Comprehensive Analysis Method Based on Multi-attribute Fuzzy Granulation in Decision Evaluation

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Abstract. In order to solve the problem in the process of supplier selection and evaluation, in this paper, granular computing theory was applied to the supplier evaluation and selection with fuzzy algorithm and analytic hierarchy process (AHP) in this paper. By using attribute value discretization algorithm, the application domain is extended to the case where attribute value is quantitative, and the decision analysis method is constructed. This method combined the qualitative and quantitative information to build a comprehensive analysis method. It has constructed a decision analysis method to realize supplier evaluation and selection of multi-attribute group decisions based on concerns, so as to provide enterprises with appropriate suppliers. This paper was applied to the evaluation and selection model of suppliers to verify the accuracy and feasibility of the decision analysis method. The enterprise with appropriate suppliers was provided in this method, which strengthened the enterprise's position in the supply chain, and then improved the core competitiveness.

1. Introduction
In the real world, decision is made everywhere. In the process of learning, people need to make decisions. In scientific research, people need to make decisions. In production and management, people need to make decisions. And in life, people also need to make decisions. As an important component of the supply chain, suppliers play an important role in the production and management activities. The quality and price of the supplier's products or services have a great influence on the final quality and price of the products or services of the manufacturer. In addition, each production and business operation unit needs to choose suppliers which are suitable for its own reality and development, so as to promote the development of the production and business operation unit and improve its competitiveness. Therefore, effective supplier evaluation and selection is the key link of each production and operation unit.

In supplier evaluation and selection, enterprises in different fields or of different nature might pay different attention to evaluation indicators at different times. Secondly, the attribute value of the evaluation index has the characteristics of qualitative (such as quality of service, timeliness of supply, environmental factors) and quantitative (such as product price, product quality acceptance rate) [1-2]. Finally, there were multiple attribute decisions in evaluation and selection [3]. It was difficult to evaluate and select the supplier, but it was difficult to achieve the best of multiple goals. For example, the buyer wanted the best supplier service and the lowest price. But the best supplier service and the lowest price were a pair of conflicting goals. In fact, to improve the service level of suppliers required increasing their construction or operation costs, and might increase exponentially with the
improvement of service level. Therefore, it was often necessary to balance the advantages and disadvantages and choose the right supplier after comprehensive analysis.

The research on supplier evaluation and selection has gone through three stages: qualitative method, quantitative method, qualitative and quantitative combination method. It included analytic hierarchy process [4-5], data envelope analysis [6], artificial intelligence [7-8] and so on. In recent years, regarding the uncertainty of supplier evaluation and selection, many scholars use rough sets [9-11] to deal with the fuzziness, incompleteness and objectivity of attribute weights in supplier evaluation and selection, and some results have been achieved.

In the research and analysis of this paper, it was found that the attribute values of the above rough set-based supplier evaluation and selection study were only qualitative, which did not reflect the concerns and other issues. Moreover, there were few literatures that apply granular computing in supplier evaluation and selection. Therefore, comprehensive analysis method based on multi-attribute fuzzy granulation in decision evaluation was proposed in this paper.

2. The relevant content of comprehensive analysis method

The method discussed in this paper is, how could the data obtained from the objective world be transformed into information through effective processing of the data, data perception, data processing, information association and reasoning. Information could be accumulated into knowledge to support relevant decisions.

People often observe problems from different perspectives, solve problems in layers, and refine the decomposition of problems, so as to find solutions to problems. Granular computing used systematic and structured methods to effectively analyze and process imprecise, incomplete and other data, mining hidden key information, and can divide complex multi-attribute problems into simple problems according to different measurement standards, and then apply to information decision-making. The simplified process of complex problems could be expressed as a multi-perspective and multi-level granulation process. In many cases, when problems involve incomplete, uncertain, or ambiguous information, it may be difficult to distinguish the different elements, and we have to consider particles. Or when the lack of information allows us to define particles rather than individuals. In some cases, information is desirable, but it costs a lot. The grain can effectively and effectively solve the problem. So granular computing is a solution to the complex problem [12].

The research object of this paper was the company's supplier decision evaluation. In the preliminary research work of this paper, through analyzing the company's supplier decision-making and evaluation process and related departments, it was found that neither product suppliers nor candidate suppliers had been systematically classified. As a result, the process node was not in line with the actual situation, increasing the complexity of work, resulting in the waste of human, material and financial resources. Therefore, according to the use of materials provided by suppliers to the company, and according to the importance of suppliers to the company's products, they were divided into important suppliers, more important suppliers and general suppliers. Through the classification of qualified suppliers, on-site evaluation that could be reduced was eliminated in some processes, and the corresponding operation process was optimized to avoid the waste of manpower, material resources and financial resources. And the division of power and responsibility of the department to ensure the effectiveness of decision-making. Through the analysis of the specific situation of the company's suppliers, the Delphi method was used to confirm the selection and evaluation indicators suitable for the company. Then, analytic hierarchy process (AHP) was used to confirm the weight coefficient of each index, and then a suitable supplier selection and evaluation system is constructed.

