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# THE ANALYSIS OF STATISTICAL CHARACTERISTICS OF CONSTRUCTION COSTS

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Construction cost estimating, control and analysis are the main tools in construction project management. Construction cost estimating influences the final project effectiveness. Construction cost estimating goals, methods and accuracy differ according to the stage of construction project. Contractors should know what the dynamics and value of construction cost is in every stage of a construction project. The object of this research was the implementation of a project of a chain of petrol stations of the same contractor in Lithuania. According to the analysis of statistical characteristics of a chain of petrol stations construction bid price, cost, duration and profit, the contractor can estimate parameters and make decisions for future similar projects. The performed research and obtained results revealed that construction bid price of petrol stations in Lithuania depends on the occupied area and land plot. The offered subordination of the mathematical expression can be used practically estimating the construction bid price of petrol stations and adopting a decision regarding contractor's participation in the tenders.

Key words: Project management, construction preparation, cost estimation.

### **1. INTRODUCTION**

Within the process of economy expansion in Lithuania, the construction market and cooperation relations among the market members are developing. The influence on cooperation relations among the market members of the construction market is forced by free market economy and legal acts, which regulate

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construction business in Lithuania. The mode of behavior and activity of the construction market members have changed entirely. Engineering, organizational, economical and management modes of activity of contractors has transformed essentially within the process of economy expansion. Under the influence of the changing construction market the adaptation of activity of the construction companies takes place. Under the current circumstances, a fierce competition among contractors prevails. Thus, a strategy of increase of a contractor's competitiveness is the application of the method of construction project management in a company. The method of construction project management has been widely employed in the USA, Western Europe and other countries for almost 30 years (Hendrickson, 2003). The International Project Management Association (IPMA) has revealed that project management enables to shorten the period of project implementation approximately by 20-30 per cent and decrease investment value by 10-15 per cent. The mentioned method has recently been employed in Lithuania.

The problems of economy efficiency are relevant in every stage of project management. Estimates of construction costs are of great importance too (Ostwald, 2000). To be more exact, the estimating of construction costs as well as control, correction and analysis of efficiency constitute a major part of construction project management.

Estimates of construction costs in the form of documents integrate knowledge from different science fields such as system engineering, technologies, economy, mathematics, computer science and law. The estimating of construction costs as well as control, correction and analysis determine the final efficiency of a project. Therefore, estimates of construction costs are a new and relevant object of integrated research in Lithuania.

The aim of the research is to prepare techniques for contractors to enable them to design competitive estimates of construction costs. The task raised in the first stage is to select the object of this research, i.e. type of building and investigate the mode of change of construction value, costs and duration of the construction works.

# 2. THE PLACE OF ESTIMATES OF CONSTRUCTION COSTS IN THE PROJECT MANAGEMENT SYSTEM

The construction project implementation system is divided into stages (Hendrickson, 2003). The construction project implementation system is shown in Fig. 1. The constructions costs are estimated in all stages of the construction project: business plan, schematic design, detail design, construction proposal, construction preparation and completion of works. Block scheme of construction

preparation is shown in Fig. 2. Construction preparation is a separate system, closely related with other stages of the project management (Fig. 1).



Fig. 1. Scheme of construction project implementation

In the stage of need analyses, tasks, restrictions and potential ways of project implementation are formulated. In the process of carrying out the financial analysis on the basis of consolidated rates or the costs of similar construction projects considering the selection of construction plots variants are estimated. The aim of such calculations is to estimate the demand in investments and financing possibilities.

Pre-project stage deals with juridical issues of the project implementation as well as such questions as whether it is purposeful to purchase or rent land plots. Furthermore, conditions raised for license to perform construction works are taken into consideration. At this stage principal technical decisions are provided in details, optimal project variants are selected, estimate of project costs on the basis of consolidated rates is presented and period of construction works is estimated.

Within the process of detail designing, a technical project of a building is prepared. Detailed estimate constitutes a part of this project. Upon conclusion of the technical project and the estimate a competition for the execution of the construction works is arranged. The contractor, who wins the competition carries out the construction preparation, designs a project of implementation of works and performs the construction works. Within the process of building adaptation for use, the discovered drawbacks of construction works are removed. Then, the building is used; its maintenance, repair and reconstruction are carried out.

