Research Article

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Estimation of Sport Facilities by Means of Technical-Economic Indicator

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Abstract: This paper is concerned with early cost estimation of sport facilities. Sufficiently precise cost estimation is essential for investors in the pre-investment stage where they decide on whether to pursue an investment and choose a suitable technical solution for the development of the project. Through a detailed analysis of the technical and economic documentation pertaining to seven sport facilities projects assembled using concrete prefabricated beam parts, as well as evaluation of the data thus obtained, three types of technical-economic indicators were set in relation to the enclosed building area, the number of spectator seats and the sports playing area. The results achieved indicate that evaluation of relations between these three indicators could contribute to a more effective use of investment funding on the part of the investor. Other conclusions include the finding that available indicators published by private companies active in the area of construction budgeting are not sufficiently accurate for the purposes of investment decision-making; specifically, these indicators greatly overestimate the costs of sport facilities, which can potentially lead to these projects being rejected. This contribution brings know-how for a more accurate early cost estimation of sport facilities in the Czech Republic which can, thanks to a generally applicable methodology, be used in other countries as well.

Keywords: cost, estimation, indicator, sport facilities

1 Introduction

The need to know the approximate costs is essential in a situation where the investor decides on whether to pursue and investment and needs to select a suitable technical solution for the project. As part of the pre-investment stage

of a construction project, the relevant documentation has not yet been prepared in sufficient detail and it is thus impossible to obtain the exact amount of construction costs in the form of the bill of costs [1]; alternatively, aggregated technical-economic indicators can be used [2].

However, to have at least some idea about the costs, the investor can use various kinds of indicators which, based on an adequate unit of measurement (e.g. cubic metres [m^3] in the case of residential buildings, square metres [m^2] in the case of roads, and metres [m] in the case of utility networks), express the unit costs of construction (e.g. EUR/ m^3).

In the Czech Republic, these indicators are published by companies doing business in the area of construction budgeting, specifically by the companies ÚRS Praha and RTS. For example, ÚRS Praha offers the KUBIX application which enables to determine an approximate price of the whole construction project, where it is only necessary to specify a type of building (single-family house, residential building, administrative building, etc.), input some additional general information (building parameters and the level of technical standard), and then specify the planned total volume of the building or the room floor area [3]. The above-indicated companies also publish books such as *Rozpočtové ukazatele 2018 (Budget Indicators 2018)* [4] and *Cenové ukazatele ve stavebnictví pro rok 2018 (Price Indicators in the Construction Sector in 2018)* [5]. Naturally, using the indicators is not the only way to carry out early cost estimating with respect to buildings. A number of authors have used neural networks for this purpose, e.g. in relation to tunnel constructions [6] or structural systems of buildings [7]; other potential approaches include e.g. approximate cost estimating based on quantity of standard work [8] and the case-based reasoning model [9]. Obviously, for adequate estimation of construction costs it is important to estimate correct scope of work, as incorrect scope estimation may lead to both cost and time overruns [10].

This article deals with specific structures, i.e. sport facilities. It is questionable how accurate the indicators used in practice are when applied to structures which are not built very often. Indicators for these structures are not necessarily subject to annual validation, i.e. the increasing of

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their accuracy based on projects implemented within the given time period. Instead, the indicator values may be updated in the form of indexing, *i.e.* multiplying the historical value of the indicator by an index expressing *e.g.* the average growth in the cost of construction works and materials. Certain indexes are published by the Czech Statistical Office, *e.g.* in the Prices of producers – time series; Prices of construction works [11].

The economic efficiency of an investment is often measured using the indicator of Net Present Value [12]. However, the investor may also benefit from a technical analysis of the building design, *i.e.* determining whether it is over- or under-designed in terms of the size of the enclosed building area. Monitoring and evaluating parameters such as the size of the enclosed area or the size of the playing area could potentially result in achieving better project value in terms of NPV.

