Risk Analysis in Construction Project - Chosen Methods

Article *in* Procedia Engineering · December 2015
DOI: 10.1016/j.proeng.2015.10.034

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Procedia Engineering 122 (2015) 258 – 265

Procedia Engineering

www.elsevier.com/locate/procedia

Operational Research in Sustainable Development and Civil Engineering - meeting of EURO working group and 15th German-Lithuanian-Polish colloquium (ORSDCE 2015)

Risk analysis in construction project - chosen methods.

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Abstract

The risk is a measurable part of uncertainty, for which we are able to estimate the occurrence probability and the size of damage. The risk is assumed as a deviation from the desired level. It can be positive or, which most often happens, it can be negative. Therefore, the risks analysis is so important for project selection and coordination of construction work. The risk analysis is regarded as the analysis of adverse events even at the stage of planning and programming of a construction project. This analysis enriches the decision-making process and provides additional arguments, which help to select the optimal variant of a construction project using the Multi-Aspects approach. This article presents three different methods of the risk analysis as well as highlighting their disadvantages, advantages and primary areas of application (selection or pre-estimation). These methods differ in their methodology from each other. The verification was started from the simplest techniques using some qualitative variables. This method is based on the considerable subjectivity of a decision maker although it is relatively simple and easy to use. The analysis was finished on the statistical method, which determines the type of used data therefore it affects the quality of the results. The areas of application and analytical capacity of the listed methods are illustrated with the short examples, simultaneously outlining their characteristics from the analysis. The research problems, which are the canvas of application of the discussed methods are not mutually interrelated. They present different aspects of variants of the investment process.

Peer-review under responsibility of the organizing committee of the Operational Research in Sustainable Development and Civil Engineering - meeting of EURO working group and 15th German-Lithuanian-Polish colloquium

Keywords: risk management, project management, decision-making process in construction project., project selection, risk identyfication and assessment.

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Peer-review under responsibility of the organizing committee of the Operational Research in Sustainable Development and Civil Engineering - meeting of EURO working group and 15th German-Lithuanian-Polish colloquium
doi:10.1016/j.proeng.2015.10.034

1. Introduction

The phenomenon of risk is a subject of investigation for many both practitioners and theorists. However, only a few of them take these problems and try to formulate the problem within the framework of a procedure. In many publications, the authors deal with the problem of identification of hazards areas and their classification in different groups, among others, due to the source of origin, the impact size, etc. [10]. The number of papers proposing a methodology of quantifying of the risk and elaboration of procedures for the adoption of appropriate actions (so called "an appropriate strategy on risk response") is relatively lower. This paper briefly outlines the area of risk management in the construction industry against the background of the selected publications [1-31]. The aim of the paper is to present the three methods used for the risk analysis with simultaneous signaling of their characteristics features and specifying of the usefulness degree in the discussed problems. The character of the presented methods, a kind of the solved decision-making problem and the type of used data made impossible their mutual comparison. However, the authors have identified the common features of the methods, reflecting the analytical decision-making process and the individual features of each of them..

2. Risk management in construction projects

In recent years, it is noticeable the increased interest of the risk problem from the perspective of the construction industry. The research areas in the risk management are focused on the identification of random factors, determination of the probability of their occurrence and their impact on the course of a construction project. The problems, which often occur in terms of the risk analysis in the listed publications, are the following ones:

- Methodology/procedure of risk analysis for a project [1, 13, 24, 25, 26, 30].
- Proposition of risk classification according to the source of origin, type, consequences [1, 10].
- Review and classification of selected methods supporting the risk management in projects [2, 21].
- Analytical application of method/tool to a specific problem in the scope of risk analysis [4-7, 13, 15, 16-19, 22-26, 28-31].
- Risk management in construction projects – theory and practice [3, 8, 9, 27].

A risk, as a measurable part of the uncertainty, is most often treated in the literature as a possibility of incurring of a loss. The number and scope of the problems associated with the realization of the project is large. Before we start their in-depth analysis (in terms of risk analysis) we should find the answers to at least three key questions (Fig. 1 (a)).

