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ANALYSIS OF ROAD CONSTRUCTION PROJECTS PRICE CHANGES IN THE SELECTED PHASES OF THEIR LIFE-CYCLE

Key words: road construction project, LCC, estimated value, contract price, actual price

Introduction

Road construction projects belong to the most costly public procurement activities worldwide. It is, therefore, crucial to manage these projects appropriately from the cost point of view from the early stages of the project through the construction phase and operation phase until demolition. Public authorities tend to apply the life-cycle cost (LCC) approach more frequently recently, however, in practice, there is a lack of data and experience in order to predict future costs precisely. Accurate estimation of the LCC is essential as it contributes to the informed decisions about the selection of the optimal project alternative from the long-term perspective. The underestimation of costs may lead to inefficient allocation of resources and it is also considered as major source of risk in project appraisal (Odeck, Welde & Volden, 2015). Makovšek, Tominc and Logožar (2012) even speak about systematic cost overruns in transport infrastructure projects that lead to distorted cost-benefit analysis, where LCC is on the side of cost, while benefits represent items such as savings in travel time or reduction in accidents (Korytárová & Papežíková, 2015).

Unfortunately, road construction projects are extremely complex and difficult to manage, and therefore frequently facing misinformation about the costs. This often results in high-cost overruns which may also affect the quality of works, service life and overall viability of the project itself. According to Kennedy, Pantelias, Makovšek, Grewe and Sindall (2018), the uncertainty in cost esti-

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mation evolves over the project life-cycle and arises from the difficulties in estimating construction, maintenance, operation and financing costs.

One of the serious problems are discrepancies between planned costs (estimated in the early stages of the project) and actual realized costs (after the completion of the works) (Peško et al., 2017). Chong and Hopkins (2016) claim that the variability between planned and actual costs may cause the reduced scope of works (the project is not implemented in the full range), cancellations and non-fulfilment of expected rates of return.

According to Tijanić, Car-Pušić and Šperac (2020), the discrepancies between planned and actual costs stem from the lack of data and information in the conceptual phase of the project. The incompleteness of the data makes the cost estimation difficult and burdened by uncertainty. As a result, errors in the project are usually transformed into price adjustments and the extended duration of the construction phase (Pilger, Machado, de Assis Lawisch-Rodriquez, Zappe, Rodriquez-Lopez, 2020).

The spectrum of cost overrun causes is wide due to the complexity of road construction projects. Numerous researchers (e.g.: Cantarelli, Flybjerg, Molin & van Wee, 2010; Adel, Elyamany, Belal & Kotb, 2016) reported four categories of cost overruns origin: technical (e.g. inadequate data), economic (e.g. deliberate underestimation due to lack of resources), psychological (e.g. tendency to underestimate time, costs and risks) and political (cost underestimation to increase the probability of project acceptance). From the economic point of view, it is also important to take into account the prices of raw materials as road construction projects are of a long-term perspective. These prices are affected by future economic development and, therefore, may be difficult to predict (Loulizi, Bichiou & Rakha, 2019). The LCC of real projects can also be affected by the contract type. It has been shown on the example of national roads in Indonesia that the use of performance-based contracts has the potential to create lower LCC compared to traditional approaches (as performance-based contracts are lowered by preventive interventions that may delay and limit road structure deterioration, i.e. reduce long-term costs (Susanti, Wirahadikusumah, Soemardi & Sutrisno, 2019). For this purpose, it is important to identify maintenance and repair works for a particular structure as well as their average repetition. For instance, Bhaskaran, Palaniswamy and Rengaswamy (2006) listed normally occurring repair works for a concrete road bridge (sealing of cracks, repairing spalled portion, worn coating, joints expansion and concrete railing). The resulting bid price is affected also by other influencing factors, such as competition of many bidders in the tender process (Hanák & Muchová, 2015) or by the use of electronic reverse auctions (Hanák & Serrat, 2018). On the other hand, the accuracy of the estimation of the planned costs might be affected by an estimator itself. As Odeck et al. (2015) claim, estimates by experts who are contracted as external consultants are more accurate compared to the estimates made by contracting authorities themselves. Therefore, it is important to cooperate with experienced stakeholders as their experience achieved from previous projects may help to prevent possible errors (Tijanić et al., 2020). According to Pilger et al. (2020), many errors result from geological, geotechnical and soil quality studies.