The main purpose of estimates is to estimate the construction costs, the value and the total investment value. An estimate is the most relevant document as a means of assistance for client to adopt appropriate decisions. As for the

contractor, an estimate is of essential importance in estimating costs, controlling and analysis of the efficiency.

The classification of costs, the standard databases and the techniques of estimating construction costs differ in various countries (Ostwald, 2000). The aim and the techniques of estimating construction costs as well as precision of the estimated price differ according to the stage of the construction project implementation.

The following construction cost estimates are estimated in the European countries (Juodis, 2001).

*Defining of the initial construction cost.* The Initial construction cost is defined in the stage of business plan. The price reveals a concept of the project. Its precision amounts to 30 percent of the actual construction cost. Consolidated rates or similar projects are used in estimating construction costs in this stage.

*Construction costs estimate in the schematic design stage.* It is used in comparison to principal technical decisions of a construction project.

*Construction costs estimate in the process of public tender for purchases.* Public tender for purchases is organized on the client's initiative aiming at the selection of a contractor (prime contractor) for the implementation of the construction works. Upon choosing a contractor the client estimates the costs and proposals submitted by experts.

*Estimate of the construction implementation costs.* It has to be prepared in the process of construction preparation (Fig. 2). Within this process a contractor may prepare alternative project decisions on construction processes, optimize and integrate them into a calculation of estimate of construction costs (Juodis, 2001). It allows a contractor to decrease construction costs up to 30 percent, and shorten the period of construction works by 50 percent (Juodis, 2002). The optimization of project decisions of construction processes the competitiveness of a contractor's proposal in the tender.

Actual estimate of construction costs. Within the process of building adaptation for use, the actual construction costs shall be calculated. It is necessary for the implementing analysis and for the defining of the ultimate efficiency of the construction project. The actual estimate of construction costs reveals the implementation level of rational decisions, effectiveness of the decisions and their reliability.

## 3. SIGNIFICANCE OF CONSTRUCTION PREPARATION TO THE COSTS OF CONSTRUCTION WORKS

In Lithuania the concept of construction preparation under the conditions in the market economy has gained a new meaning. Therefore, new construction preparation works emerged such as preparation for participation in tenders, projecting of competitive construction estimates, risk assessment etc.. Block scheme of construction preparation is provided in Fig. 2. The indicated work of construction preparation requires highly skilled specialists as well as the provision with methodological material. In this stage the optimization of project decisions of construction processes and their further implementation within the period of construction works are of great importance (Fig. 2). It enables the reduction of the construction costs and generates more profit. Optimization of the project decisions of the construction processes is made algorithmic and is implemented by the means of a PC.



Fig. 2. Scheme of construction preparation system

Within the processes of optimization and selection of rational decisions general investments into constructions in different stages of construction project implementation may be reduced (Fig.1). However, the possibilities of direct costs reduction are defined by a contractor and this is performed within the process of construction preparation (Fig.2). In this stage alternatives of construction process implementation are investigated, evaluated and optimal decisions defined, which, afterwards, are implemented. For this purpose a complex construction process is divided into simple processes, possible ways, i.e. alternatives of implementation of the mentioned simple processes are foreseen, then the alternatives are evaluated and rational decisions are selected. In order to adopt optimal decisions mathematical models of construction processes may be projected. Research methods of operations, correlation analysis and other methods are employed in this stage. Optimal decisions of construction processes are integrated into the documentation of construction implementation. The documentation includes time and financing schedules of the construction works implementation, estimates, schedules of additional project works, subcontractors' works, materials, demand for labor force and machines as well as schedules of provision and control of constructional processes.

In the first stage of this research statistical characteristics of the most important rates of petrol stations construction were planned for the analysis. Prices of petrol stations construction, construction costs, construction duration and profit variation limits were analyzed. According to the results of the research optimistic and pessimistic values of the mentioned rates may be defined and used within the process of construction preparation. The research results are provided in the section No. 4.

