

**FUZZY PRIORITIZATION OF SUPPLIERS WITH PROJECT
PROCUREMENT PLANNING USING THE META-HEURISTIC METHOD**

**PRIORIZAÇÃO NEBULOSA DE FORNECEDORES COM PLANEJAMENTO DE
AQUISIÇÕES DE PROJETOS USANDO O MÉTODO META-HEURISTICO**

**PRIORIZACIÓN DIFUSA DE PROVEDORES COM PLANIFICACIÓN DE
ADQUISICIONES DE PROYECTOS UTILIZANDO EL MÉTODO
METAHEURÍSTICO**

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Abstract

Foundations: Deciding on suppliers, investigating their performance and background, and choosing or not choosing suppliers are among the many issues that have been studied domestically and internationally.

Objective: The proposed model is solved in a few examples and then using relevant data. Given nphard, the proposed model will be solved using one of the metaheuristic approaches.

Methodology/approach: In this research, mathematical modeling is used to select the suppliers. Then, using the fuzzy multi-criteria decision-making approach (fuzzy-analytic hierarchical process, FAHP), the selected options are prioritized. After presenting the model, the supplier is prioritized using Fuzzy Hierarchical Analysis and then used this information as input data and solving the model with MATLAB software.

Originality and theoretical / methodological contributions: In general, all companies that want to choose the right supplier can use the methods and indices collected in this research, along with any changes that may require the strategy of the company.

Keywords: Hierarchical Analysis, Genetic Algorithm, Mathematical Modeling, Suppliers Selection

Resumo

Fundamentos: Decidir sobre fornecedores, investigar seu desempenho e histórico e escolher ou não escolher fornecedores estão entre as muitas questões que foram estudadas nacional e internacionalmente.

Objetivo: O modelo proposto é resolvido em alguns exemplos, usando dados relevantes. Dado o problema, o modelo proposto será resolvido usando uma das abordagens metaheurísticas.

Metodologia / abordagem: Nesta pesquisa, a modelagem matemática é usada para selecionar os fornecedores. Em seguida, usando a abordagem de tomada de decisão com vários critérios difusos (processo hierárquico analítico difuso, FAHP), as opções selecionadas são priorizadas. Após apresentar o modelo, o fornecedor é priorizado usando a Análise Hierárquica Difusa e, em seguida, usa essas informações como dados de entrada e resolve o modelo com o software MATLAB.

Originalidade e contribuições teóricas / metodológicas: Em geral, todas as empresas que desejam escolher o fornecedor certo podem usar os métodos e índices coletados nesta pesquisa, juntamente com quaisquer alterações que possam exigir a estratégia da empresa.

Palavras-chave: Análise Hierárquica, Algoritmo Genético, Modelagem Matemática, Seleção de Fornecedores.

Resumen

Fundamentos: Decidir sobre proveedores, investigar su desempeño y antecedentes, y elegir o no elegir proveedores se encuentran entre los muchos temas que se han estudiado a nivel nacional e internacional.

Objetivo: El modelo propuesto se resuelve en unos pocos ejemplos y luego utilizando datos relevantes. Dado nphard, el modelo propuesto se resolverá utilizando uno de los enfoques metaheurísticos.

Metodología / enfoque: en esta investigación, el modelo matemático se utiliza para seleccionar los proveedores. Luego, utilizando el enfoque de toma de decisiones con criterios múltiples difusos (proceso jerárquico difuso-analítico, FAHP), se priorizan las opciones seleccionadas. Después de presentar el modelo, se prioriza al proveedor mediante el análisis jerárquico difuso y luego utiliza esta información como datos de entrada y resuelve el modelo con el software MATLAB.

Originalidad y aportes teóricos / metodológicos: en general, todas las empresas que desean elegir el proveedor adecuado pueden utilizar los métodos e índices recopilados en esta investigación, junto con cualquier cambio que pueda requerir la estrategia de la empresa.

Palabras clave: Análisis jerárquico, Algoritmo genético, Modelado matemático, Selección de proveedores.

1. INTRODUCTION

Decision making in organizational affairs it is so important that some authors define organization as a "decision network" and management as "decision making", because in today's world, organizational affairs cannot depend on solely on individual genius and judgment, but decisions should be mad based on accurate scientific research, statistics and information (Memari et al., 2019). Nowadays, the complexity of organizations, the high cost of operations and the extended organizational structure make it clear to managers the need for appropriate reasoning and decision making approaches. Managers need to comfortable, trustworthy and scientific tools to help them make decisions about issues faced with constantly or occasionally. Quantitative techniques and mathematical tools are effective in this regard (Alikhani et al., 2019). Industrial environments have become a competitive environment and this has put a lot of pressure on companies in different industries. In such environments, companies need to continuous assessing for ways to improve their performance. Recently, companies have focused their efforts on reducing costs and other operations. For this reason, the supply chain and supplier selection process has received much attention (Valipour et al., 2019).

The central focus of management is decision making, and effective decision making leads managers to grow and improve organizations (Jing et al., 2019). Recently, with the advent of supply chain management and supplier selection process, the industrial and service divisions turned their attention to suppliers and concluded that the criterion of choice and cooperation with them was not only price. Supplier selection is a multi-criteria decision making problem that uses multiple factors, both qualitative and quantitative, to achieve the goal. The purpose of this approach is to select the best option from the available options or to rank the options according to the criteria considered, and sometimes the weight of the criteria is applied and decision makers can make decisions using different techniques (Chuan et al., 2018).

