Construction price assessment method based on inferential statistics

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Abstract. The paper presents a new objective price assessment method that can be used to accept, reject or negotiate prices for construction works proposed by the contractor of construction works. The method can be used as part of an acquisition of a new construction and in claim negotiation process both in private or a public sector. Price assessment is an investor’s tool for the assessment of price eligibility. It should be focussed on evaluation of direct construction costs and indirect costs of the contractor in order to establish whether the costs declared by the contractor are justified. This creates a negotiation leverage in the creation of a contract or creation of legal basis for negotiations regarding claim reimbursement which can be recognized in accordance with special contractual provisions. Price assessment is a very time consuming task, the presented method uses statistical tools to assess the contractor’s price proposal by detailed analysis of main items on the budget, which are then treated as a population sample. Population mean of difference in contractor prices and price catalogue prices are then used to establish a confidence interval which can be used for hypothesis testing, i.e. drawing conclusions and further negotiations.

1. Introduction

One of the main specificities of construction production is the uniqueness of the works that are carried out. Each construction is unique in terms of location of the construction site, conditions on the site [3], requirements for speed of execution [2], weather and other factors. This uniqueness is reflected in each part of the construction process including its price, which, moreover, is largely influenced by the situation on the market [6]. It is therefore difficult to establish a firm criterion according to which it is possible to decide what could be considered appropriate price of a construction. The main aspect that guarantees that the price stays within reasonable boundaries is competition. Public procurement procedures [5] take advantage of this fact by including “lowest bid” criterion as a main or sole criterion when selecting a contractor. While private procurement isn’t regulated by law and private investors are free to choose contractors however they see fit, the “lowest bid” principle also naturally and reliably regulates prices also on the private markets. Specific conditions arise when changes in technical parameters of a construction are required. The related costs of these changes are known as claims.

The claim is a legitimate demand for additional reimbursement of costs (or additional time) as a result of changes made by an unforeseen circumstances and conditions that weren’t laid down in the contract. For a claim to be eligible in the form of an addendum to the contract, it is first necessary to comply with the procedural rules of the requirement defined in the contract. These usually deal with technical justification of the claim rather than financial justification of items on the contractor’s claim budget.
The subject of this paper is the objective price assessment method for items on the contractor’s claim budget that can be used to negotiate prices for works submitted by the construction contractor. Price assessment is a tool for investors to assess the eligibility of declared direct construction costs and indirect costs of the contractor in order to create a legal basis for a claim for reimbursement, which can be recognized in accordance with special contractual provisions.

2. Price assessment method – methods, tool and logic
In civil engineering, the price analysis is followed by an assessment of technical justification, which evaluates the adequacy of the scope and nature of the construction work performed. Technical substantiation should be approved by the construction supervision and, in case of doubts, reviewed by the Institute of Forensic Engineering (in Slovakia) or other national authority or certified entity in the given country. Price assessment that follows uses four basic tools:

- Detailed price assessment focused on direct costs and indirect costs declared by the contractor.
- Analysis of the existing price history.
- Price comparison with an independent third party estimate.
- Comparing competing offers from multiple suppliers.
- Use of an existing price catalogue.

The analysis of direct construction costs is based on the analysis of the unit price. It is the analysis of the items technical solution – materials, machinery and professions wage used for particular unit and their unit costs:

- Direct material = Purchase price + price of transport to the construction site.
- Wage costs = Direct wages increased by 15% as additional wages (increase for holidays, visits to doctor, vacation according to annual working time fund) + statutory deductions 35.2% of direct wages, as well as additional wages.
- Machinery costs = Depreciations + operating cost (fuel, oil, repairs, etc.).

The analysis of indirect cost and profit calculation - the price of indirect costs is usually based as a percentage of direct construction costs and can be split into contractor’s production and administrative overhead, profit, or other subjective surcharges. In the calculation formula, the contractor takes into account the costs of production processes on the construction site [3], the financing of the operation of the construction company and the market effects expressing the profit. The calculation formula sets the flat rate and percentage rates for determining overheads and profit. The form and structure of the calculation formula is not standardized, it can differ not only between construction companies and contracts, but also within the budget according to the type of item - different types of calculation formulas can be applied to calculated, uncalculated, material, external, etc. items.