Therefore, the aim of this contribution is to determine the value of the technical-economic indicator (TEI) for quick approximate cost estimating of newly constructed sport facilities in the Czech Republic. These structures are defined as follows: “A building pursuant to Section 3 of Decree No. 137/1998 Coll. is an above-ground spatially-concentrated structure closed off on the outside by its enclosure walls and the roof structure” [13].

The article is structured as follows: after the description of the current state of the problem and formulation of the objective, the materials and methods used are specified; the achieved results are then presented and compared to similar publicly available indicators. The final part of the contribution also outlines the direction of future research and its limitations.

2 Materials and methods

This article analyses buildings classified according to the JKSO [14] classification under “civic buildings”, subcategory 801.5 – sport facilities. In the CZ-CPA classification, “sport facilities” and “sport halls” are indicated under a common designation, *i.e.* 41.00.28 – “Buildings serving for social and cultural purposes, sports, education, healthcare, institutional care or religious purposes”. These types of structures need to be analysed separately in terms of a closer specification and their different pricing. Sport facilities usually have a main and secondary playing area (they are normally multifunctional, *i.e.* suitable for football, basketball, volleyball and other ball games), a spectator stand, locker rooms and sanitary facilities for athletes, locker rooms and sanitary facilities for spectators, refresh-

ment units, connecting hallways and support rooms. In general, sport facilities offer a greater flexibility of use than sports halls and do not include *e.g.* football or baseball stadiums.

While these sport facilities are fairly diverse in scope (inclusion of spectator stands etc.) and this is reflected also in the different amounts of costs, we defined the following requirements for inclusion into the studied sample in order to ensure sufficient homogeneousness and comparability:

- permanent spectator stand; and
- meeting the value of free air space over the playing area (*i.e.* the sum of the volume of free air over the playing area must not exceed two thirds of the enclosed building area).

Subsequently, we found suitable sport facilities which were constructed in the past eight years or are planned for construction in the Czech Republic in the near future and a budget is already available for them, this set contained 41 potential projects. Based on the Free Access to Information Act [15], we asked project owners for the relevant documentation (project documentation, bill of costs etc.). As a result, we have received 31 positive responses. The total of 22 projects out of 31 were removed from the sample for several reasons such as the fact that the project represented a reconstruction instead of a new construction, that the facility has been built with different technology/materials or that some important data were missing in the documentation provided. It should be noted that it is the contracting authority’s responsibility to ensure the accuracy and completeness of the tender documentation, as pointed out in [16]. Finally, we were able to obtain the necessary documentation pertaining to a total of nine sport facilities, of which seven are categorised according to the main supporting structure under materials category 4 (assembled from concrete prefabricated beam parts) and two fall under category 7 (metal structure). Since these construction types differ greatly, it is necessary to study the two construction-material categories separately. Taking into account the size of the sample, only category 4 is relevant to further analysis. For each sport facility, the following details were obtained:

- year of construction
- built-up area in m^2
- size of the playing area in m^2
- enclosed building area in m^3
- price of the entire project excl. VAT
- price of the construction part excl. VAT
- number of seats in the spectator stand.

In order to get a better idea how “sports facilities” according to the Czech classification system usually look like, an illustrative example is provided on Figures 1 and 2 showing the outside view and interior (playing area with permanent spectator stand) respectively.

Figure 1: Sport facility in Kašperské Hory – outside view

Figure 2: Sport facility in Kašperské Hory – playing area with permanent spectator stand

For the purposes of the analysis, it was necessary to adjust the budgeted costs for items not directly related to sports purposes (e.g. access roads, water mains, gas pipes, sewerage, street lighting and landscaping). The analysed price thus includes the entire building of the sport facilities, air-handling technology, heating, electrical fittings and sanitary fittings. This price is called “price of the construction part excl. VAT”.