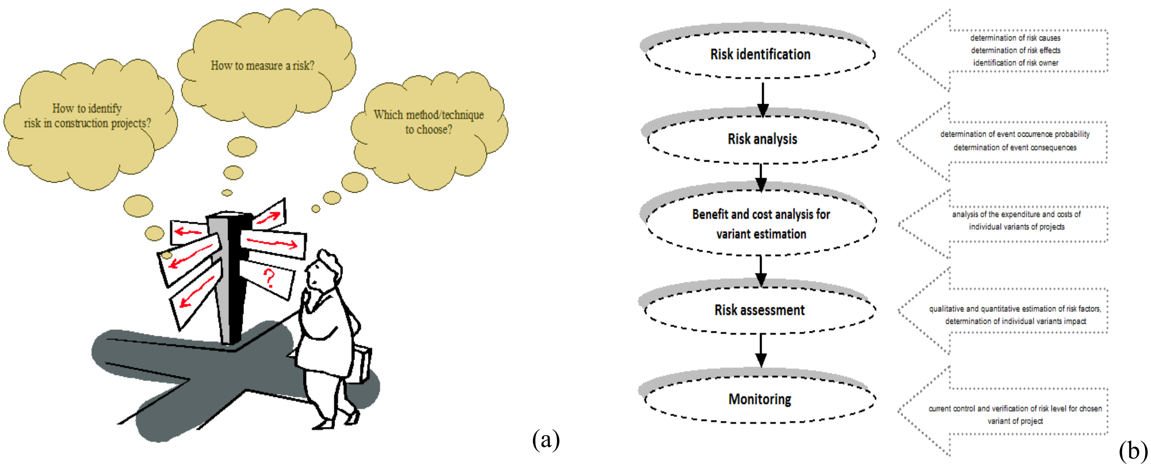

Fig. 1. (a) decision problem; (b) decision making procedure in risk management, source [own work].

In an effort to simplify the procedure (so called “the risk management”) it should be paid attention to three general links: identification, quantification (assessment) and reaction. Of course, this procedure is much more complex depending on the preferences of a decision maker and the ability of verification and analysis of the results and their subsequent implementation. Within scope of each link it might be considered another method, which results in the specific final result (Figure 1. (b)). The problem of risk was also reflected in the project management standards: POMBOK and PRINCE 2. The risk management has been designated as one of the eight main areas of the Project Management Body of Knowledge (PMBOK) by the Project Management Institute, which is the largest professional organization dedicated to the project management field [21]. An interesting and relatively clear way to identify risk is presented in the PRINCE 2, i.e. a register of risks presented by the authors of the article as an example [15].

Among the discussed areas of research in the field of risk in the construction industry it also appears a problem of development of the risk assessment procedures, the proceedings algorithms, the schematic diagrams using the system approach [1, 20, 24-26, 30].

According to the authors' opinion, the popularity of the method depends on several aspects, i.e.: the complexity of calculations, requirement of application of an appropriate computer program, the quality and clarity of the obtained results and the possibility of their verification and subsequent use during a project. Subsequently, the authors of the paper attempted to separate and list of features linking all the methods. However, the areas of use and analytic capabilities of the mentioned methods are illustrated with short examples at the same time outlining their characteristics features from the analysis..

Common features of the discussed methods:

- the subjectivity of obtained grades resulting from subjectivity in the selection of analysis criteria and the input information in the decision making process,
- repeatedly no access to information or limited scope,
- the problem with the selection of method of quantitative record of separate risk factors,
- necessity of a flexible approach!!! taking into account some additional risks associated with the specific project (the problem of the constant list of hazards for each project).

3. Chosen methods in range of identification risk in construction project

3.1. Identification of risk in construction project

At the stage of identification we should get the statement of the factors, which are possible to occur in the whole cycle of the project. The most frequently mentioned methods/tools used to identify risk factors are the following: the brainstorming, the Delphic technique, the checklists, the experts' evaluation, the internal audit in a company, the periodic document reviews, etc. The identified factors can be presented, in the next step, in the form of the Ishikawa's diagram or the risk register.

			Impact				
			1	2	3	4	5
			0-50 tys.	50 tys.-500 tys.	500 tys.-2 mln	2 mln-5 mln	5 mln-20 mln
Probability	1	0 -5%	Low	Low	Low	Medium	High
	2	5-40%	Low	Low	Medium	Medium	High
	3	40-70%	Low	Low	Medium	High	High
	4	70-80%	Low	Medium	Medium	High	High
	5	80-100%	Low	Medium	High	High	High

Fig. 2. Matrix of risk, source [own work]

An interesting proposition of the visual presentation of the risk factors in relation to the relevant construction project presents the so called “risk matrix”.

