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Locating and ranking development plans of Iron and Steel Industries in Afghanistan by using FAHP and FTOPSIS methods

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Abstract. Due to the growth of steel industry in the world, the rich resources of ore, Abundance of inputs required by the iron and steel industry and higher demand for steel in Afghanistan, the idea of designing and locating development plans in the field of iron and steel industry was created. To increase existing competitive advantages and gaining the most added value for Afghanistan requires suitable locations. In this paper, six cases as criteria and nineteen cases as sub-criteria that have a greater impact on the construction of iron and steel industries, selected after interviews with experts. The questionnaires have been arranged and distributed by google-forms and interviews have been conducted with experts. The weights of the criteria and sub-criteria were calculated based on the results of the questionnaires and using the FAHP. Then by using the FTOPSIS, the plans are ranked based on the similarity index. As a result, which the Bamyan has come in first position and Kandahar has come in recent position of development planning to invest. In the end, for more accuracy and correctness of the research after completing all preconditions, sensibility analysis among options according criteria and sub-criteria has been done in five scenarios.

Keywords: *Afghanistan, fuzz multi-criteria decision making, FAHP, FTOPSIS, iron and steel plans, locating, sensibility analysis.*

1. Introduction

According to the 2010 survey which conducted by the Geological Survey of Afghanistan, the value of these resources was estimated 1,131,840 million dollars with different mining sources and iron ore mines have the main part of these resources [1]. According to the Ministry of Commerce and Industries of Afghanistan, 4,500 tons of iron and steel are imported daily from different countries. The steel industry in Afghanistan is not in good condition because the effective investments and basic work have not been made in the field. Only a few small companies with private investments have started their activities in recent years which cannot run domestic needs [2]. Considering the above cases, it is necessary to plan and place development programs in the area of iron and steel industry in Afghanistan. If you invest, you can create a suitable value added in the industries and boom of the economic fields of the country. One of the most important issues in the mining and mining industries is the proper use of Afghanistan's minerals and natural resources, which is the priority of getting suitable facilities for the creation of iron and steel industries [3]. Development projects are one of the effective measures on development and plan of infrastructure projects in countries. Different methods of loitering are used to find suitable areas for investment for the proper development of infrastructure projects.

As it is known for all Afghanistan is a suitable country for investment, loitering areas to invest in different areas is one of the necessary in development programs of the government that has not yet been done in this field. Therefore, this article tries to identify the provinces suitable for investment in the construction of steel industries and processes and proposed except development plans. Loitering development plans in the field of Iron and Steel Industry of Afghanistan is more important because it is one of the new plans in Afghanistan.

Identifying suitable areas should be done based on specific and comprehensive criteria and these criteria are divided into their own criteria that have a direct effect on loitering. Development plans are necessary to use effective scientific method according to the many criteria and according to the importance of these criteria, a comprehensive and transparent localation can be achieved in this area [4]. Several decision making of some fuzzy method can be used in location and ranking. In this field, the method of fuzzy analysis (FAHP) and the method of similarity to the current choice (FTOPSIS) which have a strong oral and practical foundation and in the past few decades as one of the most important and applied ones, has been used to solve many problems of multi-criteria decision making in different sectors [5].

According to the research structures, first, candidate provinces for construction of steel industries and processes are determined. Then, the criteria and criteria ineffectiveness on the development of the industries are identified and among them, the criteria and the criteria that have more effectiveness are determined. The questions are developed and distributed according to the criteria and options of the candidate form a double-form in The Good form and interviews with experts. The criteria and criteria were calculated using FAHP method and the options were fisted using FTOPSIS method. At the last time, the suspense analysis of options has been done in five cases with accuracy healthiness scenarios.

1.1. Theoretical foundations of research

In any economic activity, production is a complex process of location and space relationships between factors and economic employer can achieve its goals in maximum profit by using plans to be in line with these relationships. The special reason is that the ground level is the most conflicting factors of the place and each place is the ground for a special type of economic activity due to its facilities. Change in location for a special choice means changing the income and costs that eventually leads to space changes in capital profiting. Therefore, loitering study has economic significant effect according to the criteria in effective on it and is considered as one of the most important issues in economic decision-making [6].

Proper and suitable studies will have economic impact on industrial unit's operation, social, environmental, cultural and economic effects in the area. The selection placement of the factory is one of the most key goals of the factory construction, because the results of such decision will be shown in the long term and will show their effects on the economy, environment, social issues, and so on [8]. However, in Afghanistan, due to the circumstances, no research has been done on the local development plans for iron and steel industries.

The decision making of several criteria is a research-in-operations research and is divided into two main parts: «MADM» and «MODM». The decision-making process of several branches (MADM) includes four basic steps (identifying and evaluation, weighting, selecting the best options, analysing and selecting the final choice).

In several-goal decision-making (MODM) decision making projects are considered at the same time for semanating. The semantos for each goal may be different from the other goals [10].

There is different method in decision making of several branches; these ones are divided into three categories. The first group includes methods that calculate the weight of criteria, the second group includes methods that aim to ranking options, and the third group includes methods that aim to check the effects of factors on them [11]. The first group of multi-faceted decision making (AHP) and «ANP» are the best-worst (BWM) and Lynmap (LINMAP) method. The second group of decision-making films includes TOPSIS, Vicor method, (ELECTRE), (ARAS) method, Selecting List method (PSI), and so on. The third group of multi-categories decision making includes Dyamatal method and the method of pertineal construction (ISM). In addition to the decision making of several definite lysis of some of the most definite lying branches, the best decision-making method of some of the few decision-making of the few time lists has been sedated. The most important of the steps in fazi decision making are fazi afsal analysis (FAHP, fagsian network analysis method (FANP) and timetell method, fazi topsis method (FTOPSIS) and so on [5]. In table 1, several examples of ftopsis and (FAHP) are used in different sections. In this study, the fazi afsal analysis (FAHP) method was used to get the criteria and the criteria and the method of ftopsis is used to ranking the options.