Since the sport facilities were not built at the same time, it was necessary to carry out indexing for base

year 2018. Firstly, it was necessary to determine the price change index value:

$$I_i = UP_b / UP_i \quad (1)$$

where UP_b corresponds to the unit price of the base year; UP_i corresponds to the unit price of the i^{th} year (it applies for both UP_b and UP_i that the unit price is related to m^3 of enclosed building area and is taken from the RUSO database of sport facilities – construction class 4 [4]); I_i corresponds to the price change index for the i^{th} year.

Using the subsequent indexing of prices, the historical values were converted to correspond to base year 2018.

$$PI_j = HP_j \times I_i \quad (2)$$

where PI_j corresponds to the indexed price of the j^{th} project as of the base year; HP_j corresponds to the price of the j^{th} project in the i^{th} year.

In the next step, we determined the value of three types of TEI for the individual sport facilities using the following general equation for the chosen specific units:

$$TEI_{su} = PI / SU \quad (3)$$

where SU corresponds to a concrete specific unit:

- enclosed building area (m^3)
- number of seats (pc.)
- size of the playing area (m^2).

Finally, in the last step the general value of the individual types of TEI is specified as mean and median.

3 Results and discussion

3.1 Input data set

Firstly, it should be noted that the number of sport facility projects developed in the Czech Republic is rather low. As a result of additional requirements on the projects with regard to the need to maintain the required measure of similarity (e.g. the presence of a permanent spectator stand and preparation and implementation of the project within the past five years), information on seven projects were collected. This limitation also results from the fact that the Czech Republic is a relatively small market for such a distinctive type of facilities. While they differ from each other in multiple parameters, they are classified within the same JKSO subcategory and represent (in the context of the Czech construction industry) a relevant set for the purposes of early cost estimation analysis.

Table 1: Non-price input data [17].

P.ID	Year	Built-up area [m ²]	Size of the playing area [m ²]	Enclosed area [m ³]	No. of seats
1	2018	2,055.31	1,190.10	21,088.68	161
2	2016/2017	3,268.97	1,376.81	35,967.69	402
3	2014	1,448.48	999.70	14,465.33	180
4	2015	2,894.21	1,546.80	24,561.79	189
5	2016	2,399.59	1,195.43	17,464.06	168
6	2018	1,420.55	990.20	18,866.04	70
7	2015	1,612.74	1,104.40	18,274.17	48

Table 2: Price input data [17].

P.ID	Price of the entire project [EUR]	Price of the construction part – HP_i [EUR]
no. 1	3,601,066	3,080,384
no. 2	4,335,063	3,463,132
no. 3	1,334,865	1,207,658
no. 4	2,944,736	2,647,192
no. 5	3,431,031	2,349,361
no. 6	2,322,299	2,247,340
no. 7	2,106,284	1,812,513

Table 3: Price change index

Year	RUSO [EUR/m ³] [4]	I_i
2010	196.08	1.0911
2011	193.68	1.1047
2012	187.74	1.1396
2013	189.53	1.1288
2014	189.15	1.1311
2015	195.03	1.0970
2016	200.23	1.0685
2017	205.38	1.0417
2018	213.95	base

The tables contain the basic input price data (Table 1) and non-price data (Table 2) pertaining to the studied set.

P.ID is the identification number of the project. In project No. 2, the construction had two stages, where the first and second stages took place in 2016 and 2017, respectively.

3.2 Calculation of the price change index

The price change index is specified for the individual years based on formula No. 1. The RUSO value for base year 2018 for the given construction type equals 285.74 EUR/m³. The calculated indexes for the individual years are indicated in Table 3.

The RUSO index clearly shows a drop in the years 2009 to 2012. This was a result of the economic crisis in the Czech Republic which also severely impacted the construction sector. Due to under-utilisation of production capacities, reduced investments and strong competition on the market, suppliers were forced to reduce their offering prices.

3.3 Indexing of prices for the base year

In the next step, historical prices are indexed for the base year (2018) based on formula No. 2. The resulting values are indicated in Table 4.