It is created with taking into account the most popular method of risk assessment: the product of the probability of occurrence and the extent of the loss expressed in accordance with the adopted scale (Figure 2.).

3.2. The use of risk matrix in risk registers in accordance with the PRINCE 2

The verification started from the simplest technique, using both the quantitative variables as well as the qualitative variables. This method is based on the considerable subjectivity of the decision maker although it is relatively simple, clear and easy to make. According to the PRINCE 2 methodology it was developed the risk register where, for imaging of an adequate scale of risk impact on a project, the risk matrix was used. In this case, in accordance with the procedure of risk management, at the same time some possible risk response strategies are suggested (Fig. 3). It is worth notice that there is not one collective assessment of the risk level.

					Risk assessment				
Lp.	The main of risks	Owner of risk	Reason/cause	Effect	Probability	Impact	Level of risk	Risk response strategy	Cost of strategy
Designing risk									
1	Lack of acceptance by Investor of design proposals	Investor	Delays in approval	Increase in costs due to the suspension of work of the design team	5-40%	50thous.-500thous.	Low	Market observation, alternative designing solutions	0
2	Delays and difficulties in obtaining opinions and permits	Investor	Delay of designing work, unknown scope of design	Disturbed designing process	5-40%	500thous.-2millions	Medium	Earlier diagnosis of the situation in local authorities offices, organization of meetings preceding designing process	50thous.
3	Conflict among designing team members	Designer office	Insufficient flow of information among team members	Disturbed designing process	0-5%	50thous.-500thous.	Low	Response of a team leader to all form of conflicts - mediation in a team	15thous.
4	Too optimistic assessment of employee workload	Designer office	Approval of unrealistic deadlines for individual work	Delay of designing work	5-40%	50thous.-500thous.	Low	Proposing for employees to work overtime or ordering of part of work to another designing team	120thous.
5	Incorrect information from investor/lack of clear guidelines	Investor	Design may be issued with duplicate error or detected error can generate timing constrains	Verification of errors will increase costs and increase time due to the development of the next revision of design	40-70%	2-5 millions	High	Application to investor for extension of time to complete a design due to additional circumstances	20thous.
6	Staff do not have sufficient knowledge about the subject of design	Designer office	Errors in design	Verification of errors will increase time due to the repeated checks of designing work	5-40%	2-5 millions	Medium	Designing team leader strengthens control over work, providing for employees consultation with an expert	65thous.
Time risk									
7	Acceptance of unrealistic deadlines in contract	Designer office	Faulty contractual provisions	Deterioration of design quality of failure to meet the deadline	40-70%	2-5 millions	High	Employment of new employees or ordering part of work to another party during a contract	105thous.
Budget risk									
8	Underestimation of design budget	Investor	Budget may not be sufficient to carry out designing tasks	Deterioration of design quality	40-70%	2-5 millions	High	Limiting scope of design to necessary minimum	40thous.

Fig. 3. Risk register with matrix of risk, source [own work].

Characteristic features matrix of risk:

- The main goal of application of this approach – identification and preliminary assessment of risk.
- Relatively easy in the analysis and interpretation of results and in their implementation, it is a summary of the current control of risk factors state in the project.
- The scale of variant measurement of a given criterion is the contractual scale.
- One of the few methods highlighting the project owner and a summary of the proposed risk response strategies.

4. Chosen methods in range of risk assessment in construction project

4.1. Risk assessment in construction project

The quantification stage (assessment, analysis) will help to determine the importance of selected factors, the probability of their occurrence and the degree of impact on a construction project. For the mentioned methods/tools, used to estimate the risk factors, we can include the following: the probabilistic methods and the probability theory, the computer simulation, the sensitivity analysis, the multi-criteria decision-making methods, the cost-benefit analysis during risk control, the decision trees, the methods of operations research and econometrics (e.g. the game theory), the fuzzy sets, the neural networks (incidental).

4.2. Multi-criteria decision-making methods

The multi-attribute approach is well suited to the problem related to selection, including: the variant of a project, investment, contractor, location, technology of production of particular structure elements in a building, choice of a tender strategy, evaluation of tenders, specifying utility state of a building, estimation of construction costs, evaluation of accident situation in the construction industry, etc. according to the predefined criteria (the qualitative ones and the quantitative ones) [5, 11, 12, 22, 24, 29, 31]. In the Fig. 4 it is presented an assessment of investment projects from the perspective of a risk. It was used one of the popular multi-criteria methods, namely PROMETHEE, and it was assumed the similar significance criteria as at the risk register. In this approach, we get the only one summary assessment, as well as the hierarchical ranking of projects/variants.