Table 1. Samples of using methods FAHP and FTOPSIS

Issue	Authors
Interval-valued intuitionistic fuzzy multiple attribute decision making based on nonlinear programming methodology and TOPSIS method	*Zeng et al.(2020)* [14]
Evaluation of Multimodal Transport in China Based on Hesitation Fuzzy Multiattribute Decision-Making	*Han et al. (2020)* [15]
Picture Fuzzy MCDM Approach for Risk Assessment of Railway Infrastructure	*Simić et al. (2020)* [16]
Multi-Criteria Decision Making Using TOPSIS Method Under Fuzzy Environment. Application in Spillway Selection	*Balioti et al. (2018)* [17]
The evaluation of airline service quality by fuzzy MCDM	*Tsaur et al.(2002)* [18]
Economic assessment and ranking of wind power potential using fuzzy-TOPSIS approach	*Mohsin et al. (2019)* [19]
A Fuzzy TOPSIS Method for Robot Selection	*Chu, T.-C. and Lin, Y.-C (2003)* [20]
Extensions of TOPSIS for multi-objective large-scale nonlinear programming problems	*Abo-Sinna, Amer(2005)* [21]
Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessmen	*Wang, Elhag (2006)* [22]
Multi-criteria group decision making using a modified fuzzy TOPSIS procedure	*Saghafian, Hejazi(2005)* [23]
An algorithmic method to extend TOPSIS for decision-making problems with interval data	*Jahanshahloo et al.(2006)* [24]
A fuzzy approach for supplier evaluation and selection in supply chain management	*Chen, Lin, Huang(2006)* [25]
A fuzzy TOPSIS methodology to support outsourcing of logistics services	*Bottani, Razzi(2006)* [4]
Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment	*Wang, Chang(2007)* [26]
Using fuzzy number for measuring quality of service in the hotel industry	*Benitez et al. (2007)* [27]
Machine Selection by AHP and TOPSIS Methods	*Karim, Karmaker (2016)* [27]
A hybrid data analytic methodology for 3PL transportation provider evaluation using fuzzy multi-criteria decision making	*Yayla et al. (2015)* [28]
Evaluating higher education teaching performance using combined analytic hierarchy process and data envelopment analysis	*Thanassoulis et al. (2017)* [29]
Modelling Procedure for the Selection of Steel Pipes Supplier by Applying Fuzzy AHP Method	*Zavadskas et al. (2020)* [30]
The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative technology selection	*Hsu (2010)* [31]
Research on energy conservation and emissions reduction based on AHP-fuzzy synthetic evaluation model: A case study of tobacco enterprises	*Wang et al. (2018)* [32]
The application of fuzzy analytic hierarchy process (FAHP) approach to selection of optimum underground mining method for Jajarm Bauxite Mine, Iran	*Naghadehi et al. (2009)* [33]
Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods	*Ertuğrul et al. (2009)* [10]
Integrating sustainability into strategic decision-making: A fuzzy AHP method for the selection of relevant sustainability issues	*Calabrese et al. (2019)* [34]
Performance evaluation model of romanian manufacturing listed companies by fuzzy AHP and TOPSIS	*Ban et al. (2020)* [35]

2. Materials and methods

2.1. Structure of research

In this research, a decision model has been used to locating development plans in the field of iron and steel industry in Afghanistan. The general structure of the research process is shown in Figure 1.

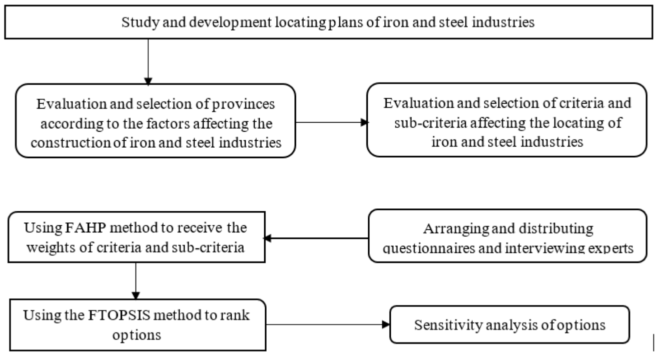

Figure 1. Research flowchart

2.2. Identifying location criteria for iron and steel industries

In the form of theories and experiences on a global scale, many principles and criteria can be proposed and analyzed for the sustainable development of development projects at the scale of construction of iron and steel industries. The selection of the most suitable places for the construction of iron and steel industries depends on the criteria related to it [36].

The selection of location criteria for iron and steel industries is based on review of regulations and interviews with experts. Which has been selected as one of the six criteria that include human-social and cultural, legal and political, technical-geological and infrastructural, geographical and environmental, economic and financial, commercial and commercial factors. Each of these criteria is distinguished by several related sub-criteria and according to them, including 19 items selected as effective sub-criteria for the location of iron and steel industries, which is included in Table 2.

2.3. Identify suitable locations for the construction of iron and steel industries

As Afghanistan has 34 provinces and most of these provinces are rich in mineral resources and also eligible to invest in the iron and steel industries. Therefore, first, all provinces are evaluated by main critera and sub-criteria and then, according to the effective factors and expert views, the provinces shown in Figure 2 on the map of Afghanistan, Selected as candidate options for the construction of iron and steel industries.

