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The Methodology of Risk Assessment in the Planning of Construction Projects

Elżbieta Szafranko
University of Warmia and Mazury, Olsztyn, Poland

Any investment project bears some burden of risk. An investor who plans to carry out a building investment must be aware of the hazards that can be encountered while pursuing the project. Risk analysis can be supported by multi-criteria methods, which allow the user to assess the risk level while taking into account various risk-affecting factors. The aim of this article is to present and compare methods for estimating the level of risk. The article shows an example of risk assessment using methods Preliminary Hazard Assessment, Hazard Matrix and the method not used to this type of calculation Indicator method. Conducted in Article calculations show the possibility of using methods from the group of multi-criteria analysis and the results show the usefulness of the methodology developed by the author. This analysis involves a construction development designed for the tourism business. This is an interesting example due to the specific nature of the object and its location. The calculations take into account the difficult implementation conditions and the results show what you should pay attention to when planning investment.

Keywords: construction activities, risk management, risk estimation, matrix method, indicator method

Introduction

Investment undertakings in the construction business represent a wide range of activities: from developing the concept of a construction to the moment when it is made available to the end-user. The process manager is responsible for elaborating the concept, making a costs breakdown, hiring designers and developers, finding suppliers, supervising the construction works and, finally, handing over the building to the user. All these activities are extremely varied in character and they all involve a great number of people participating in the building process. On each occasion, the process of completing a new construction project is unique and irreproducible (Kapliński, 2013). These two characteristics mean that investments in the building industry are loaded with much higher risk than projects undertaken in other areas of business activity (Skorupka, 2008). The hazards possibly encountered during a building development project can be broadly divided into two groups: internal and external ones. The former groups comprise all events and process occurring within a building company and are directly linked to this company's activity (Szafranko, 2001).

Internal risk can be further subdivided into:

- local risk, comprising factors directly connected with a given development project, carried out at a specific construction site. These are the conditions created at the building site, the labour force (qualifications)

Elżbieta Szafranko, Ph.D., Faculty of Geodesy, Geospatial and Civil Engineering, Institute of Building, University of Warmia and Mazury, Olsztyn, Poland.
Correspondence concerning this article should be addressed to Elżbieta Szafranko, Heweliusza 10; 10-724 Olsztyn, Poland.

and machines (reliability), dedication to completing the tasks, technologies and materials used (quality), contracted companies (reliability) hired for certain parts of the project.

• global risk, depending on the events arising from the construction and design solutions in line with the art of building and depending on the construction site. The global risk is also affected by the stipulations of the contracts drawn to complete the construction project, the legal environment, management systems, both within the building company and the ones created for the sake of a current development. The level of global risk is also affected by the contractors, the timely completion of construction works, and the sound financial standing of the prime contractor, sub-contractors, and the investor.

• External risk is inherent to any activity people undertake. However, the extent to which it affects investors engaged in various types of business activity will vary. The level of external risk depends on the geopolitical and economic circumstances, the climate and the country's economic stability. They are the factors that we cannot change but of which we should be aware. Construction projects are particularly sensitive to all types of hazards, mostly because they depend on many branches of the economy (transportation, power industry, chemical industry), but also because most of the investment process is executed outdoors (Zavadskas, Turskis, & Tamošaitiene, 2010; Qadir, Mateo-Sagasta, Jiménez, Siebe, Siemens, & Hanjra, 2015).

Theoretical Background—Literature Review

It seems pointless to explain why risk must be controlled and managed. Most investors prefer a situation where the potential hazards have been diagnosed and accounted for in a planned investment. Hence, attempts have long been made to foresee scenarios that raise the level of risk. Depending on the type of risk, there are various ways of controlling threats and lowering the risk. Among the events which affect the risk level, some appear more frequently and others which are rarer, some have graver consequences and some are less dangerous. Finally, there are such hazards that are easier to control or eliminate and there are ones which are unpredictable and whose strength cannot be reduced (Kuchta & Skorupka, 2012). Over the many years of research, different risk management strategies have been developed, depending on the specific nature of investment projects and the category of hazards involved. Literature provides numerous methods applicable to controlling the risk level or diminishing adverse consequences of risk situations. But whichever method is proposed, the most essential step is to identify the event which raises the risk level and to determine the degree to which that event will influence the undertaken project (Dziadosz, Tomczyk, & Kapliński, 2015).