Analysis of the existing price history is used mainly for items that were originally approved in the contract but unforeseen circumstances lead to increase of the item’s number of units [1]. In these cases, we usually assume that unit costs remains the same. This however isn’t always the case, if the technical and technological aspect changes, for instance earthwork increase that leads to the use of more powerful excavator, this approach is not valid anymore and detailed analysis is required. Historic prices from previous contract may also give a good estimate if new claimed contractor’s price is appropriate, the historic prices are not binding however and other factors like construction site conditions can have an influence. Price comparison with an independent third party estimate is a good method if the third party is completely independent. A third party can give an estimate on prices claimed by the contractor, however, since the third party is usually a competition to the contractor on the market a conflict of interest can lead to objections from the contractor when referred to third party prices.

Comparing competing offers from multiple suppliers is the basic principle in public procurement, namely in the bidding process and in private procurement when multiple contractors are asked to bid for the contract. This method can’t usually be used in claim management; it is usually not reasonable to search for a new contractor to provide extra construction works when original constructor has the capacity to carry them out.
Use of an existing price catalogue is a good method to assess the appropriateness of prices. The catalogue is usually ordered by a classification system. In the European union, NACE—Statistical classification of economic activities in the European Community and CPV—Common Procurement Vocabulary [4] or other national catalogue. In Slovakia the Classification of construction structures (TSKP) originated in 1977 is still the main classification system used today. Classification system ensure classification common to all normative documents, such as operational standards, price lists of construction works, etc. By assigning of a unique code to an item, the qualitative, delivery and other characteristics of the building structure or material are precisely defined. When performing price analysis, we usually consider a unit price analysis, which is a price analysis of one-unit quantity of a construction work. The requirement is the classification within the structure of classification system, which will achieve a clear definition of the subject of valuation. Quality is assumed to be at the level required by the relevant technical regulations and standards. However, the exemption of a unit price from the budget and subsequent individual assessment raises the problem of the possible absence of surcharges that are linked in the budget to the unit. These surcharges are usually items of material manipulation on the construction site, surcharges for soil stickiness, high elevation works risk surcharges etc.

![Diagram](image-url)

**Figure 1.** Price analysis and identification of items composing population and the population sample needed for inferential statistics.

Another principle used in price analysis is the Pareto principle, i.e. the 80/20 rule. In the civil engineering economics, about 80% of the total costs make up only about 20% of the items of the
construction works. The other approx. 80% of items are composing the residual 20% of the total costs. Thus, the detailed cost calculation is usually carried out only on these main items. Due to rationality, the price analysis is also carried out on these main items.

Figure 1 shows the overview where above mentioned methods and tools are applied and the constructor’s budget is divided between items that composes the population sample and the population. This will be used in the inferential statistic to estimate statistical price difference of item’s that weren’t individually assessed and aren’t included in the price catalogue.

Following the chart on figure 1, we can identify the steps of price analysis prior to the inferential statistic evaluation:

1. Identification and selection of main items on the contractor’s budget
2. Identification of main items in the classification structure.
3. Individual assessment of main items outside of the classification structure.
4. Finding equivalent items within classification structure that matches the contractor’s item – comparison of main items from the contractor’s budget with those of technologically identical/similar.
5. For contractor’s main items that don’t have equivalent in the catalogue structure – analysis of the technical and technological solution from price catalogue items for the purpose of detailed price assessment and individual negotiation of item’s price.
6. Comparison of the prices of all contractor’s items in the classification structure or those that have an equivalent in the classification structure with those in the price catalogue.
7. Consultation of items with difference of over 50% contractor vs price catalogue.
8. Clarified items used as population sample to estimate overall price difference of all item’s that weren’t subject to detailed price assessment by inferential statistics.
9. Drawing of conclusions for the strengthening of the customer’s position in the negotiations regarding unit prices of new items in order to protect public resources.

