

I. PROBLEMY WSPÓŁCZESNEGO ZARZĄDZANIA (*CONTEMPORARY MANAGEMENT ISSUES*)

Risk management in projects using the example of construction undertakings

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Keywords: management, risk, projects, construction

Słowa kluczowe: zarządzanie, ryzyko, projekty, budowa

Synopsis: The article is related to risk management in construction undertakings. The authors discuss the nature of construction undertakings and legal aspects of these types of projects. The article presents an example of risk quantification which may occur during construction projects. The presented method of risk assessment is the authors' original solution.

Introduction

The future is probabilistic, i.e. burdened with risk. This risk is a consequence of the fact that all events that take place in the future are more or less probable. None of them is absolutely certain and none of them is impossible. After an introductory analysis this statement is beyond discussion. This means that there is always some risk in planning anything and even more so in planning projects and the execution of projects. Accepting such an assumption determines the need to examine the problem of risk.

Risk assessment is quite commonly researched in numerous scientific centres all over the world and especially in the United States of America [Skorupka, 2004, 2008; Skorupka, Duchaczek, Szleszyński, 2013; Skorupka, Duchaczek, 2013].

Except for risk assessment another important issue is risk management. As a result an assumption can be put forward that one of the biggest challenges, and at the same time difficulties, in project execution is risk management. A basic element in the risk management process is appropriate identification and quantification of risk which are discussed in this article.

Legal aspects of construction undertaking management

Legal aspects discussed in this part define the specificity of construction undertakings. Two legal acts which are especially significant are: Act on Public Procurement Law and Construction Law.

Public Procurement Law encompasses legal and financial issues, it is the basis of the activity of construction entrepreneurs working on investments financed from public resources.

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Such entrepreneurs have to observe all legal regulations related to tender offers and spending public resources coming from state or municipality budgets.

On the other hand, Construction Law defines basic construction notions and forms a legal basis for execution of construction undertakings, i.e. construction objects. Construction objects encompass [Construction Law, 1994, p. 1]:

- structures with installations and technical equipment,
- structures which form one functional and technical unit with installations and equipment,
- small architectural objects.

Construction Law defines not only construction objects but also construction processes. Basic construction processes encompass [Construction Law, 1994, p. 2–3]:

- construction site – building a construction object in a particular place and reconstruction, outward extension and upward extension,
- construction works – construction and any work related to reconstruction, assembly, redecoration or demolition of a construction object,
- reconstruction – construction works as a result of which performance characteristics or technical parameters of an existing structure are changed, except for characteristic parameters such as: cubic capacity, footprint, height, length, width or number of floors; in the case of roads some characteristic parameters can be changed as long as the limits of the right-of-way are not changed,
- redecoration – construction work in an existing construction object where its original condition is reconstructed, which is not day-to-day maintenance, however, it is possible to use construction materials different from those used originally.

Construction Law also defines legal and administrative issues encompassing [Construction Law, 1994, p. 3]:

- building permit – a formal decision allowing the start and execution of construction works or to execute construction works other than the erection of a construction object,
- construction documents – a building permit with an attached construction design, a construction logbook, partial and final acceptance protocols, if need be drawings and descriptions necessary for the construction of an object, basic trig data and a quantity survey report, in the case of assembly works also an assembly construction log,
- as-built documentation – construction documentation with amendments made during construction works and post-completion setting-out.

The above mentioned documents form the basis for standardisation of all aspects of construction projects.

Risk management in projects

A project is an undertaking with defined time, budget and resources. A project has a beginning and an end as well as an estimated execution cost. In addition to this it is unique and cyclical. Project objectives are achieved through the management of an undertaking. The main components of management are: project initiation, planning, execution, monitoring, inspection and project completion.

A project is always executed in certain surroundings which are divided into close and further surroundings. These surroundings are in interaction with a project. A possible consequence of this interaction is with interference to process execution called risk factors by the authors of this article. A required reaction, resulting from the awareness of this fact, is identification and quantification of risk, which may be the basis of a risk management process. There are various definitions of this process. One simple and consequently clear definition was presented in *PMBOK* [Project Management Institute, 2008]. The method combines six basic processes:



- planning risk management,
- risk identification,
- quality risk management,
- quantity risk management,
- planned reaction to risk,
- risk monitoring and control.

