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Correct selection of risk factors for unstable construction projects under probabilistic conditions: an analysis

Anna STARCZYK – KOŁBYK [1] (*ORCID ID: 0000-0002-5448-7366*)

[1] Military University of Technology, Department of Military Engineering and Military Infrastructure, Kaliskiego 2, 00-908 Warsaw, Poland

Correspondence address: anna.starczyk@wat.edu.pl

Abstract: This paper presents the problem of correct selection of risk factors for unstable construction projects, especially those repeatedly annexed, exposed to unforeseen random events (construction disruptions) [4]. An analysis of the investment network model and the location of the disruption has been carried out (signing of a contract annex). Cost contingency studies were carried out and risk factors were estimated. The next step entailed a comparative analysis of investment costs estimated by the EVM method [5] against the backdrop of three analytical variants of the studied investment under risk conditions (favourable, average and unfavourable conditions). The obtained results were discussed.

Keywords: risk factor selection, unstable construction project, EVM.

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1 Introduction

Construction projects are often very complex. This is due to the scale and nature of the works and the manner in which a given project is implemented. Such projects have a rigid deadline for works approval and handing over buildings for use. Given operations are highly sensitive to fortuitous events such as weather conditions.

Unstable projects mean a construction site that, as a result of random forcing events and construction work disruptions cannot be carried out as planned (time extension and cost overruns). Additional economic analysis of the construction site and verification of the final deadline and total cost of the construction project is required.

The research and analysis carried out in this paper addresses these types of projects both in terms of time and cost, adversely affected by random forcing events and disruption of individual works. The management of such construction projects should make it possible to optimise resource use and expenditure allocated to their implementation. Such management should apply to planning and coordination of the project's operational activities and concerns the initiation, planning, monitoring and control as well as an evaluation of the results of these activities in relation to all project phases and stages.

The construction contract subject to analysis was for the construction of a residential building. The planned investment cost was PLN 6,219,817.87, while in reality the building cost PLN 6,699,749.63. It is a three-storey building with a basement and an attic. A number of annexes were signed, changing the price and the project completion date. The material and financial schedule for the works was also updated. It is shown hereinbelow. Particular rescheduled activities are marked in red, while delays are marked with a red frame

No.	2019					2020											
	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1			**160679**														
2															85430		
3	20000	39546	99546														
4		10000	153400	340200													
5					101378	192000	22362										
6							156420	120248									
7								204253									
8									298363								
9										119872	72427						
10											40000	100000	264019				
11								84695	14116	21174	15863						
12										97909			11023				
13										30825	20000	200000	200000	139767			
14													110000	116948			
15												140000	100000	80000	120000		31508
16														62364			
17														250000	250000	132644	
18														35000	6484		
19															30000	55000	8473
20															125000	130000	20161
21												250000	120000	114576			
22																35000	41672
23																117643	
24					90498			39382	129880	21647			50000	87008			
25		27055	27055		36073												
26			68291	100000	91215		13658										
	20000	**76600**	**508971**	**440200**	**319164**	**192000**	**192440**	**448578**	**442359**	**291428**	**148289**	**690000**	**855043**	**885663**	**616914**	**470287**	**101813**

Fig. 1. Financial schedule of the construction project.

2. Applied research methods

The risk analysis applies to the preparation and execution of construction work on the site. The risk of directive cost overruns is considered. The works are carried out by a defined set of execution resources. A bill of quantities and cost estimate for the investment were prepared in accordance with the current rules on the basis of the construction project analysis. On the other hand, random events and their influence on the course and results of construction works were determined on the basis of the implementation conditions analysis. Following the analysis of the construction works technology, a network model of the works $\boldsymbol{S}^T = \langle \boldsymbol{G}, \boldsymbol{B}, \boldsymbol{L} \rangle$ and a model of the disposable resources were developed and analysed $\boldsymbol{\pounds} = \{ \langle \boldsymbol{H}^S, \boldsymbol{T}, \boldsymbol{K} \rangle, \boldsymbol{S}^T \}$ [1].