Prior to the commencement of any building investment project it is therefore necessary to investigate thoroughly all the circumstances affecting its performance in order to identify all possible factors that may threaten its successful execution. Such analysis ought to include the investor's experience to date, gained from similar projects or projects performed in similar conditions executed previously. The subsequent step will be to select a method for assessment of the risk level inherent to the current project (Tervonen, Naci, van Valkenhoef, Ades, Angelis, Hillege, & Postmus, 2015; Akintoye & MacLeod, 1997).

Methodology of Research—Methods for Risk Level Assessment

Methods applied to analyzing risk are broadly discussed in literature (Słomka, 2005; Szafranko, 2014). Most of them rely on qualitative assessment of both the extent of damage and the consequences of negative scenarios. The assessment is based on matrices, from which an analyst can read values of the relevant parameters, estimated on a previously adopted descriptive scale. In a risk analysis conducted according to the

Preliminary Hazard Assessment (PHA), the graveness of a potential hazard is evaluated by evaluating the severity of damage (S) and the probability at which the damage may occur (P) (Table 1). The evaluation of a hazard is expressed with the hazard index (HI), which is defined by the equation:

$$HI = S * P \tag{1}$$

where: S—severity of damage, P—probability of the occurrence of a given hazard.

Table 1
Assessment of the Severity of a Damaging Effect Caused by a Hazard (S) and the Probability of the Occurrence of the Damage Caused by the Hazard (P)

Level	Description of the severity of damage S	Description of the probability of the damaging event P
1	Light injuries. Light damage	Highly unlikely
2	Minor injuries. Measurable damage	Unlikely, happens once (a few times) every 10 years
3	Major injuries. Considerable damage	Sporadic events, happen once (a few times) a year
4	Single fatal accidents. Large-scale damage	Quite frequent events, happen once (a few times) a month
5	Multiple fatal accidents. Very large-scale damage at the plant's premises	Frequent and regular events, happen once (and even more often) a month
6	Mass fatal accidents. Very large-scale damage outside the plant's premises	Highly likely (may happen even every day)

Source: Słomka (2005); Szafranko (2014).

Having assessed the parameters, the risk is evaluated according to a hazard matrix (Figure 1).

		P – probability					
S – severity of damage	**Level**	**1**	**2**	**3**	**4**	**5**	**6**
	1	**1**	**2**	**3**	**4**	**5**	**6**
	2	**2**	**4**	**6**	**8**	**10**	**12**
	3	**3**	**6**	**9**	**12**	**15**	**18**
	4	**4**	**8**	**12**	**16**	**20**	**24**
	5	**5**	**10**	**15**	**20**	**25**	**30**
	6	**6**	**12**	**18**	**24**	**30**	**36**

Figure 1. Hazard matrix. Source: Słomka (2005); Szafranko (2014).

The hazard is evaluated on three levels:

- 1-3—acceptable hazard;
- 4-9—allowable hazard after the risk assessment;
- 10-25 (36)—unacceptable hazard—the risk level must be lowered.

Another method often used in risk analysis is the Hazard Matrix. It is also a matrix-based method, designed to perform a descriptive analysis of adverse scenarios, but without determination of values of parameters. The characteristics of consequences are presented in Table 2, while Table 3 describes the probability of occurrence of the scenarios.

