RISK ASSESSMENT IN MINING-RELATED PROJECT MANAGEMENT

STANOVENÍ RIZIKA V PROJEKTOVÉM ŘÍZENÍ V PODMÍNKÁCH TĚŽEBNÍHO PODNIKU

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Abstract

Risk assessment is an integral part of the assessment of an investment project. Underestimating risks may lead to erroneous conclusions with negative impacts on the economy of the project. With regard to the level of investments and the time factor under mining company conditions, the issue of risk gains importance. The evaluation of existing practical experience shows that managers of mining companies more often approach to the risk assessment based on intuition, than through exact methods. The article is devoted to the risk assessment itself whose procedure is illustrated on a model example of assessing continuous and discontinuous alternatives of exploitation of loose overburden materials during large-scale coal mining operations in progress at pit quarries.

Abstrakt

Hodnocení rizika je nedílnou součástí posouzení investičního projektu. Podcenění rizika může vést k chybným závěrům s negativními dopady na ekonomiku projektu. S ohledem na výši investic a hledisko času v podmínkách těžebního podniku, nabývá problematika rizika na významu. Z hodnocení stávajících praktických zkušeností vyplývá, že manažeři těžebních podniků přistupují ke stanovení rizika častěji na bázi intuice, než s využitím exaktních metod. Článek se věnuje vlastnímu stanovení rizika, jehož postup naznačuje na modelovém příkladu posuzování kontinuální a diskontinuální alternativy exploatace sypkých skrývkových hmot při velkokapacitní těžbě uhlí probíhající na jámových lomech.

Key words: Risk assessment, management, NPV, mining company

1 INTRODUCTION

Managerial decision-making is one of the most important activities performed by management members within their competences (Fotr, 2010). The decision-making is the process of choosing the way which the manager and the organization entrusted to the manager will take. At the end of the decision-making process, there is a specific way, an option. Obviously, the greater the impacts of the decision, the greater the importance of the decision-making process. The complexity and difficulties related to the decision-making function consist mainly in the fact that it is impossible beforehand to verify the impacts that specific managerial decision will bring. In addition, the entire decision-making process takes place under turbulent dynamically changing conditions, and therefore to take decisions free from risks is difficult or quite impossible.

This fact should necessarily lead to the need of the manager to specify, quantify and subsequently control the risks. However, findings from economic studies show the lack of integration of risks and uncertainties into investment decision-making process when any investment project risk analysis does not take place either at all, or in a very simplified form. As a result, wrong investment decisions could be made that threaten, in particular in the case of large-scale investment projects, prosperity and financial stability of firms implementing these projects (Fotr, 2007).

Mining and mineral processing belong to such business sectors which require substantial investments in land, technology, infrastructure and other factors of production, without which miners are not able to exploit the mineral of interest. It is also the sector in which nature is an important influencing factor, because the shape of deposit, storage conditions, the amount and quality of commercial mineral, tectonic disturbances predispose the range of mining, used technology, and thus the amount of necessary investments. In connection with a deposit, it is known that the miner can recognize it only when he mined it out. This is further amplified by the fact that the management of a mining company work with a broader range of threats than the management of a company operating in another industry sector.

The extraction of a raw material from a certain deposit can take tens or hundreds of years. Changing the quarry name does not change the fact that the extraction takes place at the same deposit. The brown coal deposit in the Most Basin, where coal mining began in the 15th century for private purposes only, and since the 19th century the targeted industrial mining of this raw material has taken place here either by underground and surface mining methods, could be an example (Pokorná, 2000).

For quarrying in small quarries, discontinuous mining technology was and still is used. In the Most Basin, a merge of several smaller quarries operating at a single deposit occurred in the early second half of the 20th century, allowing the deployment of more efficient technologies and the gradual commencement of transition from the discontinuous to giant-machine continuous technology. The reason for the massive deployment of this technology was the need of ensuring the mining of large volumes in the 80s of the last century. Other causes can be seen in the fact that the then Czechoslovakia was one of the world-powers in the production of this type of technology, and not least in the fact that the discontinuous technology has not reached the required performance parameters for a long time. Since the discontinuous technology now achieves these parameters, and the continuous technology is costing as for initial investment and overhaul costs, the issue of replacement of existing continuous technological exploitation of loose materials with a discontinuous alternative is discussed for a quite long time (Seidl et al, 2011).