Table 4: Indexing of historical prices for the base year

P.ID	Price of the construction part – historical HP_i [EUR]	Price of the construction part – indexed PI_i [EUR]
no. 1	3,080,384	3,080,384
no. 2	1,789,293 (2016) 1,673,839 (2017)	3,655,554
no. 3	1,207,658	1,366,015
no. 4	2,647,192	2,904,051
no. 5	2,349,361	2,510,309
no. 6	2,247,340	2,247,340
no. 7	1,812,513	1,988,382

3.4 Determination of TEI for the selected specific units

Table 5 shows the values of TEI for the individual specific units based on formula No. 3. Specifically, three types of TEI are used: TEI_{EA} , TEI_{NS} and TEI_{PA} , which means TEI per 1 m³ of enclosed area, per 1 seat, and per 1 m² of the playing area, respectively. Table 6 indicates the statistical values of TEI (minimum, maximum, mean and median).

Table 5: Determination of TEI values for the individual projects.

P.ID	TEI_{EA} [EUR/m ³]	TEI_{NS} [EUR/pc.]	TEI_{PA} [EUR/m ²]
no. 1	146.07	19,132.82	2,588.34
no. 2	101.63	9,093.42	2,655.09
no. 3	94.43	7,588.97	1,366.42
no. 4	118.23	15,365.35	1,877.46
no. 5	143.74	14,942.32	2,099.92
no. 6	119.12	32,104.86	2,269.58
no. 7	108.81	41,424.63	1,800.42

Table 6: Determination of the general values of TEI.

P.ID	TEI_{EA} [EUR/m ³]	TEI_{NS} [EUR/pc.]	TEI_{PA} [EUR/m ²]
Min	94.43	7,588.97	1,366.42
Max	146.07	41,424.63	2,655.09
Mean	118.86	19,950.34	2,093.89
Median	118.23	15,365.35	2,099.92

Table 5 clearly shows that projects differ from each other in TEI values. As concerns TEI_{EA} , the minimum and maximum value corresponds to 94.43 EUR/m³ and 146.07 EUR/m³, respectively. This means that per 1 m³ of enclosed building area, project No. 1 was 55% more expensive than project No. 3. Both mean and median are nearly identical, i.e. 118.86 EUR/m³ and 118.23 EUR/m³, respectively. Detected differences in unit prices are caused by a number of factors. Firstly, it should be noted that analyzed prices are market prices resulting from the public tender procedure. Market prices, which are the very short-period prices in the sense that the supply of a commodity/work cannot adjust itself to demand in this period, move around the normal price. Market prices differ in time and place (all projects are located in different cities) and are also influenced by real competition in any tender (measured by the number of submitted bids) and its financial volume. For instance,

it has been detected, that for foundation slabs and strip foundation unit prices varies between 83.58 EUR/m³ and 112.08 EUR/m³ and 85.94 EUR/m³ and 112.08 EUR/m³ respectively, which represents relative change in price 34% and 30% respectively.

As concerns the indicator TEI_{NS} , the difference in values are more pronounced than in the case of TEI_{EA} . Specifically, in project No. 3 the value of TEI_{NS} is approx. 5.5 times lower than in project No. 7. This is due to the fact that project No. 3 brings a much higher number of spectator seats for a lower cost.

Finally, in the case of TEI_{PA} , the mean and median values differ only negligibly (0.03%), where the largest difference exists between projects Nos. 3 and 2, where project No. 2 is 1.94 times costlier.

Figure 3 offers an interesting comparison. The graph shows indexes of value deviations from the medians achieved within the individual projects for all three types of TEI indicators, i.e. TEI_{EA} , TEI_{NS} and TEI_{PA} . The deviation index is calculated as the ratio of the value of the relevant indicator in a specific project and the median.

Figure 3: Comparison of projects in terms of TEI deviation index.

