SOCAR
SOCAR Proceedings
Transportation, Storage of Oil and Gas
journal home page: http://proceedings.socar.az
INDEXED IN EMERGING SOURCES CITATION INDEX THOMSON REUTERS
Scopus

PROGRAM PREFERENCE WITH MULTI-ATTRIBUTE DECISION-MAKING METHOD FOR OUTGOING PIPELINE ROUTING OF SHALE GAS

J.Chunqing*, Zh.Zaixu, L.Ruifang
School of Economics and Management, China University of Petroleum (East China), Qingdao, China

Abstract

Pipelines impose a regular constraint on the outgoing transport and downstream market of shale gas in its exploration and exploitation processes, thereby affecting its commercialization. Based on the current status of China's oil and gas pipeline networks, this study presents an influencing factor index system based on the requirements for optimal outgoing pipeline routing. Specifically, this index system covers five aspects of influencing factors: engineering, economics, safety, environmental, and potential utility. After taking the related constraints into account, this study presents an optimal multi-attribute decision-making (MADM) method for outgoing pipeline routing program preference of shale gas based on intuitionistic fuzzy sets. Using the example of the alternative routing solutions for outgoing pipelines in a block, a decision-making process based on the MADM method is introduced.

Keywords:
Outgoing pipeline of shale gas;
Multi-attribute decision-making method;
Pipeline route layout;
Intuitionistic fuzzy set.

1. Introduction

Program preference for the outgoing pipeline routing of shale gas is a multi-attribute problem. To effectively address this issue, it is necessary to consider a variety of influencing factors and build an optimal planning model. This needs to be based on the expectations of decision makers in the context of China's oil and gas pipeline networks and characteristics of outgoing pipelines, thereby determining the feasibility of pipeline routing.

Among studies on the index weighting method, evaluation index system, and comprehensive evaluation system [1-5], most focus primarily on conventional oil and gas pipelines, paying little regard to unconventional ones. Optimization analyses of natural gas pipelines address their design by optimizing pipeline pressure and diameter through appropriate models, algorithms, and tools [6-7]. Studies employing optimal multi-attribute decision-making (MADM) methods focus on the approach in which the alternative preference information is an intuitionistic judgment matrix and the multi-attribute group decision-making method is based on different intuitionistic preference structures [8-9]. Such studies focus on the MADM method based on intuitionistic fuzzy and interval-based intuitionistic fuzzy information [10-12].

To address the complexity and challenge associated with the decision-making optimization model for outgoing shale gas pipelines, this study explores the program preference with multi-attribute decision making method for such pipelines.

2. Problem description and decision-making process

2.1. Problem description

Shale gas blocks with abundant reserves are generally located in remote mountainous regions, which are far from the trunk pipeline network of natural gas; therefore, outgoing pipelines are the preferred mode of transport. However, the alternative solutions to outgoing pipeline routing differ in terms of investment scale and environmental impact. A geological survey compared the three routing alternatives as follows:

1) the short-distance pipeline route needed to pass through special areas such as rivers and forests, and its investment scale was not necessarily low;

2) the low-investment route would cause severe environmental damage and encounter various obstacles in its construction;

3) the flat-topography and low-environmental-impact route was relatively long, with relatively high operation and maintenance costs, relatively low gas yield per well, longer investment payoff period, and

---

**E-mail:* jinchunqing@salyanoil.com
http://dx.doi.org/10.5510/OGP20190200390

a complex decision-making problem. Hence, it is important to select an outgoing pipeline route with low-cost, high efficiency and low-environmental-impact, based on key data/information (including geological data and environmental evaluation). This is not only a matter of urgency, but also key to shale gas commercialization.

2.2. Decision-making process complexity analysis

Based on their properties, the various attributes involved in the MADM process can be classified into qualitative attributes (including natural environments, geological structures, safety risks, traffic conditions, and socioeconomic development levels of the areas that the pipelines pass through) and quantitative attributes (including pipeline length, engineering costs, and pipeline pressure). To be specific, the diverse attributes can be classified into cost-related attributes (including engineering costs, safety risks, pipeline pressure, natural environments, and geological structures) and benefit-related attributes (including pipeline length, socioeconomic development levels, and traffic conditions). Some of these attributes can be quantified, whereas others cannot be measured accurately and are usually subjectively estimated by experts. Therefore, the MADM process is a hybrid decision-making process. To facilitate pipeline development in subsequent periods, the decision-makers also predict the future of the pipelines. In the process of solution ranking and selection, certain expectations are placed on each attribute.

