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Supplier Evaluation and Order Allocation with FANP – Multiple Objective (goal) Programming: A Case Study in Garment Industry, Vietnam

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Abstract: A supplier selection decision inherently is a multi-criterion problem. It is a decision of strategic importance to companies, which plays an important role in the business of production, construction,... However, it is not easy to select suppliers that are reliable, cost-effective and more competitive. In this study, we use a Fuzzy Analysis Network Process (FANP) that takes into account the Fuzzy factor to evaluate the performance of suppliers and rank the suppliers. After the supplier is ranked, use the Goal Programming Model Order Allocation.

Key word: Supplier selection・Multi-criterion・Fuzzy・Analysis network method・Goal programming

INTRODUCTION

Selecting effective suppliers helps to improve material quality, flexibility and reduce the total time it takes to make a product. Selecting a supplier is a multi-criteria decision and it is quite difficult to find an optimal solution to select the right supplier. Traditional supplier selection techniques are main, ambiguous and uncertain. Therefore, the development of a suitable supplier selection method is an urgent study. To select an effective supplier, businesses use a variety of criteria to choose from including business size, industry prestige, price, quality, delivery, packaging, storage, shipping transfer, environmental factors...

Some of today's multi-criteria decision methods are widely used such as hierarchical analysis (AHP), network analysis (ANP). The Analytical Hierarchy Process (AHP), also known as hierarchical analysis, was developed by Saata[1]. This is a quantitative analysis method that is often used to compare optimal options based on the analysis of comparable indicators. However, the AHP method only considers one-way relationships between factors that do not take into account interactions between factors. The Analytical Network Process (ANP) method is a method of network analysis which takes into account the hierarchy and interactions between the criteria in the system. The ANP method was born to overcome the disadvantage of the AHP method, but the ANP method has not solved the uncertainty of performing a pairwise comparison matrix. In order to overcome the limitations of AHP and ANP, FANP (FANP) network analysis was developed with the combination of fuzzy numbers and ANP. This method takes into account the interplay between the elements to give the result of the priority over the criteria and the combination with fuzzy numbers will help solve the problem. Multi-criteria decision in uncertain ambient environment.

The priority level between the criteria obtained from the calculation in the FANP model is used in the planning model as a weighting. The results obtained from the target planning model will provide an option for the distribution of orders to specific suppliers. Target planning is a form of mathematical modeling, consisting of linear or nonlinear functions with continuous or discrete variables in which all functions are transformed into targets. Targeting allows businesses to discern the limits of resources, resources and other constraints in choosing suppliers.

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Literature Review: Supplier evaluation and selection problems has attracted serious research attention in the last decade. In Dickson's [2] study, a large number of alternative methods have been used for evaluating and selecting criteria. Most of these models make decision making on supplier selection based on a set of supplier performance criteria [3]. Selected models differ from each other by having one or multi- objective or having different criteria.

Timmerman [4] proposed single objective weighted linear model in which suppliers are rated on several criteria and in which these ratings are combined into a single score. Pearson and Ellram [5] examined supplier selection and evaluation criteria in small and large electronic firms presented criteria used by purchasing managers in selecting single suppliers.

A number of conceptual papers have been published in the last decades that solved selection problems and mathematical models were developed in 1980's. Talluri and Narasimhan [6], Ng [7], Guneri *et al*. [8] proposed a solution to this problem by means of linear programming, Integer linear programming [9,10]; integer non-linear programming [11]; multi-objective programming[12-14]; goal programming [15,16]; data envelopment analysis [17-18] are some mathematical programming models which are used for supplier selection.

AHP and ANP have been used in different supplier selection problems. Kokangul and Susuz [19], Rouyendegh and Erkan [20], Labib [21] used AHP method in their studies. Bayazıt [22], Jharkharia and Shankar [23], Gencer and Gurpinar [24], Lin [25], Pang and Bai [26], Govindan *et al*. [27] used ANP method to solve supplier selection problem. Shyur and Shih [28] used ANP and TOPSIS integrated method for supplier selection. Lin [25] combined FANP (Fuzzy Analytic Network Process) with multiobjective linear programming.

Theory Basis: Fuzzy number theory: The fuzzy number theory was proposed by Zadeh [29]. According to the classical concept it will divide the space into two distinct parts. Any element in space will belong to or belong to the given set. This set is called a real set.