Figure 2. Location of candidate provinces (options) on the map of Afghanistan for the construction of steel industries

Table 2. Selected criteria and sub-criteria affecting the construction of Afghanistan's iron and steel industry

Criteria	Sub-criteria
Human, Social and Cultural Factors (A)	Possibilities (Existence of Housing, Educational Centers, Health and Hospitals) (A_1)
	Social, Cultural and Human Condition (A_2)
	Supply Human Resources (Educated and Labor Force) (A_3)
Legal and Political Factors (B)	Stability and security in any area (B_1)
	Legal and Tax Exemptions (B_2)
	The Extent of Peoples Cooperation with the Government in the Region (B_3)
Technical, Geological and Infrastructure Factors (C)	Existence of Mineral Resources (C_1)
	Existence of Water and Energy Resources (C_2)
	Communication Ways (Rail and Road) (C_3)
Geographical and Environmental Factors (D)	Appropriate Climate and Environmental Issues (D_1)
	Suitable Location for Tailings Accumulation (D_2)
	Seismicity and Potential of other Natural Disasters in each Region (D_3)
Economical and Financial Factors (E)	Infrastructure Investment (E_1)
	Reduction Capacity (E_2)
	Invest RetuArn Rate (E_3)
	Working Capital (E_4)
Commercial and Business Factors (F)	Distance to Feed Supplier Mines (F_1)
	Distance to feed Consumer Market (F_2)
	Industrial Competitors in the Region (F_3)

2.4. Determining the weights of criteria and sub-criteria by using FAHP method

After the introduction of the FAHP method by Thomas Saaty, Because of the great importance of using fuzzy concepts in decisions, In recent years, this method has been developed by a number of researchers These include the methods proposed by Buckley in 1985, Kahraman in 2005, and so on [37]. The method used in this study was proposed by Chang in 1996. After explaining the main and secondary factors affecting the location process for the construction of iron and steel industries in Afghanistan or development plans, the set of criteria and sub-criteria are categorized according to their application. Figure 3 describes the general structure of the fuzzy hierarchical analysis process and the classification of major and minor factors according to candidate options.

The work process in the Fuzzy Analytical Hierarchy Process method is performed regularly based on the defined steps (Figure 4). Fuzzy numbers used to value criteria and sub-criteria; it can be triangular and trapezoidal. In this study, in order to give importance and pairwise comparison of criteria and sub-criteria by experts, Fuzzy numbers are defined in a triangular shape that includes Table 3.

Table 3. Defined triangular fuzzy numbers for Paired comparisons of criteria and sub-criteria

Verbal expressions	Fuzzy numbers			Inverse fuzzy numbers		
Similar	1.500	1.000	0.500	2.000	1.000	0.667
Less	1.000	0.500	0.250	4.000	2.000	1.000
More Less	0.500	0.250	0.000	0.000	4.000	2.000
More	2.000	1.500	1.000	1.000	0.667	0.500
Much More	3.000	2.000	1.500	0.667	0.500	0.333

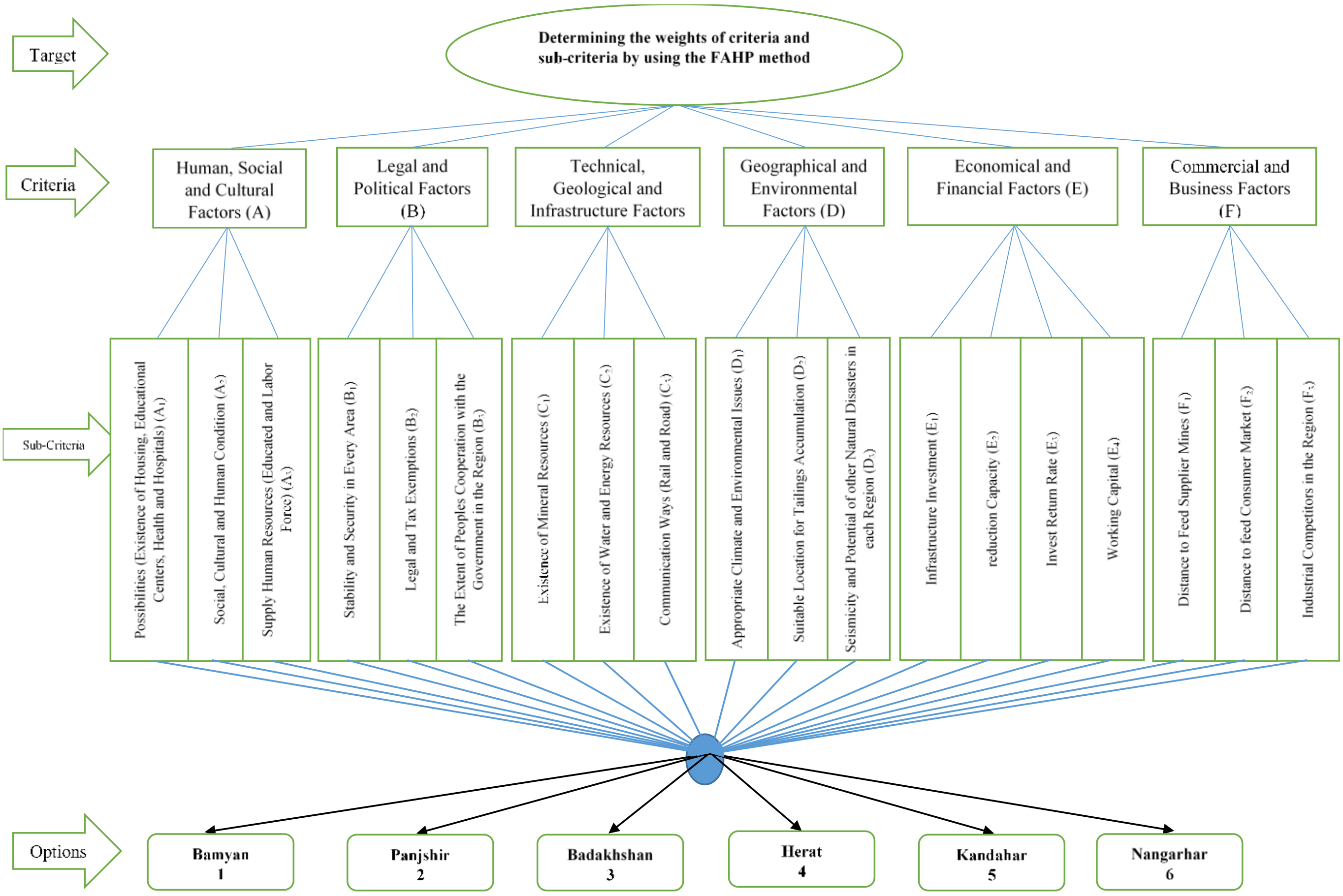

Figure 3. General structure of research in FAHP method

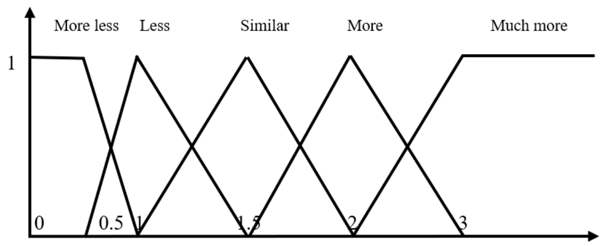

Figure 4. Defined fuzzy number membership function

According to the results of the questionnaires, Matrix of pairwise comparisons of criteria and sub-criteria have been formed using Equation 1. As an example, the results of the pairwise comparison matrix of criteria are written in Table 1 of Appendix 1.