Optimal planning for outgoing pipeline routing of shale gas involves a multi-attribute group decision-making model based on different intuitionistic preference structures. This model needs to consider changes in deviation variables as well as the degree of hesitance and uncertainty of decision-makers. However, quantifying decision-makers' subjective initiative and behavior are challenging and they can only be represented in the form of semantic values, interval number functions, and member functions. At present, solving an MADM model with intuitionistic fuzzy sets is extremely complex. Hence, it is necessary to design a reasonable algorithm to solve the model.

3. Mathematical models and algorithms

3.1. Building an MADM model based on intuitionistic fuzzy sets

3.1.1. Parameter Settings

Now, a company wants to build a shale gas pipeline with alternative solution set $A=\{A_1, A_2,...A_i, A_m\}$, attribute set $M=\{M_1, M_2,...M_i, M_n\}$, and decision matrix $B=[B_{ij}]_{m\times n}$. Based on existing information and future expectations, the decision-makers specify the expectation vector of the attributes ($E=\{E_1, E_2,...E_i, E_n\}$). Here, A_i indicates the i-th alternative solution, M_j indicates the j-th attribute, and B_{ij} indicates the j-th attribute value in the i-th alternative solution. The multiple attributes are independent of each other.

Which are denoted as M^N, M^I, and M^L, respectively. Evidently, $M^N \cup M^I \cup M^L = M$. The attribute value contained in M^L is based on language description, indicating seven states (namely «Very Poor», «Poor», «Moderately Poor», «Moderate», «Moderately Good», «Good», and «Very Good», in the given order). These are denoted as $S=\{VP, P, MP, M, MG, G, VG\}$. M^I is an interval number and M^N is a precise number [8].

In the multi-period investment decision-making process for the outgoing pipeline routing of shale gas, there are m alternative solutions, each involving k pipeline sections, with l representing pipeline length and ω_{ij} representing the investment of the j-th pipeline section of the i-th alternative solution. $S(l)_{ij}$, E_{ij}, and $R(P,l)_{ij}$ refer to the construction costs, environmental costs, and operation costs, respectively, of the j-th pipeline section of the i-th alternative solution, while α, β, γ refer to their corresponding weights and meet the following condition:

$$\alpha + \beta + \gamma = 1.$$

The investment of each pipeline section can be calculated as follows:

$$w_{ij} = \alpha \mathrm{S}(l)_{ij} + \beta \mathrm{E}_{ij} + \gamma \mathrm{R}(P,l)_{ij}$$

where, i=1,2,3,...,m; j=1,2,3,...,k.

Next, the total investment (W_i) in the i-th alternative solution can be calculated as follows:

$$W_i = \sum_{j=1}^{k} w_{ij} \left(i = 1,2,3,\ldots\ldots,m \quad j = 1,2,3,\ldots,k \right)$$

3.1.2. Model building

According to the previous information on the construction of shale gas pipelines, decision-makers need to measure the benefits or losses of each alternative solution according to the influencing factors, compare the attribute value $B^{'}_{ij}$ and expected attribute $E^{'}_{j}$ of each alternative solution, and determine the decision matrix $V=[V_{ij}]_{m\times n}$ according to the Euclidean distance of each attribute value.

The computation of the Euclidean distance between the attribute value $B^{'}_{ij}$ and expected attribute $E^{'}_{j}$ of each alternative solution when $i\in X$, is as follows [9]:

$$D_{ij} = \begin{cases} \left| B^{'}_{ij} - E^{'}_{j} \right|, j \in M^N \\ \sqrt{[(B^{L^{'}}_{ij} - E^{L^{'}}_{j})^2 + (B^{U^{'}}_{ij} - E^{U^{'}}_{j})^2]/2}, j \in M^I \\ \sqrt{[(B^{L^{'}}_{ij} - E^{L^{'}}_{j})^2 + (B^{M^{'}}_{ij} - E^{M^{'}}_{j})^2 + (B^{U^{'}}_{ij} - E^{U^{'}}_{j})^2]/3}, j \in M^L \end{cases} \quad (1)$$