The team of authors of the present article deals with the issue for a long time as well. The starting point of the work became an economic study (Seidl et al, 2011) which analysed the technological options and evaluated them in terms of investment decision-making. From this work, we know that the discontinuous technology is economically feasible. Another study (Vaněk et al , 2012) focused on the identification and evaluation of key threats associated with each of the technologies. It is directly followed by our article, as informal interviews conducted the authors with managers of mining companies indicated that although the managers know about risk management, they usually quantify risk intuitively on the basis of qualified studies.

This article aims at demonstrating the scientific risk assessment approach, and so suggesting the possibilities of its use in practice of managers of mining companies. The focus of the article then can be seen in the assessment of risk of technological alternatives for exploitation of loose overburden materials in the mass production of pit quarries.

2 METHODS AND MATERIALS

The issue of risk management is elaborated in many theoretical works. On conditions of the CR, the work by prof. Fotr and prof. Smejkal can be ranked among fundamental ones. The work of a team of prof. Mařík is important as well.

However, in the professional literature and in business practice there is some confusion about the very concept "risk". Smejkal sais to this: "If someone feels that, when discussing a risk, a confusion of terms occurs, one cannot but agree." It is due to the fact that the term "risk" is promiscuously used for both "a likelihood of event incidence" and "an impact of event incidence on a subject". This promiscuity can be prevented by mentally separating the force, event, activity, or person having an adverse effect on safety (**threat**), and the probability that an adverse event will occur (**risk**) (Smejkal, 2006).

Risk assessment is the result of a comprehensive process which can be aggregated into four basic phases (Smejkal, 2006), as follows:

1. Identification of assets
2. Identification of threats
3. Determination of the significance of threats
4. Determination of risk

Assets are meant to be the values that can be endangered by fulfilling the threats (Smejkal, 2006). When carrying out the identification of threats, such threats are determined that affect the assets. Threats can be of an economic, technological, legislative, political and natural character. Threats caused by human factor are significant as well. Threats may affect the business, organization, project, person, or assets separately or they can interconnect and interact[1] (Vaněk et al, 2012).

To understand the threats and especially their mutual relationships, cognitive maps (CM) can be successfully used. The CM is a representation of the causal relationships that exist among the decision elements of a given object and/or problem, and describe experts' tacit knowledge. CMs are composed of (a) concept nodes (i.e., variables or factors) that represent the factors describing a target problem, (b) arrows that indicate *causal relationships between two concept nodes, and (c) causality coefficients on each arrow that indicate the positive (or negative) strength with which a node affects another node* (Kun, 2009).

The significance of threats is determined essentially in two ways, in particular in an expert manner, or by means of a sensitivity analysis. The expert assessment of the significance of threats consists in their professional evaluation by employees who have the necessary knowledge and experience in the areas to which individual threats fall. In case of the sensitivity analysis, it is determined what change of a criteria indicator will be initiated by a certain change in its direct influencing factor. (Fotr, 2005).

The method of **determining the risk** depends on its nature and the purpose, for which the risk is quantified. Identifying business risks can be performed by using a **modular method** which is a comprehensive method of assessing the monitored sub-risks. The threat identified in previous steps and rated by a risk-level is then transferred to a risk premium. (Ošatka, 2004). This is a method that does not derive the risk, or the risk premium from the capital market, but determines it as the sum of the partial risk premiums being determined for a group of business and financial threats (Mařík, 2011).

In the event that the risk of a project is determined, **statistical characteristics** (variance, standard deviation, coefficient of variation) or **managerial characteristics** (robustness, flexibility) can be successfully used (Fotr, 2005).

By reason that the assessed technological alternatives of exploitation of overburden materials can be seen as projects, the approach of risk quantification through statistical characteristics was chosen.

