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Cost Risk in Water and Sewerage Systems Construction Projects

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Abstract

Due to their complexity and uniqueness, all construction projects are exposed to a high risk. The condition for this risk reduction is an identification of risk events and an evaluation of their occurrence probability and effect.

The subject of this study was the risk of an increase in the planned costs of water and sewerage systems construction projects. The data obtained from expert survey constitute the basis of the analyses. The questionnaire prepared especially for this purpose contains the list of 25 factors that generate cost risk events which can occur during construction works execution. The list of these factors is the result of literature studies, interviews, direct field observations, as well as the inspection of investment documents. These factors include the specific features of construction works such as: a large number of people involved, investment process formalization, a long duration of the investment, capital intensity, considerable material resources use, interference with natural environment, dependence on weather and ground conditions as well as topography. The experts pointed out in the survey whether they observed particular factor in their practice, and whether the factor affected the cost of the investment. The questionnaire was filled by 51 carefully selected respondents. Each of the experts had a long-standing professional experience at the managerial position in water supply and sewerage systems realization.

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The results were analyzed using statistical methods. Examination of the data set concerning the frequency of risk events, and the set of data determining the effect of these factors on investment cost increase, demonstrated the similarity in these structure sets, with similarity index over 0.9. The method of correspondence analysis revealed that the most common source of cost risk on water supply and sewerage systems construction sites include: faulty design documentation, unforeseen physical conditions, adverse

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weather and ground conditions, need of update of the design solutions as a result of technological progress, inadequate design supervision, corrective action as a result of lack of required work quality. The factor related to the quality of project documentation was the most distinctive among all the factors in the study. This indicates that particular attention should be paid to the design phase as a part of cost risk management plan. Faulty design documentation to the highest degree affects the high level of cost risk in water and sewerage systems construction projects.

1. Introduction

The risk management has an increasing significance in the case of investment decisions making. Each construction project is exposed to the risk [1,2,5,6,7,8]. This is determined by specific features of construction works such as: complexity, uniqueness, large number of people involved, investment process formalization, long duration of the investment, changeable environment conditions and many others. Therefore, the commencement of the construction process should be preceded by the identification of adverse events affecting the works course, the determination of its occurrence probability, and the evaluation of the extent of their impact on the construction process [4]. The subject of this study was the risk of an increase in planned costs. The aim of the research was to examine the factors generating this type of risk related to water and sewerage systems construction projects. The results of the work provide the data that will allow reducing cost risk and mitigating its consequences.

2. Research method

Gaining the information necessary to identify the potential risks is a crucial issue for an effective and efficient risk management. The knowledge and experience of the participants of the constructions process is one of the valuable sources of information about the cost risk. For this reason, an expert survey was applied to conduct the research.

The selection of the experts was made on the basis of two criteria. The first criterion assumed that the person selected for the study is an expert with five years' experience and participated in the realization of at least five water and sewerage systems construction projects. The second criterion assumed that the expert was involved in the construction process in managerial positions. The specified criteria were fulfilled by 51 experts, who were included into the study.

The special questionnaire was prepared in order to obtain relevant information. It contains the list of 25 factors that generate cost risk events which can occur during the construction works execution. The list of these factors is the result of literature studies, interviews, direct field observations, inspection of investment documents as well as researchers' work experience. These factors were as follows:

1. faulty design documentation,
2. need of update of the design solutions as a result of technological progress,
3. inadequate design supervision,
4. improper selection, insufficient number, defect of machinery, equipment and technology devices,
5. lack of qualified production workers,
6. inadequate human resources management by works contractor, lack of proper supervision of subcontractors,
7. wrong time assumption in the schedule of works,
8. inadequate management of construction work (e.g. lack of interbranch coordination),
9. unqualified and / or inadequate construction supervision,
10. misconduct in a tender procedure,
11. terms and Conditions not meeting the specifics of the contract (including the ambiguous definition of obligations of the parties),
12. delay payment of the investor,
13. inadequate preparation of human resources and organizational side by the investor,
14. changes in laws and / or inconsistent legal provisions,
15. excessive length, lack of coordination of administrative procedures and / or a large number of institutions involved in the investment process,
16. adverse economic conditions on the market,

17. unforeseen physical conditions / collisions,
18. adverse weather conditions,
19. adverse hydrogeological conditions,
20. extraordinary natural phenomena - floods, hurricanes,
21. force majeure events - fire, theft, vandalism,
22. adverse social activities - protests of environmentalists, residents or third parties,
23. difficulties in the preparation of areas for investments in formal, legal and technical terms,
24. misconduct in the preparation of the investment (e.g. deficiencies in completing the required permits, agreements).