The decision matrix $V=[V_{ij}\ (B_{ij})]_{m\times n}$ for pipeline routing is based on the sustained losses or risks associated with the benefits, as follows:

$$V(B_{\mathrm{ij}}) = \begin{cases} (\mathrm{D}_{ij})^{\alpha}, B^{'}_{ij} \geq E^{'}_{j} \\ -\theta \times (-\mathrm{D}_{ij})^{\beta}, B^{'}_{ij} \leq E^{'}_{j} \end{cases} \quad (2)$$

If the investment of each pipeline section is replaced with the length of the respective section, the multi-period investment decision problem can be converted into a problem for seeking the lowest cost and shortest path. Therefore, the above problem can be solved through the shortest path model. Generally, it is assumed that $G=(V,E)$ is the connected graph and l_{ij} is the weight of each side (v_i, v_j) of the connected graph. If l_{ij} =∞, there is no connection between the sides v_i, v_j, v_s, v_t are two arbitrary points in the connected graph. To determine the path μ with the lowest total weight among all paths between v_s and v_t, $L(\mu)=\sum_{(v_i,v_j)\in\mu} l_{ij}$ must be minimized.

We assume that $L(u,w)$ is the difference between each alternative solution in the solution set and all other influencing factor indices. Then, $L(u,w)=[l_1(u, w), l_2(u, w),..., l_m(u, w)]$. Without emphasizing on any particular alternative solution, the optimal planning model can be built as follows:

$$\min Z = L(u,w) = \sum_{i=1}^{m} l_i(u,w) = \sum_{i=1}^{m}\sum_{h=1}^{2} u_{Ti}^2 \times \sum_{j=1}^{n} [\mathrm{w}_j \times (r_{ij} - G_{Tj})]^2 \tag{3}$$

with the following constraint conditions:

$$\sum_{h=1}^{2} u_{Ti} = 1, \sum_{j=i}^{n} w_j = 1, 0 \le u_{Ti} \le 1, 0 \le w_j \le 1 \tag{4}$$

3.2. Algorithm analysis and design

3.2.1. Determining index weights and degree of membership

The variable fuzzy recognition model can be used to determine the attribute weight vector of each influencing factor index for pipeline routing, and the membership degree between each alternative solution and the investors' decision-making expectations.

According to the computation of distance D_{ij} in Equation (1), it can be known that $D_{ij}\in[0,1]$. When $D_{ij}\to 0$, the smaller the difference between the j-th influencing factor of the i-th plan of the pipeline construction and the expectation E_j of the decision maker is, the larger the gap is when $D_{ij}\to 1$.

Based on this, we build two levels of opposite fuzzy recognition centers to evaluate the influencing factor indices and denote them as $K=[K_{Tj}]_{m\times n}$, where $T=\{1,2\}$. When $T=1$, $K_{Tj}=0$ represents the optimal attribute set, and when $T=2$, $K_{Tj}=1$ represents the worst attribute set.

We assume that $U=[u_{Ti}]_{2\times m}$ is the membership matrix for pipeline routing. Here, u_{Ti} indicates the degree of membership between the i-th alternative solution to pipeline routing and the fuzzy recognition center. Owing to the opposition of recognition centers for pipeline routing, the condition $u_{2i}=1-u_{1i}$ is met. We let $r_{ij}= D_{ij}$ to determine the optimal degree of membership (u^*_{ij}) between an alternative solution and a recognition center, and the optimal weight vector (w^*) for pipeline routing. If the generalized weighted Euclidean distance between the expectation vector and an alternative solution is $l(w,u)$, the generalized weighted Euclidean distance between the i-th alternative solution and a fuzzy recognition center is as follows:

$$l_1(u,w) = \left\{ \sum_{h=1}^{2} u_{Ti} \times \sqrt{\sum_{j=1}^{n} [\mathrm{w}_j \times (\mathrm{r}_{ij} - G_{Tj})]^2} \right\}^2 = \\ = \sum_{h=1}^{2} \left\{ u_{Ti}^2 \times \sum_{j=1}^{n} [\mathrm{w}_j \times (\mathrm{r}_{ij} - G_{Tj})]^2 \right\} \tag{5}$$

Evidently, the smaller the $l_i(w,u)$ value, the smaller the difference between the i-th alternative solution and the decision-makers' expected objective, i.e., the more optimal the decision-makers recognition of the expectation vector for pipeline routing.

