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METHOD OF PLANNING CONSTRUCTION PROJECTS, TAKING INTO ACCOUNT RISK FACTORS

This paper presents an original method of planning construction projects, taking into account the influence of potential risk factors. The method is called the Method of Construction Risk Assessment (MOCRA). According to this method, first the material-financial plan of a project (a construction project in the example provided) is analyzed. Then risk factors are identified, taking into account the project's specificity. The end result of this stage is a list of risk factors. In the third stage the risk is reduced or minimized where possible. Finally, the specified risk factors are quantified, which is a difficult task. The effectiveness of the risk assessment depends on how thoroughly this task is carried out.

Since point scale assessment of risk does not appeal to engineers, in MOCRA quantified risk is allocated in the material-financial plan. Thanks to this, one can prepare contingency plans, i.e. plans (action variants) to be implemented when particular risk factors occur. Having completed the project, one can use MOCRA to check the accuracy of the assessment (forecast) and select the best contingency action variant, whereby the method's effectiveness in planning future projects is improved.

Keywords: *risk, scheduling, construction project*

Introduction

Construction companies are well equipped in planning tools for implementating construction projects (this statement is based on a survey of randomly selected construction companies located in the Świętokrzyski region carried out by the author). Problems appear when besides a standard material-financial plan – the principal document required when submitting a tender, one must include a project risk analysis. Although there are many risk assessment methods, e.g. NPV, IRR, they were intended mainly for project owners. But since construction companies play the role of the con-

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tractor, the risk area in this case does not always coincide with the project owner's risk area. For example, the project owner's goal is to get a return on an investment as quickly as possible (except for non-profit investments), whereas the contractor's goal is to carry out the project in the allotted time at the anticipated costs.

Currently there is no method which would deal comprehensively with the construction project contractor's risk. Therefore, the author undertook the task of developing a method enabling analysis of the different risk factors involved in the implementation of construction projects.

1. Idea of the method

The method developed is called the Method of Construction Risk Assessment (MOCRA). Using this method, risk is assessed from the construction project contractor's point of view. Risk assessment focuses on the stage of project implementation and does not cover the operation of the structure. This is a crucial assumption, since risk assessment criteria are identified on this basis. The result of this identification is a list of risk factors (a typical list of risk factors is presented in Section 2). This is followed by risk quantification, i.e. assigning measurable values to the risk factors. In the next step a strategy for reducing risk in project implementation is selected. Finally (after verification based on the risk reduction strategy), the risk is determined and allocated in the material-financial plan. Risk allocation in the plan allows one to determine the project time and cost contingency and to develop a contingency plan and budget on this basis [11]. A flow chart illustrating the assessment process and its range is shown in Figure 1.

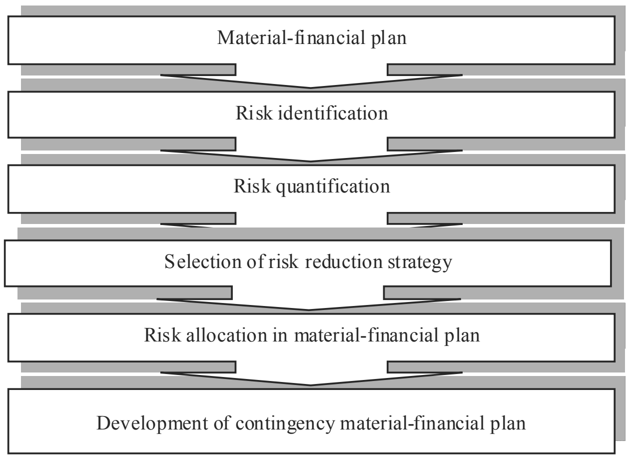

Fig. 1. Risk assessment process and its range
Source: Author's own illustration.

2. Identification and specification of risk factors

A risk identification analysis based on domestic and international literature [1]–[3], [5]–[7] was carried out. Also experts' (civil engineers, managers and research personnel) knowledge and the author's experience and reflections were taken into consideration.

An example list of risk factors is given below, broken down into three areas: the farther environment (macro level risk), the closer environment (construction market level risk) and the area directly connected with the project (project level risk) [2], [10].