Table 2

Estimation of the Severity of Consequences

Consequences	Descriptive characteristics
Low severity	Events of low severity, causing small delays and damage up to 10% of the value, e.g. damage to building materials, breakdown of a machine, unfavorable weather conditions, etc.
Medium severity	Events of more severe consequences, lasting longer or repeated, causing delays and damage between 10-50% of the value, e.g. damage of a whole load of materials, a breakdown of a machine causing a long stoppage or a need to replace the machine, unfavorable weather conditions lasting for more than a month, etc.
High severity	Events of high severity, persistent or repeated, causing the stoppage of construction works and damage above 50% of the value, e.g. damage of construction elements or materials, a construction catastrophy, natural disasters, etc.

Source: Słomka (2005); Szafranko (2014).

Table 3

Estimation of the Probability of Consequences

Probability	Descriptive characteristics
Quite improbable	Consequences of the hazards which should not occur during the whole professional career of a worker. They should not occur during the whole active life of a contractor's and investor's company
Probable	Consequences of the hazards which may occur no more than a few times during the whole professional career of a worker. They may occur no more than a few times during the whole active life of a contractor's and investor's company
Highly probable	Consequences of the hazards which may occur many times during the whole professional career of a worker. They are frequent in building practice

Source: Słomka (2005); Szafranko (2014).

Once the parameters are assessed, the risk is evaluated according to a hazard matrix on a three-grade (Figure 2) or five-grade scale.

Probability	Severity of consequences		
	Low	Medium	High
Low	Low 1	Low 1	Medium 2
Medium	Low 1	Medium 2	High 3
High	Medium 2	High 3	High 3

Figure 2. Evaluating the risk on a three-grade scale. Source: Słomka (2005); Szafranko (2014).

The norm recommends certain measures to prevent the risk from occurring, depending on the achieved value. It is suggested that the results of an assessment should be accompanied by the recommendations which lower the risk level.

Indicator method. An approach which can be proposed as an alternative solution to hazard assessment is the multi-criteria analysis method. It allows the user to take into consideration various factors which influence the final outcome of a planned investment (Szafranko, 2015; Linkov, 2016). One specific characteristic of the multi-criteria analysis method is that it can take into account negative effects of given factors on the execution of the investment, both locally (i.e. at a construction site) and more globally (e.g. the surroundings of the building site).

The indicator method uses matrices (constructed in the form of tables), in which individual events connected with the construction project are described, and each subsequent factor is assigned a weight that signifies its importance. The tables may contain a comparison of several investments, which can help an investor choose which contract to sign (the one where the risk level is lower). Table 4 illustrates the principle for constructing a matrix.

Table 4

The Matrix for Indicator Method

No	Analyzed factor	Object 1			Object 2			Object 3			Weight of the factor
1	A1	P_{11}	Q_{11}	R_{11}	P_{12}	Q_{12}	R_{12}	P_{13}	Q_{13}	R_{13}	W_1
2	A2	P_{21}	Q_{21}	R_{21}	P_{22}	Q_{22}	R_{22}	P_{23}	Q_{23}	R_{23}	W_2

Source: Szafranko (2015).

The number in the upper, left-hand corner of each cell denotes the direct effect, while the one in the lower, right-hand corner signifies an indirect effect of a given factor on the investment. In the middle of a cell, there is the sum of effects multiplied by the weight. The sum of individual consequences yields an assessment of the influence of a given factor on the general level of risk associated with the completion of the analyzed investment (Szafranko, 2015).

The partial evaluation of the risk for *i*th factor of *j*th event:

$$Qij = (Pij + Rij) * WI \tag{2}$$

where: Pij—direct effect of i factor connected with j event;

Rij—indirect effect of i factor connected with j;

Wi—weight of the analyzed factor (Szafranko, 2015).

