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A Lean Green Implementation Evaluation Method Based on Fuzzy Analytic Net Process and Fuzzy Complex Proportional Assessment

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Abstract— For the issue that the optimal selection of lean green implementation tools for performance effect, a method combining fuzzy analytic net process (FANP) with fuzzy complex proportional assessment (COPRAS) is proposed. Firstly, the main properties of the lean green performance and candidate tools are determined based on the production requirements and expert knowledge. Then, the fuzzy comparison matrix of each attribute is constructed according to the expert judgment represented by triangular fuzzy number, and the FANP method is used to obtain the importance weight of each attribute. After that, the fuzzy decision matrix between attributes with tools alternatives is constructed, and multiplying it with the attribute weight so as to obtain the weighted normalized decision matrix. Finally, the fuzzy COPRAS method is used to analyze the decision matrix to get the utility of each tools alternative. Based on the model and analysis, these results make us understand and be familiar with the most influential practice tools on performance benefits. These findings are expected to policy makers and industrial practitioners to focus on key elements of the success of the manufacturing business to facilitate both lean and green manufacturing implementation and assessment, and contribute to sustainable growth.

Keywords—lean green, performance effect, evaluation method, FANP, Fuzzy-COPRAS, sustainable development.

I. Introduction

IN the context of business globalization, in order to maintain competitiveness and achieve sustainable development, enterprises should not only pay attention to operation performance, but also pay attention to environmental performance, achieving "zero pollution, zero waste", and need to integrate and implement different manufacturing paradigms. Therefore, the implementation of lean green integration paradigm is one of the ways to improve the enterprises competitive advantage. In implementing lean green integration practice, it is necessary to consider the overall performance of

Lean green specific selection of implementation tool in production efficiency, cost, flexibility, adaptability and responsiveness, so as to choose the most suitable solution from a large number of alternatives. However, this is a very time-consuming process and is difficult to achieve. It plays a decisive role in the implementation of lean green integration strategy.

Nowadays, Most of the literatures discuss the relationship between lean, green manufacturing and organizational performance, focusing mainly on two aspects. One is the relationship between lean and green manufacturing practices and the relationship between specific tools and supply chain performance [1]-[3]. The other is the impact of specific implementation of lean and green manufacturing paradigms on environmental performance [4]-[6]. Lean green manufacturing integration is generally associated with the operational performance and environmental performance. Questions about the positive impact of integrating lean and green paradigms on corporate performance and competitiveness, this paper proposes a method based on the fuzzy analytic network process (FANP)by using language variables to construct two models: lean model and green manufacturing model for measuring the impact of selecting lean and green practices on performance benefits. Then, the fuzzy-COPRAS method is used to analyze the decision matrix to get the utility of each alternative. The results show that the method is feasible and effective. Finally, we propose bundles of lean and green practices to develop an integrated framework for lean green system for guiding firms to focus on a few vital issues to facilitate both lean and green manufacturing implementation and assessment, and towards sustainable growth.

In order to achieve the best performance goal, the optimal selection of the method tools in the lean green implementation process, an optimization method combining the fuzzy analytic network process (FANP) and the fuzzy complex proportional assessment (COPRAS) are proposed. First, the main attributes of candidates of the performance goals achieved by the lean green practice and candidate of select lean and green technical tools are determined based on the performance target optimization requirements and the expert knowledge. Then, the fuzzy comparison matrix of each attribute is constructed according to the expert judgment represented by triangular fuzzy number, and the FANP method is used to obtain the importance weight of each attribute [7-9]. Next, the fuzzy decision matrices between attributes and alternatives are constructed, between attributes with alternatives are constructed, after that, the decision matrix is analyzed by fuzzy COPRAS, and multiplying it with the attribute weight so as to obtain the weighted normalized decision matrix. Finally, the fuzzy COPRAS method is used to analyze the decision matrix to get the utility of each alternative, and a set of optimal toolkits are selected to develop a lean green system integrated framework model for guiding firms to focus on some key issues to promote the implementation and evaluation of lean and green manufacturing, and to achieve sustainable growth.