3.2.2. Ranking alternative solutions and selecting the optimal solution to outgoing pipeline routing

The attribute weight vector of pipeline routing is $w^*=(w_1, w_2,...w_j, w_n)$. Therefore, it is necessary to compare the attribute value B'_{ij} of each scheme of the shale gas outflow pipeline construction with the expected attribute E'_j. The cumulative prospect value $P(A)$ of each alternative solution can be determined by calculating the Euclidean distance of each attribute value as shown in the following equation:

$$P(\mathrm{A_i}) = \sum_{j=1}^{n} w_j \times V(\mathrm{b}_{ij}), \quad i \in M \tag{6}$$

In Equation (6), the $V(b_{ij})$ value can be calculated by Equation (2).

We let $r_{ij}= D_{ij}$. After considering only the attribute set, the larger the value of $V(b_{ij})$, the better is the Solution A_i. Hence, the alternative solutions can be ranked according to their $V(b_{ij})$ values.

We assume that $U(A_i)$ is the degree of membership between Solution A_i and decision-makers' expectations. Then, $U(A_i)=u^*_{1j}$. The larger the $U(A_i)$ value, the higher is the degree of membership of Solution A_i. If only the degree of membership of alternative solutions is considered, the alternative solutions can be ranked according to their $U(A_i)$ values.

Variable fuzzy pattern recognition and membership degree actually reflect the relationship between the construction scheme A_i and the enterprise decision expectation E_j from two angles: if and only if the variable fuzzy pattern recognition value of A_i is larger and the membership degree is higher, The better the construction plan A_i is. Therefore, this study considers the variable fuzzy pattern recognition value and degree of membership of each alternative solution (namely, the overall prospect value denoted as $O(A)$ to rank the alternatives and select the optimal solution. The corresponding calculation is as follows:

$$O(\mathrm{A}_i) = \begin{cases} P(\mathrm{A_i}) \times U(\mathrm{A_i}) & \text{if} \quad P(\mathrm{A_i}) \ge 0 \\ P(\mathrm{A_i}) \times [1 - U(\mathrm{A_i})] & \text{if} \quad P(\mathrm{A_i}) < 0 \end{cases} \tag{7}$$

The larger the overall prospect value is $O(A_i)$, the better solution is A_i.

4. Empirical case study

4.1. Problem description in the empirical case

The shale gas yield by Company X in Block A was high enough for commercial exploitation. However, the natural gas pipeline network was underdeveloped while the automobile transport and LNG were of high cost and risk. Hence, Company X could not meet actual requirements for commercial exploitation. Company X considered building outgoing pipelines to transport shale gas

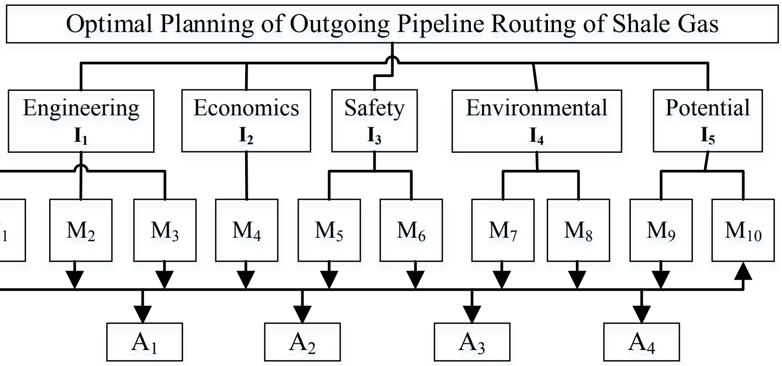

Fig. Influencing factor evaluation index system of outgoing pipeline routing of shale gas

to the trunk pipeline of natural gas, situated 50 kilometers away. Through survey and design, the company planned to select the optimal solution from among four alternatives $\{A_1, A_2, A_3, A_4\}$ to outgoing pipeline routing. According to the evaluation index system for influencing factors in a feasibility study report based on pipeline construction in Block *A*, and after considering the five factors of engineering, economy, safety, environment, and potential utility, there were a total of 10 attributes and 4 alternative solutions. Hence, the following structure was built.

Among the ten attributes, M_1~ M_{10} are the length of the pipeline (*Km*), the crossing spanning project, (m^2) the construction access road (*Km*), the project investment cost (ten thousand yuan), the pipeline pressure (*MP*), pipeline drop (*m*), geographical environment, social environment, maintenance difficulty, and potential utility. $\{M_1, M_2, M_3, M_4, M_5\}$ are precise numbers, $\{M_3, M_6\}$ are interval numbers, and $\{M_7, M_8, M_9, M_{10}\}$ are semantic values.