The research is presented in eight sections. Section 1 includes the introduction and in the section 2, problem statement is described. Literature review is involved in the section 3 and the section 4 deals with mathematical modeling. Section 5 describes the case study and Section 6 presents the genetic algorithm. Section 7 deals with prioritizing supplier evaluation indices and finally conclusion is placed in the section 8.

2. PROBLEM STATEMENT

In this study, suppliers are selected using mathematical modeling. Then, using the fuzzy multi-criteria decision-making approach (fuzzy-analytic hierarchical process, FAHP), the selected options are prioritized.

After presenting the model, prioritizing of the suppliers is conducted using FAHP and then used this information as input data and the model is solved by MATLAB software. The proposed model is used in a few examples and then using relevant data. Being nphard of the proposed model, it will be solved using one of the meta-heuristic approaches. The decision making method considered in this study is FAHP.

Among the methods, hierarchical analysis has been used mostly in management science. The hierarchical analysis process is one of the most famous multi-criteria decision making techniques first invented by Thomas El Saati in the 1970s. The hierarchical analysis process reflects natural behavior and human thinking. This technique looks at complicated issues based on their interactions and converts them into simple solutions. Figure 1 shows the structure of the methodology of research.

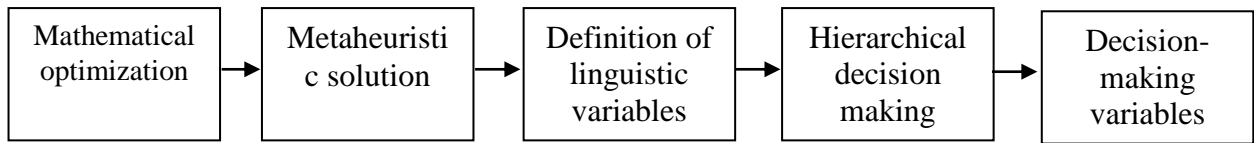


Figure 1. The methodology of research

3. LITERATURE REVIEW

Research on supplier selection and evaluation has been undertaken since 1980 and continues to this day. In the UK, Gary Levan et al., investigated this issue and developed various multi-criteria models, as well as a case study in the UK. In an article titled by "Which methods for suppliers" by Gary Holt summarizes studies conducted in this area and analyzes the methods used in supplier selection (Luan et al., 2019).

Sue et al. (2018) identified forty important criteria of bidding decision making in Singapore. Their evaluation shows that the behavior of large and small contractors is fundamentally different in selecting projects.

Zhi Ming Lu (2019), by examining bidding data in Hong Kong, showed that highly experienced contractors outperform low-experienced contractors due to having well-established management structures in competitive environments. Khorrami et al., (2019) examined international construction projects at both project and company levels and proposed a multi-criteria approach to maximize firm value. In 2019, they examined the impact of risk measures on the selection of international projects. Zhou et al. (2019) provided the presence or absence of contractors and consultants in bidding in the form of a decision support system for power plant projects. Amindost et al. (2018) studied the effects of the number of bidders on the bidding strategy of Iranian companies and proposed a bid/ no bid decision making model using data analysis. It defines the bidding opportunities that are favorable and uses prior bidding information to decide on a project to bid. Bayar et al. (2018) presented results by Balanced Scorecard (ICT) and Delphi methodology to determine evaluation criteria and identified more than 20 criteria. Then, using the questionnaire and entropy method, the importance of each criterion was assigned and finally, the criteria set by the proposed model in this study were applied in a real project. Hu et al. (2017) provided a combination of hierarchical process analysis and linear planning for explicit and implicit factors in selecting the best supplier and determining the best order in order to maximize total purchase value. Karen et al (2017) examined selective and control measures that influenced the relationship between supplier strategies and organizational performance. Oliver et al. (2017) reviewed

supplier selection research by developing a model for sourcing and purchasing at an international complex, especially in developing countries. Sayeh et al. (2017) proposed four vendor selection systems that represent customer/supplier relationships and contently places logistic versus strategic.

Jane et al. (2017) state that choosing the right source has a great impact on other items and that purchasing by it provides a significant amount of ability to create value in the logistics process. Identifying, evaluating, and acquiring available resources leads to ensuring that the company receives the right quality, quantity, time, and price. So choosing the right supplier is the key to the buying process. Chen et al. (2017) presented a fuzzy decision making approach to the problem of supplier selection. They stated that in recent years, determining the appropriate supplier has become a significant and strategic issue. Bruno et al. (2017) believe that many approaches to supplier selection fail in the first year due to providers' inability. To address this and the problem of imprecise and inaccurate information resulting from the inability of existing systems, they presented a framework based on fuzzy ideal programming. Jimens et al. (2017) reviewed multi-criteria decision-making approaches in supplier evaluation and selection. They studied 78 articles published in this field and stated that the most popular selection criteria were: quality, delivery, price, cost, production capacity, service, management, technology, financial research and development, flexibility, reputation, relationships, risk, security, and environmental criteria. Deurid Steffan et al. (2017) presented a fuzzy hybrid model of decision making with multiple criteria for the supplier selection problem and categorized the decision criteria into two categories of cause and effect. Fuzzy TOPSIS determines the viewpoints of decision makers about suppliers according to each criterion. Colean et al., 2013 by combining fuzzy AHP and fuzzy TOPSIS solved the supplier selection problem that determined the importance of decision criteria using fuzzy AHP and ranked the supplier using fuzzy TOPSIS. Thus, according to the literature review, the research gaps are as follows:

- 1- Not paying attention to construction project logistic plan and solving it with a metaheuristic approach
2. Not paying attention to the approach of selecting and prioritizing project suppliers simultaneously
3. Not paying attention to optimization and fuzzy decision-making approaches simultaneously. In this research, identifying the selected suppliers is done by optimizing and prioritizing them using the fuzzy hierarchical approach.
4. Lack of formulation of criteria and options for prioritizing suppliers using linguistic variables.