The application of control mechanisms, advanced methods and tools to manage the costs of road construction projects is highly needed since the great magnitude of cost overruns is evident. Researchers applied various approaches to improve cost estimation, e.g. neural networks were applied for early cost estimation of road tunnel construction (Petroutsatou, Georgopoulos, Lambropoulos & Pantouvakis, 2012). Their models enable decision-makers to compare design alternatives from a cost perspective which supports the creation of viable financial plans. Tijanić et al. (2020) proposed general regression neural network model of early cost estimate of road construction projects with the MAPE (mean absolute percentage error) of 13.06% providing better results than multilayer perceptron, radial basis function neural network and linear regression.

Peško et al. (2017) compared neural networks and support vector machine for the purpose of urban road construction cost and duration estimation. The best support vector machine model achieved higher precision with the MAPE of 7.06% when compared to neural networks. Wang, Yu and Chan (2012) compared the success of different models for predicting construction costs between logistic regression, artificial neural networks (ANN), more specifically single ANNs, bootstrap aggregating ANNs and adaptive boosting ANNs, and support vector machine. They have shown on the sample of 92 projects that the best overall prediction accuracy was achieved by a support vector machine. Furthermore, different models can be combined to create hybrid models, as applied by Petrusheva, Car-Pušić and Zileska-Pancovska (2019). Their support vector machine-based hybrid model achieved accuracy with the MAPE of 1.01% and correlation coefficient between actual and planned values of 0.998.

The available body of literature confirms the need for advanced LCC management of road construction projects. Although the researchers use different quantitative as well as qualitative approaches to tackle how the LCC prediction can be improved, there is a lack of data based on a detailed analysis of contractual documentation between the contracting authorities and contractors. This paper, therefore, aims to address this specific issue by examining the documentation of the sample of regional road construction projects in the South Moravian Region (Czech Republic). In particular, the presented study seeks to reveal and discuss the causes of cost overruns that are contained in contractual documentation. The study focuses on selected phases of the building object life-cycle, more specifically procurement and construction phases.

The content of this paper is structured as follows. The following section presents materials and methods employed to achieve the aim of this paper. The third section presents and discusses results of the analysis and the final section summarises general conclusions, states research limitations and outline future research directions.

Material and methods

This study effectively combines qualitative and quantitative research methods to address the researched topic. First of all, the set of contractual documentation for road construction projects in the studied area (South Moravian Region) has been collected from available public sources. In addition, the research sample contains two road bridge projects in the urban area, which seamlessly connect to the city's road networks. This involves data from contracts for works and supplementary documentation such as the investor's website where information about basic project characteristics can be obtained as well as data from the Journal of Public Procurement (ces. *Věstník veřejných zakázek*). All analysed projects are by the same contracting authority. Regarding the procurement procedure, contractors were selected on the basis of the lowest bid price under the open procedure. All projects belong to the category of below-threshold and above-threshold contracts according to the Czech Public Procurement Act (Zákon 134/2016 Sb.), i.e. small-scale contracts are not included in the dataset.

In total, data on 41 projects were collected. Each project has been characterised by numerical data and by data describing the causes of cost overruns. The project was included in the dataset under the condition that all necessary documents and variables are provided and that the execution of construction works has been completed. This has resulted in a reduced final dataset of 16 projects. Such a large reduction of the dataset points to the fact that despite the obligation to make all these data publicly available, in the reality, a significant part of the data is missing.