The following risk factors are highlighted on the *macro level*:

operating risk, including:

- the government (political continuity, attitude towards foreign investors and profits, nationalization/confiscation, enforcement of contracts, government inducements/incentives),
- the economy and finances (monetary inflation, economic growth),
- administration (red tape, communications and transport, professional services);

political risk, including:

- external factors (war with a neighbouring country or region, dependence on or great influence of other forces),
- internal factors (disintegrating political structure, fragmentation and division of the country between language, ethnic and regional groups, limited access to the workforce, mentality [including nationalism, corruption and dishonesty]),
- symptoms of instability (social conflicts [e.g. demonstrations, strikes and street riots], instability due to unconstitutional changes);

financial risk, including:

- legal determinants (the law in force),
- foreign currency (equilibrium of exchange rates, capital flow),
- international reserves (foreign currency reserves, gold reserves and other),
- foreign indebtedness (share of debt in GDP, debt service ratio),
- budget execution (size of budget deficit/surplus, sources of income and main expenditures).

The following risk factors are highlighted on the construction market level:

technological risk, including:

- the technology protection system,
- market openness to advanced technologies,
- availability of basic designs, technologies and equipment;

contracts and legal requirements, including:

- type of cooperation,
- type of agreements/contracts,
- possibility of enforcing contracts,

- tender procedures and project permits;

resources, including:
- availability and quality of local contractors,
- availability of construction materials,
- availability of skilled and unskilled workers,
- labour/production costs,
- availability of equipment and spare parts;

financing, including:
- medium- and long-term financing of construction projects,
- tax benefits in the construction industry;

business-cultural differences, including:
- cooperation of foreign managers with local contractors,
- relations between owners or customers in construction firms.

Typical risk factors on the project level are shown in Table 1. The above list does not exhaust all potential risks to construction projects. It is only the starting point for analyses, which to a large extent depend on the specificity of a given construction project.

3. Quantification of risk factors

A fragment of the mathematical description used for the quantitative assessment of risk is presented below. A detailed description of the algorithm can be found in papers [4], [8]–[11] by the author.

Risks on the macro level:

$$S^{rk} = \sum_{i=1}^{n} R_i^{rk} w_i^{rk} [\%], \tag{1}$$

where:

S^{rk} – the weighted sum of risks (the comprehensive risk on the macro level),

w_i^{rk} – the i-th weight on the macro level,

R_i^{rk} – the i-th risk associated with the occurrence of factor a_i^{rk} on the macro level,

a_i^{rk} – a potential i-th factor (an unfavourable event) on the macro level.

Risk on the construction market level:

$$S^{rb} = \sum_{i=1}^{l} \psi_i^{rkb} S^{rk} + \sum_{i=1}^{m} R_i^{rb} w_i^{rb} [\%], \tag{2}$$

where:

S^{rb} – the comprehensive risk on the construction market level,

ψ_i^{rkb} – a correlation coefficient defining the influence of the overall macro level risk on the *i*-th factor of construction market risk,

l – the number of risk factors related to the macro level,

m – the number of risk factors unrelated to the macro level,

R_i^{rb} – the *i*-th risk associated with the occurrence of factor a_i^{rb} on the construction market level,

a_i^{rb} – the *i*-th risk factor on the macro level,

w_i^{rb} – the *i*-th weight on the market level.

Risk on the project level:

$$S^{rp} = \sum_{i=1}^{v} \psi_i^{rkp} S^{rk} + \sum_{i=1}^{z} \psi_i^{rbp} S^{rb} + \sum_{i=1}^{c} R_i^{rp} w_i^{rp} [\%], \tag{3}$$

where:

S^{rp} – the ultimate comprehensive risk on the project level,

v – the number of project risk factors related to the macro risk level,

z – the number of project risk factors related to the construction market risk level,

c – the number of risk factors unrelated to other risk levels,

ψ_i^{rkp} – a correlation coefficient defining the influence of the macro level risk on the *i*-th factor of project level risk,

ψ_i^{rbp} – a correlation coefficient defining the influence of the overall construction market level risk on the *i*-th factor project level risk,

R_i^{rp} – the *i*-th risk associated with the occurrence of factor a_i^{rp} on the project level, unrelated to construction market level risk and macro level risk,

w_i^{rp} – the *i*-th weight on the project level.

In the next stage of risk analysis the possibility of employing a risk reducing strategy is examined.