4. MATHEMATICAL MODELING

The parameter, indices, variables and model constraints are as follows:

Object: To minimize the total cost of the project

Problem Parametric Model:

Indices and Categories:

I: Collection of all projects

i: Project Index ($i \in I$)

J: All suppliers ($J = 1 \dots, 9$.)

j: Supplier Index ($j \in J$)

j': Supplier Index of Class I ($((j' \in J) \text{ and } j' = \{1,2,4\})$)

j'': Supplier Index of Class II I ($((j'' \in J) \text{ and } j'' = \{3,5\})$)

Parameter:

p_{ij} : Cost of project i by supplier j

D_i : Supplier demand i

Variable:

y_i : Optimal order for each supplier i

$x_{ij} \begin{cases} 1 & \text{project i assigns to contractor j} \\ 0 & \text{project i dont assigns to contractor j} \end{cases}$

$$\text{Min} \sum_i \sum_j p_{ij} x_{ij}$$

$S.t$		
$\sum_j x_{ij} = 1$	$\forall i$	(1)
$\sum_i x_{ij} \leq K$	$\forall j$	(2)
$\sum_i x_{ij} \geq 1$	$\forall j$	(3)
$\sum_i x_{ij'} \leq 2$	$\forall j' \in J$	(4)
$\sum_i x_{ij''} \leq 1$	$\forall j'' \in J$	(5)
$\sum_i p_{ij} x_{ij''} \leq 10$	$\forall j'' \in J$	(6)
$\sum_i x_{ij} - x_{Ej} \leq 2(1 - x_{Ej})$	$\forall j$	(7)

$x_{Cj} = x_{Bj} \quad \forall j$	(8)
$\sum_j x_{Dj} \leq \sum_j x_{Ej}$	(9)

$$\sum_{i=1}^n y_i = \sum_{i=1}^n D_i \quad (10)$$

Constraints of problem

1. All projects must be completed and a project cannot be divided between two suppliers.
- 2- The maximum number of projects K are assigned to each supplier.
- 3- The highest ranked supplier can be allocated more than one project.
- 4- Suppliers Class I should be allocated maximum two projects.
- 5- Suppliers Class II should be allocated maximum one project.
- 6- Projects assigned to each supplier Class II should cost less than 10 billion Rials.
- 7- If Project E is assigned to a supplier, no other project will be allocated to that supplier because of the volume of Project E.
- 8- Projects i and i' must be allocated to one supplier due to the proximity of the location and the common lines.
- 9- Project i is subject to Project i'(due to common line map).
- 10- This constraint also determines the optimal order quantity of each supplier.

5- DESCRIPTION OF A CASE STUDY

In this study, two methods includes library and field research were used. Libraries, scientific journals and various scientific databases on the Internet have been used for research literature. The main data of the research (Supplier Evaluation Criteria) were collected by field method through questionnaire distribution and interview. After designing the initial questionnaire and consulting the experts of Iran Construction Group during several steps and final modifications, the final questionnaire was completed and provided for them. The company has 9 suppliers.

In this regard, experts are first asked to rate the importance of supplier performance indices in a company based on a Likert scale with significance levels ranging from "Very Low = 1 to" Very High = 5 ". After reflecting the opinions of managers and experts in the questionnaire, the average importance of each index was calculated (for this index, the number of linguistic expressions of importance of the index was multiplied by the corresponding numbers of these terms and after calculating the sum of scores, the mean of importance of each index and option was calculated). In consultant and decision maker team, it was decided that comprehensive indices are considered and cases with importance lower

than 3.5 were diminished from next calculations. Indices omitted at this step include frequency of delivery, number of cargoes, small cargoes, collaboration relationships, statistical process control, product design capability, production capacity and facilities, policies and guarantees, financial status, favorite of transaction ability, packaging ability, future prospects, responsiveness to customer demands, e-commerce capability, on-time production capability, operation facilities, supplier attitude and catalog. Experts were then asked about other effective factors and there are not in the model and the degree of importance of these cases from range of 1 (very low) to 5 (very high). Table 1 depicts the results of localization of supplier evaluation criteria in Iran Construction Group and finally the indices listed in Table 2 were considered to evaluate and rank suppliers of Iran Construction Group

Table 1

The importance of criteria using the Likert scale.