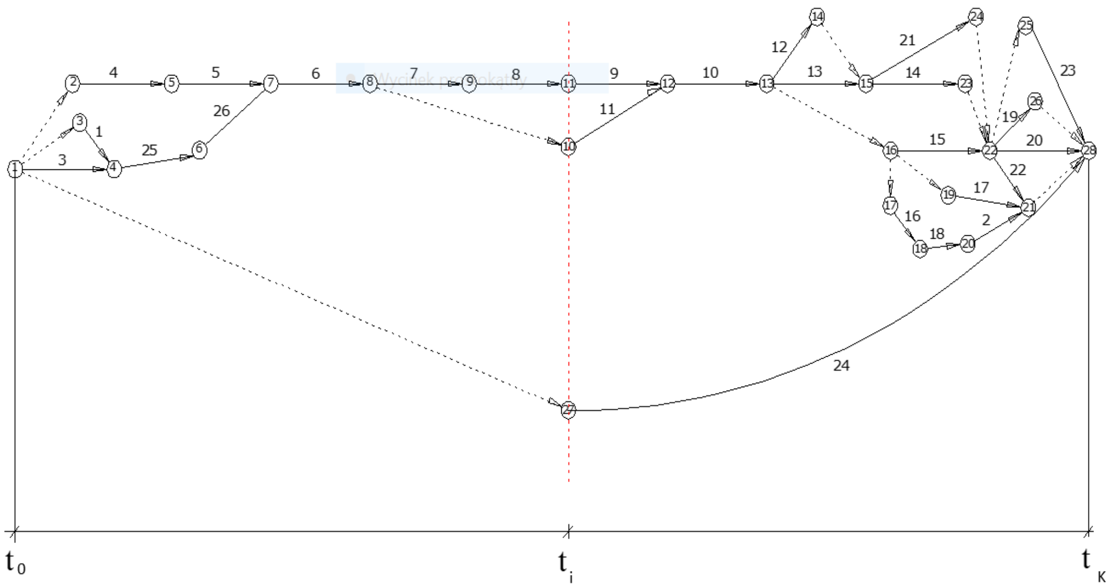

Fig. 2. A network model of a construction investment project.

In such models, graph $\boldsymbol{G}$ and function $\boldsymbol{B}$ describe the bill of quantities for the construction works and the state of a structure once the specified works have been carried out. Function L described on the set of arcs of the graph determines the expected number of units for the bill of quantities. This value is calculated on the basis of estimated optimistic, most likely and pessimistic values. Set of construction site crews $\boldsymbol{H}^S$ can carry out construction works $\boldsymbol{S}^T$ in expected time $\boldsymbol{T}$ and at expected cost $\boldsymbol{K}$. The expected costs of the works were determined after analysing optimistic, most likely and pessimistic values. A cost estimate and works schedule $\mathcal{H} = \langle \boldsymbol{G}, \boldsymbol{B}, \boldsymbol{T}, \boldsymbol{K} \rangle$ were determined for model $\boldsymbol{S}^T$, values $\boldsymbol{T}$ and $\boldsymbol{K}$. In addition, analysis of the network described by function $\boldsymbol{K}$ makes it possible to analyse the cost risk of executing construction works.

The probability that the expected costs $E[K^S]$ of works $\boldsymbol{S}^T$ will exceed any directive costs k^d can be determined by the following relationship:

$$P\left[E[K^S] \geq k^d\right] = 1 - P\left[E[K^S] \leq k^d\right] \approx 1 - \Phi\left[\frac{k^d - E[K^S(E)]}{\sqrt{D^2[K^S(E)]}}\right] \tag{1}$$

Calculation of values $P\left[E[K^S] \geq k^d\right]$ for different values of k^d made it possible to develop of a contingency graph for the cost of construction works.

Risk factors $\underline{p}_{j,r}$ and $\overline{p}_{j,r}$ had to be identified to complete the calculations.