II. THE BASIC FRAMEWORK OF THE EVALUATION METHOD

Analytic hierarchy process (AHP) is an effective and robust technology for modeling and deciding complex problems. AHP can decompose the complex problems into various components and form an orderly hierarchical structure according to the top-down hierarchy relationship, but it cannot deal with the multi-level decision-making problems of the interaction and feedback, internal dependence and external dependence between the hierarchy and the internal elements and the internal elements. A method of analytic network process (ANP), which takes account of the interdependence between elements, can solve the problem of interdependence. This method uses the network to replace the hierarchical structure in the analytic hierarchy process (AHP), so that ANP can model the relationship between the decision elements. By taking into account the interdependence between elements, it generate the priority or relative importance of elements in complex network models to solve nonlinear and complex problems. Usually, fuzzy set theory is combined with ANP to form a more robust and flexible method for solving complex decision problems.

COPRAS is a more accurate decision-making method based on grey decision theory. According to the two aspects of importance and utility of decision attributes to be sorted and estimated step by step, so as to select the best plan from multi-attribute alternative decision plan. However, attributes and expert judgments may contain uncertain information. Therefore, the fuzzy set and COPRAS are combined to form a fuzzy COPRAS method in this paper, which is used to evaluate the utility of lean green paradigm method under given attribute weight.

The basic framework of the evaluation model presented in this paper is shown in Fig 1. First, collect data needed in decision-making process from literatures and expert judgments. Then, according to the evaluation attribute of the expert resolution, and the comparison relationship between the attributes, the pairwise comparison matrix is used as the input of the FANP with preference relation. Then, the weight of the importance of each attribute is calculated by FANP. Finally, the output of FANP is used as the input of the fuzzy COPRAS to determine the utility of the alternative method tool. The decision maker can choose the most suitable solution based on the final decision results. If the decision results are not satisfied, the decision maker makes the final decision and corrections the input data of the FANP. The complexity of the overall framework of proposed evaluation method in the diagram of Fig.1 is how to reasonably determine the weight of each attribute and the priority of constructing a robust and flexible lean green practice tools.

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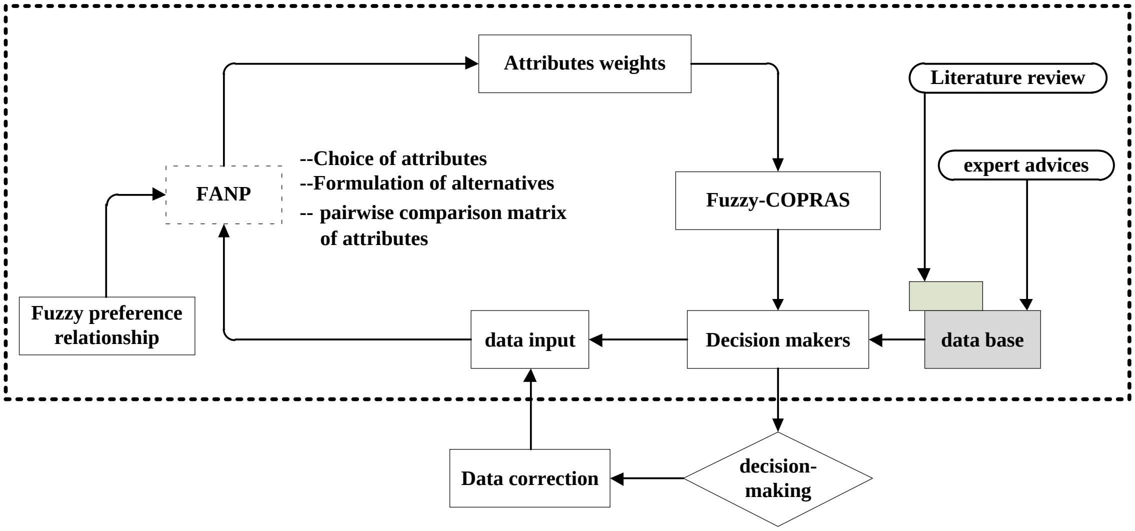

Fig.1 The overall framework of proposed evaluation method

Based on the decision process of FAHP and fuzzy COPRAS, this paper mainly consists of three stages:

1) The decision-makers collect information and determine the alternative methods and attributes according to the current manufacturing industrial situation. And build the pairwise comparison matrix of attributes
2) Compute the weight of attributes by using FANP with linguistic preference relations.
3) Taking the decision matrix between attributes and alternatives as input and combining attribute weights, we calculate the utility of each method by fuzzy COPRAS.