Importance Average	Very low importance	Low importance	Medium importance	High importance	Very high importance	Evaluation criteria	رتبه
	1	2	3	4	5		
4.66			2		10	Quality	1
4.25			2	5	5	On-time delivery	2
3.41		5	1	2	4	Number of Deliveries	3
3.25	2	2	2	3	3	Number of cargoes delivered	4
2.25	5	2	2	3		Small cargo	5
2.5	5		3	4		collaboration relationships relationships	6
4.6				4	6	Technical skill (technical ability)	7
4.2			1	6	3	Price	8

2.83		7	1	3	1	Statistical Process Control	9
2.41	3	3	4	2		Product Design Ability	10
4.2			1	6	3	Communication System	11
4.5				5	5	Flexibility	12
3.25		3	3	6		Production capacity and facilities	13
4.8				2	8	Obligation	14
4.1			1	7	2	Background	15
3.41		2	3	7		Policies and Guarantees	16
3.08		3	5	4		Financial situation	17
3.08		3	5	4		Favorite of transaction ability	18
4			2	6	2	Management and Organization	19
4.3			2	3	5	After sales services	20
3.41		2	4	5	1	Packaging ability	21
4.1			3	3	4	Reputation	22
4.1		4	3	6		geographical location	23
3.25		2	5	5		Future Perspective	24
3.25		3	3	6		Meeting customer needs	25
2.75	1	4	4	3		E-commerce capability	26
3.08		5	2	4	1	On-time production ability	27
3.1	2		3	5		Operation facilities	28
3		4	4	4		Supplier attitude	29
3	1	3	4	3	1	Catalog	30

Table 2
Indigenous Criteria by Iran Construction Group

ID	Index	ID	Index
C ₇	Technical ability	C ₁	Price
C ₈	Flexibility	C ₂	Quality
C ₉	Obligation	C ₃	On-time delivery
C ₁₀	Geographical location	C ₄	After sales services
C ₁₁	Credibility	C ₅	Background
C ₁₂	Communication system	C ₆	Management and Organization

5-1- Identification of Suppliers

Iran Construction Group needs various suppliers to supply the raw materials of manufacturing and has a contract with them. Referring to the documentation available in the company, and consultant with decision maker team, due to the importance of the materials needed in the company's products, the evaluation and rating of suppliers was included in the agenda of this study. Six of the nine suppliers identified as described in Table 3 for the considered section.

Table
List of Suppliers of Iran Construction Group

ID	Supplier	ID	Supplier
A ₄	Azar	A ₁	Bazargani Jahan
A ₅	Ziggurat Nama	A ₂	Persian Sazeh
A ₆	Kar Afarin	A ₃	Baran Novin

5-2- Hierarchical tree structure

In order to understand precisely a complicated problem, considering the different and important aspects of the problem and decision making (choosing the right supplier), as well as understanding the relationship of each element to the other elements in the hierarchical decision tree, Figure 2 exhibits hierarchical tree as the initial step in any AHP. .

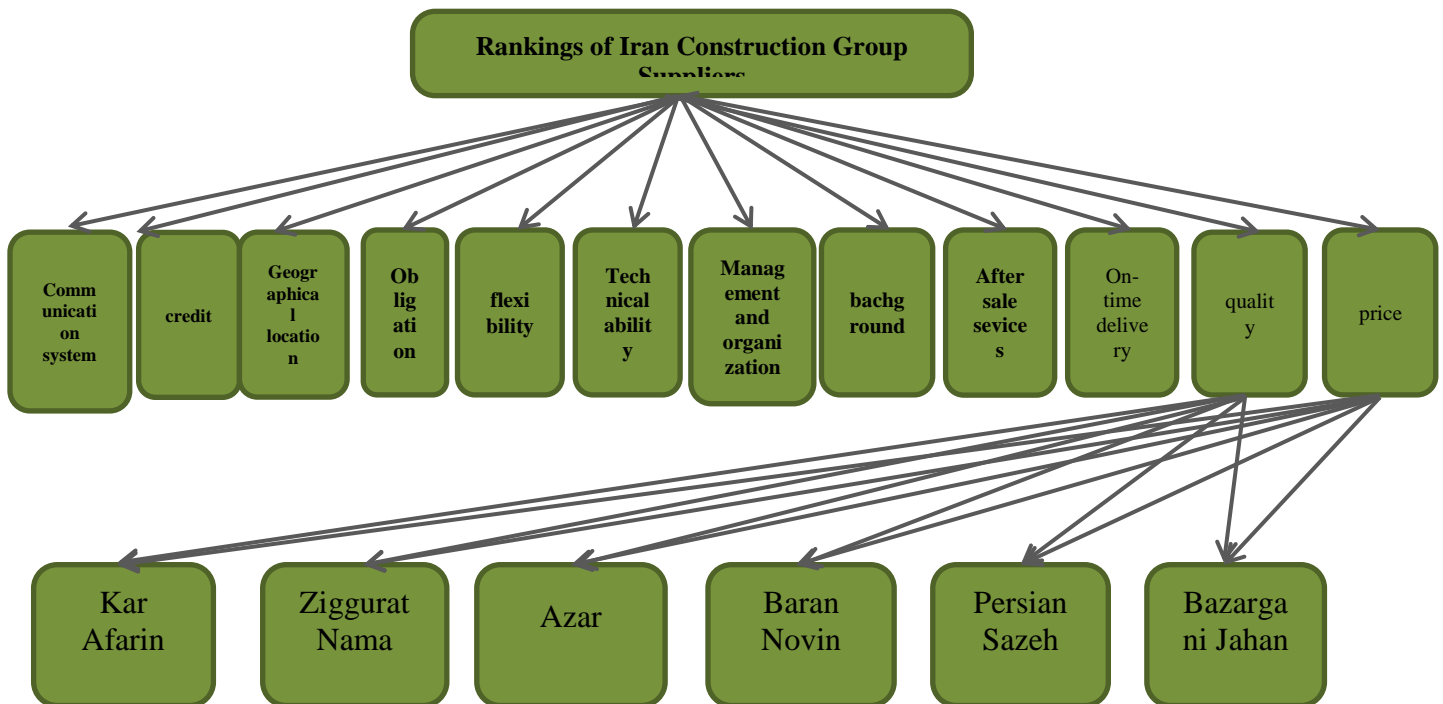


Figure 2. Hierarchical tree structure of the ranking of Iran Construction Group's suppliers.