Identification and Assessment of Investment Hazards—Research Results

In this case study, an investor is planning to build a holiday resort on a lake shore, near a highly valuable, protected nature area. The chosen site lies in a very attractive landscape and offers many opportunities to pursue a wide range of activities by tourists and holidaymakers. An analysis of similar investment projects has generated the following observations:

When a holiday resort is to be created in an exceptionally attractive location, it is likely to cause protests on behalf of groups engaged in nature conservation. The investor has learnt from his own experience that such a reaction is possible. He has previously built similar developments and has been challenged by protesters. The consequences were delays of construction works and measurable losses. The description of the risk—hree out of the 10 examined cases involved social protests. It was necessary to run an information campaign to explain that the planned development would not harm the natural environment but could bring profits to the local community (risk of social protests).

When planning to construct buildings on a lakeshore in a forest, it is necessary to explore well the surroundings. The soil conditions, if not recognized thoroughly (and especially when they are unsuitable for building), may lead to serious complications, including a construction catastrophy. In his ten-year practice as a developer, the investor has been faced with such a situation once. In two other cases, problems appeared during construction works due to the difficult and erroneously assessed soil and water conditions. The consequence was delays and changes in the design (risk of bad soil conditions).

The planned resort lies far from public roads and the passage of heavy vehicles through forest and field dirt roads will be extremely difficult. An analysis of similar cases showed that this was a cause of delays and damage of transported materials. Also, lorries used for transport are damaged. Such problems occurred at least once a month and caused measurable losses. Due to the location of the building sites, the problem of transporting supplies was raised in all the analyzed cases (risk of delayed and damaged supplies).

Changes in the scope of works, due to mistakes in the design or misunderstandings between the designer and investor, are commonplace. In seven out of the 10 analyzed cases, there were such alterations, which led to delays. In most cases, the investor had to go through the red tape to make such changes legal. This happened three times a year but did not cause any serious complications (risk of changes in the design).

Calculation of the Risk Level With the Preliminary Hazard Assessment (PHA) Method

The Hazard Index is derived from formula (1), for which we determine S—the severity of damage, based on Table 1, and P—the probability of the occurrence of damage due to a hazard, and the Hazard Index HI—from Figure 1.

The results presented in Table 5 enable us to analyze the hazards which occurred when similar investments were executed. For the events which were more likely to appear, the hazard index is higher. This is a warning signal for the investor and contractors that they should constantly monitor the level of risk caused by event number 3.

Table 5

Specification of the Calculations Performed With the PHA Method

Example	Severity of damage S	Probability P	Hazard Index HI
1	2	3	6
2	3	2	6
3	2	4	8
4	1	3	3

Risk Assessment—The Risk Matrix Method According to PN-N-18002

The procedure was applied to the cases described above. The method relies on a descriptive analysis and evaluation of certain events, presented in Tables 2 and 3. Table 6 contains the risk assessment results and some prophylactic measures.

Table 6

Risk Assessment According to the Risk Matrix Method

Example	Severity of consequences	Probability of consequences	Level of risk (Table 5)	Preventing measures
1	Low severity—small delays	Probable—has happened several times over the past 3 years	Low (1) acceptable	A campaign to make the community aware of benefits derived from the project. Dispelling worries about the adverse impact on nature
2	High severity —a building catastrophy	Quite improbable – one such case over the past 10 years	High (3) unacceptable	Recommendation to make early and complex examination of the soil conditions at a site chosen for the construction.
3	Medium severity —damage of transport vehicle/load	Highly probable —happens as often as several times a month	High (3) unacceptable	Prepare transportation routes, repair road surfaces, choose lighter vehicles for transport
4	Low severity	Probable—has happened a few times a year previously	Low (1) acceptable	While developing the design, maintain constant contact and run consultations between the investor and designers

Analysis Performed According to the Proposed Indicator Method

This approach to the analyzed risk level is slightly different. First, we need to estimate the importance (weight) of individual factors that can cause danger. They are determined on a scale from 0 to 9, and the sum equal to 100% is 1. The second step is to assess the potential impact on the immediate and further surroundings in which a hazardous event might occur. An important characteristic of this method is that it enables one to assess negative effects of the analyzed factors. Regarding hazards, each hazardous event has a potential, negative effect on the planned investment. The assessment was made on a scale from -5 to 5. The calculations are contained in Table 7.