4.2. Building and solving the model

According to the feasibility study report on the pipeline design in Block A for Company X, this study proposed the expected values for each attribute of alternative solution. Based on a 1-9 scoring scale, experts used the analytic hierarchy process (AHP) to subjectively score the evaluation indices. Table 1 lists the experts' expected values and the corresponding index weights.

Table 1

Experts' expected values (EXP) and subjective index weights (AHP) for the outgoing pipeline routing of shale gas

Solution	M_1	M_2	M_3	M_4	M_5
EXP	[175,185]	[800,2000]	[15,30]	[8.0,8.3]	[6.0,6.5]
ω	0.0864	0.0869	0.0998	0.0993	0.0884
Solution	M_6	M_7	M_8	M_9	M_{10}
EXP	[6.0,8.0]	M	MG	M	MG
ω	0.0778	0.0858	0.0819	0.0661	0.0654

Original data on the indices of each alternative solution were collected. Specifically, data on precise numbers and intervals were cited from the feasibility study report, and data on semantic languages was generated based on the description of outgoing pipelines in the report. Table 2 lists the original data.

Table 2

Original index data on alternative solutions to outgoing pipeline routing of shale gas

Solution	M_1	M_2	M_3	M_4	M_5
A_1	178	950	[15,30]	8.41	6.87
A_2	210	2300	[17,32]	8.16	6.53
A_3	185	1550	[15,35]	8.63	6.74
A_4	190	3700	[16,37]	8.24	6.35
Solution	M_6	M_7	M_8	M_9	M_{10}
A_1	[4.6,6.8]	MP	VP	MP	P
A_2	[5.8,8.0]	M	MG	M	G
A_3	[7.2,9.8]	MG	M	MG	MG
A_4	[7.2,9.0]	M	P	P	VP

Pipeline routing is a multi-type and multi-objective hybrid MADM problem, so it was necessary to first process the original data of the indices for each alternative solution. According to the experts' expected values and data on the indices of alternative solutions generated by triangular fuzzy quantification using equation (3), the original data in table 2 was normalized using Equation (4). Based on the normalized data, the Euclidean distance between each alternative solution and the decision-makers' expectation vector was calculated using Equation (2). Then, the variable fuzzy recognition model was estimated using cross loop iterations according to Equations (5) and (6), to calculate the variable fuzzy recognition index weight. Table 3 describes the optimal weight vector determined through cross loop iteration.

Finally, the matrix of optimal degree of membership (u^*_{Ti}) is as follows:

$$u^*_{Ti}=\begin{bmatrix}0.9731, & 0.9950, & 0.9612, & 0.9714\\ 0.0269, & 0.0050, & 0.0388, & 0.0286\end{bmatrix}$$

When T is equal to 1, u^*_{Ti} indicates the degree of

Table 3

Optimal weight vector for outgoing pipeline routing of shale gas (fuzzy recognition model)

Weight	M_1	M_2	M_3	M_4	M_5
ω	0.0864	0.0869	0.0998	0.0993	0.0884
Weight	**M_6**	**M_7**	**M_8**	**M_9**	**M_{10}**
eω	0.0778	0.0858	0.0819	0.0661	0.0654

membership between an alternative solution and the decision-makers' expectations. Therefore, the degree of membership of the alternative solutions is U=(0.973, 0.9950, 0.9612, 0.9714) in order. Using Equation (7), we can calculate the variable fuzzy recognition value of each alternative solution according to the different index weights in tables 1 and 3. Table 4 describes the three types of decision-making results regarding outgoing pipeline routing, which were obtained based on the degree of membership and variable fuzzy recognition values.

Based on table 4, the ranking of alternative solutions by the three decision-making methods is consistent. Specifically, the priority of the plan is $A_2 \succ A_1 \succ A_4 \succ A_3$.

4.3. Result analysis

It can be seen from the above that the A_2 is a decision-maker who comprehensively considers the five major factors of engineering, economy, safety, environment, and potential utility, compares the attribute values of the four candidate schemes with the expected values of the experts, and optimizes the gains and losses of each scheme. The optimal solution is low cost, highly efficient, low risk, causes small environmental damage, and has good potential utility. Moreover, since this study adopts comprehensive consideration of foreground values and membership degrees, it shows that the A_2 is not only the closest to the decision-makers' expectations, but also has a high foreground value. Therefore, the shale gas pipelines proposed in this study are more preferred. The attribute decision-making method not only considers the risk attitude of the decision-makers but also the difficulty of maintenance during the operation of the pipeline construction and the convenience of the new pipeline access in the future, to measure the potential utility of the pipeline. It is a dynamic decision-making process. The results are more easily accepted by decision makers.