Optimistic values $\underline{K}_{j,r}$ for works $u_j \in \boldsymbol{U}^r$ – lower than most likely:

- optimistic costs $\underline{K}_{j,r}$:

$\underline{K}_{j,r} = \hat{K}_{j,r} - \underline{p}_{j,r}\,\hat{K}_{j,r}$, where, on the basis of expert analyses, it is recommended to adopt $\underline{p}_{j,r} \in [0{,}05,\ 0{,}1,\ 0{,}15,\ 0{,}20]$

Pessimistic values $\overline{K}_{j,r}$ for works $u_j \in \dot{U}^r$ - higher than most likely:

- pessimistic costs $\overline{K}_{j,r}$:

$\overline{K}_{j,r} = \hat{K}_{j,r} + \overline{p}_{j,r}\,\hat{K}_{j,r}$, where, on the basis of expert analyses, it is recommended to adopt $\overline{p}_{j,r} \in [0{,}1,\ 0{,}15,\ 0{,}20,\ 0{,}25]$.

3. Research results

Based on the analyses of completed construction projects, the values of risk factors $\underline{p}_{j,r}$ and $\overline{p}_{j,r}$ were estimated.

Results of the analysis for selected risk factor values $\underline{p}_{j,r}$ and $\overline{p}_{j,r}$ are shown below.

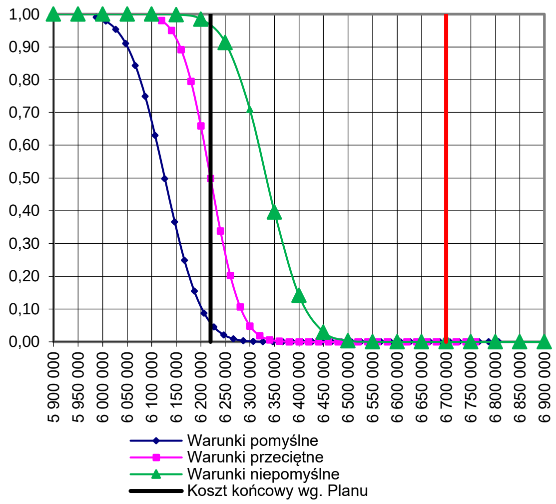

Fig. 3.1. Cost contingency graph for $\overline{p}_{j,r} = 0{,}1$.

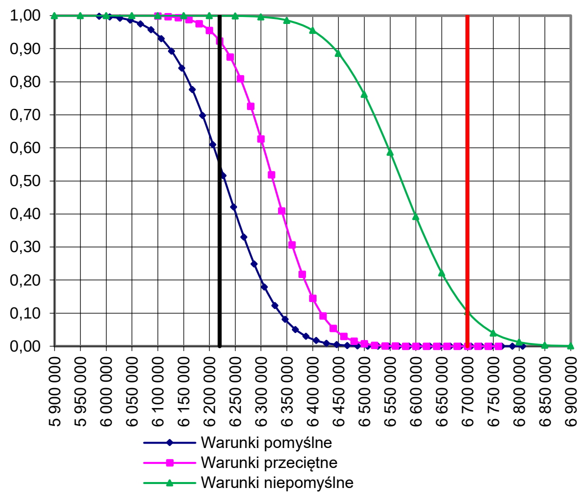

Fig. 3.2. Cost contingency graph for $\underline{p}_{j,r} = 0{,}1$; $\underline{p}_{j,r} = 0{,}1$; $\overline{p}_{j,r} = 0{,}2$.

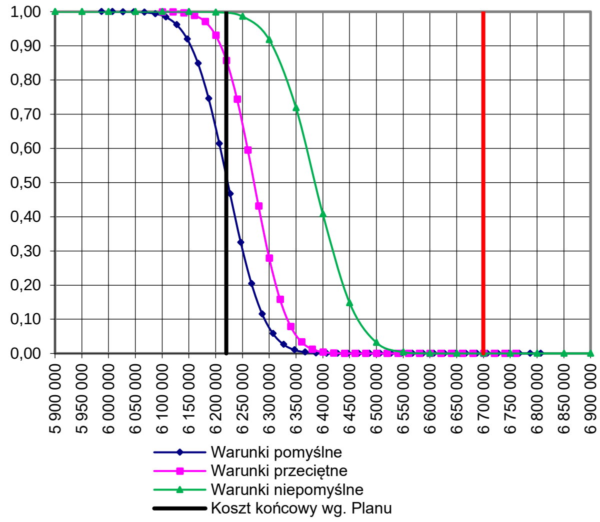

Fig. 3.3. Cost contingency graph for $\underline{p}_{j,r} = 0{,}05$; $\overline{p}_{j,r} = 0{,}10$.