3. Price assessment of constructor’s budget with the use of inferential statistic

If the investor follows the procedure described in previous chapter, he will have items that compose a population sample and the population. Compared to equivalent items in the price catalogue, the price of contractor’s items in the population sample will have a price difference against prices in the price catalogue. We will use this to estimate average price difference of all item’s that weren’t subject to detailed price assessment by inferential statistics.

This process can be therefore split in two steps:

1. price assessment of items in the population sample, and
2. statistical analysis – estimating average price difference and confidence interval.

3.1. Price assessment of items in the population sample

Comparison of contractor’s item with the price catalogue will produce a price difference. Since we want to apply the price difference on other items, we will work with percentages instead of financial units. Equation 1 and table 1 show how to calculate the percentile price difference of items in the population sample. Upper row for each item is the Contractor’s price, lower row is the Price catalogue price.

\[
PD = \frac{(CP - PCP) \cdot 100}{PCP}
\]

\[PD\] Price difference [%]
\[CP\] Contractor’s price [€]
\[PCP\] Price catalogue price [€]
The error of the mean advanced statistical methods are the arithmetic mean of a population μ, we can proceed to now that we have the price difference of all items in the population sample expressed as percentages, Table 1. Example of calculated price difference of items in the population sample.

| No. | Item code      | Description | Unit | Quantity | Unit costs | Price | Price difference |
|-----|----------------|-------------|------|----------|------------|-------|------------------|
| 99  | 460510201 Item 1 |             | pcs | 70.000   | 5.331      | 373.180 | 19.75%           |
|     |                |             | pcs | 70.000   | 4.45       | 311.64  |                  |
|     | Difference     |             |      |          | 0.879      | 61.540  |                  |
| 101 | 460510202 Item 2 |             | m   | 6.000    | 4.366      | 26.190  |                  |
|     |                |             | m   | 6.000    | 5.38       | 32.26   | -18.79%          |
|     | Difference     |             |      |          | -1.010     |         |                  |
| 103 | 460200174 Item 3 |             | m   | 26.000   | 15.523     | 403.600 |                  |
|     |                |             | m   | 26.000   | 15.67      | 407.47  | -0.95%           |
|     | Difference     |             |      |          | -0.149     | -3.872  |                  |
| 104 | 460560174 Item 4 |             | m   | 26.000   | 3.318      | 86.280  |                  |
|     |                |             | m   | 26.000   | 3.24       | 84.24   | 2.42%            |
|     | Difference     |             |      |          | 0.078      | 2.040   |                  |
| 105 | 460200304 Item 5 |             | m   | 44.000   | 29.474     | 1296.850|                  |
|     |                |             | m   | 44.000   | 27.05      | 1190.11 | 8.97%            |
|     | Difference     |             |      |          | 2.426      | 106.738 |                  |
| 106 | 460560304 Item 6 |             | m   | 44.000   | 7.090      | 311.950 |                  |
|     |                |             | m   | 44.000   | 6.50       | 286.18  | 9.00%            |
|     | Difference     |             |      |          | 0.586      | 25.774  |                  |
| 108 | 460120002 Item 7 |             | m³  | 3.360    | 19.335     | 64.970  | 61.61%           |
|     |                |             | m³  | 3.360    | 11.96      | 40.20   |                  |
|     | Difference     |             |      |          | 7.371      | 24.771  |                  |
| 109 | 460490012 Item 8 |             | m   | 70.000   | 0.544      | 38.080  |                  |
|     |                |             | m   | 70.000   | 0.58       | 40.32   | -5.56%           |
|     | Difference     |             |      |          | -0.032     | -2.240  |                  |
| 111 | 584121111 Item 9 |             | pcs | 3.000    | 69.088     | 207.260 |                  |
|     |                |             | pcs | 3.000    | 7.85       | 23.54   | 780.33%          |
|     | Difference     |             |      |          | 61.240     | 183.716 |                  |
| 113 | 210950203 Item 10 |            | m   | 6.000    | 1.809      | 10.850  |                  |
|     |                |             | m   | 6.000    | 2.14       | 12.82   | -15.32%          |
|     | Difference     |             |      |          | -0.327     | -1.966  |                  |
| 114 | 130001101 Item 11 |            | m³  | 1.000    | 19.611     | 19.610  | 14.08%           |
|     |                |             | m³  | 1.000    | 17.19      | 17.19   |                  |
|     | Difference     |             |      |          | 2.421      | 2.420   |                  |
| 129 | 330510240 Item 12 |            | m   | 1.000    | 3.019      | 3.020   |                  |
|     |                |             | m   | 1.000    | 25.30      | 25.30   | -88.07%          |
|     | Difference     |             |      |          | -22.281    | -22.280 |                  |
|     | Average weighted difference (weight=price) | | | | | 65.63% |
|     | Average weighted difference (without local extremes) | | | | | 9.41% |
| Contractor's price | | | | | 2 841.84 € |
| Price according to price catalogue | | | | | 2 471.27 € |
| Difference between contractor's price and price catalogue price | | | | | 370.57 € |

