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Risk Assessment of Investments with Fuzzy Efficiency Indicators for Oil and Gas Production Industry

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Abstract

In the process of investment decision making, next to financial indicators many other aspects of investment projects are increasingly often considered. This leads to the multi-criteria evaluation of a project. The advantage of multi-criteria methods is the ability to take into account all (not only financial) aspects of the attractiveness of an investment project. The selection of criteria of project assessment must take into account the specificity of organization that makes a decision. Along with traditional method this paper introduces new approach for risk assessment based on each criterion characterizing the investment project on hydrocarbon resources exploitation.

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INTRODUCTION

In the contemporary period of transition to market economy, the decision-making on assessment and selection of investment projects has an essential importance for the full-scale investments in exploitation of oil & gas resources. Evidently, each investment project is characterized with many groups of efficiency criteria, such as reliability, affordability and environment- friendliness (Rebiasz et al., 2014). Each of these criteria, on its turn, creates a multitude of other criteria. The transition to market economy in upstream oil & gas industry, while maintaining the values of the reliability and environment-friendliness criteria, intensifies the attention to economic criteria, such as: net present value (NPV), internal rate of return (IRR), payback period of project (PP), project profitability index (PI) and other criteria (Nedosekin, 2003).

All above-noted criteria are necessary prerequisites for selection of oil production projects. However, they are clearly not sufficient for making investment decisions, as decisions on selection of investment project cannot be made by using just one criterion. Indeed, the nature, purpose and requirements of each specific project are different (Pashayev et al., 2014). The process of oil resources exploitation itself is very complicated, and in most case it is accompanied with uncertainty and fuzziness. In this case, none of criteria can, on its own, provide sufficient information which can be used as a basis for judgment on the project's attractiveness. Such judgment is possible only after study and assessment of each criterion (indicator) of efficiency and risk (resulted from the fuzziness of criteria), and after estimation of the attractiveness of the project and the cumulative risk based on all criteria (Andereu et al., 1995).

The presented paper examines the common methods of risk assessment by each separate criterion of investment efficiency in the process of hydrocarbon resource exploitation. These methods enable to assess risk based on each of criteria which are necessary for determination of cumulative risk for hydrocarbon resource exploitation projects.

Research background

In the process of investment decision making, next to financial indicators many other aspects of investment projects are increasingly often considered. This leads to the multi criteria evaluation of a project. The advantage of multi criteria methods is the ability to take into account all (not only financial) aspects of the attractiveness of an investment project. The selection of criteria of project assessment must take into account the specificity of organization that makes a decision.

There are several critical factors that are involved in the process of project's selection, including financial aspects, market conditions, availability of raw materials, technical aspects, ecological problems, personnel problems, regional aspects, government regulation, different interests of stakeholders, etc. (Rebiasz et al., 2014; Rebiasz, 2013). Analysis of decision-making situations shows that the selection of projects very often involves different goals, hence it is necessary to evaluate the level of importance of each goal and the weight that each project has in comparison with each goal. Many decision problems are not clear-cut and the decision makers have to find their way in the jungle of conflicting objectives (Ustundag et al., 2010). In some cases, there is also a lack of consensus on the relevance of each goal and on the performance of each project in comparison with each goal (Agrell et al., 2013).

Summarizing one can say that the decision-making process in the selection of investments has some specific characteristics:

1. It has to take into consideration either financial or non-monetary effects
2. It has to take into consideration either quantitative or qualitative effects
3. Naturally occurring competitiveness and even contradiction of criteria
4. It has to take into consideration both the uncertainty of each alternative and the uncertainty originating from the difficulty to establish the importance of every goal (Podgorski, 2015).

The pair-wise comparison method and the hierarchical model were developed in 1980 by Saaty in the context of the Analytical Hierarchy Process (Saaty,1980؛Merino,1995؛Arche et al., 1999). Many studies have explored the field of the fuzzy extension of Saaty's theory: (Van laarhoven et al., 1983), (Buckley., 1989), (Buckley et al., 1989), (Chang, 1996), (Chanas et al., 1999), (Lootsma, 1997), (Ruoning et al, 1992), (Pan,1997), Enea et al., 2004), Chan et al., 2000), McKown et al., 2001).