The graph shows that project No. 4 can be considered a “standard project” since the values of TEI_{EA} , TEI_{NS} and TEI_{PA} are close to the median. In projects No. 6 and 7, it is clear that the seating capacity in the spectator stand was undersized in comparison to the other projects, given the financial scope of the projects. In project No. 1, it is clearly discernible that the cost was higher in all parameters (indi-

cating either that the project accentuated quality, or that a bid with a higher offering price was selected in the tender procedure); on the other hand, project No. 3 can be considered rather less expensive. It should be noted that values of TEI_{EA} and TEI_{NS} deviation indexes are almost the same for projects No. 1 and 4, therefore TEI_{NS} marks overlap TEI_{EA} marks on Figure 3.

3.5 Comparison of TEI_{EA} with the values of ÚRS and RTS indicators

Table 7 shows a comparison of the TEI_{EA} value with the indicators published by ÚRS and RTS companies. The table indicates a number of sport facilities based on which the indicator was determined (this information is not available for the RTS indicator), the value of the indicator and the relative difference in comparison to TEI_{EA} .

Table 7: Comparison of TEI_{EA} values with ÚRS and RTS indicators [EUR/m³].

Indicator	TEI_{EA} (median)	ÚRS [4]	RTS [5]
Sample size	7	3	unknown
Value	118.23	213.95	204.10
Relative difference	100%	181%	173%

Table 7 shows that the TEI_{EA} indicator is based on a larger number of representative sport facilities than the ÚRS indicator. The same information is not available in the case of RTS indicator. It is of interest that the ÚRS and RTS indicator values do not differ from each other very much, but comparison with TEI_{EA} reveals a deviation of 181% and 173% for ÚRS and RTS indicators, respectively. The analysis indicates that the compared ÚRS and RTS indicators do not express a realistic price levels of sport facilities structures assembled using concrete prefabricated beam parts. This assertion can be documented on e.g. project No. 1, which shows the highest value of $TEI_{EA} = 146.07$ EUR/m³. Nevertheless, this value is still considerably below that of the RTS indicator. Therefore, it can be concluded that the use of publicly available indicators can lead to an overvaluation of the approximate costs associated with the construction of sport facilities structures assembled using concrete prefabricated beam parts. The columns in Figure 4 show TEI_{EA} values for individual projects (No. 1 – 7 and ÚRS and RTS indicators).

Figure 4: Comparison of project TEI_{EA} , ÚRS and RTS indicators [EUR/m³].

4 Conclusion

This paper addresses the issue of early cost estimation in the construction of sport facilities. Specifically, the analysis deals with a specific type of construction, i.e. sport facilities structures assembled using concrete prefabricated beam parts. This contribution aims to determine the value of the technical-economic indicator (TEI), where three specific units were specified (enclosed area, number of seats, and size of the playing areas).

The results show that the use of indicators published by the companies ÚRS and RTS leads to overestimation of the approximate investment costs of implementing the construction parts of these projects, which in turn suggests there is a need to regularly validate the indicators using data on current projects.

The use of the TEI indicator for various specific units has the potential to contribute to a more effective use of funds in various regards such as the size of the enclosed area and the number of spectator seats. Figure 1 enables to identify projects which could be modified to bring a higher added value in relation to the investment costs expended for the construction part of the project. This is an important issue if we take into account that developing sport facilities is a risky process requiring complex financial arrangements [18].

This contribution faced a research limitation consisting in a small sample containing data points in different time periods led to the need to index historical prices in relation to the selected base year. With a higher number of representative projects cost-evaluated within a shorter

time period, it would potentially be possible to specify a more accurate value of TEI and carry out additional analyses of the costs and selected technical parameters.

Future research should thus focus on a systematic collection of data not only in the category analysed in this contribution, but also regarding other types of construction projects where an activity in the form of validation of publicly available data used for early cost estimation could be valuable.

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