Table 7

The Calculations With the Multi-criteria Method

No	Analyzed factor		Analyzed investment		Weight of the factor
	1	-2	-0.5	-3	0.1
2	2	-5	-3.2	-3	0.4
3	3	-3	-1.8	-3	0.3
4	4	-2	-0.6	-1	0.2
	Total		-6.1		

The results found in Table 7 suggest that the gravest threat to the investment may be posed by the difficult and incompletely investigated ground conditions.

Analysis of the Research Results

All the calculations and estimations, carried out with the three methods, are set in Table 8. The results obtained with the first method suggest that the gravest threat stems from the difficulty in assuring timely supplies. In this case, the high risk level is mostly due to the high likelihood and frequency of the occurrence of a problem. The second method implicates that factors 2 and 3 pose the highest risk. The second factor—the hazard due to poor soil conditions – scored high because of the extreme severity of the problem if it should occur. This method, based on descriptive analysis, allows the user to obtain a detailed description of the hazards and recommendations on how to avoid them and lower the risk.

Table 8

Comparison of the Results Yielded by the Three Methods

No	Type of hazards	Result of the PHA method—level of risk	Results of the matrix method (descriptive)	Results of the indicator method
1	Risk of social protests	6—acceptable after assessment	Low (1) acceptable	-0.5
2	Risk of bad soil conditions	6—acceptable after assessment	High (3) unacceptable	-3.2
3	Risk of delayed and damaged deliveries	8—acceptable after assessment	High (3) unacceptable	-1.8
4	Risk of changes in the design	2—acceptable	Low (1) acceptable	-0.6

The third method comprises an analysis that accounts for negative effects of the analyzed events. The results produced with this method implicate that the most dangerous threat to the planned investment arises from the second factor. As previously, this outcome is due to the high score assigned to this factor both in terms of direct and indirect effects.

The graphic representation of the results obtained with the two former methods (Figure 3) shows that the risk to the investment posed by the first and fourth factor is lower than that caused by the second and third groups of hazards. This can be read from the position of the circles corresponding to the factors.

