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Optimal decision-making in oil extraction under imprecise information

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Abstract

The issue on investing was examined with probabilities given in the form of interval in oil extraction. The solution ways of decision-making on investment with three alternatives and four criteria have been investigated and alternative which will be invested in has been identified. It is shown that it is more appropriate to use the method based on interval probabilities in order to carry out geological and technical measures during investing, unlikely decision-making based on the classical probabilities.

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Keywords: coating, production; hydraulic fracturing, bottom-hole area; annular space, reagent; polymer solution; decision making, imprecise probability; interval probability; interval outcome.

1. Introduction

Various geological and technical measures are implemented in order to prevent declining in the level of oil production and to enhance it during oil extraction processes. Therefore, almost every day there is need to make a decision in oil extraction institutions. Such decision-making is associated with investing directly.

Hydraulic fracturing of formation (HFF), downhole development (DD) and applying various reagents and polymer solution into the annular space are mostly occurred among the geological and technical measures carried out to increase production in the oil fields[1].

HFF event is carried out in mining conditions in the cases of a sharp decrease of permeability of the downhole area, but oil bearing capacity of the coating is still quite a lot. HFF process itself is considered as a complex operation, so using various sands containing granulometry, and splitter, carrier, vibrating fluids prepared at the well-

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head and various technical means to prepare them, including the use of pumping units which can cause high pressure required during its implementation. These all lead to the increase of costs incurred to the measure and the growth of costs investing. However, as a result of the successful completion of HFF, the production of the wells can be increased several times compared to the other measures, so it shows its efficiency.

DD method is carried out in connection with contamination of downhole area as a result of collapse of various components in the composition of the hydrocarbons extracted, decline in permeability of layer and fall in production in the long-term working process of oil-well. The sequence of systems applied in downhole area is composed of two or three processes, so incurring of general expenses is characterized with relatively low in the result of the small number of both reagents and technical means used. At the same time, the increase in production of the wells is comparatively less than the method of HFF as the result of DD application.

The most cost-effective method is applying polymer solutions into the annular space of oil wells. The essence of this method is to reduce the hydraulic losses applying various polymer solutions in downhole, thus to increase production of well, at the same time to prevent the collapse of sand in sandy wells, thereby to increase inter-repair period. The goal is to increase oil production more with little expense.

However, investing is required for the implementation of all these measures. Reasonable question arises: What should the investing direct to, which of measures listed above should be preferred? In such a condition, it is significantly important to make the right decision in order to achieve the desired result.

It is known that investment-is putting up capital in different areas and fields of economics, as well as entrepreneurial activity. As in other fields, revival of the investment climate in the oil industry causes the stable economic development of the oil-production enterprise. Such a situation leads not only to increase in long-term investments, but also application of advanced management methods of the investment activity to enhance the competitiveness[2]. The main objective of the investing process consists of concentration of financial resources in the areas and directions that provide the acceleration of scientific and technological advance by taking into account innovations[3].

At the same time, the main purpose of investing process on any kind of investment activity is to obtain a high income. The basis of investment management is to maximize income received by investors and minimize risks on putting up capital[4]. There are many methods to achieve this goal; one of them is multi-criterion decision-making method in the case of interval[5].

In the case of interval with superiority degree during multi-criterion decision-making, the width of intervals beside upper and lower borders of them is taken into consideration during rational and natural methods of arranging alternatives. Imprecise probabilities are widely used in case when inaccuracy should differ from alteration. At this time, inaccurate intervals are directly applied to assess the reliability based on generalized intervals[6].

In this paper we consider a problem of multicriteria decision making on oil production under interval valued information on choice criteria. The rest of the paper is organized as follows. In Section 2 we provide necessary formal definitions. In Section 3 we consider a real-world problem of decision making in oil production. Section 4 concludes.

2. Preliminaries

Definition 1. Interval probabilities[8]. The intervals $\overline{p}_i = [p_{*i}, p_i^*]$ are reffered to as interval probabilities if for any $p_i \in [p_{*i}, p_i^*]$ there exist $p_1 \in [p_{*1}, p_1^*], \ldots, p_{i-1} \in [p_{*i-1}, p_{i-1}^*]$, $p_{i+1} \in [p_{*i+1}, p_{i+1}^*]$,…, $p_n \in [p_{*n}, p_n^*]$ such that the following is satisfied:

$$\sum_{i=1}^{n} p_i = 1 \qquad (1)$$

Definition 2. The superiority degree of intervals[9]. For evaluation of comparison and superiority intervals d (I, J) the following formula is used.

$$d(I,J)=\begin{cases}\dfrac{\overline{I}-\overline{J}}{\left|(\overline{I}-\overline{J})+(\underline{I}-\underline{J})\right|} & \overline{I}>\overline{J},\ \underline{J}>\underline{I}\\ 1 & \overline{I}=\overline{J},\ \underline{I}>\underline{J}\\ & \overline{I}>\overline{J},\ \underline{I}\geq\underline{J}\\ & \overline{I}=J,\ \underline{I}=\underline{J}\\ 1-d(J,I) & \end{cases}$$

3. Formulation and solving of the investment problem in oil production

Let us consider a problem of investment decision making on oil production. The problem is characterized by imprecision and uncertainty of a set of decision criteria. The formal statement of problem is as follows.