6. GENETIC ALGORITHM

Genetic algorithm as an optimization computational algorithm, it efficiently searches for different areas of the solution space by considering a solution space point sets in each computational iteration. In the search mechanism, although the value of the objective function of the entire space of solution is not calculated, the calculated value of the objective function for each point is involved in the statistical averaging of the objective function for each point, and another words in the statistical averaging of the objective function in all subspaces to which that point depends on. These subspaces are paralleled in terms of the objective function averaging. This mechanism is called an implicit parallelism. This process leads to space search in areas where the statistical mean of the objective function is high and the probability of having an absolute optimal point is higher. In this method, unlike single-path methods, solution space search comprehensively, there is less chance of convergence to a local optimal point.

The following are the operators considered in this study:

6-1 Two-point combination

In the two-point combination, two positions P_1 and P_2 as the combination positions are randomly selected between 1 and the length of the chromosomes (N). The method of creating children is like a single point combination.

The first child inherits genes $1...(P_1-1)$ from the first parent, genes $1...(P_2-1)$ from the second parent, and genes P_2-N from the first parent again.

The second child inherits genes $1...(P_1-1)$ from the second parent, genes $1...(P_2-1)$ from the first parent, and genes P_2-N from the second parent again.

In this combination method also generates two children from one pair, in which the probability of the parents are transferred without changing to the next population. Examples of these combinations are illustrated with combination positions P_1 and P_2 .

Parent 1	37	35	71	55	54	42
	26	42	19	62	19	56
	42	11	13	54	165	101
	18	31	28	100	301	56
Parent 2	11	36	73	28	31	78
	73	25	81	11	40	63
	48	45	77	205	78	39
	201	21	93	45	67	54
Child 1	37	35	73	25	54	42
	26	42	81	11	19	56
	42	11	77	205	165	101
	18	31	93	45	301	56
Child 2	11	36	71	55	31	78
	73	25	19	62	40	63
	48	45	13	54	78	39
	201	21	28	100	67	54

Figure 3. Two-point cross section operator used in this study.

6.2- Inversion mutation

Inversion mutation happens very much in nature but is rarely used in genetic algorithms because of its high degradation. This operator reverses the chromosome.

Parent	100	321	32	63	123	91
	75	461	401	57	44	47
	25	73	42	401	461	55
	81	54	46	62	71	47
Child	100	321	32	63	123	91
	47	44	57	401	461	75
	25	73	42	401	461	55
	81	54	46	62	71	47

Figure 4. Inversion mutation used in this study.

After solving the case study using the genetic approach 3, the project is eliminated and six projects are selected as optimal ones. Then, six existing projects will be ranked.

7. PRIORITIZING SUPPLIER EVALUATION INDICES

Experts' comments on factors affecting customer loyalty, collected on a range of nine options in clockwise, can be converted to triangular numbers in various ways. Interactive scales to determine the weight of supplier evaluation indices are in accordance with Table 4.

Table 4
Fuzzy Numbers Spectrum and Linguistic Scale for Weighting Supplier Evaluation Indices

Linguistic Scale	Same importance)VL(	Low importance)L(	More importance)ML(	High importance)H(	Very high importance)VH(
Triangular fuzzy Numbers	1),1,(1	5),3,(1	7),5,(3	9),7,(5	11),9,(7

Twelve evaluation criteria (price, quality, on-time delivery, after-sales service, background, management and organization, technical capability, flexibility, obligation, geographical location, credit, and communication systems) to identify factors using experts' opinions, refer to similar research and localization questionnaire. From the geometric mean of the estimation obtained from the paired triangular fuzzy matrix, the comprehensive expert opinion matrix was compiled according to Table 5, which was used to calculate the weight of each index

Table 5
Expert opinion aggregation matrix.

Prioritizing supplier evaluation metrics	Price	Quality	On-time delivery	After sales service	Background	Management and organization	Technical capability	Flexibility	Obligation	Geographical location	credit	Communication system
Price	(1, 1, 1)	(0,83, 0,83)	(0,38, 0,38)	(0,59, 0,59)	(0,66, 0,66)	(0,19, 0,19)	(0,46, 0,46)	(0,86, 0,86)	(0,76, 0,76)	(0,59, 0,59)	(48, 48, 48)	(0,61, 0,61)
Quality	(0,9, 0,9, 0,9)	(1, 1, 1)	(0,53, 0,53)	(0,62, 0,62)	(0,78, 0,78)	(0,50, 0,50)	(0,86, 0,86)	(0,73, 0,73)	(0,33, 0,33)	(0,53, 0,53)	(48, 48, 48)	(0,59, 0,59)
Timely delivery	(0,29, 0,29, 0,29)	(0,22, 0,22, 0,22)	(1, 1, 1)	(0,14, 0,14, 0,14)	(0,29, 0,29, 0,29)	(0,16, 0,16, 0,16)	(0,03, 0,03, 0,03)	(0,60, 0,60, 0,60)	(0,44, 0,44, 0,44)	(0,74, 0,74, 0,74)	(98, 98, 98)	(0,41, 0,41, 0,41)
after sales services	(0,39, 0,39, 0,39)	(0,92, 0,92, 0,92)	(0,14, 0,14, 0,14)	(1, 1, 1)	(0,42, 0,42, 0,42)	(0,48, 0,48, 0,48)	(0,58, 0,58, 0,58)	(0,74, 0,74, 0,74)	(0,91, 0,91, 0,91)	(0,88, 0,88, 0,88)	(45, 45, 45)	(0,25, 0,25, 0,25)