## 4. THE OBJECT OF THE RESEARCH, METHODS AND RESULTS

#### 4.1. The object of the research and methods

The object of this research was the implementation of the project of a chain of petrol stations of the same contractor in Lithuania. The project includes construction of 80 new petrol stations. One-type petrol stations selling 95, 98 petrol, diesel and LPG constitute the chain. The characteristics of petrol station building are the following: framework is made of light metal structure, foundation is made of drilled monolithic slabs, roof is flat and heated by stone wool, outside walls are made of steel sheets, the inner part of the outside walls is painted gypsum carton sheets, floor is made of ceramic tiles, ceiling is suspended with mounted luminaries lighting fixtures. Electric radiators heat the interior. All petrol stations are equipped with three liquid fuel filling petrol

pumps of 60m<sup>3</sup> fuel tank. Domestic wastewater and rain drainage treatment facilities are also fitted in the petrol stations.

Major calendar schedule of the construction works is provided in Table 1. The construction works of the petrol stations were carried out by different contractors in different places. The average duration of construction works is 131 days.

	Construction duration, days															
	0	10	20	30	40	50	60	70	80	90	100	) 11	0 1	20	130	140
Earth works						ſ										
Foundation							Optimistic									
Mounting of metal frame							value									
Siding									Me	an	٦.			_		
Shelter mounting									IVIC	an	┚			Λ	•	
Roofing									Pessimistic value							
Sewage																
Outside engineering networks								L	┺┯┯┯┯┹╂╶╂┈┤							
Inside engineering networks																
Technological equipment																
Concrete laying of car park																
Laying of asphalt																
Finishing																

Table 1. Time-scaled diagram of construction works

39 inter-comparative petrol stations were chosen for the analysis of construction price, costs and duration rates. The petrol stations were built in the year of 2003. The algorithm of the data analysis of them is provided in Fig. 3.



Fig. 3. Block scheme of analysis of the data

SPSS computer software was used to perform the computation.

### 4.2. Research results

Descriptive statistics of the construction prices, costs, durations and profit rates of petrol stations are provided in table 2 and 3. The data has a normal law distribution (Table 2), because value of asymp.sig. > 0,05. Thus, we can calculate confidence intervals of data and use them in defining their optimistic and pessimistic meanings.

The hypotheses for testing indexes under investigation of normal law distribution are provided in the Table 2.

		Construc- tion bid price, EUR	Construc- tion cost, EUR	Construc- tion dura- tion, days	Profit, %
Normal Parameters	Mean	213157	200626	131	7,9
	Std. Deviation	38675	38384	19	3,26
Most Ex- treme	Absolute	0,117	0,146	0,107	0,156
Differences	Positive	0,115	0,098	0,086	0,156
	Negative	-0,117	-0,146	-0,107	-0,154
Kolmogorov-Smirnov Z		0,509	0,636	0,466	0,682
Asymp. Sig. (2-tailed)		0,958	0,813	0,982	0,741

Table 2. Hypotheses for testing indexes under investigation of normal law distribution

The histograms of construction bid price, cost and profit indexes are provided in the Fig. 5, Fig. 6 and Fig. 7.



Fig. 5 Histogram of construction cost values









In all histograms axis X is divided into 8 intervals. In each interval its average value is indicated. Y axis indicates number of observations in each interval.

The collected data are casual values. On the basis of the present data general conclusions for the whole group of objects under investigation shall be drawn. For this purpose the confidence level or probability is defined, in the presence of which we will be able to state that errors will not exceed certain

limits. The precision between the value of the search parameter  $\Theta$  and observational value  $\stackrel{\wedge}{\Theta}$  must be less than primarily defined error  $\varepsilon$  (Abranovic, 1997; Anderson, 1999).

$$|\Theta - \Theta| < \varepsilon, \tag{4.1}$$

Probability of the equation validity

$$P(|\Theta - \Theta| < \varepsilon) = 1 - \alpha, \quad \text{or}$$
(4.2)

$$P(\hat{\Theta} - \varepsilon < \Theta < \hat{\Theta} + \varepsilon) = 1 - \alpha, \qquad (4.3)$$

Whereas:

:  $(\hat{\Theta} - \varepsilon; \hat{\Theta} + \varepsilon) - \text{confidence interval},$   $1 - \alpha - \text{confidence level} = (0,9; 0,95; 0,99),$  $\varepsilon - \text{error.}$ 

According to the provided formulas, point estimates and confidence interval (Table 3) of the rates under the investigation were defined. Confidence interval provides a range of plausible values for the unknown parameter. The construction cost estimators are essential to forecast the rates.