4. Risk reducing strategy

A risk reducing strategy should be developed to reduce the influence of potential adverse factors to a minimum or to completely eliminate them. The whole investment process, and in the case of the contractor, the whole process of implementing a construction project, should be taken into account when deciding on a risk reducing strategy [7], [9], [10].

The following risk reduction categories are highlighted:

1. *Risk acceptance* – the probable time and place of the occurrence of certain negative events are known, the influence of the risk on the project is judged to be allowable.

2. *Risk avoidance* – the elimination of specific hazards, since the risk associated with them is too high and unacceptable.

3. *Risk protection and insurance* – making use of the possibility of insuring against risk.

4. *Risk research* – modelling the processes of project implementation and acquiring all possible information.

5. *Risk reserves* – creating budget reserves in the project plan to protect against risk.

6. *Risk transfer* – risk transfer to other organizations.

The introduction of a risk reducing strategy depends on the contractor's capabilities and preferences and on the project owner's flexibility. Although unfavourable events cannot be excluded, their consequences can be eliminated, e.g. through proper stipulations in the contract.

MOCRA assumes that the selection of elements in the risk reducing strategy depends on the decision-makers. This means that the author of the method does not impose any constraints on this strategy, assuming that the most rational solution is to refer the contractor's experience. One should note that some elements of a risk reducing strategy are imposed by the project owner and in the near future they will also be imposed (after consultation with construction industry engineers and managers) by law.

As a result of the application of a risk reducing strategy, one gets a verified list of risk factors and reduced risk called "residual risk". This can be written as

$$\overline{S}^{rp} = \sum_{i=1}^{v^1} \psi_i^{rkp} S^{rk} + \sum_{i=1}^{z^1} \psi_i^{rbp} S^{rb} + \sum_{i=1}^{c^1} R_i^{rp} w_i^{rp} [\%] , \tag{4}$$

where:

$\overline{S}^{rp}$ – verified (reduced) risk on the project level,

v^1 – the post-verification number of project risk factors related to the macro risk level,

z^1 – the post-verification number of project risk factors related to the construction market risk level,

c^1 – the post-verification number of risk factors related to other risk levels.

The other parameters are defined as previously.

5. Example of project planning

No full risk analysis is presented here, since it is very numerically complex and so extensive. A complete case study can be found in [10]. Nevertheless, the selection presented covers the main elements of the analysis.

5.1. Preliminary risk assessment

The figures for particular risk factors represent a subjective opinion, but are based on a thorough analysis carried out by "the tender preparing team" working for the KARTEL construction firm. The analysis preceded project implementation. The aim of the project was to build a gymnasium with an indoor swimming pool at a complex of schools – The Centre of Lifelong Education in Żarnowiec. An excerpt from the original material-financial plan of the project is shown in Figure 2.

	Nazwa zadania	Cz. trw.	Rozp.	Zak.	Poprzedniki	Koszt	Nazwy :
1	Roboty ziemne	21 dn	04-04-22	04-05-20		92 495,58 zł	Z1
2	Fundamenty	13 dn	04-04-22	04-05-10		98 358,04 zł	Z2
3	Ściany i ścianki	46 dn	04-05-11	04-07-13	2	192 534,76 zł	Z2
4	Tynki, sufity podwieszone	70 dn	04-08-10	04-11-15	3ZR+19 dn	91 926,74 zł	Z2
5	Posadzki i podłogi	81 dn	04-08-10	04-11-30	6ZR+10 dn	430 683,41 zł	Z3
6	Konstrukcje żelbetowe	52 dn	04-05-14	04-07-26		65 708,03 zł	Z3
7	Dach i pokrycie	55 dn	04-06-15	04-08-30	1ZR+17 dn	475 195,58 zł	Z1
8	Stolarka cz. 1	45 dn	04-08-16	04-10-15	11ZR+42 dn	207 520,38 zł	Z4
9	Stolarka cz. 2	4 dn	04-12-01	04-12-06	8ZR+32 dn	17 235,10 zł	Z4
10	Roboty zewnętrzne	33 dn	04-09-15	04-10-29	7ZR+10 dn	37 848,14 zł	Z1
11	Instalacja kotłowni	39 dn	04-04-22	04-06-15		54 273,58 zł	Z4

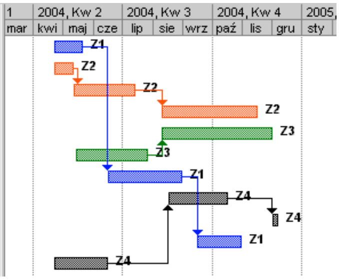

Fig. 2. Deterministic material-financial plan for gym in Żarnowiec.
S o u r c e: Author's own illustration made using computer software [6].