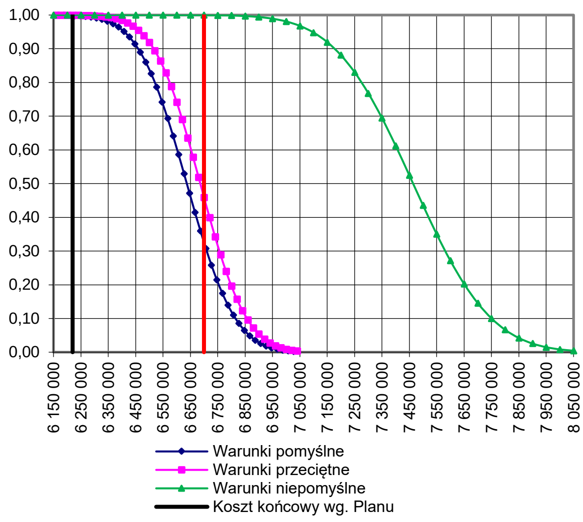

Fig. 3.4. Cost contingency graph for $\underline{p}_{j,r} = 0{,}05$; $\overline{p}_{j,r} = 0{,}50$.

A contingency graph for a pessimism coefficient well above the recommended values is shown on Figure 3.4 in order to illustrate how the chosen coefficient affected the different conditions subject to analysis, especially the unfavourable conditions, which are all outside the range of the actual costs incurred for the analysed project.

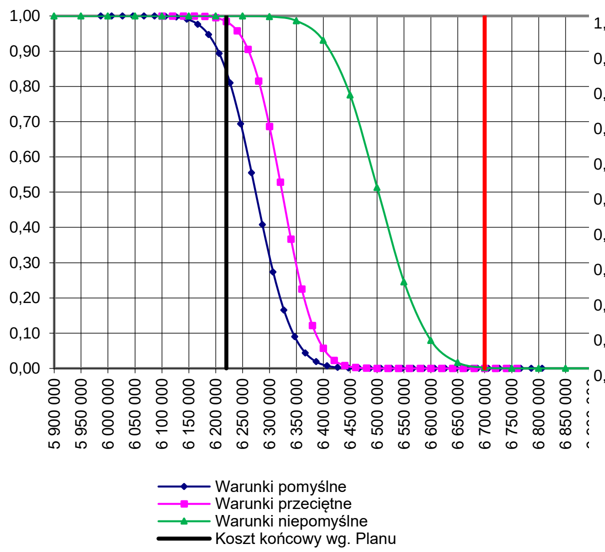

Fig. 3.5. Cost contingency graph for $\underline{p}_{j,r} = 0{,}05$; $\overline{p}_{j,r} = 0{,}15$.

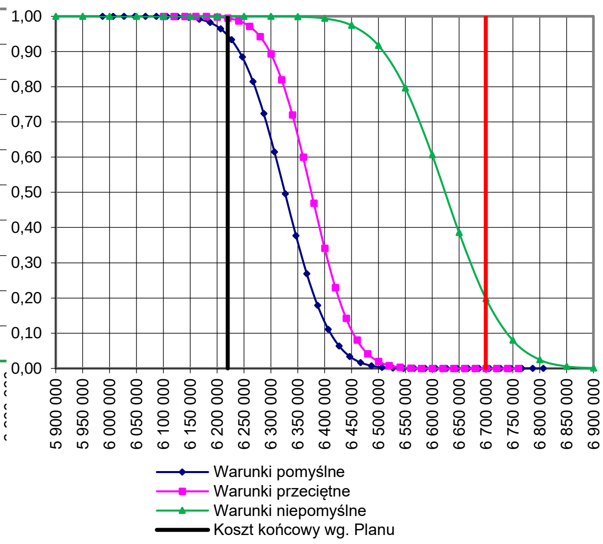

Fig. 3.6. Cost contingency graph for $\underline{p}_{j,r} = 0{,}05$; $\overline{p}_{j,r} = 0{,}20$.