3.2. Statistical analysis – estimating average price difference and confidence interval

Now that we have the price difference of all items in the population sample expressed as percentages, we can proceed to perform a statistical analysis [7] [8]. The basic indicators that enter into more advanced statistical methods are the arithmetic mean of a population μ, standard deviation σ and standard error of the mean σμ. The arithmetic mean equation 2 follows:
\[ \mu = \frac{\sum_{i=1}^{n} PD_i}{n} \]  
\( \mu \) arithmetic mean of a population [%]  
\( PD_i \) price difference of a unit [%]  
\( n \) population sample size (number of main items)  

The standard deviation \( \sigma \) (equation 3), is a measure of statistical dispersion in probability theory and statistics. Simply put, it talks about how widely the values are distributed in a set, i.e. “how close the scores are to the mean.” Low value of standard deviation means that price differences of main items lie close together, high number means they are dispersed.

\[ \sigma = \left( \frac{\sum_{i=1}^{n} PD_i - \mu}{n-1} \right)^{\frac{1}{2}} \]  
\( \sigma \) standard deviation  

The standard error of the mean \( \sigma_{\bar{x}} \) (equation 4) is the standard deviation of a random variable, i.e. sampling mean obtained as a random sample from the base population set, this is called sampling distributions. The sampling distribution of a population mean is generated by repeated sampling and recording of the means obtained. Simply put, the standard error of the mean is a number that indicates how much the average of a random sample differs from the arithmetic mean of a population. We can imagine the mean error of the average as a random variable, which would be created by the repeated random selection of population samples groups from the population and the calculation of the average in each individual group.

\[ \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \]  
\( \sigma_{\bar{x}} \) standard error of the mean

**Table 2.** Example of basic statistical indicators performed on the population sample.

| Population sample | Arithmetic Mean of Population µ | n | Standard Deviation σ | Standard Error of the Mean \( \sigma_{\bar{x}} \) |
|-------------------|---------------------------------|---|-----------------------|---------------------------------------------|
|                   | 63.96%                          | 12| 2.28                  | 65.87                                       |

Final step is to apply inferential statistics and find the confidence interval for the arithmetic mean. Ideally, all items submitted by the contractor would be analysed in detail. This usually isn’t rational for constructions with budgets that contains dozens of items, or is outright impossible for constructions that contains hundreds. However, since we can (and should) analyse in detail at least the main items of the building and determine their deviation from price catalogue prices, we acquire a population sample that we can statistically process (see previous chapter) and apply the result to the rest of the whole population (budget with all items), this procedure is called inference statistics. The essence of inference statistics is to determine the probability that the results obtained on a population sample will be valid for the whole population. In the case of this method, the sample is therefore a set of price differences of main items, that we assessed in detail. We assume that the contractor used his internal price catalogue and price settings procedures when valuing his construction works, these will be reflected in both the population sample and the population. We could assume that the average price difference in the sample and the base set will be therefore the same. But that doesn't have to be true. We can only say this with a certain probability. The degree of this probability is expressed by the confidence interval \( CI \) (equation 5). If we determine the average price deviation on the sample, the confidence interval will tell us in what interval falls the deviation of the whole population and with what probability, i.e. confidence.

\[ CI = \mu \pm (z \times \sigma_{\bar{x}}) \]  
\( z \) Gaussian probability distribution coefficient
The coefficient $z$ is based on the Gaussian probability distribution. It is possible to calculate it, or use coefficients from statistic tables for the probability percentage of interval we are interested.