This study defines fuzzy sets as follows (Dubois and Prade[30]; Kaufmann and Gupta [31]): A fuzzy set A defined in space X is defined as follows:

$$A = \{(x, f_A(x)) \mid x \in X\} \text{ vi} f_A(x) \in [0,1] \quad (1)$$

In it, f_A is called the dependency function of the fuzzy set A and $f_A(x)$ is the value of $x \in X$ into A. The definite range of the function fA (x) is the [0,1] where the value of 0 indicates the degree of non-belonging, while the value of 1 indicates the degree of belonging entirely.

There are many forms of fuzzy numbers such as trapezoid fuzzy numbers, triangular fuzzy numbers,…However, triangular fuzzy numbers are often used for efficiency and ease of use. In this study, supplier valuation is based on triangular fuzzy numbers, so this fuzzy form is focused on research. triangular fuzzy numbers are shown in Figure 2:

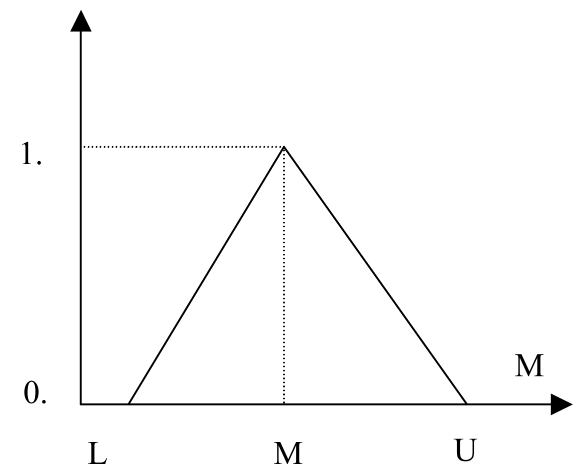

Fig. 2: Triangular fuzzy numbers

$$\mu(x) = \begin{cases} \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & otherwise \end{cases} \quad (2)$$

November 30, 2006If a = b = c = d, fuzzy number A becomes real. Thus, real numbers are special cases of fuzzy numbers.

FANP Theory: Network analysis model (ANP) developed by Saaty[32] to overcome the limitations of the AHP, is considering hierarchical properties and the interaction between the supplier selection criteria. However, the downside of the ANP is still not yet solved the problem of uncertainly when making comparative matrix pairs. FANP method implementation process is as follows:

Step 1: Build the ANP model.
Step 2: Collect data by table reviews.
Step 3: Shape the folder comparison matrix.
Step 4: Fuzzy number.

Step 5: Calculate the value of the largest private and check consistency. Calculate your own vector matrix.
Step 6: Form the super matrix
Step 7: Calculate the super matrix and giving results.

Target planning model: Goal planning model is a model of optimization to solve the maximum target. Each result is given as a goal or target value should be reached. Goal planning model was a applied to make the goal type:

- Determine the resources needed to achieve a desired goal.
- Determine the level of achievement of the objectives with the available resources.
- Provide optimum solutions under are source bound and prioritize the most essential goals.

Research Structure: This study proposes an integrated FANP - Multiple Objective (goal) Programming method, which consists of two stages, to evaluate suppliers and facilitate optimal order allocations given a number of criteria. In the first stage, the FANP method, is used to measure the weights of the selected suppliers. In the second stage of the model, the weights are used as coefficients in the fourth objective function of the Multiple Objective (goal) Programming method to allocate optimal order quantities to the suppliers.

The FANP method: The process of building supplier selection models is as follows:

Proposed approach:

- Build models of ANP:

Clearly identify the objectives, the selection criteria, suppliers.

- Collect data using the evaluation board

Based on the ANP structure has been built, the Panel reviews are used to collect the opinions of the experts on the importance of different criteria. Fuzzy numbers are used to calculate the combined uncertainty when making comparisons between the criteria.

Forming Pairwise Comparison Matrices: Pairwise comparison matrix is used to perform pairwise comparisons between criteria together. Pairwise comparison matrix is presented as follows:

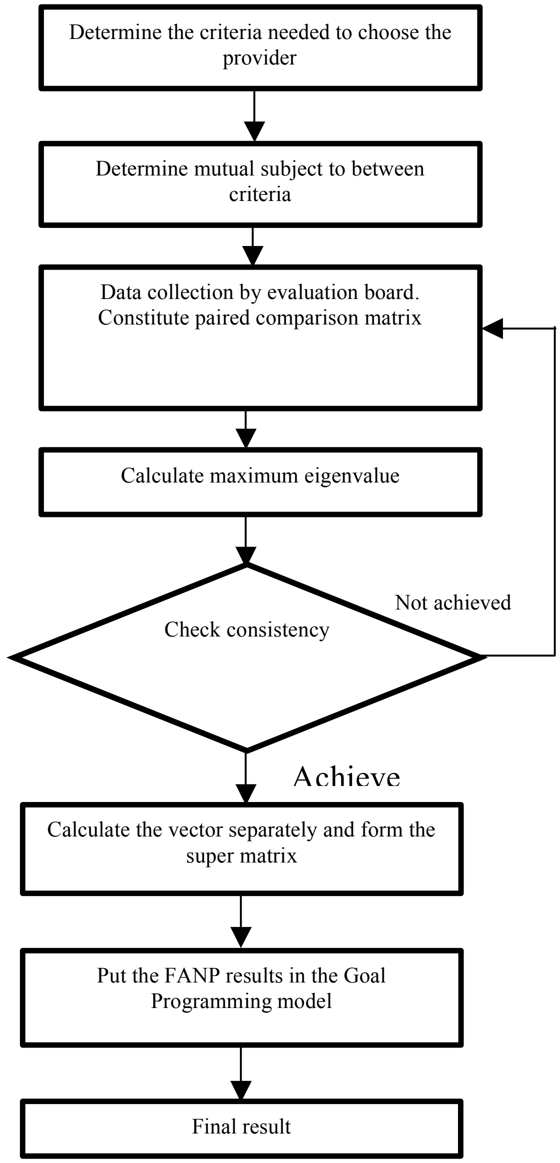

Fig. 1: Methodology diagram

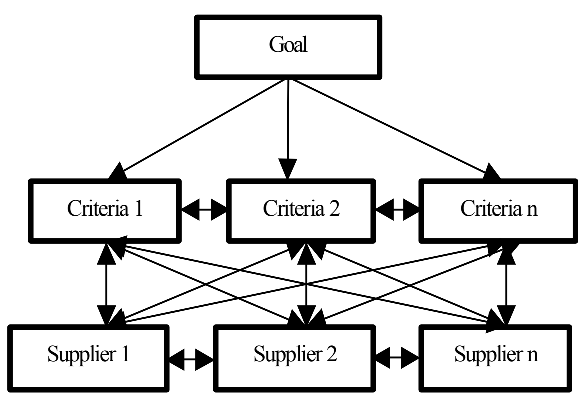

Fig. 3: ANP diagram

Table 1: The importance of the criteria

Intensity of fuzzy scale	Linguistic variables for relative weights of criteria
$\tilde{1}$	Equally important
$\tilde{3}$	Moderately important
$\tilde{5}$	Strongly important
$\tilde{7}$	Very strongly important
$\tilde{9}$	Extremely strongly important
$\tilde{2}\ \tilde{4}\ \tilde{6}\ \tilde{8}$	Intermediate values between two adjacent judgments; $\tilde{2}=(1,2,3)$; $\tilde{4}=(3,4,5)$; $\tilde{6}=(5,6,7)$; $\tilde{8}=(7,8,9)$;

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{d_{11}^k} & \widetilde{d_{12}^k} & \cdots\widetilde{d_{1n}^k} \\ \widetilde{d_{21}^k} & \widetilde{d_{22}^k} & \cdots\widetilde{d_{2n}^k} \\ \cdots & \cdots & \cdots \\ \widetilde{d_{n1}^k} & \widetilde{d_{n2}^k} & \cdots\widetilde{d_{nn}^k} \end{bmatrix} \quad (3)$$

- Defuzzification

For the transformation of fuzzy numbers into real numbers and fuzzy numbers, the solution triangle is presented as follows:

$$ga_{,\beta}(\bar{\alpha}_{ij}) = [\beta.f_a(L_{ij})(1-\beta).f_a(U_{ij})] \quad (4)$$
$$0 \le \beta \le 1, 0 \le a \le 1$$

where

$$f_a(L_{ij}) = (M_{ij} - L_{ij}).a + L_{ij}$$
$$f_a(U_{ij}) = U_{ij} - (U_{ij} - M_{ij}).a \quad (6)$$

When taken through diagonally symmetric matrix we have:

$$g_{a,\beta}(\bar{\alpha}_{ij}) = \frac{1}{g_{a,\beta}(\bar{\alpha}_{ij})} \quad (7)$$
$$0 \le \beta \le 1.0 \le a \le 1, i > j$$

Table 2: Matrix comparing pairs of real numbers

Criteria	C1	C2	...	C N-1	C N
C1					
C2					
...					
C N-1					
C N					

Calculate the Largest Eigenvalues And Check Consistency: Formula largest eigenvalues as follows:

$$|A - \lambda_{max}| = 0$$

where
λ_{max} is the value of own matrix

A the pairwise comparison matrix between the elements

I is a matrix of units of the same level with the matrix A.