Through the analysis of the previous research work in this paper, it is found that although indicators are analyzed and divided into corresponding levels by delphi method and analytic hierarchy process. At the same time, the relative importance of each level and its corresponding indicators was carefully considered, but analytic hierarchy process could not describe the fuzzy information contained by experts in detail.

In view of the above problems, relevant theoretical methods of fuzzy set and rough set were introduced in this paper, which combines them with delphi method and analytic hierarchy process. A
comprehensive analysis method based on multi-attribute fuzzy granulation was proposed and applied to the decision-making of supplier evaluation and selection.

3. The proposed method

This paper was to propose a comprehensive analysis method based on multi-attribute fuzzy granulation in decision evaluation. The method flowchart was the analysis decision evaluation system and the method of scoring indicators.

3.1. The analysis decision evaluation system

People often observe problems from different perspectives, solve problems in layers, and refine the decomposition of problems, so as to find solutions to problems. Information granulation is the division of a class of objects into a series of small particles. And complex problems were divided into a series of smaller and simpler problems which reduce the cost of solving them. The solution of many simple problems was used to solve complex problems. The grains in granular computing could be groups, classes, or clusters. According to the information of different decision evaluation systems, the relationship between the granule layers was obtained, and the granule model was constructed, which could be used to provide a method to distinguish different systems.

Uncertainty and fuzziness in rough set theory were boundary-based concepts. Each uncertain concept was represented by a pair of exact concepts of the upper approximation and the lower approximation [13-14].

3.2. The method of scoring indicators

Step 1: establish comprehensive evaluation index. According to the conclusion mentioned above, the evaluation indexes of criterion layer and factor layer were established.

According to the fore-order study, delphi method is used to determine the evaluation index of suppliers. The quality, cost, delivery and service of each selected supplier in criterion layer were evaluated. And present of pass, quality restriction, quality compliance rate, quality process control, price competition, depreciate, delivery accuracy, delivery rate, communication, product design and fault diagnosis in elements layer were evaluated.

Step 2: establish the weight of the indicator. According to the experts to the evaluation index of the evaluation weight analysis.

According to the preceding order, the analytic hierarchy process is used to calculate the index weight [15].

Where: criterion layer weight was

$$\omega_1 = (0.49, 0.143, 0.308, 0.059)$$

Elements layer weight was

$$\omega_2 = (0.092, 0.409, 0.36, 0.25, 0.5, 0.5, 0.455, 0.09, 0.455)$$

The total weight of elements layer was

$$\omega_3 = (0.045, 0.2, 0.176, 0.068, 0.108, 0.036, 0.154, 0.154, 0.027, 0.005, 0.027)$$

Step 3: establish the scoring results of the indicators.

In supplier evaluation and selection, qualitative or quantitative scores are made on indicators. The qualitative indicators were scored according to their qualitative results and with reference to qualitative indicators. The quantitative indicators were graded according to the calculation results and the quantitative index scoring standard. In addition, due to the process of evaluation, sometimes it was not directly targeted at a good, medium or poor evaluation index. It also needed to be evaluated according to the evaluation indicators.

The granularity layering of evaluation condition attribute and decision attribute and the granularity layering between experts were established by using the idea of granular computing. For example, it was necessary to consider the communication and coordination indicators, such as the smoothness of communication, the timeliness of feedback and the quality of products supplied. So this was where the idea of information granulation comes in. The attribute values in each evaluation index could be divided into sets with different weights.
The quantization transfer relation between the layers was transformed into the fuzzy membership function of fuzzy control. Fuzzy control was based on the fuzziness of human thinking. Fuzzy control is essentially different from traditional control. Unlike classical control, fuzzy control does not require the transfer function described by precise numbers, nor does it require the equation of state expressed by matrices as in modern control theory. The core of fuzzy control is that it uses fuzzy language conditional statements as control rules to implement control. The control rules were usually given by specialists who were very familiar with the controlled process, so fuzzy control was a kind of expert control in essence. The control rules of this control fully reflect the human intelligence activities.