The prerequisite for the use of statistical characteristics is the knowledge of probability distribution of an evaluation criterion, which may be e.g. a net present value (Fotr, 2005). To determine the probability distribution, scenarios were used while working with the discrete nature of threats.

The scenarios are usually regarded as mutually consistent combinations of values of major threats. Each scenario thus represents a different future development of the evaluation criterion. In the event of two or more threats, probability trees in a form of graphs formed by situational nodes and edges are a useful tool for displaying scenarios. The probability of each scenario is the result of the product of the probabilities of values of considered threats which is based either on the numerical values of the past or on the experience of experts (Fotr, 2005).

The variance is determined by the following relationship (Fotr, 2005):

$$R = \sum_{i=1}^{n} (NPV_i - M)^2 \times p_i \qquad (1)$$

Where:

R – NPV variance,

NPVi – net present value of project of i-th scenario,

M – NPV mean value,

Pi – probability of i-th scenario,

n – number of scenarios.

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[1] For example, a change of an exchange rate – the threat of an economic nature will cause a threat on the part of the supplier which specifically reveals itself in higher investment costs of the project (in case of foreign supplier).

The mean value of NPV is then:

$$M = \sum_{i=1}^{n} NPV_i \times p_i \tag{2}$$

The coefficient of variation is determined as follows:

$$k = \frac{\partial}{M} \tag{3}$$

Where:

k – coefficient of variation,

δ – standard deviation,

M – NPV mean value,

The determination of threatened assets is one of the starting points of risk quantification. The overview of the assets considered in the model coal pit quarry in prices of the year 2012 is shown in Tab. 1. Since the continuous technology is supplied by domestic manufacturers, the prices are listed only in CZK.

Tab. 1 Threatened assets

Continuous technology		
Costs	**in thous. €**	**in thous. CZK**
Excavator	XX	1,650,000
Back filler	XX	455,000
DPD – long-distance belt haulage	XX	1,230,000
Total	**XX**	**3,335,000**
Discontinuous technology		
Costs	**in thous. €**	**in thous. CZK**
Excavator RH120 - RH120 - BH	3,700	92,944
Excavator RH120 -RH120 - FS	3,700	92,944
Caterpillar Cat 785D Dump Truck (8x)	17,600	442,112
Caterpillar 16M Motor Grader	700	17,584
Caterpillar 730 BWT Ejector	400	10,048
Caterpillar 824 H Wheel Dozer	600	15,072
Caterpillar Cat D8T Dozer	500	12,560
Cat D10T Dozer	820	20, 598
Cat D11TCD Dozer	1,800	45,216
M318D Excavator	200	5,024
Total	**30,020**	**754,102**

Source: Inherent processing

3 RESULTS

These results can be understood as a recommended decision with the consideration of accurate risk assessment.

The study aimed at determining the significance of threats (Vaněk, 2012) showed that in case of continuous technology the following key threats were identified: capital expenditure, energy consumption, repairs and related services, and in case of discontinuous technology: costs of services – repairs, fuel and capital expenditure.

The starting points for creating scenarios are foreseen value statuses of major threats and the probabilities of the occurrence of the statuses. The bases for quantifying were the results of a panel discussion with experts on the issue. The discussion results are summarized in Tabs. 2 and 3.

Tab. 2 Input data for continuous technology

Threat / Status	**Change in capital expenditure**	**P**	**Change in energy costs**	**P**	**Change in costs of repairs and related services**	**P**
1	0%	0.50	0%	0.10	0%	0.10
2	5%	0.40	10%	0.40	2.5%	0.40
3	10%	0.10	20%	0.50	5%	0.50

Source: inherent processing

Tab. 3 Input data for discontinuous technology

Threat / Status	Change in capital expenditure	P	Change in fuel costs	P	Change in costs of services	P
1	5%	0.10	0%	0.10	5%	0.10
2	10%	0.50	10%	0.40	10%	0.40
3	15%	0.40	20%	0.50	15%	0.50

Source: inherent processing

Since the significance of threats was determined by analysing the sensitivity of NPV, the net present value at the same time became the evaluation criterion. In order to determine the probability distribution of NPV, 27 alternative scenarios were created for each technology, resulted from the combination of the statuses of major threats, see Tab. 2 and 3. In total 54 scenarios were created.