III. THE DETAILED PROCEDURE OF THE FANP AND FUZZY-COPRAS

A. The detailed procedure of FANP technique

In order to obtain the weight of the hierarchical structure in the multi criteria decision making model, we use the ANP technology, and the algorithm steps are as follows:

Step 1: Define the problem and find out the factors that depend on each other. The decision problems are analyzed and assembled systematically, and the elements and elements set are formed to determine whether the level of elements is independent, and there is dependency and feedback.

Step 2: The network hierarchical structure of the ANP is constructed. Firstly, the control layer is constructed to set decision goals, and construct decision criteria (the attributes or standards of evaluation), and then the network level is constructed to establish the network hierarchy of decision-making process.

Step 3: The weight of each attribute is calculated based on FANP. First, do not consider the dependencies relation between attributes or elements, calculate and establish pairwise comparative fuzzy relation matrix of attributes $\tilde{W}_a$. Where, W_i (i =1, 2... N) is an attribute, $\tilde{a}_{ij}$ (i, j=1, 2,... N) is the relative importance between attributes W_i and W_j, so that we can get pairwise comparison matrix $\tilde{W}_a$. The importance of the attributes of the computing criteria layer is represented by Triangular Fuzzy Number (TFN), because in the complex evaluation system, empirical knowledge is expressed in linguistic term. This research project uses TFN, which is an effective tool to deal with uncertain information decision problems, and the linguistic variables used in the pairwise comparison process, as shown in Table 1.

Table 1 Fuzzy linguistic variables in FANP

linguistic term	Triangular Fuzzy Number
very poor（VP）	（0, 0, 0.1）
poor（P）	（0, 0.1, 0.3）
lower-middle（LM）	（0.1,0.3,0.5）
middle（M）	（0.3,0.5,0.7）
upper-middle（UP）	（0.5,0.7,0.9）
good （G）	（0.7,0.9, 1 ）
very good（VG）	（0.9, 1 , 1 ）

Step 4: Relative to other attribute factors of rule level, the internal dependency matrix of every attribute factor of rule layer is calculated. In the pairwise comparison between a certain attribute factor and the remaining attribute factors, the expert constructs the corresponding matrix based on the linguistic variables judgment, which are also expressed in TFN, thus obtaining the dependency comparison matrix $\tilde{W}_b$.

Step 5: Measure the priority sequence of each attribute factor of rule layer. Calculating $W_{factors} = \tilde{W}_a \times \tilde{W}_b$ is performed in this step.

Based on expert judgments, a pairwise comparison fuzzy matrix $\tilde{A}$ is established by using certain attributes of linguistic variables, and the fuzzy matrix is calculated as follows.

$$\tilde{X} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{12}^{-1} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{1n}^{-1} & \tilde{a}_{2n}^{-1} & \cdots & 1 \end{bmatrix} \tag{1}$$

In the upper matrix, the attribute values in pairwise comparison matrix are reciprocal. In the process of concrete calculation, when $\tilde{a}_{ij} = (\tilde{a}^L{}_{ij}, \tilde{a}^M{}_{ij}, \tilde{a}^U{}_{ij})$, the element $\tilde{a}_{ji} = (\tilde{a}^L{}_{ji}, \tilde{a}^M{}_{ji}, \tilde{a}^U{}_{ji}) = \tilde{a}^{-1}{}_{ij}$, $\tilde{a}^L{}_{ji} = 1 - \tilde{a}^U{}_{ij}$, $\tilde{a}^M{}_{ji} = 1 - \tilde{a}^L{}_{ij}$, $\tilde{a}^U{}_{ji} = 1 - \tilde{a}^M{}_{ij}$. So the $\tilde{A}_i$ fuzzy mean importance of attributes is $\bar{A}_i$

$$\bar{A}_i = \frac{1}{n}\sum_{j=1}^{n} a_{ij} = \left(\frac{1}{n}\sum_{j=1}^{n} a^L{}_{ij}, \frac{1}{n}\sum_{j=1}^{n} a^M{}_{ij}, \frac{1}{n}\sum_{j=1}^{n} a^U{}_{ij} \right) \tag{2}$$