(First column – Task name, Earthworks, Foundations, Walls and partitions, Plasters and suspended ceilings, Floors, Reinforced concrete structures, Roof and roofing, First fix joinery, Second fix joinery, Exterior works, Boiler room installation.
First type line – Task name, Duration, Start, End, Antecedents, Cost, Names, Mar., Apr., May, Jun., Jul., Aug., Sept., Oct., Nov., Dec., Jan.)

First a quantitative assessment of risk on the macro level was made. Then risk on the construction industry level and risk on the project level were assessed (Table 1).

Table 1. Analysis of risk on project level

Criteria	Subcriteria (risk factors)	Hierarchical risk assessment (AHP)	Risk influence a	Influence level	Risk assess-ment	Weight risk assessment
1	2	3	4	5	6	7
Technology	Unfavourable soil conditions	0.073	–	–	28	2.055
Contracts & legal matters	Possible disputes between contractors	0.050	–	–	25	1.301
	Difficulties in resolving disputes because of law in given country	0.039	–	–	50	1.950
Resources	Lack of skilled labour	0.063	2	0.80	44.131	2.780
	Access to specialist equipment	0.033	2	1.00	55.163	1.820
	Delays in materials deliveries	0.034	2	1.00	55.163	1.875
	Equipment failures	0.032	–		50	1.600
Design	Delays in design permits	0.089	2	0.80	44.131	3.927
	Faulty design, errors, additional work	0.085	–	–	50	4.250
Quality	Bad quality materials	0.059	2	1.00	55.163	3.254
	Carelessness of subcontractors	0.074	2	1.00	55.163	4.080
Finances	Difficulties in financing projects due to tax reasons or restrictions in capital flow	0.174	1	0.80	53.880	9.375
	Change in material and operating resource prices	0.077	–	–	50	3.850
Other	Weather conditions	0.062	–	–	50	3.100
	Physical destruction or halting of project by riots, demonstrations or acts of terror	0.054	1	0.80	53.880	2.909
[Sum]	–	1.000	–	–	small risk	48.121

Source: Author's own illustration based on [2].

5.2. Allocation or remaining risk in material-financial plans

After the specification, quantification and verification of the risk factors, their correlation with particular tasks in the material-financial plan was analyzed and their influence on a change in the duration and cost of particular operations and the whole project was determined (an approx. 70 page description can be found in [10]).

The end result was a contingency plan (a variant of the material-financial plan), which suggests how the duration and cost of the construction project will change when anticipated risk factors occur (Fig. 3).

	Nazwa zadania	Cz. trw.	Rozp.	Zak.	Poprzedniki	Koszt	Nazwy :
1	Roboty ziemne	21,99 dn	04-04-22	04-05-21		93 178,94 zł	Z1
2	Fundamenty	13,19 dn	04-04-22	04-05-11		109 341,20 zł	Z2
3	Ściany i ścianki	47,77 dn	04-05-11	04-07-15	2	220 031,78 zł	Z2
4	Tynki, sufity podwieszone	72,05 dn	04-08-10	04-11-18	3ZR+17 dn	101 802,23 zł	Z2
5	Posadzki i podłogi	83,39 dn	04-08-11	04-12-06	6ZR+10 dn	454 660,25 zł	Z3
6	Konstrukcje żelbetowe	53,08 dn	04-05-14	04-07-28		74 956,49 zł	Z3
7	Dach i pokrycie	59,3 dn	04-06-15	04-09-07	1ZR+17 dn	507 330,00 zł	Z1
8	Stolarka cz. 1	46,58 dn	04-08-16	04-10-20	11ZR+42 dn	229 844,93 zł	Z4
9	Stolarka cz. 2	4,12 dn	04-12-03	04-12-09	8ZR+32 dn	18 332,81 zł	Z4
10	Roboty zewnętrzne	33 dn	04-09-21	04-11-05	7ZR+10 dn	39 280,98 zł	Z1
11	Instalacja kotłowni	40,51 dn	04-04-22	04-06-17		60 955,74 zł	Z4