(Liu et al., 2011) introduces an evaluation method based on an uncertain linguistic weighted operator to the risk evaluation of the high-tech project investment.

(Rębiasz, 2013) presents the usage of probabilistic and fuzzy approach for the evaluation of projects and selection of the most profitable project from the steel industry.

Fuzzy theory

By introducing the fuzzy theory for the first time, (Zadeh, 1988) provided preliminaries for modeling and simulation of inaccurate information and approximate reasoning by mathematical equations which in turn have led to a renaissance in classical mathematics and logic. Fuzzy approximate reasoning approach- which is known as fuzzy system- is proposed for systems with high complexity and uncertainty that adequate and accurate information is not available. In recent decades the fuzzy sets theory has been a useful tool in dealing with uncertain and ambiguous data and models and some researchers have developed and expanded a variety of useful fuzzy ways considering this ambiguity and uncertainty (Braya et al., 2015).

According to the definition, if $M_{ij}= (l_{ij}, m_{ij}, u_{ij})$ is considered as a triangular fuzzy number. The sum of two fuzzy numbers $M_1= (l_1, m_1, u_1)$, $M_2=(l_2, m_2, u_2)$ and inverse is defined as follows:

$$(l_1,m_1,u_1) \oplus (l_2,m_2,u_2) = (l_1+l_2,\ m_1+m_2,u_1+u_2)$$

$$(l_1,m_1,u_1)^{-1} = (1/u_1, 1/m_1, 1/l_1) \quad (1) \qquad [27]$$

Risk assessment for investments under fuzzy indicators of efficiency

Let's assume that the efficiency indicator of an investment project N is given as fuzzy set $\tilde{N}=(N_{min}, \mu_N, N_{max})$, where μ_N - membership function, N_{min}, N_{max} - respectively, left and right frontiers of the set carrier $\tilde{N}$, i.e. $\mu_N=0$ when $x \le N_{min}$ and when $x \ge N_{max}$.

As far the limitary parameter C, we would assume that it is given as a fuzzy set, too $\tilde{C} = (C_{\min}, \mu_C, C_{\max})$ with the conditions $\mu_C=0$ if $x \le C_{min}$ or $x \ge C_{max}$. μ_C - is taken as a membership function.

The graphs of $\mu_N(x)$ and $\mu_C(x)$ functions may have different shapes and may lay differently in respect to each other. For the ease of explanation, we would assume that these graphs are located on a coordinate plane as shown on Figure 1.

Following (Rebiasz et al., 2013; Pashayev et al., 2014) we can determine the risk zone and the assessment of risk by means of α- levels of $\tilde{N}$ and $\tilde{C}$ fuzzy sets.

For certainty we will take the case when investment project is considered affordable for N indicator, if the value of N is not below than that of the limitary parameter. Then, the risk zone of N and C for the given α-level will be the area where N<C.

As seen from Figure 1, for α -levels with $\alpha \ge \alpha_0$, the risk zone is empty set (i.e. no risk exists), and when $\alpha<\alpha_0$ the risk zone is $[N_{min}, C_{max}]$ segment. In this case, each α -level ($\alpha<\alpha_0$) will correspond to some part of this segment. When $\alpha=0$, the whole segment will become a risk zone.

Now, to estimate the risk relevant to the given α-level ($\alpha<\alpha_0$), we will apply two approaches:

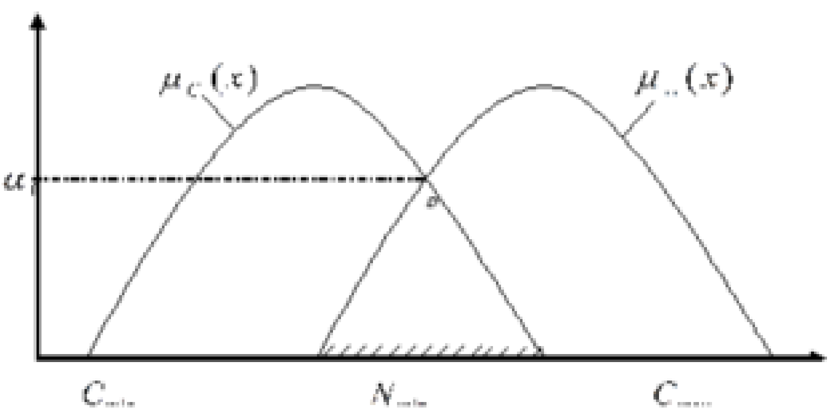

Fig 1. The graphs of membership function

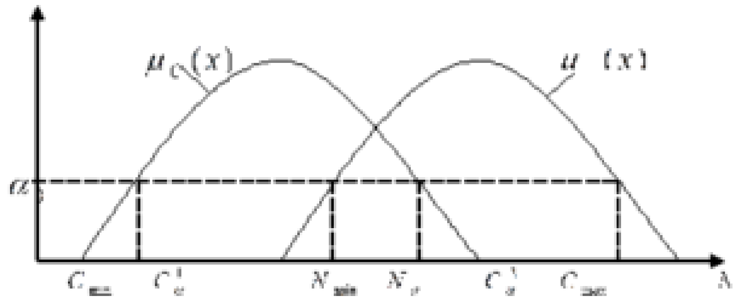

Fig 2. The frontiers of the fuzzy set

1. The approach where α-level of two $\tilde{N}$ and $\tilde{C}$ fuzzy sets is used – in this traditional approach (Rebiasz et al., 2013; Pashayev et al., 2014; Mckown et al., 2001; Liu et al., 2011), we identify the frontiers of the α-level for both $\tilde{N}$ and $\tilde{C}$ fuzzy sets.

The frontiers are marked as C^1_α and C^2_α for the fuzzy set $\tilde{C}$ and as N^1_α and N^2_α for the fuzzy set $\tilde{N}$ on Figure 2. These frontier points are then depicted on C and N axis, and the risk zone is defined.

The geometric probability of the incidence of point (C, N) to the risk zone (see Figure 3) is taken as the estimation for the risk relevant to α-level. The rectangle with bolded lines on Figure 3 – is the area of probable values of pairs (C, N) for α-level, and the hatched area is the risk zone.

Thus, each $0 \le \alpha \le \alpha_0$ will correspond to following value:

$$\varphi(\alpha) = \frac{S_\Delta}{S_\Box} = \frac{(C^2_\alpha - N^1_\alpha)^2}{2(C^2_\alpha - C^1_\alpha)(N^2_\alpha - N^1_\alpha)} \tag{2}$$

Where S_Δ- is the square of the hatched triangle on Figure 3, $S_\Box$- is square of the rectangle with bolded sides. We note that C^1_α, C^2_α, N^1_α, N^2_α values are derived from evident correlations:

$$C^1_\alpha = \mu^{-1}_{CL}(\alpha);\ C^2_\alpha = \mu^{-1}_{CR}(\alpha);$$
$$N^1_\alpha = \mu^{-1}_{NL}(\alpha);\quad N^2_\alpha = \mu^{-1}_{NR}(\alpha) \tag{3}$$

where $\mu^{-1}_{CL}(\alpha)$, $\mu^{-1}_{CR}(\alpha)$, $\mu^{-1}_{NL}(\alpha)$, $\mu^{-1}_{NR}(\alpha)$ - are the values of the invest function for the left (L) and the right (R) parts of the membership function μ_C and respectively μ_N.

Further, the final risk level of non-affordability (inefficiency) of investment project is determined with the following formula in the traditional approach [28]:

$$Risk = \int_0^{\alpha_0} \varphi(\alpha)d\alpha \tag{4}$$

However, in our viewpoint, determination of inefficiency risk of project with the formula (4) cannot always accurately (correctly) reflect its real value (estimation).