**Table 3.** Gaussian probability distribution coefficients.

| Confidence | 85.00% | 90.00% | 95.00% | 97.50% | 99% | 99.50% |
|------------|--------|--------|--------|--------|-----|--------|
| $z$        | 1.036  | 1.282  | 1.645  | 1.960  | 2.326| 2.576  |

For this case study, the arithmetic mean of population is 63.96% price difference. Following equation 5 we can estimate confidence interval for 95%, 90% and 85% probability. This means that the price difference of the whole contract/claim budget will fall in these intervals with said probabilities.

**Table 4.** Example of confidence interval calculation for the presented case study.

| Confidence | 85.00% | 90.00% | 95.00% |
|------------|--------|--------|--------|
| Mean       | 63.96% | 63.96% | 63.96% |
| Confidence interval | 11.92% | 23.89% | 35.96% |
| Upper limit of CI | 69.92% | 75.90% | 81.94% |
| Lower limit of CI | 57.99% | 52.01% | 45.98% |

The confidence interval gives the upper limit $ULCI$ and lower limit $LLCI$ (see equations 6 and 7) from arithmetical mean of a population sample in which we expect the arithmetical mean of entire population will fall with certain probability.

$$ULCI = \mu + \frac{CI}{2}$$  \hspace{1cm} (6)

$$LLCI = \mu - \frac{CI}{2}$$  \hspace{1cm} (7)

As seen from table 4 and figure 2, the interval expands with rising probability. Thus we can say that we are 95% confident that the arithmetic mean of the population lies between 45.98% – 81.94% but we are only 85% confident that it lies between 57.99% – 69.92%.

![Figure 2. Graphical representation of confidence interval.](image-url)
Chart such as one shown in figure 2 should be presented by the employer to the contractor. It should be used to negotiate deduction of contractor’s claim for items that weren’t part of the population sample. Simply stating that the average price difference of contractor items was a 63,96% increase compared to price catalogue prices is a statement that doesn’t give much space to negotiate a consensus between the contractor and the employer. Working with intervals may give a better framework for such discussion, and give the employer more space to propose deductions that don’t look like an arbitrary percentage.

4. Conclusion and discussion
Assess the financial justification of contractor’s budget remains the main concern for both private and public investors. The process is time consuming and requires a good knowledge of price setting which is usually lacking in the public sector. Comparison budget from third party or a comparison to the price catalogue remains the main method to assess financial justification of contractor’s works. There are however severe limitations how this methods, the main being the sheer volume of budget counting sometimes hundreds of items. The described method can be used to give the investor objective data supporting his claim agenda and give him an advantage when negotiating price for additional construction works. The main items are to be negotiated separately. The price difference of main items from price catalogue (or comparison budget) can be used to estimate the average price difference that can be used for all other items. Two main question arise when considering this method: What if our population sample is very slim and the price differences are extremely disparate? Due to the nature of inferential statistics, these disparities will be reflected in the statistical analysis, you will end up with very wide confidence intervals. We recommend to increase the population by adding item’s that can be individually assessed by direct and indirect cost calculations. You may also consider to exempt the local extremes that range over 200% price difference, these items should also be considered for clarification by the contractor.

Which confidence interval should we use? Generally, the lower probability interval should be used if you expect the average priced difference be aggressively pushed downward by the contractor. Higher confidence should be preferred when you expect you can drive the price difference higher. Who will have the better leverage when negotiating the price will be determined by factor such as technical justification of claimed works, overstepping of budget specified in the contract, additional revenue possibilities from future contracts, etc. For instance, dubious technical justification of claimed works, high overstepping of the budget and further contract possibilities should give the investor upper edge when negotiating, thus you can push for the higher price difference in high confidence percentage.

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