The weight of the fuzzy importance of the attribute $\tilde{A}_i$ is $\tilde{w}_{A_i}$

$$\tilde{w}_{A_i} = \left(\tilde{w}^L_{A_i}, \tilde{w}^M_{A_i}, \tilde{w}^U_{A_i} \right) = \frac{\bar{A}_i}{\sum_{i=1}^{n} \bar{A}_i} = \frac{\left(\frac{1}{n}\sum_{j=1}^{n} a^L{}_{ij}, \frac{1}{n}\sum_{j=1}^{n} a^M{}_{ij}, \frac{1}{n}\sum_{j=1}^{n} a^U{}_{ij} \right)}{\bar{A}_1 + \bar{A}_2 + \cdots + \bar{A}_n} \tag{3}$$

Finally, according to the fuzzy mean method, defuzzify the weights of the attributes $\tilde{A}_i$, and a clear weight value w_{A_i} is obtained.

$$w_{A_i} = \frac{w^L{}_{A_i} + w^M{}_{A_i} + w^U{}_{A_i}}{3} \tag{4}$$

B. The detailed procedure of fuzzy COPRAS

The Fuzzy-COPRAS (fuzzy complex proportional assessment) is used to evaluate the utility of all the alternatives on the basis of the weighting of the evaluation attributes of the criteria layer. In the Fuzzy-COPRAS evaluation, the level of the program is expressed by fuzzy number of linguistic variables. The basic theory and steps of the method are as follows [10].

Step 1: First, define the fuzzy linguistic variable of expert judgments, as shown in Table 2.

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Table 2 Fuzzy linguistic variables in COPRAS

linguistic term	Triangular Fuzzy Number
very low（VL）	（0,1,3）
low（L）	（1,3,5）
middle（M）	（3,5,7）
height（H）	（5,7,9）
very height（VH）	（7,9,10）

Step 2: The fuzzy decision matrix is constructed. Determine the aggregated fuzzy rating of the alternative A_i, i=1,2,…m, under criterion C_j, j=1,2,…n

$$\tilde{X} = \begin{array}{c c} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_j \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_i \end{array} & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array}, \ i=1,2,\ldots,m;\ j=1,2\ldots n$$

$$\tilde{x}_{ij} = \left(x_{ij1}, x_{ij2}, x_{ij3}\right), \quad \begin{aligned} x_{ij1} &= \min_k \left\{x_{ijk1}\right\} \\ x_{ij2} &= \frac{1}{k}\sum_{k=1}^{k} x_{ijk2} \\ x_{ij3} &= \max_k \left\{x_{ijk3}\right\} \end{aligned} \tag{5}$$

In the formula, $\tilde{x}_{ijk}$ is the evaluation of linguistic variables based on alternatives A_i with respect to the criterion attribute C_j by the kth expert, $\tilde{x}_{ijk} = \left(x_{ijk1}, x_{ijk2}, x_{ijk3}\right)$.

Step 3: The fuzzy decision matrix is defuzzification, and the matrix data are normalized to get matrix elements x_{ij} .

$$x_{ij} = \frac{\left\lfloor \left(x^U{}_{ij} - x^L{}_{ij}\right) + \left(x^M{}_{ij} - x^L{}_{ij}\right) \right\rfloor}{3} + x^L{}_{ij} \tag{6}$$

Step 4: Calculation weighted normalization decision matrix $\hat{x}_{ij}$.

$$\hat{x}_{ij} = w_{factors} \times f_{ij} \tag{7}$$

Step 5: The weighted normalized dimensionless values are calculated separately according to the optimal direction of optimization and minimization respectively. P_i is the sum of optimizing directions for maximizing, R_i is the sum of optimizing directions for minimizing .