$$M^{\sim} = \begin{pmatrix} M_{g_1}^1 & M_{g_1}^2 \cdots\cdots & M_{g_1}^m \\ M_{g_2}^1 & M_{g_2}^2 \cdots\cdots & M_{g_2}^m \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ M_{g_n}^1 & M_{g_n}^2 \cdots\cdots & M_{g_n}^m \end{pmatrix} \quad (1)$$

The calculation of the fuzzy compound expansion (S_i) for each of the rows of the pairwise comparison matrix of the criteria was performed using Equation 2 and the results are written in Table 4.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \quad (2)$$

M_{gi}^{j} are triangular fuzzy numbers of matrix pairwise comparisons. Values $\sum_{j=1}^{m} M_{gi}^{j}$, $\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}$ and $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$. Calculated by Equations 3, 4 and 5 and includes Table 4.

$$\sum_{j=1}^{m} M_{gi}^{j} = \left\{ \sum_{j=1}^{m} l_{ij} \cdot \sum_{j=1}^{m} m_{ij} \cdot \sum_{j=1}^{m} u_{ij} \right\} \quad (3)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left\{ \sum_{i=1}^{n} l_i \cdot \sum_{i=1}^{n} m_i \cdot \sum_{i=1}^{n} u_i \right\} \quad (4)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left\{ \frac{1}{\sum_{i=1}^{n} u_i} \cdot \frac{1}{\sum_{i=1}^{n} m_i} \cdot \frac{1}{\sum_{i=1}^{n} l_i} \right\} \quad (5)$$

In the above equations l_i, m_i and u_i are the first to third components of fuzzy numbers, respectively.

The degree of preference of S_i over each other was calculated using Equation 6 and the results are written in Table 5. Since $S_k = \{l_1, m_1, u_1\}$ and $S_k = \{l_2, m_2, u_2\}$ are two triangular fuzzy numbers, the magnitude of S_i relative to S_k is defined as follows:

$$V\left(S_i^{\sim} > S_k^{\sim}\right) = \alpha_{si}(d) = \begin{pmatrix} 1 & m_i \geq m_k \\ 0 & l_k \geq u_i \\ \dfrac{l_k - u_i}{(m_i - u_i) - (m_k - l_k)} & otherwise \end{pmatrix} \quad (6)$$

Here d corresponds to the largest point of intersection between α_{sk} and α_{si}. Assume that $k=1.2 \ldots n$. $K\neq 1$ and $d\cdot(A_1)=MinV(S_i\geq S_k)$. Therefore, the calculation of non-normalized weights of the criteria was performed using Equation 7 and includes Table 6.

$$W=(d\cdot(A_1).d\cdot(A_2).\ \ldots\ .d\cdot(A_n))^T \quad A_i(i=1.2\ldots\ \ldots\ \ldots\ .n) \qquad (7)$$

The weights of the criteria were normalized by using Equation 8 and the results are written in Table 6. The mentioned indicators have also been performed for the sub-criteria. Finally, by multiplying the normalized weights of the criteria by the normalized weights of their respective sub-criteria, the final weights of the sub-criteria were calculated and included in Table 7.

$$W=(d(A_1).d(A_2).\ \ldots\ \ldots\ .d(A_n))^T \qquad (8)$$

Table 4. Developmental analysis values and fuzzy compound expansion of criteria

Criteria	Geometric mean of fuzzy (R_i)			Fuzzy compound expansion (S_i)		
A	3.333	7.770	7.167	0.060	0.166	0.372
B	5.667	12.225	8.500	0.103	0.262	0.442
C	6.250	12.917	10.500	0.113	0.276	0.545
D	1.583	4.409	9.000	0.029	0.094	0.468
E	1.667	6.038	12.500	0.030	0.129	0.649
F	0.750	3.375	7.500	0.014	0.072	0.390
	19.25	46.73	55.17			
	0.02	0.02	0.05			

Table 5. Criteria Preference Index

Criteria		A			B			C			D			E			F		
		0.06	0.17	0.37	0.10	0.26	0.44	0.11	0.28	0.55	0.03	0.09	0.47	0.03	0.13	0.65	0.01	0.07	0.39
	0.06																		
A	0.17		1.000			0.739			0.702			1.000			1.000			1.000	
	0.37																		
	0.10																		
B	0.26		1.000			1.000			0.957			1.000			1.000			1.000	
	0.44																		
	0.11																		
C	0.28		1.000			1.000			1.000			1.000			1.000			1.000	
	0.55																		
	0.03																		
D	0.09		0.850			0.686			0.661			1.000			0.926			1.000	
	0.47																		
	0.03																		
E	0.13		0.941			0.805			0.785			1.000			1.000			1.000	
	0.65																		
	0.01																		
F	0.07		0.778			0.602			0.575			0.942			0.863			1.000	
	0.39																		

Table 6. Non-normalized and normalized weights of criteria

Criteria	A	B	C	D	E	F
Non- normalized weights	0.702	0.957	1.000	0.661	0.785	0.575
Normalized weights	0.150	0.205	0.214	0.141	0.168	0.123