In short, the values of the selected risk factors were analysed on the basis of data from completed construction investments. The recommended risk factors and the resulting cost contingency graphs compared with actual construction costs were considered. Given the numerous examples of overruns to overall construction cost, it was noted that risk factor $\overline{p}_{j,r}$ (pessimistic) should be estimated to be greater than factor $\underline{p}_{j,r}$ (optimistic) and that it will have a significant impact on the final costs result. Therefore, an appropriate value for the pessimism coefficient should be determined first, before selecting the coefficients. The diagram below shows a situation in which the maximum recommended value of the pessimism coefficient has been chosen: $\overline{p}_{j,r} = 0,25$.

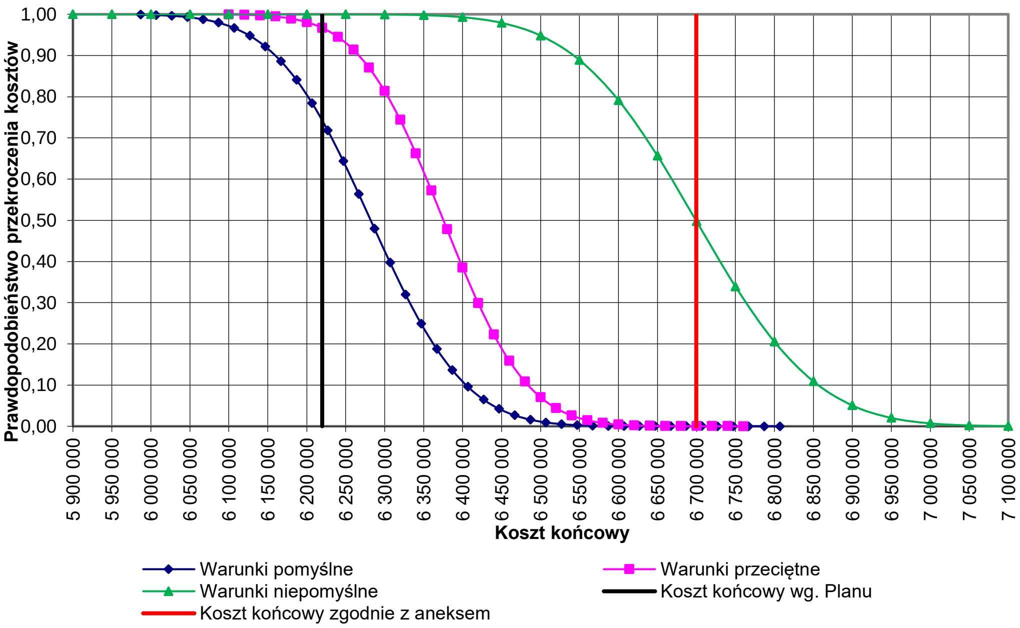

Fig. 3.7. Cost contingency graph for probabilities $\underline{p}_{j,r} = 0,10$; $\overline{p}_{j,r} = 0,25$.

As demonstrated by the above diagram, by selecting the maximum recommended pessimism coefficient during analysis of risk conditions [2], we obtain the correct risk contingency graph for unfavourable conditions, i.e. conditions in which the deadlines and costs of individual works, as well as the entire project, are exposed to construction disruptions, which in turn may result in a need to annex the contract [3] associated with a deadline extension or an increase of investment costs.