Denote $A=\{a_1,a_2,...,a_m\}, m\geq 2$ a set of alternatives. Let every alternative $a_i, i=1,...,n$ be characterized by n interval-valued criteria $C_j, j=1,...,n$. Each criterion C_j has an interval-valued importance weight $W_j=[w_{j1},w_{j2}]\subset[0,1]$. The importance weights W_j are formally considered as interval probabilities. The multiattribute decision making problem under interval-valued information can be considered as the following decision matrix $D_{n\times m}$:

$$D_{m\times n}=\begin{bmatrix} & W_1 & W_2 & \dots & W_n\\ & C_1 & C_2 & & C_n\\ a_1 & X_{11} & X_{12} & \dots & X_{1n}\\ a_2 & X_{21} & X_{22} & \dots & X_{2n}\\ \dots & \dots & \dots & \dots & \dots\\ a_m & X_{m1} & X_{m2} & \dots & X_{mn}\end{bmatrix},$$

where $X_{ij}=[x_{ij1},x_{ij2}]$ is an interval valued evaluation of a_i with respect to criterion C_j . Thus, each alternative a_i can be considered as an interval valued vector $a_i=(X_{i1},X_{i2},...,X_{in})$.

For example, mechanical properties, electrical properties etc. The considered multiattribute decision making problem under interval-valued information consists in determination of a best alternative a^* :

$$\textit{Given decision matrix } D_{n\times m} \textit{ find } a^*\in A \textit{ such that } a^*\succ a_i,\ \forall a_i\in A, \tag{2}$$

where $\succ$ is a preference relation.

The considered problem can be solved as follows.

Step 1. For every alternative $a_i, i=1,...,n$ compute an interval weighted average $WA(a_i)=[WA_{i1},WA_{i2}]$ of its criteria evaluations by solving the following problems:

$$WA_{i1}=\sum_{j=1}^{n} w_{ij}x_{ij}\rightarrow \min,\ WA_{i2}=\sum_{j=1}^{n} w_{ij}x_{ij}\rightarrow \max \tag{3}$$

subject to

$$x_{ij} \geq x_{ij1},\quad x_{ij} \leq x_{ij2},\quad w_j \geq w_{j1},\quad w_j \leq w_{j2},\quad \sum_{j=1}^{n} w_j = 1 \qquad (4)$$

Step 2. Compare the obtained intervals $WA(a_i) = [WA_{i1}, WA_{i2}]$ and find the best alternative a^* as an alternative for which the following is satisfied:

Find $a^* \in A$ such that $d(WA(a^*), WA(a_i)) \geq d(WA(a_i), WA(a^*)),\ \forall a_i \in A$.

Let us consider now a real-world problem. Oil production enterprise intends to invest its capital assets in 3 directions:

a_1- hydraulic fracturing of formation;
a_2 - downhole development;
a_3 - applying the polymer solution into the annular space.

Each of these alternatives is characterized by 4 criteria:ecological disturbance, increase of turnaround interval, production, degree of investments' justification. For each alternative, criteria evaluation has been given by one expert.And the goal is to identify a single expert evaluation for these alternatives on all 4 criteria, and choose the most productive one. In this connection, preliminary data are provided in Table 1, including the interval importance weights.

Table 1. Criteria evaluation of the experts over the alternatives

Attributes \ Alternatives	a1	a2	a3
C1(ecological disturbance), $W_1 = [0.2, 0.3]$	[0.2,0.6]	[0.3,0.8]	[0.4,0.7]
C2 (turnaround interval), $W_2 = [0.1, 0.15]$	[0.3,0.7]	[0.5,0.8]	[0.7,0.9]
C3 (production increase), $W_3 = [0.15, 0.2]$	[0.6,0.7]	[0.4,0.6]	[0.5,0.7]
C4 (degree of investments justification) $W_4 = [0.3, 0.35]$	[0.4,0.8]	[0.5,0.9]	[0.3,0.8]

Undoubtedly, a person (expert), making the decision, determines the dependence between the results of alternative investments and statuses ofthe implemented measures on the basis of existing experience, taking into account the results of previous similar geological and technical measures.

By using the approach described above, we have solved the considered investment problem. Intervals resulting from the calculations are given in the Table 2.

Table 2. Interval results of calculations on the alternatives

Alternatives	Results
T1	[0.28,0.705]
T2	[0.32,0.795]
T3	[0.315,0.765]

Then, the achieved intervals are compared:
Between 1 and 2nd intervals
d_y=0.31;
Between 1 and 3rd intervals

d_y=0.368;
Between 2 and 3rd intervals
d_y=1;
Between 2 and 1stintervals
d_y=1;
Between 3 and 1st intervals
d_y=1;
Between 3 and 2nd intervals
d_y=0.625.

Based on the comparison, d_{ij} between 2 and 3rd intervals and 3 and 2nd intervals receives the largest estimate, and this shows that the investment in downhole development method is more efficient.

4. Conclusion

Investment issue consisting of 4 criteria and 3 alternatives was considered. The decision relevant information is presented in the form of intervals. The utility function was calculated for each alternative. The decision was made on the basis of intervals arranging.

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