Table 7. Final weights of sub-criteria

Criteria	A			B				C		
Normalized weights Criteria	0.150			0.205				0.214		
Sub-criteria	A_1	A_2	A_3	B_1	B_2		B_3	C_1	C_2	C_3
Normalized weights sub-criteria	0.306	0.291	0.403	0.359	0.329		0.312	0.385	0.287	0.329
Final weights of sub-criteria	0.046	0.044	0.060	0.074	0.067		0.064	0.082	0.061	0.070
Criteria	D			E				F		
Normalized weights Criteria	0.141			0.168				0.123		
Sub-criteria	D_1	D_2	D_3	E_1	E_2	E_3	E_4	F_1	F_2	F_3
Normalized weights sub-criteria	0.363	0.313	0.324	0.226	0.264	0.251	0.259	0.479	0.230	0.291
Final weights of sub-criteria	0.051	0.044	0.046	0.038	0.044	0.042	0.044	0.059	0.028	0.036

2.5. Ranking of developmental plans by using FTOPSIS method

Ranking projects to investment in all government development programs is a principle and should be considered. In order to better investment in Afghanistan's iron and steel industry, there is a greater need to prioritize these plans. In this research, after calculating the weights of criteria and sub-criteria, ranking of development plans in the iron and steel industries is done by using the FTOPSIS method.

The Fuzzy Technique for Order of Preference by Similaring to Ideal Solution (FTOPSIS) method has been studied by many scientists such as Delgado in 1988. But the main development of this method was done by Chen in 2000 [37]. In FTOPSIS method similar to FAHP method, the questionnaires were arranged and distributed according to the sub-criteria and candidate options in the form of pairwise comparison and interviewed with experts. According to the triangular fuzzy numbers defined in Table 8, The value of the options is calculated relative to the sub-criteria. The membership function of the fuzzy numbers defined in Figure 5 is also explained.

According to the results of the questionnaires, the fuzzy decision matrix of the sub-criteria for the candidate options was calculated by using Equation 9 and the results are written in Table 2 of Appendix 1.

Table 8. Defined triangular fuzzy numbers for evaluating options according to criteria and sub-criteria

Verbal expressions	Fuzzy numbers		
Very Good	6.000	5.000	4.000
Ratio Good	5.000	4.000	3.000
Medium	4.000	3.000	2.000
Ratio Weak	3.000	2.000	1.000
Weak	2.000	1.000	0.000

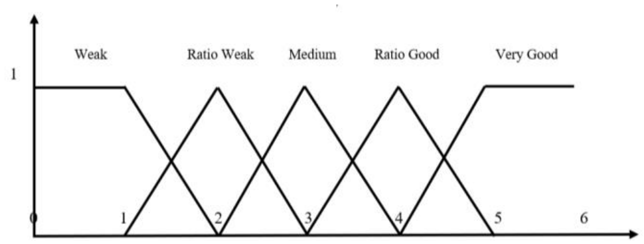

Figure 5. Defined fuzzy number membership function to evaluate the importance of options

$$D^{\sim} = \begin{pmatrix} X_{11}^{\sim} & X_{12}^{\sim} \ldots\ldots & X_{1n}^{\sim} \\ X_{21}^{\sim} & X_{22}^{\sim} \ldots\ldots & X_{2n}^{\sim} \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ X_{m1}^{\sim} & X_{m2}^{\sim} \ldots\ldots & X_{mn}^{\sim} \end{pmatrix} \tag{9}$$

Since, in this study fuzzy numbers are defined in a triangular shape, So $X_{ij}^{\sim} = (a_{ij}.b_{ij}.c_{ij})$ and shows the function of option *i (i=1.2….m)* relative to the sub-criteria *j (j=1.2….n)*. Then the matrix is unscaling by using Equation 10 and in the next step, it becomes weighted by using Equation 13. Since fuzzy numbers are defined as triangles, So the unscaled matrix elements for the sub-criteria positive and negative, expressed by using Equations 11 and 12.

$$R^{\sim} = \left[r_{ij}^{\sim} \right]_{m \times n} \tag{10}$$

$$r_{ij}^{\sim} = \left\{ \frac{a_{ij}}{c_j^{*}} \cdot \frac{b_{ij}}{c_j^{*}} \cdot \frac{c_{ij}}{c_j^{*}} \right\} \rightarrow c_j^{*} = Max_i c_{ij} . j \in B \tag{11}$$

$$r_{ij}^{\sim} = \left\{ \frac{a_j^{-}}{c_{ij}} \cdot \frac{a_j^{-}}{b_{ij}} \cdot \frac{a_j^{-}}{a_{ij}} \right\} \rightarrow a_j^{-} = Min_i a_{ij} . j \in C \tag{12}$$

$$V^{\sim} = \left[V_{ij}^{\sim} \right]_{m \times n} . \quad i=1.2\ldots m \qquad j=1.2\ldots.n \tag{13}$$

Indicators of fuzzy ideal solution (A^+) and Fuzzy Conflict-ideal solution (A^-) were calculated According to the steps of the method and by using Equations 14 and 15, And its results are written in Table 3, Appendix 1. Indicators of distance from fuzzy ideal solution (d^+) And the distance from the fuzzy Conflict-ideal solution (d^-) Calculated by using Equation 16 and the results are shown in Tables 4 and 5 of Appendix 1.

$$A^{\sim +} = \left\{ v_1^{\sim +} . v_2^{\sim +} \ldots\ldots\ldots . v_n^{\sim +} \right\} \tag{14}$$

$$A^{\sim -} = \left\{ v_1^{\sim -} . v_2^{\sim -} \ldots\ldots\ldots . v_n^{\sim -} \right\} \tag{15}$$

In the above equations, $v_i^{\sim +}$ the best value of sub-criteria and $v_i^{\sim -}$ the worst value of the sub-criterion is relative to options. The options in A^+ and A^- represent completely better and completely worse options, respectively.

$$d(A^{\sim}.B^{\sim}) = \sqrt{\frac{1}{3}\left[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2 \right]} \tag{16}$$

Here is the amount $d(v_{ij}^{\sim}.v_j^{\sim +})$ and $d(v_{ij}^{\sim}.v_j^{\sim -})$ respectively the distance value of option *i* from the ideal solution value is positive and negative in the criteria *j*.