When calculating the NPV, the values of discount rate of 8 % were used. In the publication (Fotr, 2005), the value is recommended for the renewal of existing technology (the case of continuous technology). For the introduction of new machinery, which corresponds to the deployment of discontinuous technology instead of continuous one, the publication (Fotr, Souček) recommends to use a rate of 10 % which reflects the increased risk for standard projects. Due to the specific way of spending capital expenditures and non-standard monetary revenues of the surveyed project, the use of the higher discount rate induces a decrease in the resulting net present value, which makes the criterion indicator of the more risky project more advantageous. Therefore, the uniform above mentioned discount rate of 8 % was used. Tab. 4 shows the value of NPV for each scenario of relevant transport technology and the resulting probability of the scenario.

Tab. 4 NPV scenarios and their probability

	Continuous technology		Discontinuous technology	
Scenario	**NPV**	**Probability**	**NPV**	**Probability**
1	-4,711,906	0.005	-3,964,002	0.001
2	-4,790,486	0.020	-4,026,732	0.004
3	-4,805,198	0.025	-4,089,462	0.005
4	-4,838,544	0.020	-4,077,384	0.004
5	-4,853,256	0.080	-4,140,114	0.016
6	-4,867,968	0.100	-4,202,844	0.020
7	-4,901,314	0.025	-4,190,765	0.005
8	-4,916,026	0.100	-4,253,496	0.020
9	-4,930,738	0.125	-4,316,226	0.025
10	-4,908,925	0.004	-4,019,978	0.005
11	-4,923,637	0.016	-4,082,708	0.020
12	-4,938,349	0.020	-4,145,438	0.025
13	-4,971,696	0.016	-4,133,360	0.020
14	-4,986,407	0.064	-4,196,090	0.080
15	-5,001,119	0.080	-4,324,111	0.100
16	-5,034,466	0.020	-4,312,033	0.025
17	-5,049,178	0.080	-4,374,763	0.100
18	-5,063,889	0.100	-4,437,493	0.125
19	-5,042,077	0.001	-4,178,342	0.004
20	-5,056,789	0.004	-4,241,072	0.016
21	-5,071,500	0.005	-4,303,803	0.020
22	-5,104,847	0.004	-4,291,724	0.016
23	-5,119,559	0.016	-4,354,454	0.064
24	-5,071,500	0.020	-4,417,185	0.080
25	-5,167,617	0.005	-4,405,106	0.020
26	-5,182,329	0.020	-4,467,836	0.080
27	-5,197,041	0.025	-4,530,566	0.100

Source: inherent processing

In order to be able to assess competently the risk of the considered technological alternatives, statistical parameters, the mean value, variance, standard deviation and the coefficient of variation were calculated, see Tab. 5.

Tab. 5 Values of statistical characteristics

Technology	Mean value	Variance	Standard deviation	Coefficient of variation
Continuous	-4,962,565	9,419,620,327	97,055	-0.0196
Discontinuous	**-4,347,135**	**14,848,639,348**	**121,855**	**-0.0280**

Source: inherent processing

Due to the higher difference in values of the calculated variances, the coefficient of variation (5,429,019,021) is crucial for the risk assessment.

The value of the coefficient of variation is higher in the discontinuous technology, but only by 0.0084. This difference is negligible, therefore both technological alternatives can be considered equivalent in terms of risk.

4 DISCUSSION

The authors do not conceal that the result achieved by the risk analysis is a certain surprise for them. However, the result is based on the relevant bases, therefore there is no choice but to accept it.

A certain pitfall of the risk analysis is that the quantification of major threats is usually based on expert estimates, so it is necessary to pay due attention to the selection of experts. This is the only way how to ensure the bases for determining the risk of a project to be valid.