$$P_i = \sum_{j=1}^{k} \hat{x}_{ij} \; ; \; R_i = \sum_{j=l+1}^{m} \hat{x}_{ij} \tag{8}$$

Step 6: Calculate the comprehensive evaluation value of each alternatives (method tool), Q_i :

$$Q_i = P_i + \frac{\sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \frac{1}{R_i}} \tag{9}$$

Step 7: Determine the optimality criteria, K=max $\{Q_i\}$, i=1,2, ,... I, and obtain the utility of the alternative to sort the alternatives, N_i .

$$N_i = \frac{Q_i}{Q_{\max}} \times 100 \tag{10}$$

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IV. Application of the FANP and Fuzzy-COPRAS for Evaluating Lean Green Practices

A total of two hierarchy structural model are developed based on gathering the opinions of industrial experts and collecting through extensive literature review. The purpose of the FANP analysis is to assess the weight of each paradigm evaluating criteria attribute of hierarchy structural model, and the importance of the alternatives are assessed by fuzzy COPRAS technology. Finally, according to the results of the fuzzy COPRAS method, the alternatives are ranked.

A. Constructing lean and green paradigm hierarchy structural model

Looking back on different literatures, we find different literatures have different views on the implementation of lean production and different the implementation of lean production tools. On the basis of expert judgments, it is necessary to determine the importance of quantificationally studying the importance of the following different tools in lean production, such as 5S, Kaizen (continuous improvement), Single minute exchange of die (SMED), Visual control (VC), KANBAN, Value stream mapping(VSM), Cellular manufacturing(CM) and Total Productive Maintenance (TPM)[11].

The lean level of the company can be measured with performance impact factors such as cost reduction, quality improvement, reduction cycle time, and on-time delivery [12]-[13]. The lean improvement effect of the organization can be determined by the above performance factors. Therefore, these performance evaluation factors can be used as the criteria attribute level of the lean paradigm ANP analysis model. However, these factors are not independent of each other, and there is an interaction between them, such as the improvement of quality and delivery capacity, which will inevitably increase the cost, reduce the time of the cycle and reduce the cost, and there are interdependence in the standard layer. Similarly, in order to achieve the ideal lean level, the necessary practical tools and techniques are needed. The main eight tools can be the lowest level of the alternatives layer elements. The implementation level of these practical tools affects the performance of lean production organizations. Therefore, a lean mode practice model is shown in Fig 2.