In this part of the research, the similarity index of the options was calculated by using Equation 17 and the results are included in Table 9. According to the degree of similarity index, the option with the highest similarity index (Bamyan), in the first row and the option that has the lowest similarity index (Kandahar) is in the last row of development plans for investment. The rest of the options are in different positions according to the degree of similarity index. The ranking results of the options are shown in Table 9.

$$CC_i = \frac{d_i^{-}}{d_i^{-} + d_i^{+}} \qquad i=1.2.\ \ldots\ \ldots\ .m \tag{17}$$

Here d_i^{+} and d_i^{-} the sum of the distances from the fuzzy ideal solution to the fuzzy Conflict-ideal solution is calculated by the following equations:

$$d_i^{+} = \sum\nolimits_{j=1}^{n} d(v_{ij}^{\sim}.v_j^{\sim +}) \quad i=1.2.\ \ldots\ \ldots\ .m \tag{18}$$

$$d_i^{-} = \sum\nolimits_{j=1}^{n} d(v_{ij}^{\sim}.v_j^{\sim -}) \quad i=1.2.\ \ldots\ \ldots\ .m \tag{19}$$

Table 9. Ranking of options based on similarity index

Options	Sum of the distances from the fuzzy ideal solution (d_i^{+})	Sum of the distances from the fuzzy Conflict-ideal solution (d_i^{-})	Similarity index (CC_i)	Rank
Bamyan	0.393	0.641	0.620	1
Badakhshan	0.405	0.610	0.601	2
Herat	0.438	0.599	0.577	3
Panjshir	0.448	0.592	0.569	4
Nangarhar	0.522	0.488	0.483	5
Kandahar	0.568	0.459	0.447	6

2.6. Sensitivity analysis of options relative to criteria

In this paper, for more accuracy and precision of the Content after completing all the preconditions, Sensitivity analysis between options was performed according to criteria and sub-criteria. Using the overall purpose of sensitivity analysis and using effective metrics, the weights of the criteria were changed in ascending and descending form and their results were compared. This process had a direct effect on the similarity of the options index, but which did not affect the ranking of the options. The lack of intersection of the scenario lines indicates that the results of the weights of the selected criteria for sensitivity analysis are not affected by the change in the results. Sensitivity analysis was performed based on five scenarios by using FTOPSIS method and the results are described in Figure 6. The figure below shows the vertical axis of the similarity index and the horizontal axis of the candidate options (provinces).

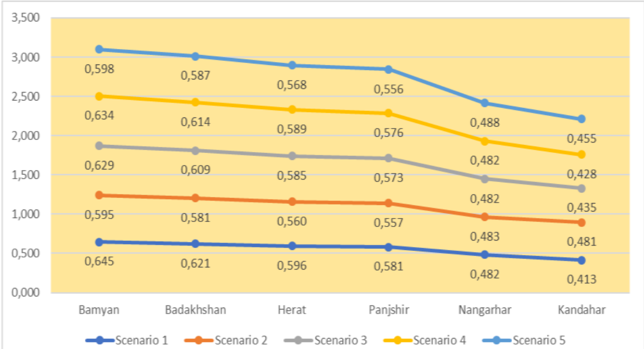

Figure 6. Sensitivity analysis of options in different scenarios according to the degree of similarity index

4. Conclusion

Based on the research model, criteria and sub-criteria through library studies, Review of regulations and obtaining expert opinions have been collected in the form of 6 main criteria and 19 sub-criteria. The main criteria include (Human, Social and Cultural Factors), (Legal and Political Factors), (Technical, Geological and Infrastructure Factors), (Geographical and Environmental Factors), (Economical and Financial Factors) and (Commercial and Business Factors). And each criterias are divided into its respective sub-criteria and their classification is shown in Figure 3.

As Afghanistan has 34 provinces and most of these provinces are rich in mineral resources and are also eligible to investment in the iron and steel industries. In this paper, first, all provinces were evaluated in terms of main criteria and sub-criteria and then according to the effective factors and the views of experts, the provinces (Bamyan, Herat, Badakhshan, Panjshir, Nangarhar and Kandahar) have been selected as candidate options and are shown in Figure 2 on the map of Afghanistan.

According to the structure of the research, the weights of the criteria and sub-criteria were calculated by using the FAHP method and then by using the FTOPSIS method ranking the options performed, which includes Table 9. According to the ranking results, Bamyan province in the first row and Kandahar province in the last row are development plans in the field of iron and steel industries for investment and the rest of the provinces are in different positions according to their similarity index.

Recently, for more accuracy and validity of research, Sensitivity analysis between candidate options was performed according to criteria and sub-criteria. According to the results of sensitivity analysis, Increasing and decreasing the weights of criteria and sub-criteria had a direct effect on the similarity index of options but which did not affect the ranking of options. The lack of intersection of the scenario lines indicates that the results of the weights of the selected criteria for sensitivity analysis are not affected by the change in the results. Sensitivity analysis was performed based on five scenarios and the results are described in Figure 6.

Appendix 1

Table 1. Matrix of pairwise comparison of criteria

Criteria	A			B			C			D			E			F		
A	0.50	1.00	1.50	0.33	0.62	1.00	0.33	0.50	0.67	0.50	1.00	4.00	0.67	1.45	0.00	1.00	3.20	0.00
B	1.00	1.63	3.00	0.50	1.00	1.50	0.50	0.80	4.00	1.00	3.20	0.00	0.67	1.60	0.00	2.00	4.00	0.00
C	1.50	2.00	3.00	0.25	1.25	2.00	0.50	1.00	1.50	2.00	4.00	0.00	1.00	2.00	4.00	1.00	2.67	0.00
D	0.25	1.00	2.00	0.00	0.31	1.00	0.00	0.25	0.50	0.50	1.00	1.50	0.33	0.62	4.00	0.50	1.23	0.00
E	0.00	0.69	1.50	0.00	0.63	1.50	0.25	0.50	1.00	0.25	1.63	3.00	0.50	1.00	1.50	0.67	1.60	4.00
F	0.00	0.31	1.00	0.00	0.25	0.50	0.00	0.38	1.00	0.00	0.81	2.00	0.25	0.63	1.50	0.50	1.00	1.50