Dataset of road construction projects

Each project has been characterized by a set of variables that were taken from collected documentation. This involves the estimated value (*EV*) of the project set before the public procurement procedure has started, contract price (*CP*) that has been negotiated between the contracting authority and winning supplier in the contract for work, actual price (*AP*) representing the resulting price from the contract when all the amendments and changes to the project are taken into account. If follows that only completed projects were considered and analysed. Furthermore, the number of tenderers (*NoT*) and the number of amendments (*NoA*) subsequently agreed to the contract are also provided for each project (Table 1).

TABLE 1. Basic description of the dataset

ID	Project	*EV* [EUR]	*CP* [EUR]	*AP* [EUR]	*NoT*	*NoA*
1	II/379 Tišnov – Drásov	2 756 242	2 278 646	2 329 758	4	2
2	II/413 Dobelice – Hostěradice	1 549 609	929 688	1 007 877	6	2
3	II/373, III/37367 Březina transit	2 763 594	1 732 422	1 841 804	12	3
4	III/49918 Hrubá Vrbka transit	1 792 373	1,239 839	1 248 275	8	3
5	II/431 Kojátky relocation	2 265 670	1 660 155	1 784 674	3	2
6	II/408 Hrádek transit	2 381 967	1 845 055	1 836 386	6	3
7	II/432 Kyjov – Milotice – Ratíškovice	2 110 664	1 126 126	1 083 382	10	2
8	II/408 Krhovice transit	1 321 836	945 341	958 565	5	2
9	II/421 Terezín – Velké Pavlovice	4 426 793	3 426 768	3 501 449	4	3
10	II/602 Brno Jihlavská, bridge	1 236 680	734 346	753 952	6	2
11	II/152 Jamolice transit	2 561 016	1 791 016	1 918 373	14	6
12	II/602 Ostrovačice transit, 2nd construction	847 305	605 437	681 151	11	1
13	II/430 Tučapy – Vyškov (non-urban area)	2 843 453	2 296 057	2 388 838	9	2
14	II/380 Moutnice transit	2 740 586	1 898 170	1 933 059	8	6
15	II/422 Podivín – Lednice	3 066 406	2 295 987	2 390 955	6	4
16	III/15289 Brno Evropská, bridge	3 945 313	3 108 418	3 145 540	8	3

Tenders' data processing

The following variables were defined in order to reveal the magnitude of the relative differences between *EV*, *CP* and *AP*:

$$CP\_EV = \frac{CP - EV}{EV} 100\%$$

where *CP_EV* stands for the ratio between the contract price and the estimated value. This variable indicates whether the resulting price from the public tender is lower or higher when compared to the estimated value.

The next variable *AP_CP* (actual price – contract price ratio) shows how the price for the contract changed since signing the contract for work until the completion of works and invoicing. *AP_CP* is defined by the following equation:

$$AP\_CP = \frac{AP - CP}{CP} 100\%$$

Finally, the *AP_EV* ratio is calculated in order to find out whether the actual price tends to get closer to the estimated value when compared to the tender price as a consequence of negotiation of contractual amendments with extra works, price adjustments etc.

$$AP\_EV = \frac{AP - EV}{EV} 100\%$$

Finally, the tender documentation was analysed from the qualitative point of view in order to reveal potential causes of project value/price relative differences. In particular, contract for works and all related amendments were considered from this perspective.

Results and discussion

Quantitative evaluation

A comparison of construction costs in individual project phases (stated in prices without VAT) is shown in Figure 1. The three variables analysed (*CP*, *EV*, *AP*) show the difference between the contract price and the estimated value, the actual price and the contract price, the actual price and the estimated value.