Point estimates, which are under investigation, and confidence intervals are provided in the Table 3.

Values	Min	Mox	Maan	95 % confidence interval			
v alues	IVIIII	IVIAX	Ivicali	Lower	Upper		
Land plot, m <sup>2</sup>	470	16978	7025	4631	9419		
Occupied area, m <sup>2</sup>	208	421	381	341	420		
Construction dura- tion, days	86	169	131	122	141		
Construction bid price, EUR	143993	284541	218637	199325	237948		
Construction cost, EUR	127450	265775	204327	185105	223550		
Profit, %	1,35	13,50	7,35	5,38	9,32		

Table 3. Point estimates and confidence intervals

We may claim that in the case of the probability of 95% the upper and lower limits of confidence interval shall not be exceeded. For example, while constructing petrol stations of such type the profit of a company may range from 5,38% to 9,32%.

Consequently, with the probability of 95 percent we can claim the following:

- The period of construction works of a petrol station fluctuate from 122 to 141 day;
- The offer price of a petrol station fluctuates from EUR 199325 to EUR 237948;
- Construction costs of a petrol station fluctuate from EUR 185105 to EUR 223550;
- The profit from construction of petrol station fluctuates from 5,38 to 9,32 percent.

Results of correlation analysis of indexes of construction price, costs and constructions works duration are provided in Table 4.

	Land plot,	Occupied area,	Con- struction duration,	Con- struction bid price,	Con- struction cost,	Profit,
	$m^2$	m <sup>2</sup>	days	EUR	EUR	%
Land plot, m <sup>2</sup>	1,000	0,581	0,154	0,703	0,699	-0,250
Occupied area, m <sup>2</sup>	0,581	1,000	0,427	0,826	0,813	-0,261
Construction duration, days	0,154	0,427	1,000	0,420	0,479	-0,521
Construction bid price, EUR	0,703	0,826	0,420	1,000	0,982	-0,294
Construction cost, EUR	0,699	0,813	0,479	0,982	1,000	-0,465
Profit, %	-0,250	-0,261	-0,521	-0,294	-0,465	1,000

 Table 4. Results of correlation analysis of indexes of construction bid price, cost, construction duration and profit.

In the process of carrying out the correlation analysis the following significant relations among the mentioned indexes were defined:

- The relation between the construction offer price and the costs for implementing the construction works (r = 0,982);
- The relation between the construction offer price and the occupied area (r = 0,826);
- The relation between the construction offer price and the land plot (r = 0,703).

It has also been defined that in case of longer duration of construction works, profit of a constructional company decreases. This phenomenon may be explained by the demand in the increase of the additional costs with the longer construction period.

The construction offer price of petrol stations in Lithuania depends on the occupied area and the land plot. The subordination is expressed by the following mathematical expression:

$$Y = 1,332*X_1 + 512*X_2 \tag{4.4}$$

Whereas: Y – Construction offer price, EUR,  $X_1$  – occupied area, m<sup>2</sup>,  $X_2$  – land plot, m<sup>2</sup>.

The significance of the regression coefficients of the above equation was tested according to the t-Student criteria and the approximation rate was tested according to F-Fisher's criteria.

The concluded equation can be used practically estimating the construction bid price of petrol stations and adopting a decision regarding the contractor's participation in tenders.

### **5. CONCLUSIONS**

The performed research and the obtained results revealed that values of the indexes of the construction price, costs, profit and the duration of the construction works of petrol stations have normal distribution law. In the process of the correlation analysis significant relations among the following indexes were defined:

- The relation between the construction bid price and the costs for implementing construction works (r = 0,982);
- The relation between the construction bid price and the occupied area (r = 0,826);
- The relation between the construction bid price and the land plot (r = 0,703).

The construction bid price of petrol stations in Lithuania depends on the occupied area and the land plot. The offered subordination of the mathematical expression can be used practically estimating the construction bid price of petrol stations and adopting a decision regarding the contractor's participation in the tenders. It has been established that the profit of a construction company decreases as the period of the construction works extends.

Further research shall be performed in the field of project decision optimization of individual construction processes with the application of operating research and other methods. The algorithm of handling such optimization tasks is planned to be integrated into the process of projecting competitive estimates of the construction costs.

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