Steps of the algorithm:
(1) The granularity layering of application objects was established by granular computing. Those were the granularity layering of evaluation condition attribute and decision attribute and the granularity layering between experts.
(2) Convert the exact value of the score into a fuzzy quantity according to the scoring situation.
By using attribute value discretization algorithm, the application domain is extended to the case where attribute value is quantitative, and the decision analysis method is constructed. “better excellent, excellent, better good, good, medium, poor, bad, very bad” were adopted to describe the state of input and output variables of fuzzy controller.
There were abbreviated as
\{BE, EX, BG, GO, ME, PO, BA, VB\}
Input and output variables were fuzzy, so they are represented by fuzzy set.
For example, the scope of Sample quality test was:
\[ SQT = \{0, 60, 70, 75, 80, 85, 90, 95, 100\} \]

| Language value | 0 | 60 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|----------------|---|----|----|----|----|----|----|----|-----|
| BE             | 0 | 0  | 0  | 0  | 0  | 0  | 0.2| 0.8| 1   |
| EX             | 0 | 0  | 0  | 0  | 0  | 0.2| 0.8| 1   | 0.8 | 0.2 |
| BG             | 0 | 0  | 0  | 0.2| 0.8| 1   | 0.8| 0.2 | 0   |
| GO             | 0 | 0  | 0.2| 0.8| 1   | 0.8| 0.2 | 0   | 0   |
| ME             | 0.2| 0.8| 1   | 0.8| 0.2 | 0   | 0   | 0   |
| PO             | 0.2| 0.8| 1   | 0.8| 0.2 | 0   | 0   | 0   |
| BA             | 0.8| 1   | 0.8| 0.2| 0   | 0   | 0   | 0   |
| VB             | 1  | 0.8| 0.2| 0   | 0   | 0   | 0   | 0   |

The corresponding membership function table can also be provided for present of pass, quality restriction, quality compliance rate, quality process control, price competition, depreciate, delivery accuracy, delivery rate, communication, product design and fault diagnosis.

Note: when constructing two fuzzy membership functions that are spaced apart from each other, they should not intersect as much as possible, otherwise there may be conceptual conflicts between related fuzzy subsets. When two adjacent membership functions overlap, it is necessary to ensure that the same point in the domain cannot have the maximum membership to both membership functions at the same time.
(3) Calculate the score results.
The particle matrix algorithm based on expert evaluation was established by considering the expert decision problem. According to the fuzzy quantity and fuzzy control rules of the score value, the score result was calculated according to the fuzzy reasoning rules. In other words, the score results were de-
fuzzification. The evaluation team could give the evaluation of each supplier. Moreover, the final score was used to select the appropriate supplier.

By applying the granular computing theory to the methods of multi-attribute decision making and group decision making, the multi-attribute group decision making method based on information granulation was realized, and then applied to the evaluation and selection of suppliers, providing reference for enterprises to choose suppliers.

4. Application effect analysis

According to the research results in the preceding order of this topic, when a certain supplier was evaluated and selected, there were two potential suppliers for a certain product of the company, and one of them needs to be selected as the supplier.

In the preorder of the research results of this subject, the evaluation table provided to the experts (the evaluation table in accordance with the analytic hierarchy process). The experts in the scoring team would score the two suppliers according to the rating scale and select the final supplier according to the calculated score. In the fore-order research results, the subjective factors of evaluators were avoided, and the evaluation on quality, price and delivery time was increased, which was expected to reduce the repair rate of product in process, reduce the rate of defective products, reduce the purchase cost of enterprises, reduce the risk of stock shortage, and avoid the delay of delivery due to the shortage of incoming materials. Through analysis, we can know the evaluation and selection of suppliers.

According to the research results in the preceding order, the new system of supplier selection and evaluation was applied, and the score of supplier A was 8.8279 and that of supplier B was 8.5775 according to the calculation results of factor level indicators and weights. Therefore, company A is selected as the company's new supplier.

The method proposed in this paper improved the scoring rules by analytic hierarchy process. When the supplier selection and evaluation team scores the two suppliers, it was not necessary to give a specific value for each qualitative indicator, but only a vague value. For quantitative indicators, specific score results were given directly according to their indicators.

According to the research results in this paper, the score of supplier A was \{BE, EX, BE, EX, BA, VB, EX, EX, PO, EX\}; the score of supplier B was \{EX, ME, EX, ME, BG, ME, BG, ME, BA, BA\}. According to the method in this paper, supplier A was also selected as the supplier to be selected.

This method reflected the emphasis of supplier evaluation and selection, and found out the advantages and disadvantages of the supplier to be selected, so as to improve the accuracy of the results.