Table 2. Fuzzy decision matrix below the criteria for candidate options

Criteria	A									B								
Sub-criteria/ Options	A_1			A_2			A_3			B_1			B_2			B_3		
Bamyan	2.00	3.50	5.00	3.00	4.75	6.00	3.00	4.75	6.00	4.00	5.00	6.00	2.00	4.25	6.00	4.00	5.00	6.00
Panjshir	3.00	4.25	6.00	2.00	3.75	5.00	1.00	3.25	5.00	4.00	5.00	6.00	1.00	2.75	4.00	3.00	4.75	6.00
Badakhshan	3.00	4.25	6.00	3.00	4.75	6.00	4.00	5.00	6.00	1.00	2.50	4.00	2.00	3.75	6.00	3.00	4.00	5.00
Herat	3.00	4.50	6.00	4.00	5.00	6.00	4.00	5.00	6.00	1.00	2.75	4.00	1.00	2.75	4.00	3.00	4.25	6.00
Kandahar	2.00	3.75	5.00	0.00	1.50	4.00	1.00	2.75	4.00	0.00	1.00	2.00	3.00	4.25	6.00	0.00	2.25	4.00
Nangarhar	3.00	4.00	5.00	2.00	3.25	5.00	2.00	3.75	5.00	1.00	2.50	4.00	2.00	3.00	4.00	1.00	3.00	5.00
	6.000			6.000			6.000			6.000			6.000			6.000		
Criteria	C									D								
Sub-criteria/ Options	C_1			C_2			C_3			D_1			D_2			D_3		
Bamyan	4.00	5.00	6.00	1.00	4.25	5.00	1.00	2.75	5.00	1.00	2.5	4.00	1.00	3.50	5.00	2.00	3.75	5.00
Panjshir	3.00	4.50	6.00	1.00	4.25	5.00	1.00	2.75	5.00	1.00	2.50	4.00	2.00	3.50	5.00	0.00	2.50	5.00
Badakhshan	3.00	4.50	6.00	3.00	4.75	5.00	2.00	3.75	5.00	1.00	2.75	4.00	3.00	4.25	6.00	0.00	1.25	3.00
Herat	3.00	4.25	6.00	1.00	3.50	5.00	2.00	3.75	5.00	3.00	4.00	5.00	2.00	3.50	5.00	1.00	3.25	5.00
Kandahar	0.00	1.25	3.00	1.00	3.00	5.00	1.00	3.00	5.00	3.00	4.00	5.00	3.00	4.00	5.00	3.00	4.00	5.00
Nangarhar	0.00	1.50	3.00	2.00	3.75	5.00	2.00	3.75	5.00	3.00	4.00	5.00	2.00	3.25	5.00	2.00	3.75	5.00
	6.000			5.000			5.000			5.000			6.000			5.000		
Criteria	E																	

Sub-criteria/ Options	E_1			E_2			E_3			E_4		
Bamyan	1.00	2.75	5.00	1.00	3.25	5.00	2.00	4.00	6.00	1.00	3.50	5.00
Panjshir	0.00	3.00	5.00	2.00	3.75	5.00	2.00	4.00	6.00	1.00	3.00	5.00
Badakhshan	2.00	3.75	5.00	2.00	3.50	5.00	1.00	3.50	6.00	1.00	3.75	6.00
Herat	2.00	3.75	6.00	2.00	3.75	6.00	1.00	3.50	6.00	1.00	2.75	5.00
Kandahar	2.00	3.50	5.00	2.00	3.50	5.00	1.00	3.50	6.00	1.00	2.75	5.00
Nangarhar	2.00	3.25	5.00	2.00	3.75	6.00	1.00	3.50	6.00	1.00	3.00	5.00
	6.000			6.000			6.000			6.000		
Criteria	F											
Sub-criteria/ Options	F_1			F_2			F_3					
Bamyan	4.00	5.00	6.00	1.00	3.75	6.00	3.00	4.50	6.00			
Panjshir	3.00	4.25	6.00	2.00	3.7	5.00	3.00	4.50	6.00			
Badakhshan	3.00	4.25	6.00	4.00	5.00	6.00	3.00	4.50	6.00			
Herat	2.00	4.00	6.00	0.00	2.75	5.00	0.00	2.00	6.00			
Kandahar	0.00	1.00	2.00	0.00	3.25	5.00	1.00	3.50	5.00			
Nangarhar	0.00	1.00	2.00	2.00	3.50	6.00	0.00	1.25	3.00			
	6.000			6.000			6.000					

Table 3: Fuzzy Ideal Solution (A^+) and Fuzzy Conflict-ideal solution (A^-) Indicators

Criteria	A											
Sub-criteria	A_1			A_2			A_3					
A^+	0.05	0.05	0.05	0.04	0.04	0.04	0.06	0.06	0.06			
A^-	0.02	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.01			
Criteria	B											
Sub-criteria	B_1			B_2			B_3					
A^+	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06			
A^-	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00			
Criteria	C											
Sub-criteria	C_1			C_2			C_3					
A^+	0.08	0.08	0.08	0.06	0.06	0.06	0.07	0.07	0.07			
A^-	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01			
Criteria	D											
Sub-criteria	D_1			D_2			D_3					
A^+	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05			
A^-	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00			
Criteria	E											
Sub-criteria	E_1			E_2			E_3			E_4		
A^+	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
A^-	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Criteria	F											
Sub-criteria	F_1			F_2			F_3					
A^+	0.06	0.06	0.06	0.03	0.03	0.03	0.04	0.04	0.04			
A^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			

Table 4: Indicator of distance from fuzzy ideal solution (d^+)