Risk management is defined here as a systematic planning, identification, quality and quantity analysis process as well as reaction to risk. The most important distinctive elements in the risk management process are risk monitoring and control.

In the monograph entitled *Managing Project Risk* [Brown, Chong, 2000, p. 258] authors describe common risk analysis stages. In practice risk analysis, and risk management which is related to it, depends on the type of project. The following part of this article describes risk analysis aspects relevant to construction undertakings.

Risk management in construction undertakings

Construction undertakings involve risk which is characteristic for this sector. Realistic project execution is connected with high risk. A division of risk factors is proposed for the purpose of increasing the clarity of their specification. This division depends on the place of occurrence of a given factor. For example, a potential risk factor may be closely linked to the project or it could come from indirect, more distant influences. It may also be directly related to the undertaking. Risk management factors, whether from close or distant sources, can be generally considered universal, i.e. related to any type of construction undertakings. Risk factors directly related to a project depend on the project type. For example, there are different risk factors in road construction undertakings and different ones in general construction undertakings or industrial construction projects.

Below there is an example of risk factors specification for general construction undertakings:

- calculation errors in the project (K1),
- wrong measurements,
- loss of financial liquidity (K2),
- contract precision,
- wrong land classification,
- technological changes,
- equipment faults (K3),
- delays in resources delivery,
- changes to resources prices,
- changes to materials prices (K4).

The following part of this article presents introductory risk assessment on the basis of four of the above mentioned risk factors.

Sample risk quantification

In primary sources the notion of risk is understood and defined in various ways. The authors have suggested that risk R_i – the occurrence of interferences in construction process execution, should be defined using expression (1), i.e. the product of probability p_i of the occurrence of a given factor and consequence c_i resulting from its occurrence divided by the sum of these products for all n analysed construction objects [Skorupka, Duchaczek, 2013]:

$$r_i = \frac{p_i c_i}{s} \quad (1)$$



where

$$s = \sum_{i=1}^n (p_i c_i) \quad (2)$$

assuming that the value of probability p_i and consequence c_i is a number in interval $\langle 0;1 \rangle$. Assuming that the sum of probability p and interference in the execution of all construction processes is:

$$p = \sum_{i=1}^n p_i = 1, \quad (3)$$

and the sum of the consequence c of these interferences occurrence:

$$c = \sum_{i=1}^n c_i = 1, \quad (4)$$

then risk R of interference in construction process execution n is equal to:

$$r = \sum_{i=1}^n r_i = 1. \quad (5)$$

The authors suggest using two selected optimisation methods, i.e. the AHP analysis and Bellinger's method in the assessment of probability p_i and consequence c_i . Their advantage is that the adopted hierarchy of decision variants can be scientifically explained in a very simple way without referring only to one's knowledge, experience or intuition.

The Analytic Hierarchy Process (AHP) was developed and described by T. L. Saaty [Saaty, Vargas, 2001]. A clear description of this method was presented by A. Ostręga [Ostręga, 2004, pp. 59–66] who described the theoretical background of its applications in practical engineering problems.

Among the numerous advantages of AHP analysis, one should distinguish the two most important ones. The first one is presenting a decision problem in a hierarchical model and the other one is the possibility to use measurable and non-measurable factors [Ostręga, 2004, p. 60].

In the case of measurable values (numerical ones) the authors suggest using Bellinger's method which was named after its author B. Bellinger. It is a multi-criteria analysis method which arranges objects on the basis of the value of their total assessment determined from a set of adopted partial criteria. P. Górny showed a detailed algorithm used in the discussed method and presented it in eight stages [Górny, 2004, p. 75].

A definite advantage of this method is its simplicity and clarity of calculations, at the same time, as it was shown by the authors of this article, calculation results are concurrent with the results obtained using more sophisticated methods, e.g. the Electre III method [Skorupka, Duchaczek, Szleszyński, 2013].

Taking into account the fact that calculations made using a multi-criteria optimisation method is often quite mundane, the authors have developed a simple computer application "Risk assessment – ver. 2.0" (Fig. 2) which makes the analysis process completely automatic [Skorupka, Duchaczek, 2013].



