structure of elements is compared with the element structure for the Kozjak HPP for the following civil works: bottom outlet, headrace tunnel, powerhouse, machine circle with access roads, draining trough, civil works for a 110 KV plant, and downstream cofferdam. The verification of the structure of elements and their participation in the sliding scale calculation formula was made for the purposes of this paper. These data were not used in the contract documents, nor were they used for the calculation of price differences.

Comparing the fixed part of 4 % and the cost of living of 35 % at the water engineering system Prvonek, it can be seen that these figures are almost identical to the cost of living of 43 %, consisting of the salaries, accommodation and food for the direct labour and overhead staff at the Kozjak Hydropower Plant. The relationship is also similar between the Prvonek water system with 50 % for construction material and 11 % for transport services (61 % percent in total) and the Kozjak HPP with 57 % for materials, machinery, and energy.

It can therefore be concluded that the analysis of the two facilities provides compatible results, with an almost identical sliding scale structure. It should be noted that the calculations of works according to cost items were made for both facilities with a detailed analysis and calculation of costs, based on the properly defined technology and a good-quality design documentation.

4. Conclusion

Water engineering systems are complex facilities and their construction is a long-lasting and expensive process. Sudden or significant changes in the market prices of oil, metals, energy products, and other elements are almost always registered during the construction of such systems. These changes can have a significant impact on the construction of the facility and on

the operations of the contractor, investor and other participants in the construction process. Therefore, a particular attention should be paid to the study and definition of the structure of elements used in the calculation of price differences.
In addition to construction works, the electrical, mechanical, hydromechanical and other equipment also participate to a great extent in the total cost of water engineering systems. It would therefore be reasonable to devise special formulas in order to calculate price differences by type of facility.
The number of elements and their proportion in the structure of the price-difference calculation formula could be indicated in the bidding documents by the client/investor. In this case, the contractor only gives its approval to the proposed methodology. However, the investor will not get additional data, nor will the methodology be taken as a scoring element of the bids submitted in the bidding procedure.
It is recommended that the methodology for the calculation of price differences be proposed by the bidder (legally allowed). Thereby the contractor is placed in the position in which it has to propose realistic participation of elements in the price-difference calculation methodology, to make a realistic financial scheduling, and to estimate price differences based on time schedules and the proposed financial scheduling. The prognostic price difference would be calculated by contractor for the period offered as construction time, using coefficients for the same time period as adopted prior to the bid preparation. The planned price difference should be added to the bid price, and then the total amount would be graded.
In this way the client/investor would get a significant information, i.e. the prognostic price difference that would probably be incurred due to change in the price of materials and costs, as well as a significant information about the final cost of the investment. On the other hand, the contractor would not be able to object to the price difference calculation methodology because the contractor himself would have fully defined the project construction management and technology before preparation of the bid, and the same can be checked by the investor before it makes the final selection of the most favourable bidder.
The authors hope that this paper will prove useful to all participants in the construction of water engineering systems, and that it will also contribute to the improvement of legislation in this field of activity.

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