	/67 (1	/52 (1	0/88 (								/63 (0	
Past performance	71) 3/ 43 2 49 (1	/15) 4 39 32 (1	/12) 1 65 0 43 (	/91) 1 95 0 46 (0	1 1) (1	1/04) 0/52 (0/30	1/25) 0/63 (0/36	1/84) 1/20 (0/70	0/42) 0/22 (0/15	5/99) 3/98 (2/26	73) 0/ 38 0 25 (0	1/41) 0/69 (0/41
Management and Organization	87) 1/ 28 1 83 (0	/17) 2 15 1 66 (0	/95) 5 4/30 0 46 (	/12) 4 57 2 28 (1	6/57) 4/52 (2/37	1 1) (1	2/15) 0/33 1/04 (0/52	0/79) 0/26 (0/17	0/48) 1/37 (0/78	2/15) 1/37 (0/78	86) 0/ 44 0 24 (0	2/46) 1/25 (0/59
Technical ability	47) 6/ 39 4 15 (2	/48) 1 83 0 51 (0	/04) 3 68 0 85 (	/81) 2 96 1 34 (1	5/86) 3/87 (2/17	1/28) 0/72 (0/46	1 1) (1	0/63) 0/29 (0/19	1/50) 0/69 (0/38	0/70) 0/34 (0/20	55) 0/ 25 0 16 (0	0/75) 0/37 (0/22
flexibility	50) 3/ 06 2 15 (1	/89) 3 39 2 41 (1	/98) 1 30 0 67 (	/41) 1 83 0 54 (0	2/57) 1/44 (0/66	4/76) 2/85 (1/41	3/92) 0/60 (1/36	1 1) (1	1/22) 0/71 (0/40	1/03) 0/54 (0/29	50) 0/ 24 0 16 (0	1/70/31) (0/42 0
obligation	53) 3/ 26 2 30 (1	/28) 1 68 0 42 (0	/31) 3 89 0 95 (	/89) 4 96 2 26 (1	2/44) 1/40 (0/81	3/36) 1/78 (0/92	4/07) 2/31 (1/18	4/04) 2/29 (1/20	1 1) (1	3/61) 1/93 (0/83	40) 0/ 21 0 14 (0/	2/79) 1/68 (0/93
geographical location	75) 1/ 01 1 57 (0	/33) 1 69 0 39 (0	/59) 0 36 0 24 (	/03) 5 38 3 58 (1	2/21) 1/08 (0/57	1/19) 0/51 (0/27	6/04) 3/98 (1/80	2/21) 1/28 (0/70	1/67) 0/79 (0/40	1 1) (1	82) 0/ 43 0 24 (0	0/46) 0/23 (0/15

Credibility	78)	/02)	/46)	/52)	·0/66)	·0/57)	6/21)	·2/50)	·4/52)	·1/07)	·1)	·0/69)
	·1/	·1	·0	·6	·0/34	·0/32	·	·1/40	·2/68	·0/59	·1	·0/28
	/07	/49	0/25	/46	(0/21	(0/20	·4/15	(0/79	(1/32	(0/35	(1	(0/17
	·1	·0	·	·4			(1/98					
	/67	/28	0/17	/26								
(0	(0	(	(2									
Communication system	73)	/55)	/72)	/14)	·0/44)	·1/60)	6/80)	·3/11)	·2/36)	·6/38)	59)	(1 ·1 ·1)
	·1/	·4	·3	·5	·0/25	·1/14	·	·1/88	·1/41	·4/33	·5/	
	/91	/96	1/57	/13	(0/16	(0/70	·4/71	(0/91	(0/75	(2/17	/55	
	·0	·2	·	·3			(2/46				·3	
	/56	/68	0/79	/09							/44	
(0	(1	(	(1							(1		

To calculate the weight of each criterion, first calculate the fuzzy combination expansion of each criterion by Chang's development analysis method, and after calculating the degree of feasibility for each possible binary case, is obtained the least degree of feasibility of each criterion relative to the other criteria for attaining weight vector of indices. The results are indicated in Tables 6 to 8, respectively. Calculation of each step about price index are mentioned as an example.

Table 6

Fuzzy combination expansion value of main factors.

l_{ij}	m_{ij}	u_{ij}	C_i
0/014	0/035	0/098	Price
0/021	0/060	0/172	Quality
0/036	0/093	0/251	Timely delivery
0/034	0/090	0/241	after sales services
0/028	0/073	0/211	Past performance
0/034	0/095	0/262	Management and Organization
0/029	0/080	0/224	Technical ability
0/029	0/081	0/232	flexibility
0/033	0/10	0/298	obligation
0/024	0/072	0/208	geographical location
0/029	0/083	0/231	Credibility
0/042	0/131	0/355	Communication system

$$\left[\sum_{i=1}^m \sum_{j=1}^n M_{ij} \right]^{-1} = (116/64, 204/27, 325/29)^{-1} = (0/003, 0/0049, 0/0085)$$

$$SC_1 = [(4/85 \times 0/003, 7/23 \times 0/0049, 11/47 \times 0/0085)] = (0/01, 0/035, 0/098)$$