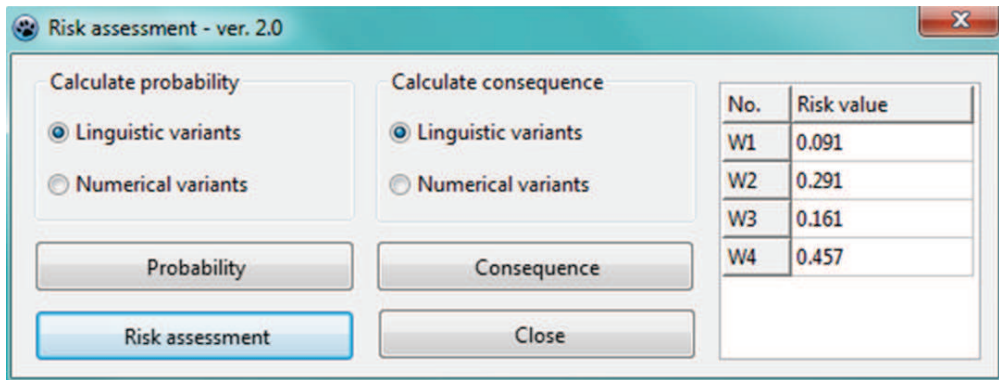


Fig. 2. Application dialogue box “Risk assessment – ver. 2.0”
 Source: [Skorupka, Duchaczek, 2013].

To illustrate the principle of operating the above method, an example of risk assessment r_i has been presented, it shows interferences within the construction process of four hypothetical construction objects.

In the discussed example, due to the fact that most variants used in calculations were linguistic (non-measurable), the AHP method was used to assess probability p_i and consequence c_i of the occurrence of construction process interferences.

At this stage of research, in the assessment of the probability p_i of interference work on selected construction objects, and the assessment of their consequence c_i , only four of the selected criteria described above (risk factors K1 – K4) were adopted.

Table 1 presents criteria weights adopted in the analyses. A subjective assessment expressed by the priority value showed that Criterion 3 (equipment faults) had the largest influence on interference probability in a construction process, while the most significant consequence for the execution of a construction process were related to the occurrence of Criterion 1 (calculation errors in a project).

Tab. 1. The analysis of adopted criteria weights

Specification		Probability assessment					Consequences assessment				
		K1	K2	K3	K4	Priority	K1	K2	K3	K4	Priority
Criterion 1	K1	1	0.5	0.25	0.5	0.111	1	1.5	3	2	0.396
Criterion 2	K2	2	1	0.5	1	0.222	0.67	1	2	1.5	0.272
Criterion 3	K3	4	2	1	2	0.444	0.33	0.5	1	0.5	0.124
Criterion 4	K4	2	1	0.5	1	0.222	0.5	0.67	2	1	0.208
Coefficient		CI = 0.00 CR = 0.00%					CI = 0.01 CR = 0.66%				

Source: Own work

Tables 2–5 present risk assessments for particular construction objects in accordance with the adopted criteria. In this case, in two table columns there are priority values for each variant, both for probability p_i and consequence c_i , of the occurrence of interferences in selected construction processes. Analyzing the values of consequence coefficient CR presented in tables 2–5, one may conclude that the assessments of particular solutions were very consistent because the value of CR was much lower than 10% [Ostręga, 2004, p. 60].



Tab 2. Assessment of particular objects according to criterion No. 1

Specification		Probability assessment					Consequences assessment				
		O1	O2	O3	O4	Priority	O1	O2	O3	O4	Priority
Object 1	O1	1	0.75	1.5	0.5	0.194	1	0.75	0.5	0.25	0.120
Object 2	O2	1.33	1	3	0.75	0.294	1.33	1	0.66	0.33	0.159
Object 3	O3	0.67	0.33	1	0.25	0.109	2	1.52	1	0.5	0.240
Object 4	O4	2	1.33	4	1	0.403	4	3.03	2	1	0.481
Coefficient		CI = 0.01 CR = 0.68%					CI = 0.00 CR = 0.00%				

Source: Own work

Tab. 3. Assessment of particular objects according to criterion No. 2

Specification		Probability assessment					Consequences assessment				
		O1	O2	O3	O4	Priorytet	O1	O2	O3	O4	Priorytet
Object 1	O1	1	0.33	0.50	0.25	0.100	1	0.75	1.25	3	0.288
Object 2	O2	3.03	1	1.33	0.75	0.293	1.33	1	2	4	0.401
Object 3	O3	2	0.75	1	0.50	0.207	0.8	0.5	1	2	0.201
Object 4	O4	4	1.33	2	1	0.401	0.33	0.25	0.5	1	0.100
Coefficient		CI = 0.00 CR = 0.07%					CI = 0.00 CR = 0.14%				