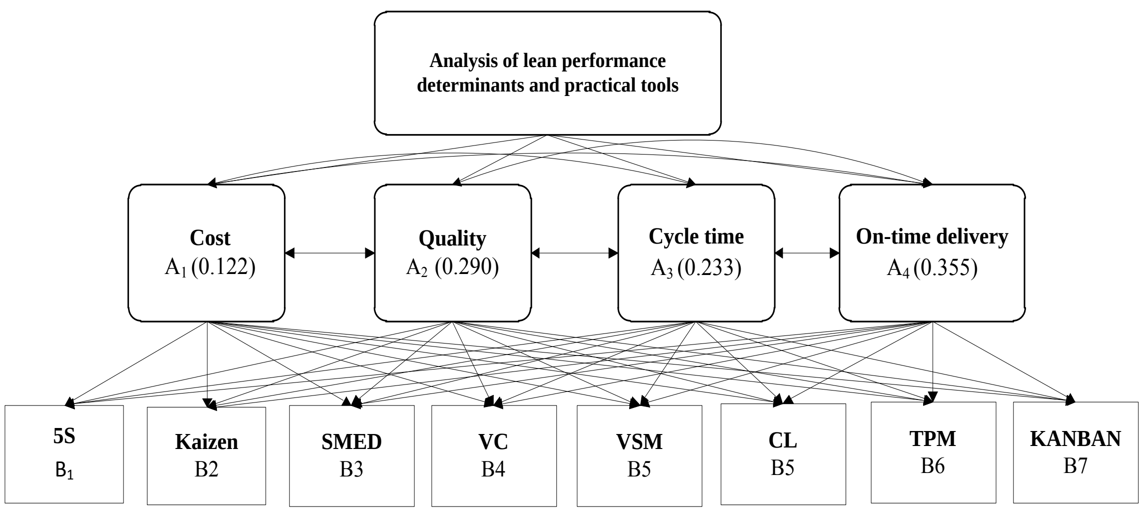

Fig. 2 Net hierarchical model to analyze lean paradigm

Green manufacturing is a modern manufacturing model that considers environmental impact and resource consumption. The goal is to make the product that have the negative impact on the environment is minimal, the utilization of resources is high, and the social and economic benefits and social benefits are coordinated and optimized from the whole life cycle of design, manufacture, packaging, transportation, and waste disposal. Scholars have conducted an empirical study to find out the positive impact of green manufacturing implementation on manufacturing performance. So, based on different literatures and expert judgments, we chose the following green practice tools to do research, such as Life cycle assessment (LCA), Environmental Management Systems (EMS), Design for Environment (DFE), Environmental emission control & influence remedies (EEC & IR), Green supply chain practice (GSCP), ISO14001, Reduction, reusing, and recycling(3R), Optimal use of natural resources (OUNR)[11]. The main eight tools can be the lowest level of the alternatives layer elements.

Similar to the lean paradigm model, a green paradigm model was also developed in consideration of the performance gains obtained by implementing green manufacturing practices (Fig.3).The green improvement effect can be determined by these performance determinants, which are wastewater reduction (WWR), reduced emissions (RE), solid waste reduction (SWR)and reduced energy consumption (REC)[14]-[16].

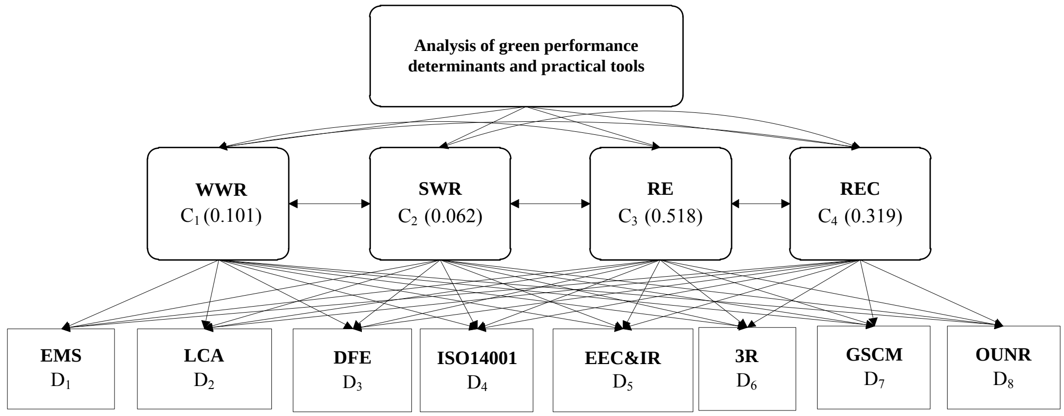

Fig. 3 Net hierarchical model to analyze green paradigm

B. Calculating the weight of each attribute based on FANP technique

The analytic hierarchy process (AHP) is used to analyze Fig 2. On the basis of consulting the relevant literature and the suggestions given by the experts, the matrix factors are graded according to table 1. According to detailed procedure of FANP technique and the calculation formulas (1), (2), (3) and (4), and the relative importance of the hierarchical structure evaluation criterion A to the target level is obtained:

$$W_{L-a} = (A_1, A_2, A_3, A_4)^T = (0.093, 0.339, 0.182, 0.386)$$

By calculating the interrelation between attributes A and the fuzzy matrix, the final comparison matrix is:

$$W_{L-b} = \begin{bmatrix} 1 & 0.093 & 0.153 & 0.176 \\ 0.230 & 1 & 0.240 & 0.312 \\ 0.333 & 0.297 & 1 & 0.281 \\ 0.276 & 0.441 & 0.4431 & 1 \end{bmatrix}$$

Therefore, the relative importance of attributes A, which is relative to the target layer, is normalized, which is:

$$W_{L-factors} = W_{L-a} \times W_{L-b} = (0.220, 0.525, 0.422, 0.641)$$

After normalization: (0.122, 0.290, 0.233, 0.355)

The same application of network analytic process (ANP) is used to analyze Figure 3 and construct judgment matrix. According to the same calculation method of lean paradigm model above, the relative importance of the relative total target of attributes C level elements in the consistency of judgment matrix is obtained: （0.101，0.062，0.518，0.319）.