The length of the pipeline of the A_1 is the shortest, the cross-crossing project is the least, the terrain is flat, and the pipeline gap is small. However, it passes through densely populated urban areas, with more farmlands, forests, houses, and other surface coverings, and the land acquisition cost is higher. Improper handling can easily lead to disputes, delays in construction period, and higher maintenance costs later. Therefore, the comprehensive feasibility of the A_1 is not as good as the A_2.

The pipelines of the A_4 have too many tunnels, highways, rivers, etc., which are difficult high-tech projects. The construction cost accounts for more than 30% of the total line cost. The pipeline construction project is too big, which affects the pipeline safety and construction period. Far from the natural gas pipeline network, the potential value of future planning is poor, and these factors make it less feasible than A_2 or A_1.

The geographical environment, maintenance difficulty, and potential utility of the A_3 scheme are better, but the key quantitative data such as pipeline investment cost, pipeline pressure, and gap are not in line with the expected requirements of the project; the scheme risk is too high, and the degree of membership expected by the decision makers is the lowest. Therefore, it is the least feasible among the four programs.

This empirical case involved building a fuzzy MADM model and ranking alternative solutions through the multi-attribute group decision-making method based on different intuitionistic preference structures. An optimal solution was finally selected, which could be used to verify the fuzzy MADM model.

Table 4

Ranking of alternative solutions to outgoing pipeline routing of shale gas by different decision-making methods

Decision-making Method	A_1	A_2	A_3	A_4	Rank
Degree of membership (fuzzy recognition)	0.9865	0.9912	0.9637	0.9748	$A_2 \succ A_1 \succ A_4 \succ A_3$
AHP (subjective weight)	-0.6142	-0.3749	-0.8266	-0.6897	$A_2 \succ A_1 \succ A_4 \succ A_3$
Entropy weight method (objective weight)	-0.3259	-0.1814	-0.5879	-0.4617	$A_2 \succ A_1 \succ A_4 \succ A_3$

5. Conclusions

In China, storage areas of shale gas are mostly distributed in mountainous or hilly areas, where laying pipelines is challenging. Therefore, the investment decision-making process is complex and comprises of a typical multi-attribute, multi-objective, and multi-period investment decision-making problem. Using a combination of methods (including MADM, intuitionistic fuzzy set theory, and combination weighting), this study provides a formal description of the pipeline investment decision-making problem and presents an optimal planning model for outgoing pipeline routing, thereby deepening the understanding of MADM theory under uncertainty conditions. Through an empirical analysis, this study verifies the feasibility and effectiveness of the proposed model and method.

Acknowledgements
This study is supported by «The Fundamental Research Funds for the Central Universities» (17CX06052B).

References

1. *Z.Hussain, S.A.A.Naqvi, S.J.H.Kazmi, et al*. Demarcation of right of way (ROW) and re-installation of damaged carkers of transmission pipeline in Balochistan, Pakistan through geomatics technologies: a case study of Zarghun to Quetta high pressure natural gas supply //Journal of Basic and Applied Sciences. -2015. -No.11. -P.52-61.

2. *Y.Liu, Y.Wang, M.Fu, et al.* The interval mathematical model of optimization evaluation of gas pipeline design scheme //Natural Gas Technology. -2009. -No.3(5). -P.36-39.

3. *A.Chebouba.* Multi objective optimization of line pack management of gas pipeline system //Journal of Physics: Conference Series. IOP Publishing. -2015. -No.574(1). -Article 012114.

4. *M.E.Pfetsch, A.Fügenschuh, B.Geißler, et al.* Validation of nominations in gas network optimization: models, methods and solutions //Optimization Methods and Software. -2015. -No.30(1). -P.15-53.

5. *X.Wu, M.Li, W.Jia, et al*. Optimal operation of trunk natural gas pipelines via an inertia-adaptive particle swarm optimization algorithm //Journal of Natural Gas Science and Engineering. -2014. -No.21. -P.10-18.

6. *A.H.A.Kashani, R.Molaei.* Techno-economical and environmental optimization of natural gas network operation //Chemical Engineering Research and Design. -2014. -No.92(11). -P.2106-2122.