For the management of the mining enterprise that intends to replace the continuous technology with the discontinuous technology, the result is crucial in that the risk does not disqualify any of the alternatives and the management can focus in decision-making entirely on technical and economic issues.

NPV suggests which technology of exploitation of loose overburden materials in the model example of a coal pit quarry is economically advantageous for miners. Since the NPV method was applied to the process that does not generate revenues, the net present value takes negative values. Therefore, it is recommended to implement the one of the two technologies for which the NPV takes a value closer to zero. In our case it is the discontinuous technology.

5 CONCLUSION

The complexity of managerial decision-making lies among other things in that managers are fully responsible for their decisions. It is therefore up to them on which kind of decision-making methods and forms they ground their decisions.

Pitfalls of decision-making that is based solely on intuition and experience can be seen in a minor strength of arguments. However, if the manager will rely on exact and heuristic approaches, not only the persuasiveness of his arguments will increase, but also the quality of the resulting decisions. This quality can be crucial for achievements of the manager in the management of a project, a company (institution), or its organizational units.

In the comprehensive assessment of an investment plan, it is also necessary to evaluate the risks associated with the project. Especially, when the manager (management) decides on a project that requires high investment costs and potential long life.

To these criteria, a series of projects implemented in the extraction and processing of raw materials corresponds as well. These include, among others, the restoration project of technological equipment deployed in the large-scale mining of loose overburden materials taking place at coal pit mines. The project became a model example of the application of risk management in terms of a mining company, within which the risks of existing continuous and discontinuous solution alternatives were assessed.

The discontinuous technological solution requires lower initial investments. It is also flexible in time. It would thus appear that this alternative is less risky as well. However, it is apparent from the results of the risk analysis presented in this paper that both assessed technologies are in principle equivalent in terms of the level of risk. Thus, the investment decision made on the basis of intuitive risk assessment can be misleading, if not completely wrong. With regard to economic aspects and the NPV value, the management of a (model) mining company could be recommended to change to the discontinuous technology as a better alternative.

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RESUMÉ

Těžba a zpracování nerostných surovin patří k podnikatelským odvětvím, které vyžadují nemalé investice do výrobních činitelů zajišťující samotnou exploataci a následnou úpravu zájmové nerostné suroviny. Tyto investice mají charakter projektů a management těžebního podniku tak musí (v souvislosti s těmito projekty) přijmout investiční rozhodnutí a také rozhodnout o způsobu jejich financování.

Nedílnou součástí posuzování investičních projektů je problematika zhodnocení rizik, jejíž akcentování managementem může eliminovat chybné závěry se všemi dopady na ekonomiku projektu.

Jednou z aktuálně diskutovaných oblastí je nahrazení kontinuální technologie přepravy sypkých skrývkových hmot při velkokapacitní těžbě na jámovém lomu technologií diskontinuální. Článek stanovuje rizika obou technologií (projektů), přičemž navazuje na předchozí studii zaměřující se na určení významnosti hrozeb. Posouzení rizika obou dopravních alternativ je provedeno prostřednictvím statistických charakteristik rozdělení pravděpodobnosti hodnotícího kritéria. Tímto kritériem je NPV projektu. Ke stanovení rozdělení pravděpodobnosti bylo využito metodologie scénářů, přičemž se pracovalo s diskrétním charakterem hrozeb. Pro každou technologickou alternativu bylo vytvořeno 27 scénářů, které vznikly kombinací stavů významných hrozeb. Celkem tak bylo vytvořeno 54 scénářů.

Vzhledem k vyššímu rozdílu hodnot vypočtených rozptylů je pro posouzení rizika rozhodující variační koeficient. Hodnota variačního koeficientu je sice vyšší u diskontinuální technologie, avšak pouze o 0,0084. Tento rozdíl je zanedbatelný, a proto lze obě technologické alternativy považovat z hlediska rizika za rovnocenné.

Poněvadž metoda NPV byla aplikována na proces, který negeneruje příjmy, nabývá čistá současná hodnota záporných hodnot. Proto se doporučí ta technologie, která nabývá hodnoty bližší nule. V našem případě se jedná o diskontinuální technologii.