	Selection criteria for risk	Weight of criterion	Project A	Project B	Project C	Surrogate criterion	δ (a,b)	δ (a,c)	δ (b,a)	δ (b,c)	δ (c,b)	δ (c,a)
Designing risk	Lack of acceptance by Investor of design proposals	0,100	7	5	3	δ_1	2	4	-2	2	-4	-2
						P_1	0,666667	1	0	0,666667	0	0
	Delays and difficulties in obtaining opinions and permits	0,110	4	6	4	δ_1	-2	0	2	2	0	-2
						P_1	0	0	0,666667	0,666667	0	0
	Conflict among designing team members	0,030	2	6	3	δ_1	-4	-1	4	3	1	-3
						P_1	0	0	1	1	0,333333	0
	Too optimistic assessment of employee workload	0,060	3	3	6	δ_1	0	-3	0	-3	3	3
						P_1	0	0	0	0	1	1
	Incorrect information from investor/lack of clear guidelines	0,190	4	5	3	δ_1	-1	1	1	2	-1	-2
						P_1	0	0,2	0,2	0,6	0	0
	Staff do not have sufficient knowledge about the subject of design	0,105	4	4	3	δ_1	0	1	0	1	-1	-1
						P_1	0	0,2	0	0,2	0	0
Time risk	Acceptance of unrealistic deadlines in contract	0,210	3	4	7	δ_1	-1	-4	1	-3	4	3
						P_1	0	0	0,2	0	1	1
Budget risk	Underestimation of design budget	0,195	5	4	4	δ_1	1	1	-1	0	-1	0
						P_1	0,2	0,2	0	0	0	0

Aggregate of preferences indices					0,105667	0,198	0,183333	0,305	0,28	0,27
	A	B	C	Φ^+	Φ^-	Φ	The accepted level of preference p=3		
A	0	0,106	0,2	0,1518	0,231667	-0,07983	The accepted level of indifference q=0,5		
B	0,183	0	0,31	0,2442	0,187833	**0,05633**			
C	0,28	0,27	0	0,275	0,2515	0,0235			

Fig. 4. project selection using multi attribute approach, source [own work].

Characteristic features multi attribute approach:

- Relatively easy in application and interpretation of the results and in their implementation.
- This approach is mainly used in the selection of the decision-making variants, hierarchy of problem solutions.
- They allow the application in the decision-making process of the twofold character of the data: qualitative and quantitative.
- Possibility of combining with other methods forming the so-called "hybrids".
- The scale of measurement of variant of a given criterion is the contractual scale.

4.3. Statistic approach

As the last, it was presented an analysis based on the statistic approach, which determines the type of used data by what it affects on the quality of the obtained results. The minority of statistical indicators base on the quantitative data, by what it would seem that the results will be qualitatively better to than the results obtained in other techniques. This is not always true. The quality of data and reliability of their collection and classification are very important to. The incorrect data will generate the misleading results. The methods, that can be used to determine the relationship between the variables risk factors, we can include the following: the correlation, the regression analysis, analysis of variance. The used, in the example, regression analysis is to determine the strength and direction of the relationship between variables. At the same for this method the quantitative data are preferred. Thus, it was adopted the numerical scales for the qualitative features (the level of risk and the realization system). After developing a regression model the key issue plays the degree of fit of the model to the empirical data, as well as checking the type of relationships between variables (linear, nonlinear). The authors of the paper have focused on the possibility of using the regression analysis in determining the amount of the reserve at a risk for a contract developing the model based on the data from the previously completed projects.

Table 1. Distribution parameters, source [own work].

	Coefficients	Standard deviation
Intersection	223 265,47	27 682,73
Size of contract	0,0028	0,0006

	Coefficients	Standard deviation
Intersection	118 982,80	57 577,88
Level of risk [1-10]	28 875,36	14 534,18
Size of contract	0,0013	0,0009

	Coefficients	Standard deviation
Intersection	139 571,85	77 677,24
Level of risk [1-10]	28 790,00	15 462,47
System project implementation [1-3]	-6 780,98	15 733,59
Size of contract	0,0011	0,0011

Table 2. Statistic regression, source [own work].