C. Calculating the utility of each alternative based on fuzzy COPRAS

Combined with the steps of Fuzzy-COPRAS evaluation method, the corresponding matrix is constructed by the lean paradigm analytic hierarchy process, and the calculation results are described below.

The experts use the fuzzy language in Table 2 to evaluate the attributes of eight practical method tools in the lean production paradigm, establish a fuzzy decision matrix $\tilde{X}_{Lean}$, and convert it into a language fuzzy number according to the formula (5), and get the fuzzy decision matrix $\tilde{X}_{Lean}$, as shown in Table 3.

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Table 3 The decision matrix of lean paradigm represented by fuzzy number

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
A_1	(5,8.31,10)	(1,5.12,9)	(0,3.25,7)	(1,3.78,9)	(3,6.76,10)	(3,6.89,10)	(1,4.24,9)	(0,3.2,7)
A_2	(3,6.78,10)	(0,3.56,7)	(1,4.76,9)	(3,7.21,10)	(5,8.34,10)	(3,7.21,10)	(1,3.65,7)	(1,3.25,7)
A_3	(5,7.52,10)	(1,4.23,7)	(0,3.21,7)	(5,7.79,10)	(0,3.21,7)	(1,5.23,9)	(3,5.87,9)	(1,4.21,9)
A_4	(3,5.21,9)	(1,5.16,9)	(1,4.57,9)	(1,4.34,9)	(1,4.89,9)	(1,4.87,9)	(1,4.78,9)	(0,3.2,7)

The fuzzy decision matrix is defuzzification by formula (6), and the result is shown in Table 4.

Table 4 The decision matrix of lean paradigm after defuzzification

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
A_1	7.77	5.04	3.42	4.59	6.59	6.63	4.75	3.40
A_2	6.59	3.52	4.92	6.74	7.78	6.74	3.88	3.75
A_3	7.51	4.08	3.40	7.60	3.40	5.08	5.96	4.74
A_4	5.74	5.05	4.86	4.78	4.96	4.96	4.93	3.40

The decision matrix in table 4 is normalized, and the final normalized decision matrix, as shown in Table 5, is obtained by multiplying the normalized values by the formula (7) by the weight of the corresponding attributes.

Table 5 The weighted normalized decision matrix of lean paradigm

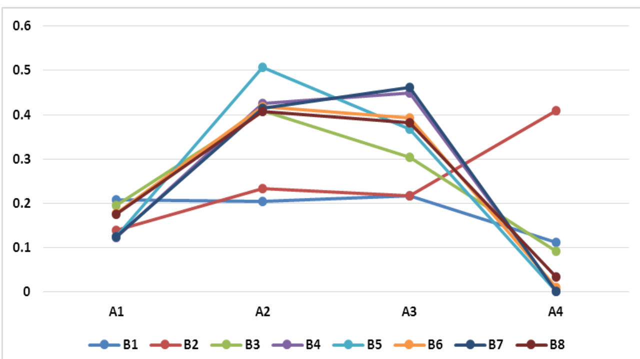
	optimization direction	$\mathbf{B_1}$	$\mathbf{B_2}$	$\mathbf{B_3}$	$\mathbf{B_4}$	$\mathbf{B_5}$	$\mathbf{B_6}$	$\mathbf{B_7}$	$\mathbf{B_8}$
$\mathbf{A_1}$ **(0.122)**	minimization	0.208	0.140	0.195	0.123	0.124	0.178	0.124	0.176
$\mathbf{A_2}$ **(0.290)**	maximization	0.205	0.233	0.409	0.425	0.507	0.419	0.414	0.407
$\mathbf{A_3}$ **(0.233)**	minimization	0.217	0.217	0.304	0.449	0.367	0.393	0.461	0.382
$\mathbf{A_4}$ **(0.355)**	minimization	0.112	0.410	0.093	0.003	0.001	0.011	0.001	0.034

The P_i, R_i, Q_i, N_i values are calculated by formula (8), (9) and (10), and methods and tools of the lean practical are ranked. The results are shown in Table 6.