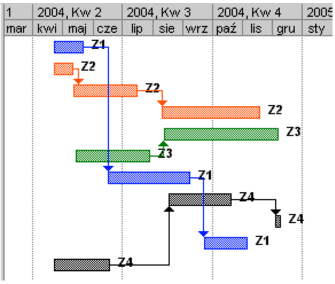

Fig. 3. Material-financial plan for gym in Żarnowiec, taking into account risk conditions.
S o u r c e: Author's own illustration made using computer software [6].

A quantitative approach to risk makes it possible to determine the time and cost contingency. The cost contingency was calculated from the difference between the total cost of individual operations with risk taken into account (the *Cost* column in Fig. 3) and the total cost of the same operations conducted in deterministic conditions (the *Cost* column in Fig. 2). The time contingency was determined for particular operations from the differences between the *Duration* columns (Figs 3 and 2) [11].

Conclusion

The proposed method of planning construction projects, taking into account risk, cannot be treated as a magic box (a comparison often used in the American literature on the subject), which solves all the problems involved in the prediction of potential risks and their influence on project implementation. However, it can be employed as a tool aiding the making of decisions related to planning the implementation of construction projects. A thorough analysis of project risks allows the contractor to assess the overall potential risk and should contribute to the effectiveness of project implementation. Moreover, an appropriate strategy of risk avoidance or risk reduction can be worked out and the budget and time contingency can be assessed on the basis of such an analysis.

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Metoda planowania przedsięwzięć budowlanych z uwzględnieniem czynników ryzyka

W artykule przedstawiono autorską metodę planowania przedsięwzięć budowlanych z możliwością uwzględniania wpływu potencjalnych czynników ryzyka. Metoda nosi nazwę MOCRA (*Method of Construction Risk Assessment*). W pierwszym etapie proponowanej metody przeprowadza się analizę planu rzeczowo-finansowego przedsięwzięcia (w przedstawionym przykładzie jest to przedsięwzięcie budowlane). Następnie, biorąc pod uwagę specyfikę wykonywanego obiektu, dokonuje się identyfikacji czynników ryzyka. Ten element analizy jest jednocześnie drugim etapem metody MOCRA, którego finalny efekt sprowadza się do opracowania zestawienia – listy czynników ryzyka. Etap trzeci polega na redukcji lub zminimalizowaniu ryzyka tam, gdzie jest to możliwe. W kolejnym etapie dokonuje się kwantyfikacji wyspecyfikowanych czynników ryzyka. Etap ten jest trudny, ale od rzetelności jego wykonania zależy w dużym stopniu efektywność oceny ryzyka.

Ocena punktowa ryzyka nie trafia do wyobraźni inżynierów, dlatego w metodzie MOCRA dokonuje się alokacji skwantyfikowanego ryzyka w planie rzeczowo-finansowym. Konsekwencją takiego działania jest możliwość budowy planów awaryjnych, czyli planów realizowanych na wypadek wystąpienia poszczególnych czynników ryzyka. Taki plan awaryjny można traktować jako wariant działania. Po zrealizowaniu inwestycji istnieje możliwość, na bazie metody MOCRA, określenia trafności oceny (prognozy) i wybrania najlepszego wariantu awaryjnego, co poprawia skuteczność metody w planowaniu kolejnych przedsięwzięć.

Biorąc pod uwagę aspekt utylitarny metody, przedstawiono przykład jej zastosowania w planowaniu realizacji przedsięwzięcia budowlanego, którego wykonawcą była średnia firma budowlana.

Podsumowując, przedstawiona metoda nie może być traktowana jako „magiczna skrzynka”, która rozwiązuje wszystkie problemy predykcji potencjalnych zagrożeń oraz ich wpływu na realizację inwestycji. Można jednak traktować ją jako narzędzie wspomagające proces decyzyjny, związany z planowaniem realizacji przedsięwzięcia budowlanego.

Słowa kluczowe: *ryzyko, harmonogramowanie, przedsięwzięcia budowlane*