The experts pointed out in the survey whether they observed particular factor in their practice, and whether the factor affected the cost of the investment. Two sets - Z, K, were the result of the expert survey. Each of them consisted of 25 elements, corresponding to the considered risk factors. Factors marked by the experts as source of risk events formed the Z set, while the factors identified as affecting the investment costs were defined as K set.

The results were analyzed using statistical methods. The comparison of the two sets was done in a first step. The similarity index (P) was applied for this purpose. It was calculated using the following formula [3]:

$$P = \sum \min(u_{iZ}; u_{iK}) \quad (1)$$

where:

$0 < P \leq 1$, u_{iZ} ; u_{iK} - structure indicators of Z and K sets.

Structure indicators, showing the share of elements in the whole set, were calculated using the following formula:

$$u_i = \frac{w_i}{\sum w_i} \quad (2)$$

where:

u_i – structure indicator, w_i – number of elements.

In the next step of the research, the data from the survey were studied in the terms of their correlations. The method of correspondence analysis was applied for this purpose.

3. Results

The results of the survey are presented in Fig. 1. Considered risk factors are numbered 1-25. The bars on the graph represent the percentage of the respondents who pointed out that they observed particular factor in their practice, while the solid line indicates the percentage of the survey participants who noted that this factor caused the additional cost of the investment.

The analysis of the graph indicates that each factor considered in the survey constitutes greater or smaller source of the cost risk events. The number of experts' indications of particular factors is differentiated, which makes that the set is inhomogeneous. It also demonstrates the random nature of the problem in this question. The data presented in Fig. 1 indicate that the additional cost of investment is a result of the occurrence of only certain factors from all of the identified. However, such a situation is frequent. The similarity index, calculated according to the formula no. 1, was over 0.9. This result proves that the occurrence of particular risk factor may with a high probability contribute to the investment cost increase. The importance of particular factors in the area of financial risk was identified in the next stage of the study. The method of correspondence analysis was used for this purpose. The frequency of risk events and the effect on the investment cost increase was included in the analysis.

The calculations were carried out using statistical program "R". The Fig. 2. represents the result of this analysis. The two-dimensional projection area contains 25 points corresponding to the considered cost risk factors. The

intersection of the axes in the presented graph constitutes the point of reference. This point is an average profile of the considered variables.

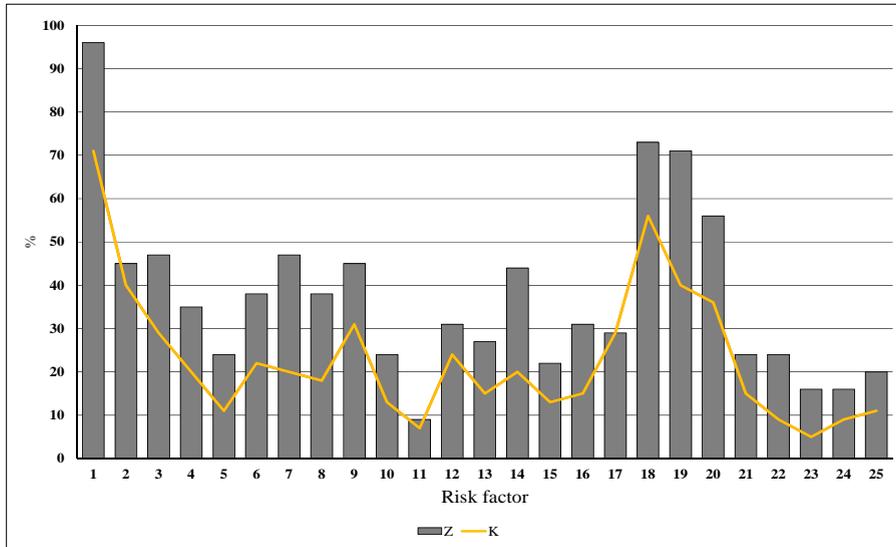


Fig. 1 The frequency of risk factor occurrence (Z) and its effect on the cost of the investment (K).