The reason of such circumstance can be ex-

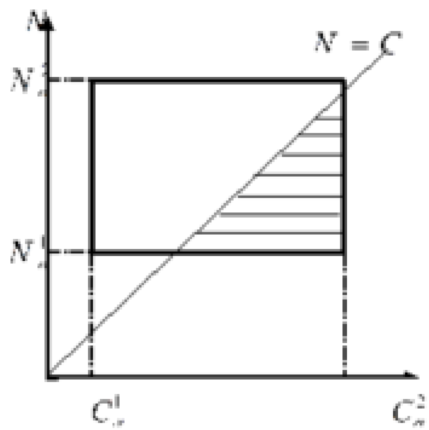

Fig 3. The geometric probability of the incidence of point to the risk zone

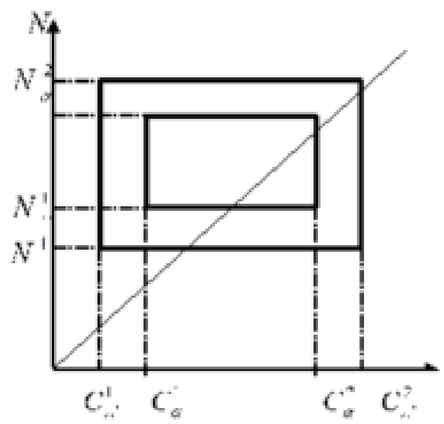

Fig 4. The areas of realization and risk

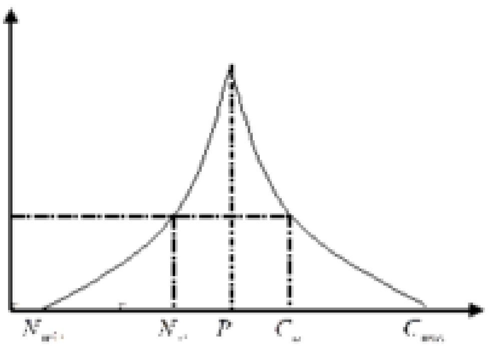

Fig 5. The α-level of primary $\tilde{C}$ and $\tilde{N}$ sets

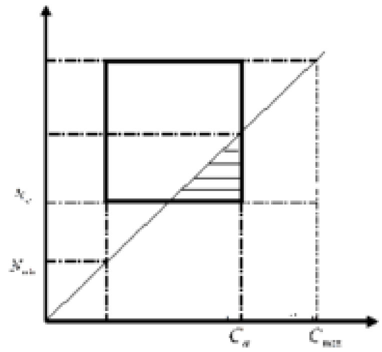

Fig 6. The risk zone for the indicator *N*

plained with following considerations:

Assume that we have defined the areas of all possible realizations of the indicator and the limitations of *C* (see Figure 3) for some α-level and identified risk zone in this area. Now, if we take other α`-level, where $\alpha`<\alpha$, then the corresponding areas of realization and risk will have previous areas respectively (as shown on Figure 4). So, with consistent decrease of α, each consecutive derived areas of the realization (rectangle) and the risk (triangle) will contain preceding areas respectively. Therefore, the results of the operation on integration with such mutually-embedded areas will contain much excess (surplus) information, and may provide distorted view about the genuine level of risk.

For that reason, we believe that it is more appropriate to deal with the maximum risk level which is determined as the maximum of the variable of α function:

$$Risk = \max_{0\le\alpha\le\alpha_0} \varphi(\alpha) = \max_{0\le\alpha\le\alpha_0} \frac{[\mu_{CR}^{-1}(\alpha) - \mu_{NL}^{-1}(\alpha)]^2}{[\mu_{CR}^{-1}(\alpha) - \mu_{CL}^{-1}(\alpha)][\mu_{NR}^{-1}(\alpha) - \mu_{NL}^{-1}(\alpha)]} \tag{5}$$

The computation of risk with the formula (4) uses relatively less number of excess (i.e. not relating to risk zone) information. The excess information is contained in the denominator of the *φ(α)* function. The excessiveness of information is due to the fact that the calculated square of the rectangle contains the non-risk area as well.

2. The second approach that we propose doesn't use such excess information. The essence of this approach is that the function *φ(α)* is defined only by means of the parameters of risk zone at each *α*. To clarify the essence of this approach, let's examine the intersection of fuzzy sets $\tilde{C}$ and $\tilde{N}$.

$$\tilde{I} = \tilde{C} \cap \tilde{N}, \text{ where } \mu_I(x) =$$

$$\begin{cases} 0, & \text{if } x \le N_{\min} \text{ or } x \ge C_{\max} \\ \mu_{NL}(x), & \text{if } N_{\min} \le x \le P \\ \mu_{CR}(x), & \text{if } P < x \le C_{\max} \end{cases} \tag{6}$$

P – Is the point at which $\mu_N(P)=\mu_C(P)$.