Table 7
Degree of feasibility for any possible binary mode

$V(S_{c1} \geq S_{c4})$	$V(S_{c2} \geq S_{c3})$	$V(S_{c3} \geq S_{c4})$	$V(S_{c4} \geq S_{c1})$	$V(S_{c4} \geq S_{c2})$	$V(S_{c4} \geq S_{c3})$	$V(S_{c4} \geq S_{c1})$	$V(S_{c4} \geq S_{c2})$	$V(S_{c4} \geq S_{c3})$	$V(S_{c4} \geq S_{c1})$	$V(S_{c4} \geq S_{c2})$	$V(S_{c4} \geq S_{c3})$
1	1	1	1	1	1	1	1	1	1	1	1
0/75	1	1	1	1	1	1	1	1	1	1	1
0/51	0/80	0/98	0/89	1	0/93	0/94	1	0/89	0/95	1	1
0/53	0/82	1	0/91	1	0/94	0/95	1	0/90	0/96	1	1
0/64	0/91	1	1	1	1	1	1	0/99	1	1	1
0/51	0/797	0/98	0/97	0/88	0/92	0/93	1	0/88	0/94	1	1
0/60	0/87	1	1	0/96	1	1	1	0/95	1	1	1
0/59	0/87	1	1	0/95	1	0/99	1	0/95	1	1	1
0/49	0/77	0/97	0/95	0/87	0/98	0/90	0/91	0/86	0/92	1	1
0/66	0/92	1	1	1	1	1	1	1	1	1	1
0/58	0/86	1	1	0/94	1	0/98	0/99	0/94	1	1	1
0/36	0/64	0/84	0/82	0/74	0/85	0/78	0/79	0/89	0/73	0/79	1

$$\begin{cases} V(M_1 \geq M_2) = 1 & \text{if } m_1 \geq m_2 \\ V(M_1 \geq M_2) = \text{hgt}(M_1 \cap M_2) & \text{else} \end{cases}$$

$$\text{hgt}(M_1 \cap M_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)} = \frac{0.098 - 0.021}{[(0.098 - 0.021) + (0.06 - 0.03)]} = 0.75^{**}$$

Table 8

Final weight and ranking of supplier evaluation indices.

Prioritizing supplier evaluation metrics	Price	Quality	On-time delivery	After sale service	Background	Management and organization	Technical capability	Flexibility	Obligation	Geographical location	credit	Communication system
Minimum degree of feasibility	37/0	64/0	84/0	82/0	74/0	85/0	78/0	792/0	89/0	737/0	797/0	1
The final weight of the indices	04/0	07/0	091/0	089/0	08/0	092/0	084/0	085/0	096/0	079/0	086/0	108/0
Ranking	12	11	4	5	9	3	8	7	2	10	6	1

Finally, based on the results of the research, the ranking of supplier performance indices in Iran Construction Group are as follows: communication system, obligation, management and organization, on-time delivery, after sales service, credit, flexibility, technical ability, background, geographical location, quality and price.

7-1- Prioritization of Suppliers in terms of localized indices in Iran Construction Group

In order to prioritize suppliers for each of the twelve indices, FAHP technique and fuzzy numbers are used in Tables 4-7, respectively, which expert opinion matrix, fuzzy combination expansion value, degree of feasibility for possible binary modes. The final weight and rank of each supplier in accordance with the relevant index are in accordance with Tables 9 -12.

Table 9

Expert opinion aggregation matrix on the price index.

	Bazargani Jahan	Persian Sazeh	Baran Novin	Azar	Ziggurat Nama	Kar Afarin
Bazargani Jahan	(1·1·1)	·0/33 ·0/53 (0/23)	·0/32 ·0/56 (0/21)	·1/23 ·1/76 (0/82)	·3/50 ·5/16 (1/83)	·5/99 ·8/04 (3/84)
Persian Sazeh	·3/4 ·00/30 (1/88)	(1·1·1)	·5/95 ·8/01 (3/79)	·5/66 ·7/24 (4/011)	·4/91 ·6/62 (3/18)	·5/35 ·7/43 (3/71)
Baran Novin	·3/04 ·4/64 (1/75)	·0/16 ·0/26 (0/13)	(1·1·1)	·4/95 ·7/04 (2/20)	·4/68 ·6/34 (2/07)	·3/43 ·5/07 (2/15)
Azar	·0/80 ·1/20 (0/56)	·0/17 ·0/24 (0/13)	·0/20 ·0/31 (0/14)	(1·1·1)	·1/61 ·2/55 (0/90)	·1/80 ·2/58 (1/20)
Ziggurat Nama	·0/28 ·0/54 (0/19)	·0/20 ·0/31 (0/150)	·0/21 ·0/32 (0/15)	·0/61 ·1/10 (0/39)	(1·1·1)	·1/16 ·2/33 (0/65)
Kar Afarin	·0/16 ·0/25 (0/12)	·0/18 ·0/26 (0/13)	·0/29 ·0/46 (0/19)	·0/53 ·0/79 (0/37)	·0/85 ·1/52 (0/42)	(1·1·1)

Table 10
Value of fuzzy combination expansion of price index.

l_{ij}	m_{ij}	u_{ij}	C_i
0/08	0/183	0/37	Bazargani Jahan
0/187	0/382	0/75	Persian Sazeh
0/125	0/264	0/55	Baran Novin
0/037	0/07	0/158	Azar
0/023	0/043	0/098	Ziggurat Nama
0/027	0/051	0/11	Kar Afarin

Table 11
Degree of feasibility for each possible binary mode.