	1 variable	2 variables	3 variables
Statistics regression			
R multiples	85,68%	91,10%	91,38%
R-squared	73,40%	82,99%	83,50%
Adjusted R-squared	70,08%	78,13%	75,25%
Standard error	36364,58261	31086,71625	33069,50459
Observations	10	10	10
Variables	Size of contract	Size of contract	Size of contract
		Level of risk [1-10]	Level of risk [1-10]
			System project implementation [1-3]

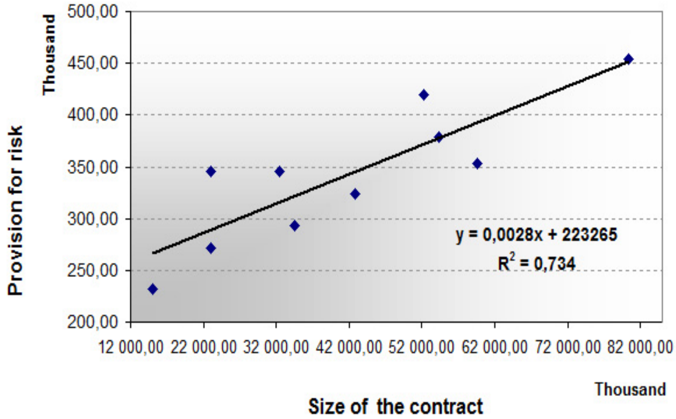

Fig. 5. linear regression curve for one variable (size of the contract), source [own work].

In the developed example, on a set of 10 construction projects, the authors identified three variables that can affect the level of risk reserve, i.e.: the size of a contract, the level of risk and the system project realization. Table 1 and table 2 shows that together with the increase of the number of explanatory variables increase the degree of fit of the model. The R-squared is 83.5% for 3 variables. It is worth noting how great impact on the amount of the reserve has a size of the contract (Fig. 5, Tab. 2). Both the R-multiples (the Pearson correlation coefficient) as well as the R-squared are relatively high, and they are 85.68% and 73.40% respectively. The high R-multiples reflect the linear relationship between the variables. In the presented model, with the known value of size of the contract, as well as a certain level of risk for a project, we can calculate the corresponding amount of the reserve at a risk. It is worth noting that the increase of the number of variables in the model does not always improve the quality of the obtained results.

Characteristic features statistic approach:

- Fulfillment of restrictive assumptions (size of research sample, type of data).
- Impact of the data character (no possible application of certain measures for quality data).
- An introduction to simulation with known distribution of the random variable.
- The standard deviation, coefficient of variation and coefficient of variation are the basis for the selection of projects and determine the safety margin of projects.

5. Monitoring and controlling of risk in construction project

The aim of risk management is quantification of the undesirable, previously selected random factors, determination of their impact on time and cost of a construction project and the development of an alternative variant of realization, the actions minimizing damages or, for instance, the emergency time schedule [25, 26]. At the final stage of the procedure it is developed the response strategies – the method/procedure which could take some appropriate actions, or minimizing of the further effects of the undesirable events for the smooth realization of a project i.e. avoid, mitigation, transfer, etc.). The examples of some possible strategies are presented in the appropriate column of the Risk Register (Fig. 3).

6. Conclusion

The character and specifics of the construction industry makes that the analysis of the impact of risk factors on a construction project is more often taken, despite the major difficulties of their quantification. The problem of risk management is not only current but it is essential for the efficient planning and realization of a construction project. When choosing a method of analysis and the final risk assessment one should be guided by its usefulness and readability and ease of interpreting the obtained results, which in this article the authors have tried to present in a concise way.

The risk management in the construction industry requires a complementary, interdisciplinary, flexible approach allowing to capture the changing character of risk factors (qualitative, quantitative) as well as it requires a precise description and explanation of the mechanisms involved in the organization of construction production. Therefore, in developing of a risk assessment model in the construction projects it should be emphasized on the compilation even available and already recognized tools so to use a hybrid approach.

The most popular methods (of project risk analysis) are the following: the methods for the identification and preliminary assessment of risk (the matrix of risk or sometimes the Ishikawa's diagram) and the methods supporting the decision-making process in the assessment and selection of projects (the multi-attribute and the statistic approach). The scope of application and degree of difficulty of particular tools are different, however these should not discourage their use depending to the accepted aim of analysis. There are only few studies using the artificial neural networks. Perhaps, this is mainly due to the need to use the right software and the complexity of the method.

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