Let's examine some -level of this set. Since this *α*-level is the *α*-level of primary $\tilde{C}$ and $\tilde{N}$ sets (Figure 5), then

As seen from figures 2 and 5, the risk zone for the indicator N is the segment and for the indicator C is the segment . If we depict these areas to coordinate plane , then the following figure will appear (Figure 6).

If we take the ratio of the triangle's square to the rectangle's square as the value of risk relevant to *α*-level, then the value of risk is calculated with the following formula:

$$\varphi_1(\alpha) = \frac{(C_\alpha - N_\alpha)^2}{2(C_\alpha - N_{\min})(C_{\max} - N_\alpha)} \tag{7}$$

In this case, it is also expedient to consider the cumulative risk not as the integral of *φ1(α)* but as the maximum value of *φ1(α)*, i.e.

$$Risk = \max_{0\le\alpha\le\alpha_p} \varphi_1(\alpha) = \max_{0\le\alpha\le\alpha_p} \frac{[\mu_{CR}^{-1}(\alpha) - \mu_{NL}^{-1}(\alpha)]^2}{2[\mu_{CR}^{-1}(\alpha) - N_{\min}][C_{\max} - \mu_{NL}^{-1}(\alpha)]} \tag{8}$$

Where $\alpha_p=\mu_{ML}(P)=\mu_{CR}(P)$

As seen from the formula (8), in the approach we propose the value of risk on inefficiency of the project is determined only through the parameters of the primary risk zone. Thereby, it is possible to more precisely determine the risk.

Hence, by determining risk level for each criterion on efficiency assessment of hydrocarbon resource exploitation projects, we can conduct a multi-criterion analysis of the project's efficiency based on aggregate criteria. For instance, the cumulative risk of a project, being the aggregate of all criteria, can be determined as the weighted sum of all risks:

$$Risk_{\Sigma} = \sum \sigma_i \cdot Risk_i \tag{9}$$

Where n-number of criteria; σ_i- the level of importance of i^{th} criterion Determination of the level of importance (σ_i) can be done by means of expert estimations or based on paired comparison (Nedosekin, 2003; Andreu et al., 1995).

CONCLUSION

Summarizing one can say that the decision-making process in the selection of investments has some specific characteristics:

• It has to take into consideration either financial or non-monetary effects;

• It has to take into consideration either quantitative or qualitative effects;

• Naturally occurring competitiveness and even contradiction of criteria; and

• It has to take into consideration both the uncertainty of each alternative and the uncertainty originating from the difficulty to establish the importance of every goal.

The advantage of multi criteria methods is the ability to take into account all (not only financial) aspects of the attractiveness of an investment project. The selection of criteria of project assessment must take into account the specificity of organization that makes a decision. The last decades have shown that the number and complexity of dependencies both inside and outside a company makes it difficult to use the probability theory to represent all kinds of the uncertainty appearing in case of the evaluation of investment projects. Many authors have applied the alternative description of the uncertainty. First of all, fuzzy numbers may be mentioned as an example of the above. This leads to the hybrid description of the uncertainty in the process of the evaluation of the investment.

Along with traditional method this paper introduces new approach for risk assessment based on each criterion characterizing the investment project on hydrocarbon resources exploitation.

The approach is grounded on the use of fuzzy sets which allow the determination of maximum risk per each of criteria associated with the efficiency assessment of hydrocarbon resources exploitation. These criteria, in aggregate, enable us to determine the cumulative risk of a hydrocarbon resources exploitation project.

REFERENCES

Agrell, P. J., Bogetoft, P., & Mikkers, M. (2013). Smart-grid investments, regulation and organization. *Energy Policy*, 52, 656-666.

Archer, N. P., & Ghasemzadeh, F. (1999). An integrated framework for project portfolio selection. *International Journal of Project Management,* 17(4), 207-216.