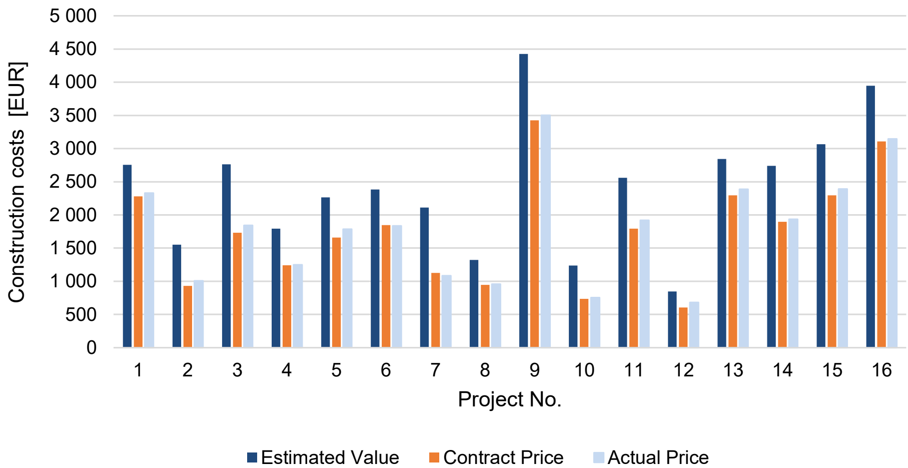

FIGURE 1. Comparison of construction costs in individual project phases

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Data in Figure 1 and Table 2 clearly show significant differences between the estimated value and contract price. The mean value for the *CP_EV* variable is –29.25% and the median value is –28.51% indicating that contract price is considerably lower if compared to the estimated value. Such difference can be attributed to two potential causes: (1) the estimated value was not set correctly, in other words, it is overestimated and (2) the competition between individual suppliers on the market is pushing the market price down. On the other hand, when regarding the *AP_CP* values, it is clear that projects tend to increase the actual value of the works carried out compared to the price resulting from the works contract.

TABLE 2. Basic statistics of the dataset

Variable	Min	Max	Mean	Median
	%			
CP_EV	–17.33	–46.65	–29.25	–28.51
AP_CP	–3.80	12.51	3.62	2.46
AP_EV	–15.47	–48.67	–26.68	–24.00

It is clear from the market analysis which includes the bid prices of the contractors in each tender, that the bid prices of each unique contract have a relatively wide range. Table 3 shows the contract price (*CP* in Column b) of each public tender and the maximum relative difference of contract price from the bid price of the most advantageous bid which was assessed on the basis of the lowest tender price criterion (Column c) and the relative difference between the contract price and the expected value (Column d).

It is clear from the comparison of the relative differences in Table 3 Columns c and d that the maximum bid price for Projects 6, 7, 8, 11, 13, 15 and 16 is close to the estimated value of the project, in other cases the estimated value is always higher.

TABLE 3. Market analysis of individual tenders

ID	*CP* [EUR]	Max relative difference of bid price from *CP* [%]	Relative difference of *EV* from *CP*
a	b	c	d
1	2 279	12.38	17.33
2	930	10.09	40.01
3	1 732	52.82	37.31
4	1 240	18.14	30.83
5	1 660	15.10	26.73
6	1 845	20.13	22.54
7	1 126	45.60	46.65
8	945	23.74	28.48
9	3 427	8.74	22.59
10	734	64.59	40.62
11	1 791	36.71	30.07
12	605	39.93	28.55
13	2 296	21.40	19.25
14	1 898	10.04	30.74
15	2 296	19.41	25.12
16	3 108	19.41	21.21

It is possible to identify projects where *CP* may be considered to be of an exceptionally low bid price nature by looking at Figure 1. In particular, Projects 2, 7 and 10 show a *CP_EV* value lower than –40%, which means that their *CP* has fallen by more than 40% compared to the *EV*. Given the fact that the decrease in bid prices is dependent on the number of bids submitted in the tender (Hanák & Muchová), it was further investigated whether there is any relationship existing between *NoT* and *CP_EV*. The R^2 value of a logarithmic trend line is 0.1213 indicating that there is no strong relationship between examined variables (Fig. 2a). Therefore, it cannot be statistically claimed that a higher number of tenderers cause a higher difference between *EV* and *CP*.