Source: Own work

Tab. 4. Assessment of particular objects according to criterion No. 3

Specification		Probability assessment					Consequences assessment				
		O1	O2	O3	O4	Priorytet	O1	O2	O3	O4	Priorytet
Object 1	O1	1	0.33	0.50	0.25	0.100	1	0.75	1.5	0.5	0.194
Object 2	O2	3.03	1	1.33	0.75	0.293	1.33	1	3	0.75	0.294
Object 3	O3	2	0.75	1	0.50	0.207	0.67	0.33	1	0.25	0.109
Object 4	O4	4	1.33	2	1	0.401	2	1.33	4	1	0.403
Coefficient		CI = 0.00 CR = 0.07%					CI = 0.01 CR = 0.68%				

Source: Own work

Tab. 5. Assessment of particular objects according to criterion No. 4

Specification		Probability assessment					Consequences assessment				
		O1	O2	O3	O4	Priorytet	O1	O2	O3	O4	Priorytet
Object 1	O1	1	0.75	0.5	0.25	0.120	1	0.75	1.25	3	0.288
Object 2	O2	1.33	1	0.66	0.33	0.159	1.33	1	2	4	0.401
Object 3	O3	2	1.52	1	0.5	0.240	0.8	0.5	1	2	0.201
Object 4	O4	4	3.03	2	1	0.481	0.33	0.25	0.5	1	0.100
Coefficient		CI = 0.00 CR = 0.00%					CI = 0.00 CR = 0.14%				

Source: Own work

Table 6 presents the final results of calculations made using formulae (1-2). The calculations showed explicitly that the object involving the highest risk is *Object No. 4* ($r_4 = 0.457$). Conducted analyses showed that this object is four more times at risk of interference than *Object No. 1*.

During the analysis of the results presented in table 6 it was found out that most probably interference would occur in the case of *Object No. 4* ($p_4 = 0.419$), however, the most significant consequences of interference would be related to *Object No. 2* ($c_2 = 0.292$).

Tab. 6. Calculation results for risk R_i assessment for construction process interference.

No.	Construction object name	Probability p_i	Consequence c_i	Risk r_i
O1	Object 1	0.115	0.210	0.091
O2	Object 2	0.263	0.292	0.291
O3	Object 3	0.203	0.210	0.161
O4	Object 4	0.419	0.288	0.457

Source: Own work

Conclusions

The execution of undertakings, especially construction undertakings, without any risk analysis leads to a significant reduction in the probability of achieving set goals. This assumption has been proved to be right in practice on numerous occasions. A good example are construction enterprises involved in road building as part of preparation for Euro 2012. A significant number of them incurred serious losses instead of increasing enterprise value. In numerous cases these losses led to a loss of liquidity and as a consequence to bankruptcy. The reason quite often was inappropriate management including bad risk management.

Risk management does not solve all problems faced by entrepreneurs working on construction projects. However, it contributes to a more precise analysis of planned processes and thus to a better diagnosis of potential threats. Moreover, it allows the construction industry to prepare their reactions to potential threats. Such an approach limits unpredicted costs of project execution.

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Zarządzanie ryzykiem w projektach na przykładzie przedsięwzięć budowlanych

Streszczenie

Realizacja projektów, w szczególności budowlanych, bez analizy ryzyka prowadzi do znaczącego obniżenia prawdopodobieństwa osiągnięcia wyznaczonych celów. To założenie zostało potwierdzone przez praktykę, czego dobry przykładem były projekty budowy dróg przed Euro 2012.

Zarządzanie ryzykiem nie rozwiązuje wszystkich problemów pojawiających się podczas realizacji projektów budowlanych. Pozwala jednak zidentyfikować część potencjalnych zagrożeń oraz przygotować odpowiednie działania zapobiegawcze.

Artykuł dotyczy zarządzania ryzykiem w przedsięwzięciach budowlanych. Autorzy omawiają specyfikę oraz uwarunkowania prawne tego typu projektów. W artykule zaprezentowano kwantyfikację ryzyka mogącego wystąpić w projektach budowlanych. Przedstawiona metoda oceny ryzyka jest autorskim rozwiązaniem.