Table 6 The ranking results of lean paradigm alternatives

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
P_i	0.205	0.233	0.237	0.192	0.207	0.205	0.4144	0.204
R_i	0.537	0.767	0.591	0.575	0.493	0.581	0.586	0.593
Q_i	0.278	0.306	0.310	0.265	0.280	0.277	0.487	0.277
N_i	56.97	62.79	63.59	54.44	57.53	56.92	100.00	56.86
Rank	5	3	2	8	4	6	1	7

The results show that the effectiveness of the lean paradigm implementation method is ranked, which is: $B_7 > B_3 > B_2 > B_5 > B_1 > B_6 > B_8 > B_4$. Similarly, The same application of fuzzy-COPRAS is used to analyze green paradigm, we can obtain the result: D4>D3>D6>D5>D7>D2>D8>D1. In order to determine the robustness of the results obtained through the two ANP models and allow generalization, the expert selection software is used for dynamic sensitivity analysis by increasing the weight of each criterion from the weight of the baseline scenario (i.e. the weight of the initial expert judgment analysis) by about 10 % to the proceed weight of each attribute (Fig. 4). This result is very robust. According to the feedback and practical operation of the technicians, the feasibility and effectiveness of the method are proved.



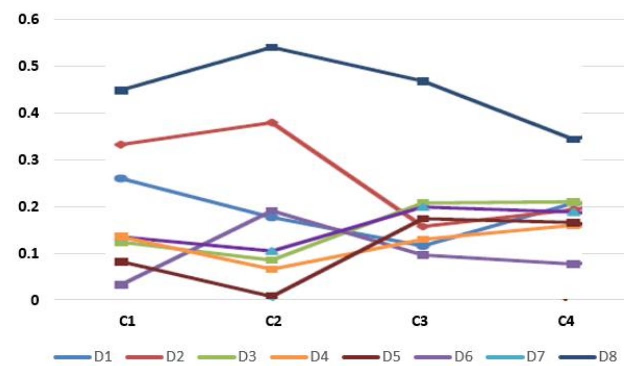


Fig. 4 Dynamic sensitivity analysis by the expert selection software for lean and green paradigm models

V. Conclusion

In this study, we develop a new model based on MCDM approaches by using linguistic variables under fuzzy environment. The importance weight of evaluation indexes are calculated by using ANP technology based on the pairwise comparison matrix. The ANP technology takes account of the relationship among the criteria considered. So we can correctly obtain the overall weight of the evaluation criteria. In order to calculating the relative rating of alternatives, Fuzzy-COPRAS is used to prioritize alternatives based on the criteria considered. The ANP technology is used to achieve the aim, which is a very time-consuming and troublesome process. The FANP and fuzzy-COPRAS analysis results provide some important management insights for understanding the impact of the evaluation criteria and practice tools of lean green paradigms for organizational performance evaluation. Results of ANP analysis suggest that just in time delivery and quality control are key criteria for thinness, while green depends on reduced emissions and energy consumption. The results of fuzzy-COPRAS analysis show that TPM, SMED and Kaizen are the most influential lean practice tools, while ISO 14001, DFE and 3R are the leading green practice tools. In this study, it is assumed that the attributes of lean and green are independent of each other, and the interdependence between them is not considered. In the future research work, we will consider using the house of quality matrix in the development of quality function to express the dependencies between attributes, so as to obtain a more accurate FANP pairwise comparison matrix. At the same time, the future research may apply fuzzy ANP and fuzzy-COPRAS analysis methods to explore the potential interrelationships between various performance standards and enabling factors. For example, you can test the relationship between "business/cost performance" and "environmental performance", and their impact on the importance of lean and green paradigms, because these relationships may affect the extent to which the overall performance of the company can be improved.

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