In order to confirm the need to analyse the results obtained mainly for unfavourable conditions and to select the pessimism factor at the maximum recommended level, i.e. $\overline{p}_{j,r} = 0,25$, as well as to control unstable construction projects only under probabilistic conditions (i.e. departing from a deterministic analysis), a comparison of the cost contingency graph with costs estimated using the EVM method as well as the planned and actual cost of the investment is presented below.

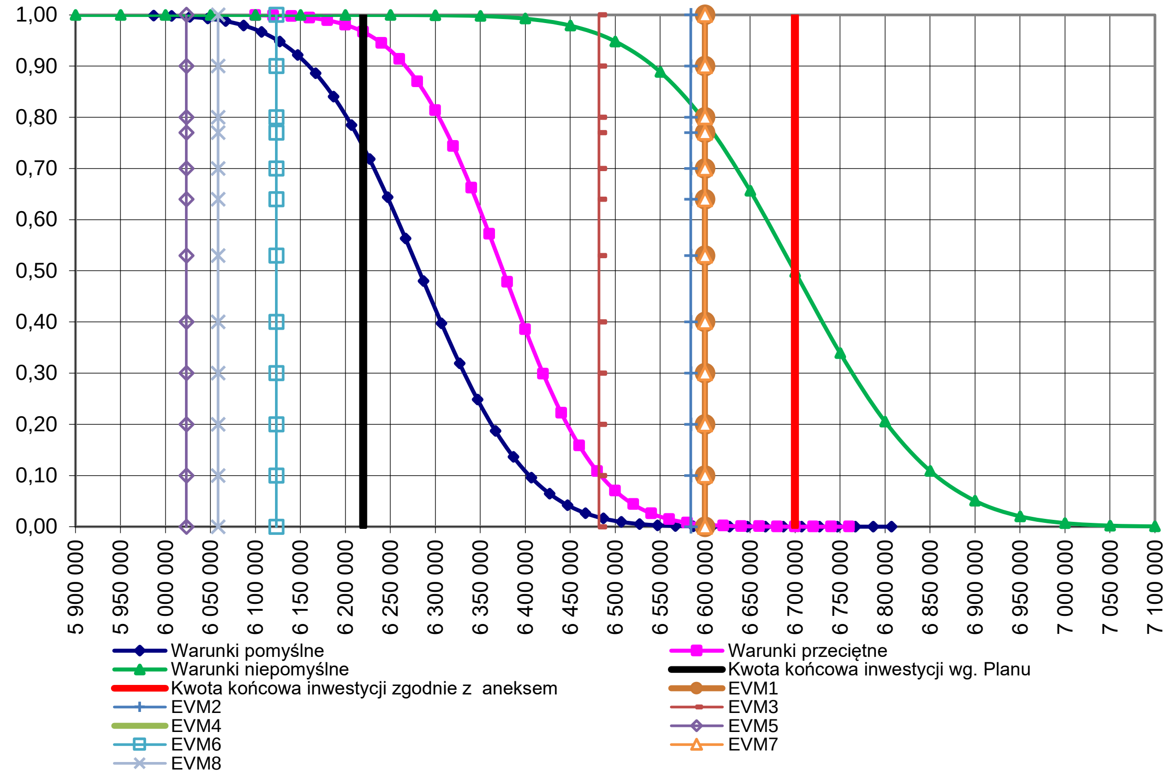

Fig. 3.8. A comparison of cost contingency with costs estimated using the EVM method as well as the planned and actual cost of the project.

The spread of the final cost estimated using the EVM method on the basis of the formulas proposed in this method is significant. Only a cost contingency carried out under unfavourable conditions determines the probability of the project being completed.

6. Final conclusions

The carried out research clearly demonstrates the need to analyse unstable construction investments under probabilistic conditions. It is necessary to analyse the optimism and pessimism probability for individual construction investments, which will enable correct control and estimation of final investment costs.

A false picture of an existing state of a specific construction project in progress is caused by:

- an investment analysis carried out under deterministic conditions (no risk analysis), or

- taking into account all possible disruptions, including the probabilities of these occurring (same for different construction investment projects).

Analysis and selection of risk factors should be investment-specific and based on disruptions which occur during the implementation thereof.

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