The risk factor events situated in the vicinity of this point are characterized by the values close to the average ones, both in terms of the frequency of risk factor occurrence and its effect on the cost of the investment.

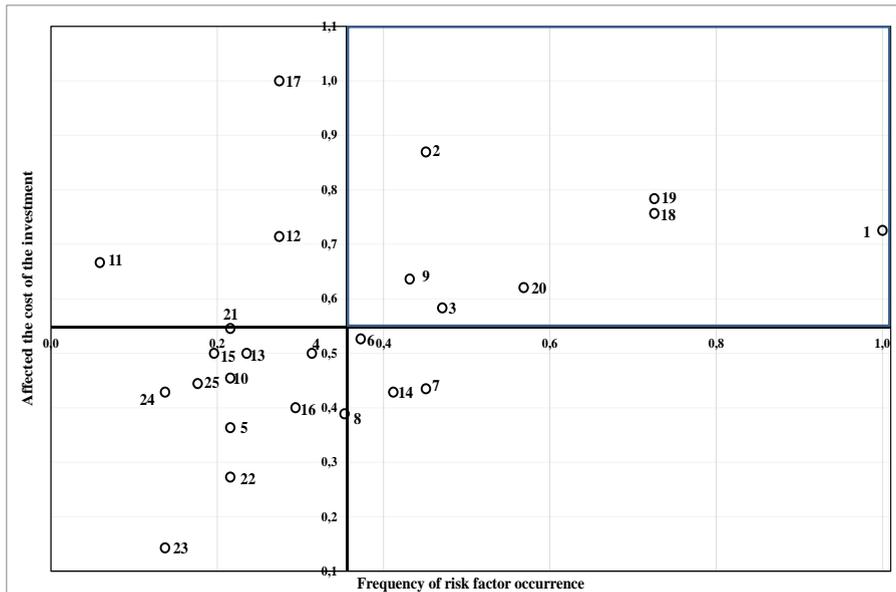


Fig. 2 The relation between the frequency of risk factor occurrence and effect on the cost of the investment.

The analysis of the distance from the vertical axis refers to the frequency of the risk factor occurrence. Risk factors which frequency is higher than the average are situated on the right side of the reference point - the greater distance of a point representing risk factor is from the intersection of the axis, the greater is the frequency of its occurrence during construction works. Vertical dispersion of the points is identified with the frequency of an effect on the cost of the investment. Risk factors above the reference point have higher than average degree of impact on the investment cost.

The analysis of the points position in Figure 2 indicates that factors located in the upper right quadrant of the chart have to be considered in priority in the cost risk management plan in water and sewerage systems construction projects.

These are as follows:

- faulty design documentation (1),
- unforeseen physical conditions, collision (18),
- adverse weather conditions (19),
- adverse hydrogeological conditions (20),
- need to update the design solutions as a result of technological progress (2),
- corrective action as a result of lack of required work quality (9),
- inadequate design supervision (3).

These factors constitute the highest level of cost risk on the construction of water and sewerage systems. This results both from their high frequency of occurrence, as well as a strong impact on the investment cost. It should be pointed out that the source of these factors is generated at different stages of the investment process: planning, designing and construction. They also relate to various aspects of the investment: technical, organizational and environmental. Dominant factor in the defined group of the highest risk events is the faulty design documentation. This factor poses the biggest threat to the planned budget preserving.

4. Conclusions

The risk management of the construction project requires the gathering of relevant data to evaluate it. The studies consider 25 factors, which generate cost risk in the water and sewerage systems construction projects. The occurrence of these factors has a random character. The analysis indicates that in the most cases, these events affect the planned costs of the water and sewerage systems construction projects, albeit to different degrees.

Factors related to the quality of project documentation distinguish among all the concerned in the study. This indicates that particular attention should be paid to the design phase as part of the cost risk management plan. Faulty design documentation has the biggest impact on the high level of cost risk in water and sewerage systems construction projects.

Presented in the paper research these results could be helpful in making decisions concerning the choice of the best risk handling strategies. The obtained data can be used by both the investor and the contractor. The value of these data will increase if they are verified by a systematic risk monitoring of construction projects.

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