$V(S_{c21} \geq S_{ci j})$	$V(S_{c22} \geq S_{ci})$	$V(S_{c23} \geq S_{ci})$	$V(S_{c24} \geq S_{ci})$	$V(S_{c25} \geq S_{ci})$	$V(S_{c26} \geq S_{ci})$
	1	1	0/403	0/087	0/18
0/48		0/75	0/104	0/35	0/28
0/75	1		0/147	0/138	0/05
1	1	1		0/65	0/77
1	1	1	1		1
1	1	1	1	0/35	

Table 12
Final weight and Ranking

	Kar Afarin	Ziggurat Nama	Azar	Baran Novin	Persian Sazeh	Bazargani Jahan
Minimum degree of feasibility	0/48	1	0/75	0/104	0/087	0/05
The final weight of the indices	0/195	0/406	0/305	0/041	0/033	0/02
Ranking	3	1	2	4	5	6

The results of Table 13 show that the highest priority was obtained by Persian

Sazeh and the lowest priority by the "Kar Afrin" in terms of price index in Iran Construction Group. In general, all companies that want to choose the right supplier can use the methods and indices collected in this research, along with any changes that may require a firm strategy.

Table 13
Final weight and ranking.

	Kar Afrin	Ziggurat Nama	Azar	Baran Novin	Persian Sazeh	Bazargani Jahan
Summary	2/562	4/723	3/204	0/788	0/426	0/315
Ranking	3	1	2	4	5	6

The results of the research indicate that the "communication system" index has the highest priority and the "price" index is the lowest priority among the evaluating indices of suppliers.

Based on the results in Table 4-60, the suppliers' ratings for each index are as follows: In terms of price index, the best suppliers in order of priority are: Persian Sazeh, Baran Novin, Bazargani Jahan, Azar, Ziggurat Nama and Kar Afrin; In terms of quality index, the best suppliers in order of priority are: Baran Novin, Persian Sazeh, Bazargani Jahan, Ziggurat Nama, Azar and Kar Afrin; In terms of on-time delivery index, the best suppliers in priority order are: Persian Sazeh, Baran Novin, Bazargani Jahan, Kar Afrin, Ziggurat Nama and Azar; In terms of background index, the best suppliers in order of priority are: Persian Sazeh, Baran Novin, Bazargani Jahan, Ziggurat Nama, Azar and Kar Afrin; in terms of management and organization, the best suppliers in order of priority are: Persian Sazeh, Baran Novin, Bazargani Jahan, Ziggurat Nama, Kar Afrin and Azar. In terms of technical capability, the best suppliers in the order of priority are: Persian Sazeh, Baran Novin, Bazargani Jahan, Azar, Kar Afrin and Ziggurat Nama. In terms of flexibility index, the best suppliers in order of priority are: Persian Sazeh, Baran Novin, Bazargani Jahan, Azar, Ziggurat Nama and Kar Afrin; in terms of obligation index, the best suppliers in priority order are: Persian Sazeh, Bazargani Jahan, Baran Novin, Ziggurat Nama, Azar and Kar Afrin. In terms of geographical location, the best suppliers in order of priority are: Persian Sazeh, Baran Novin, Bazargani Jahan, Azar, Kar Afrin and Ziggurat. In terms of credit index, the best suppliers in order of priority are: Persian Sazeh, Bazargani Jahan, Baran Novin, , Azar, Kar Afrin and

Ziggurat Nama; From the point of view of communication system, the best suppliers in the order of priority are: Persian Sazeh, Bazargani Jahan, Baran Novin, Azar, Kar Afrin and Ziggurat Nama.

Based on the results presented in Table 61-4 in the final summary, the ranking of suppliers in order of priority are: Persian Sazeh, Baran Novin, , Bazargani Jahan, Azar, Ziggurat Nama and Kar Afarin.

8. CONCLUSION

In this research, after identifying supplier evaluation indices, fuzzy multi-criteria decision making technique is used to prioritize these indices. Most of the variables are expressed as subjective, qualitative and verbal variables, and due to difficulty of their measurement by definite and mathematical numerical methods, fuzzy approach was used. Research innovations include:

1. Considering a new mathematical model for planning high-volume logistics and solving it with a meta-heuristic approach.
2. Considering the approach of selecting and prioritizing project suppliers simultaneously.
3. Combining fuzzy decision-making and optimization approaches. Identifying selected suppliers using the optimization approach and prioritizing them with the fuzzy hierarchical approach.
- 4- Determine the available criteria and options for prioritizing suppliers using linguistic variables.

In this study, by identifying available articles on relevant topics and referring to information on websites, as well as conducting interviews with managers and experts, affecting factors on evaluation and ranking of suppliers were broadly identified over 30 indices. After localization, indices (price, quality, on-time delivery, after-sales service, background, management and organization, technical capability, flexibility, obligation, geographical location, credit and communication systems) as indices of evaluation were considered in the supplier ranking of Iran Construction Group.

Research has attempted to address some of the investigational gaps. There are still many issues that can be considered as a study guide for futures:

- Considering other decision-making methods, including Promethee
- Considering other uncertainty approaches such as contingency or scenario
- Considering other meta-heuristic approaches such as the Bird Flight approach, the Tabu Search of the ant Ant Colony algorithm etc.

- Understanding the impact of supplier capacity constraints and quality constraints.
- Understanding the influencing criteria on selection of international suppliers
- Considering the time limitation for selecting suppliers.

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