5. Conclusion

In this paper, multi-attribute, group decision, fuzzy algorithm and information granulation were introduced into analytic hierarchy process by using fuzzy theory, rough set and granular computing theory. The comprehensive analysis method based on multi-attribute fuzzy granulation in decision evaluation was put forward, which was applied to the decision-making research of supplier evaluation and selection, and the accuracy and feasibility of the decision analysis method is verified.

Therefore, the method proposed in this paper was feasible and efficient in the decision-making process of supplier selection and evaluation. This method provides the enterprise with appropriate suppliers, strengthens the enterprise's position in the supply chain, and then improves the enterprise's core competitiveness. In the next stage, the application of multi-attribute fuzzy granulation in decision-making evaluation is further explored to reduce the loss of quantitative information and the redundancy of information decision-making.
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References
[1] Pi Zhenyang, Fang Weiguo, Zhang Baofeng. Service and pricing strategies with competition and cooperation in a dual-channel supply chain with demand disruption[J]. Computers & Industrial Engineering, 2019, 138: 106-130.
[2] Lu, Huiyun, Jiang, Shaojun, Song Wenyu, et al. A Rough Multi-Criteria Decision-Making Approach for Sustainable Supplier Selection under Vague Environment[J]. Sustainability, 2018, 10(8): 1-20.
[3] Shukla N, Kiridena S. A fuzzy rough sets-based multi-agent analytics framework for dynamic supply chain configuration[J]. International Journal of Production Research, 2016: 1-13.
[4] Sasan Torabzadeh Khorasani. Green Supplier Evaluation by Using the Integrated Fuzzy AHP Model and Fuzzy COPRAS[J]. Process Integration and Optimization for Sustainability, 2018, 2(1): 17-25.
[5] Bai Jianguang, Wang Jianjun, Ji Xiaodong, et al. Evaluation to urban flooding ecological control based on analytical hierarchy process and fuzzy analysis method[J]. Science Technology and Engineering, 2018, 18(16): 7-11.
[6] Wang Chianan, Van Thanh Nguyen, Duy Hung Duong. A Hybrid Fuzzy Analytic Network Process (FANP) and Data Envelopment Analysis (DEA) Approach for Supplier Evaluation and Selection in the Rice Supply Chain[J]. Symmetry Basel, 2018, 10(6): 2073.
[7] Paunovic M., Ralevíc N.M., Gajovic V., et al. Two-Stage Fuzzy Logic Model for Cloud Service Supplier Selection and Evaluation[J]. Mathematical Problems in Engineering, 2018, 2018: 7283127.
[8] Li Xuerui, Yu Suihuai, Chu Jianjie. Optimal selection of manufacturing services in cloud manufacturing: A novel hybrid MCDM approach based on rough ANP and rough TOPSIS[J]. Journal of Intelligent & Fuzzy Systems, 2018, 34(6): 4041-4056.
[9] Keshavarz Ghorabaee Mehdi, Amiri Maghsoud, Zavadskas Edmundas Kazimieras, et al. A new multi-criteria model based on interval type-2 fuzzy sets and EDAS method for supplier evaluation and order allocation with environmental considerations.[J]. Computers & Industrial Engineering, 2017, 112: 156-174.
[10] Cheng Xiu, Long Ruyin, Chen Hong. Obstacle diagnosis of green competition promotion: a case study of provinces in China based on catastrophe progression and fuzzy rough set methods[J]. Environmental Science and Pollution Research, 2018, 25(5): 4344-4360.
[11] Liang Decui, Pedrycz Witold, Liu Dun. Determining Three-Way Decisions With Decision-Theoretic Rough Sets Using a Relative Value Approach[J]. IEEE Transactions on System man Cybernetics-Systems, 2017, 47(8): 1785-1799.
[12] Liu Peide, Yang Hongyu. Three-Way Decisions with Single-Valued Neutrosophic Decision Theory Rough Sets Based on Grey Relational Analysis[J]. Mathematical Problems in Engineering, 2019, 1-12.
[13] Zhan Feng. Supplier Evaluation and Selection Method Based on Multi-attribute Granulation[J]. IOP Conference Series: Materials Science and Engineering, 2019, 490(3): 163-168.
[14] Zhan Feng. SDG Fault Diagnosis System Based on Information Granulation Theory and its Simulation Platform[D]. Tai yuan: Taiyuan University of Technology, 2010.
[15] Huo Yunliang, Hu Xiaoning, Yang Xiong, et al. Case retrieval strategy based on fuzzy comprehensive evaluation method[J]. Journal of Sichuan University (Natural Science Edition), 2018, 55:1197-1203.