7. *R.Z.Ríos-Cercado, M.Borraz-Sánchez*. Optimization problems in natural gas transportation systems: a state-of-the-art review //Applied Energy. -2015. -No.147. -P.536-555.

8. *Z.Xu.* The integration method of interval intuitionistic fuzzy information and its application in decision making //Control and Decision. -2007. -No.22(2). -P.215-21.

9. *Z.Xu*. Multi-attribute group decision - making method based on fuzzy language evaluation and GIOWA //Systems Science and Mathematics. -2004. -No.24(2). -P.218-224.

10. *Q.Zhang, Z.Fan.* A sorting method of interval numbers in uncertain multi-attribute decision making //Systems Engineering: Theory & Practice. -1999.

11. *Z.Fan, T.You*. Sensitivity analysis of attribute value based on weighted model in multi-attribute decision making //Journal of Northeastern University. -2002. -No.23(1). -P.83-86.

12. *G.Wei, Y.Wei.* The interval number multi-attribute grey relational decision model with preference to the scheme //Chinese Management Science. -2008. -No.16(1). -P.158-162.

Программа-рекомендация с многофакторным методом принятия решений для прокладки трубопровода сланцевого газа

Ц.Чуньцин, Ч.Цзайсюй, Л.Руифан
Институт экономики и менеджмента, Китайский Нефтяной
Университет (Восточный Китай), Циндао, Китай

Реферат

Действующие трубопроводы, которые являются неотъемлемым элементом процессов разведки и разработки месторождений, накладывают определенные ограничения на транспортировку сланцевого газа до потребительского рынка, тем самым влияя на его коммерциализацию. В статье, с учетом текущего состояния сети трубопроводов Китая, предлагается система индексирования влияющих факторов, основанная на требованиях к оптимальному маршруту прокладки трубопровода. В частности, это система индексирования охватывает пять аспектов влияющих факторов: инжиниринг, экономика, безопасность, окружающая среда и коммерческий потенциал. С учетом всех возможных ограничений, представлен оптимальный многофакторный метод принятия решений (ММПР) для проектирования маршрутов транспортировки сланцевого газа основанный на интуиционистских нечетких множествах. На примере вариантных решений маршрутов транспортировки, представлен процесс принятия решений на основе ММПР.

Ключевые слова: трубопровод сланцевого газа; многофакторный метод принятия решений; планирование маршрута трубопровода; интуиционистские нечеткие множества.

Şist qaz boru kəmərlərinin çəkilməsi üçün həllərin qəbulunun çoxfaktorlu üsulu ilə proqram-tövsiyyə

S.Çunsin, Ç.Tsaysuy, L.Ruifan
İqtisadiyyat və İdarəetmə İnstitutu, Çin Neft Universiteti
(Şərqi Çin), Tsidao, Çin

Xülasə

Yataqların kəşfiyyatı və işlənməsi prosesinin ayrılmaz hissəsi olan mövcud boru kəmərləri şist qazının istehlak bazarına çatdırılımasına müəyyən məhdudiyyətlər yaradır ki, buda onun komersialaşmasına təsir edir. Məqalədə, Çinin boru kəmərləri şəbəkəsinin cari vəziyyətini nəzərə almaqla, boru kəmərlərinin çəkilməsinin optimal marşrutuna tələbləri əsasında təsir edici amillərin indeksləşmə sistemi təklif edilir. Bu indeksləşmə sistemi əsasən təsiredici amillərin beş aspektini əhatə edir: mühəndislik, iqtisadiyyat, təhlükəsizlik, ətraf mühit və kommersiya potensialı. Bütün mümkün məhdudiyyətləri nəzərə almaqla, intuisionist qeyri-səlis çoxluqlara əsaslanan şist qazının nəql marşrutlarının layihələndirilməsində optimal həllərin qəbul edilməsi üçün çoxfaktorlu üsulu (HQÇÜ) təqdim edilmişdir. Nəqletmə marşrutlarının həll variantlarının nümunəsində, HQÇÜ əsasında həllərin qəbul edilməsi prosesi təqdim edilmişdir.

Açar sözlər: şist qaz boru kəməri; həllərin qəbul edilməsi üçün çoxfaktorlu üsul; boru kəmərlərinin marşrutlarının planlaşdırılması; intuisionist qeyri-səlis çoxluqlar.