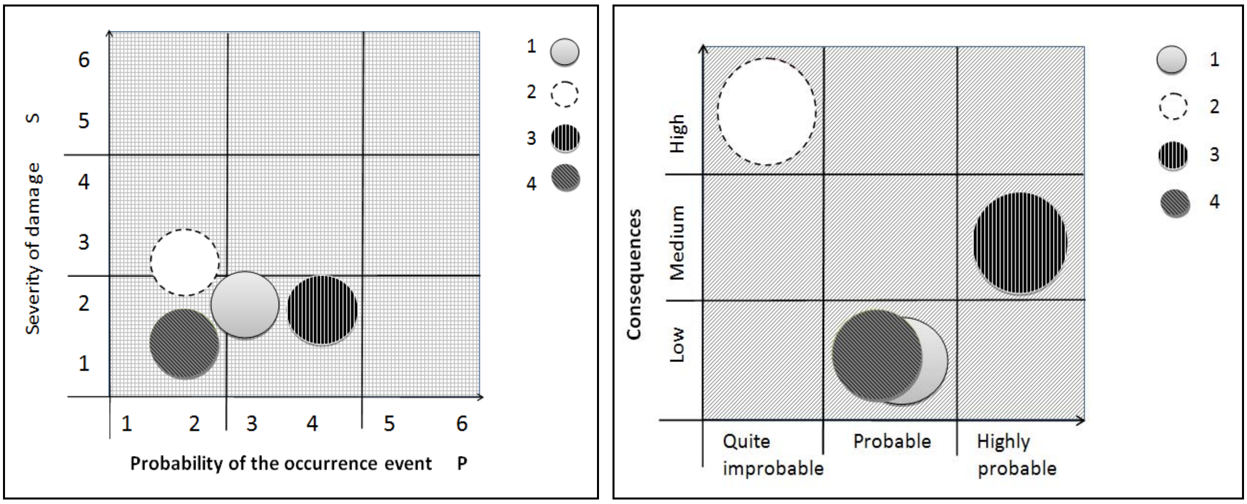

Figure 3. Graphic representation of the results of risk assessment achieved according to the PHA and matrix-descriptive methods.

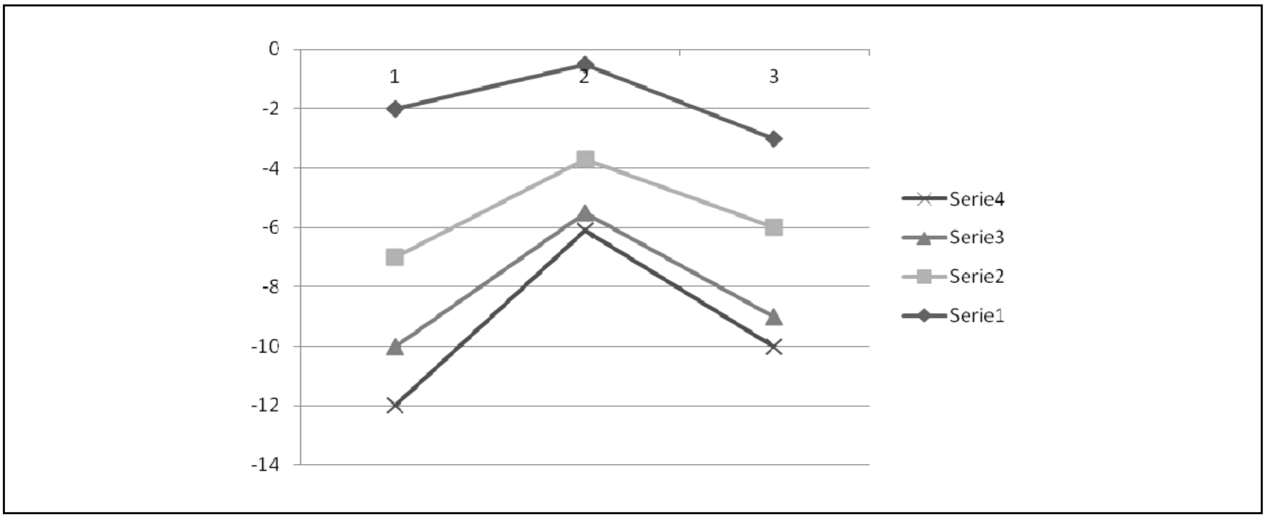

Figure 4. Graphic representation of the results of risk assessment achieved with the indicator method.

The graphic representation of the results yielded with the third method (Figure 4) shows an accumulated impact of the effects, including weights of the analyzed factors. The distance between the line representing factors 2 and 3 indicates the highest total risk to the investment.

Conclusions

An adequate appraisal of the risk associated with the execution of construction development projects is an extremely important component of risk management systems. The whole procedure is based on the identification of factors which pose a threat to an investment project and their subsequent evaluation. The examples discussed in this article illustrate how we can apply the principal methods for risk assessment recommended by legal regulations (norms like PN-N-18002) and literature. The first method is the simplest to use, but the results are more like approximations. The second method, based on matrices and descriptions, is more exact but must be preceded by a detailed analysis of the researched scenarios and involves a specific description of the severity of hazards and probability of their occurrence. The indicator method, which is a multi-criteria analysis, offers other options, for example negative effects of events can be accounted for. An application of this method also allows for a simultaneous evaluation and comparison of several investment projects, which may help contractors to choose a project loaded with a lesser risk.

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