Analysis of the *AP_CP* variable reveals how the actual price paid by the contracting

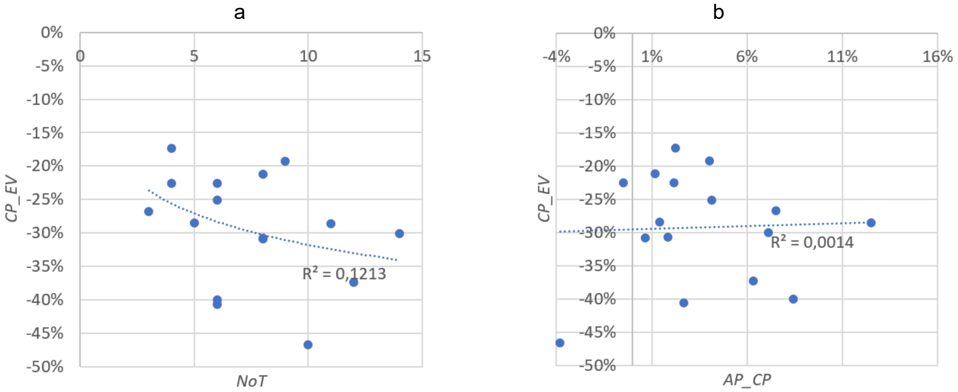

FIGURE 2. Relation between NoT and CP_EV (a), and CP_EV and AP_CP (b)

authority after the competition of the project has changed when compared to the contract price. Both the mean and the median values are close to 0% (3.62 and 2.46% respectively). Accordingly, it can be stated that generally, award prices and contract prices values do not differ much from each other. Nevertheless, if minimum and maximum values are considered (–3.80 and 12.51%), it is clear that for individual projects there can be significant changes made to the budget. It might be of interest to check whether the higher value of *AP_CP* is connected to the lower value of *CP_EV*. In particular, this idea leads to the potential application of the bidding strategy of submitting lower (*CP*) bids in the tender procedure followed with the expectation of *AP* increase e.g. as a result of extra works, i.e. unbalanced bidding (Nyström & Mandell, 2019).

Data in Figure 2b clearly shows that there is no relation between the examined variables *CP_EV* and *AP_CP*. For example, for Project 4 (that is the project with the *CP_EV* = –30.83%), *CP* is almost equal to *AP* (*AP_CP* = 0.68%), thus there was no change to the project price during its implementation. In contrast, Project 12 with a similar value of *CP_EV* (*CP_EV* = –28.55%) reaches *AP_CP* = 12.51%. From this, we can conclude that variations between *CP* and *AP* depend not just on extra works, but also on cancelled work and other types of amendments that can be caused by various causes.

Finally, when taking into consideration the results of *CP_EV* and *AP_CP* analysis, it is not surprising that *AP_EV* values are close to the *CP_EV* values. Of course, several relative differences can be observed, e.g. for Project 12 for which *CP_EV* = –28.55% and *AP_CP* = –19.61%. Results of the above-stated analyses indicate the need for qualitative analysis, which may help to reveal the causes of differences between *CP* and *AP*. In particular, such analysis needs a detailed study of project contractual documentation related to its real implementation.

Analysis of contractual documentation for project implementation

In order to understand the causes of variations between *CP* and *AP*, an in-depth study of contractual documentation has been conducted for all 16 analysed projects. In particular, attention has been paid to the contracts for work and all related amendments that were negotiated in connection with modifications to the project during its implementation phase. Table 1 provides the number of amendments for each project. Data suggests that negotiation on amendments belongs to the common practice for road construction projects. The number of amendments varies from 1 to 6 for a particular contract.

When all the contracts for work with amendments were collected, the causes of project modifications were sought. It has been revealed that modifications mostly relate to the changes in the scope and extent of the project (i.e. extra work and cancelled work).

The actual causes of changes in construction costs, the difference between the contract price and the final price of individual projects recorded in the amendments to the contracts between the contracting authority and the construction contractor are summarized in Table 4.