Bray, S., Caggiani, L., & Ottomanelli, M. (2015). Measuring transport systems efficiency under uncertainty by fuzzy sets theory based Data Envelopment Analysis: theoretical and practical comparison with traditional DEA model. *Transportation Research Procedia*, 5, 186-200.

Buckley, J. J. (1985). Ranking alternatives using fuzzy numbers. *Fuzzy sets and systems*, 15(1), 21-31.

Buckley, J. J. (1989). A fuzzy ranking of fuzzy numbers. *Fuzzy sets and systems,* 33(1), 119-121.

Buckley, J. J., & Chanas, S. (1989). A fast method of ranking alternatives using fuzzy numbers. Fuzzy sets and systems, 30(3), 337-338.

Chan, F. T. S., Chan, M. H., & Tang, N. K. H. (2000). Evaluation methodologies for technology selection. *Journal of Materials Processing Technology*, 107(1), 330-337.

Chanas, S., & Zieliński, P. (1999). Ranking fuzzy interval numbers in the setting of random sets–further results. *Information Sciences*, 117(3), 191-200.

Chang, D. Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European journal of operational research,* 95(3), 649-655.

Enea, M., & Piazza, T. (2004). Project selection by constrained fuzzy AHP. *Fuzzy optimization and decision making,* 3(1), 39-62.

Liu, P., Zhang, X., & Liu, W. (2011). A risk evaluation method for the high-tech project investment based on uncertain linguistic variables. *Technological Forecasting and Social Change*, 78(1), 40-50.

Liu, P., Zhang, X., & Liu, W. (2011). A risk evaluation method for the high-tech project investment based on uncertain linguistic variables. *Technological Forecasting and Social Change*, 78(1), 40-50.

LOOTSMA, F. A. (1997). Fuzzy logic for planning and decision making.

Mas-Colell, A., Whinston, M. D., & Green, J. R. (1995). *Microeconomic theory* (Vol. 1). New York: Oxford university press.

Merino, J. P. (1995). R & D Project Selection. New York: Wiley.

Mohamed, S., & McCowan, A. K. (2001). Modelling project investment decisions under uncertainty using possibility theory. *International Journal of Project Management*, 19(4), 231-241.

Nedosekin, A. O. (2003). Metodologicheskie osnovy modelirovaniia finansovoy dejatelnostis ispolzovaniem nechetko-mnozhestvennykh opisanii: Ph. *Diss. dokt. jekon. nauk.*

Pan, Y. (1997). Revised hierarchical analysis method based on crisp and fuzzy entries. *International Journal Of General System*, 26(1-2), 115-131.

Pashayev, R.T., Mamedov, K.S., & Valiyev, V. M. (2014). Quality criterion selecting best project investment. *Social finance and IT magazine – international conference, Baku pages*, 100-104.

Podgórski, D. (2015). Measuring operational performance of OSH management system–A demonstration of AHP-based selection of leading key performance indicators. *Safety Science*, 73, 146-166.

Rebiasz, B. (2013). Selection of efficient portfolios–probabilistic and fuzzy approach, comparative study. *Computers & Industrial Engineering*, 64(4), 1019-1032.

Rębiasz, B., & Macioł, A. (2014). Hybrid data in the multiobjective evaluation of investments. *Procedia Computer Science,* 35, 624-633.

Ruoning, X., & Xiaoyan, Z. (1992). Extensions of the analytic hierarchy process in fuzzy environment. *Fuzzy sets and Systems*, 52(3), 251-257.

Saaty, T. L. (1980). The Analytical Hierarchy Process, Planning, Priority. *Resource Allocation. RWS Publications, USA*.

Shavandi, H. (2005). Fuzzy sets theory and its application in industrial engineering and management. Gostareshe Olome Payeh publication, Tehran.

Ustundag, A., Kılınç, M. S., & Cevikcan, E. (2010). Fuzzy rule-based system for the economic analysis of RFID investments. *Expert systems with applications,* 37(7), 5300-5306.

Van Laarhoven, P. J. M., & Pedrycz, W. (1983). A fuzzy extension of Saaty's priority theory. *Fuzzy sets and Systems*, 11(1-3), 229-241.

Zadeh, L. A. (1988). Fuzzy logic. *Computer*, 21(4), 83-93.