	Options	A			B			C			D		
		A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
d^+	Bamyan	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.03	0.04	0.03	0.02	0.02
	Panjshir	0.02	0.02	0.03	0.02	0.04	0.02	0.03	0.03	0.04	0.03	0.02	0.03
	Badakhshan	0.02	0.01	0.01	0.05	0.03	0.02	0.03	0.01	0.03	0.03	0.01	0.03
	Herat	0.01	0.01	0.01	0.04	0.04	0.02	0.03	0.03	0.03	0.01	0.02	0.02
	Kandahar	0.02	0.03	0.04	0.06	0.02	0.05	0.07	0.03	0.04	0.01	0.02	0.01
	Nangarhar	0.02	0.02	0.03	0.05	0.03	0.04	0.06	0.02	0.03	0.01	0.02	0.02
	Options	E				F							
		E_1	E_2	E_3	E_4	F_1	F_2	F_3					
d^+	Bamyan	0.02	0.02	0.02	0.02	0.01	0.01	0.01					
	Panjshir	0.02	0.02	0.02	0.02	0.02	0.01	0.01					
	Badakhshan	0.02	0.02	0.02	0.02	0.02	0.01	0.01					
	Herat	0.02	0.02	0.02	0.03	0.03	0.02	0.02					
	Kandahar	0.02	0.02	0.02	0.03	0.05	0.02	0.02					
	Nangarhar	0.02	0.02	0.02	0.02	0.05	0.01	0.03					

Table 5: Indicator of distance from fuzzy Conflict-ideal solution (d^-)

	Options	A			B			C			D		
		A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	D_1	D_2	D_3
d^+	Bamyan	0.01	0.03	0.04	0.06	0.04	0.05	0.07	0.04	0.04	0.02	0.02	0.03
	Panjshir	0.02	0.03	0.03	0.06	0.02	0.05	0.06	0.04	0.04	0.02	0.02	0.03
	Badakhshan	0.02	0.03	0.04	0.03	0.04	0.04	0.06	0.04	0.04	0.02	0.03	0.02
	Herat	0.02	0.04	0.04	0.04	0.02	0.05	0.06	0.03	0.04	0.03	0.02	0.03
	Kandahar	0.02	0.02	0.02	0.02	0.04	0.03	0.03	0.03	0.04	0.03	0.02	0.04
	Nangarhar	0.02	0.03	0.03	0.03	0.02	0.04	0.03	0.04	0.04	0.03	0.02	0.03
	Options	E				F							
		E_1	E_2	E_3	E_4	F_1	F_2	F_3					
d^+	Bamyan	0.02	0.02	0.02	0.02	0.05	0.02	0.03					
	Panjshir	0.02	0.02	0.02	0.02	0.05	0.02	0.03					
	Badakhshan	0.02	0.02	0.02	0.02	0.05	0.02	0.03					
	Herat	0.03	0.02	0.02	0.02	0.04	0.02	0.02					
	Kandahar	0.02	0.02	0.02	0.02	0.01	0.02	0.02					
	Nangarhar	0.02	0.02	0.02	0.02	0.01	0.02	0.01					

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FAHP және FTOPSIS әдістерін қолдана отырып, Ауғанстанның металлургия өнеркәсібінің даму жоспарларын іздеу және саралау

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Аңдатпа. Әлемдегі болат өнеркәсібінің өсуіне, кен ресурстарына бай, қара металлургияға қажетті ресурстардың көптігіне және Ауғанстандағы болатқа деген сұраныстың артуына байланысты қара металлургия өнеркәсібі саласындағы даму жоспарларын әзірлеу және орналастыру идеясы пайда болды. Қолданыстағы бәсекелестік артықшылықтарын арттыру және Ауғанстан үшін максималды қосымша құн алу үшін қолайлы жер орындар қажет. Бұл мақалада қара металлургия кәсіпорындарының құрылысына үлкен әсер ететін критерийлер ретінде алты жағдай және он тоғыз жағдай сарапшылармен сұхбаттан кейін таңдалады. Сауалнамалар google нысаналары арқылы ұйымдастырылды және таратылды, сарапшылармен сұхбат жүргізілді. Критерийлер мен ішкі критерийлердің салмағы сауалнама нәтижелері бойынша және FAHP көмегімен есептелді. Содан кейін FTOPSIS көмегімен жоспарлар ұқсастық индексіне негізделген. Нәтижесінде Бамиан бірінші орынға, ал Кандагар инвестициялау үшін жоспарланған даму жоспарында соңғы орынға шықты. Соңында, барлық алғышарттарды орындағаннан кейін зерттеудің дәлдігі мен дұрыстығы үшін критерийлер мен ішкі критерийлер бойынша нұсқалардың сезімталдығын талдау бес сценарий бойынша жүргізілді.

Негізгі сөздер: *Ауғанстан, көп критерийлік шешімдерді бұлыңғыр қабылдау, FAHP, FTOPSIS, металлургиялық жоспарлар, орналасқан жері, сезімталдықты талдау.*

Поиск и ранжирование планов развития металлургической промышленности Афганистана с использованием методов FAHP и FTOPSIS

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Аннотация. В связи с ростом сталелитейной промышленности в мире, богатыми ресурсами руды, обилием ресурсов, необходимых для черной металлургии, и более высоким спросом на сталь в Афганистане, возникла идея разработки и размещения планов развития в области чернометаллургической промышленности. Для увеличения существующих конкурентных преимуществ и получения максимальной добавленной стоимости для Афганистана необходимы подходящие места. В данной статье шесть случаев в качестве критериев и девятнадцать случаев в качестве подкритериев, которые оказывают большее влияние на строительство предприятий черной металлургии, выбраны после интервью с экспертами. Анкеты были организованы и распространены с помощью google-форм, проведены интервью с экспертами. Веса критериев и подкритериев рассчитывались по результатам анкетирования и с использованием FAHP. Затем с помощью FTOPSIS планы ранжируются на основе индекса сходства. В результате Бамиан вышел на первое место, а Кандагар - на последнее место в плане развития, планируемого для инвестирования. В конечном итоге, для большей точности и корректности исследования после выполнения всех предварительных условий, анализ чувствительности вариантов по критериям и подкритериям был проведен по пяти сценариям.

Ключевые слова: *Афганистан, нечеткое принятие многокритериальных решений, FAHP, FTOPSIS, металлургические планы, локация, анализ чувствительности.*

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