TABLE 4. The frequency of main causes of changes in construction costs of projects under research during their implementation

Cause of change	Project number
C1: Completion to/change in technical design	1, 16
C2: Increase in asphalt layers and milling area	2, 8
C3: No need for implementation documentation and geometric plans	2
C4: Unbearable subsoil/ /replacement of base layer	3, 9, 11, 13, 14, 15
C5: Replacement of unsuitable material	4, 5, 6, 13, 14, 16
C6: Conflicts with existing utilities	6, 9, 11, 12
C7: Demolition of unknown structure	6, 11, 12
C8: Change in rock classification	11
C9: Emergency condition of the culver Culvert disrepair	12
C10: Requests from other organisations (police, technical building management)	10, 13
C11: Reinforcement of diversion routes	14
C12: Another acreage	7

In total, causes were grouped into 12 categories, where unbearable subsoil/replacement of underlayer and replacement of unsuitable material were the most frequent. This is mainly due to inadequate structural testing during the construction phase and refinement of the survey plan according to reality, i.e. change of the scope of work project/reality. Due to the fact that these projects are carried out in built-up areas, unplanned conflicts with existing utilities and current requirements of administrations, e.g. public lighting or requirements for the addition of traffic signs, also appear to be a more frequent cause.

Conclusions

It is clear from the overall project analysis that there is a relatively high level of interest from contractors in public works contracts for regional road construction, which is evident from the number of contractors who tendered for the contracts under research (3 to 14 tenders) in the sample studied. The market has therefore significantly reduced the construction costs in the first phase compared to the expected value. Another issue is the difference between the contract price and the final price, which in all cases has increased due to various implementation reasons, among which, in the project area, the survey and design work – unbearable subsoil leading to the replacement of the proposed underlayer, changes in material properties, conflicts with existing utilities or the need to demolish unknown structures during the project. The relative differences between the contract price and the final price can be considered satisfactory (the mean 3.62% and the median 2.46% based on an interval between –3.8 and 12.51%).

Information and knowledge about the cost progress in the implementation phase should lead to the refinement of the expected value in particular, which is a very important aspect of investment activities, as it is one of the basic items of information on how many financial resources will be needed for the implementation of the project, what type of tender needs to be launched and whether the investor is able to finance the project from his own or other available sources (especially EU subsidies). From the managerial perspective, the findings presented in this paper aim to help construction professionals, among others, by identifying the most common causes of negotiating contractual amendments for road construction projects.

It was unfortunately not possible to proceed to a more detailed analysis that would allow, for example, to study the detailed financial impact of the specific identified causes on the construction project due to the extent of the documentation and the structure of the data available. Following research could therefore provide further interesting findings in this respect, which have the potential to help investors to prepare projects in a way that would further minimise the need to adjust the scope/method of works and negotiate contractual amendments.

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Zákon ze dne 19. dubna 2016 o zadávání veřejných zakázek. 134/2016 Sb.

Summary

Analysis of road construction projects price changes in the selected phases of their life-cycle. This paper deals with an analysis of causes that lead to the change in price (value of construction costs) of road infrastructure projects in selected phases of the building structure life-cycle, more specifically procurement and construction phases, with the aim to refine the price estimation in the estimated value determination phase. The sample of regional road construction projects in the South Moravian Region (Czech Republic) documentation forms the basis for the research. The methodological procedure is aimed at monitoring changes in the value of construction costs during the preparation and implementation phase of the construction. Estimated values, contract prices and actual prices of individual projects are compared to determine them and the reasons for their differences are discussed. The changes (decrease) in the values of construction costs determined by estimated value and contract price show the strong influence of the construction market and the interest of construction companies in the implementation of public works contracts in the field of road infrastructure projects. The relative differences range up to 47%. The changes (increase) in construction costs determined by contract price and actual price are much lower, up to 13%, and result from specific situations during the implementation of the construction, for which subsoil bearing capacity problems and material changes were determined as the most significant.