Consistency ratio is calculated by the following formula:

$$CI = \frac{\lambda_{max} - n}{n-1}$$
$$CR = \frac{CI}{RI} \quad (8)$$

where
CI: Consistency index
RI: Random index
n: Number of elements in the matrix

If CR $\le$ 0.1 then satisfactory, conversely if CR $\ge$ 0.1, we must proceed to the re-evaluation of the comparative matrix pairs.

After a consistent ratio to be checked, to make assessment results between the elements, own vector matrix is calculated. Formula own vector calculation matrix is presented below:

$$A.\omega = \lambda_{max}.\omega \quad (9)$$

where
ω is matrix's own vector

A is a matrix of pairwise comparisons between elements of real numbers

$\lambda_{max}.\omega$ is the largest private values of A matrix Calculator super matrix:

Table 4: Super matrix

0	W_{12}	0
W_{21}	W_{22}	W_{23}
0	0	0

- W12 is the matrix formed from your own vector matrix when comparing the choices for each criteria.
- W21 is the matrix formed from the vector when comparing the criteria with each choice.
- W22 is formed from the vector matrix separately when comparing the influence the interaction between the criteria.
- W23 matrix is formed from the vector matrix's own when compared with other criteria.

MOLP Model Formulation

Target Planning Model: The notations used to formulate the problem under consideration can be stated as follows:

X_i Is order quantity from suppliers i.
U_i Is the capacity of supplier i.
D_i Is the defect rate of the provider i
Q_i Is the delivery rate of the vendor on time i.
C_i Is the purchasing cost of supplier i.
W_i Is the weight of supplier i.
d_j^+ Is the upper bound of the goal i.
d_j^- Is the lower deviation of the goal i.
T Is the demand of the product.
M Is the maximum acceptable defect rate

The Multiple Objective Model (MOM) for procuring an item from multiple suppliers is formulated as follows:

$$M\,inf_i(x) = \sum_{i=n}^{n} c_i x_i \quad (10)$$

$$M\,inf_2(x) = \sum_{i=1}^{n} q_i x_i \quad (11)$$

$$M\,inf_3(x) = \sum_{i=1}^{n} d_i x_i \quad (12)$$

$$M\,inf_4(x) = \sum_{i=1}^{n} w_i x_i \quad (13)$$

Contraints:

$$\sum_{i=1}^{n} x_i \geq T \quad (14)$$

$$x_i \leq D_i \quad (15)$$

$$\sum_{i=1}^{n} D_i x_i \leq \sum_{i=1}^{n} M x_i \quad (16)$$

$$i = 1, 2, 3, \ldots n$$

Eqs. (10), (11) are minimum purchase cost, minimum defect rate and (12), (13) are maximum deliver on time, Optimize order quantity. The demand is satisfied by constraint (14). Constraint (15), (16) ensures that the order quantity assigned to supplier i does not exceed its capacity and constraints on the maximum acceptable defect rate

As mentioned above, one of the most common techniques is Goal programming (GP). GP approach requires the DMs to determine the most desirable value or goal for each objective as the aspiration level and then attempts to minimize the deviations from goals. Since our proposed approach is based on GP. Firstly, introduce the above MO model using GP as follows:

Target function: the minimum Z with Z is the total of all deviation

$$Min\ Z = \sum_{i=1}^{n} (d_i^+ + d_i^-) \quad (17)$$

Contraints

•Goal

$$\sum_{j=1}^{n} a_{ij} x_{ij} - d_i^+ + d_i^- = b_i \ \ voii = 1, \ldots, m. \quad (18)$$

•System

$$\sum_{j=1}^{n} a_{ij} x_{ij} \begin{bmatrix} \leq \\ = \\ \geq \end{bmatrix} b_i \ \ v\dot{o}ii = m+1, \ldots, m+p \quad (19)$$

•On the maximum acceptable defect rate

$$\sum_{j=1}^{n} D_i x_i \leq \sum_{j=1}^{n} M x_i \quad (20)$$

where

$$d_i^+, d_i^-, x_j \geq 0; i = 1, \ldots, m; j = 1, \ldots, n$$

m: Number of binding targets, p is binding system and n is the number of decision variables.
a_{ij}: The co-efficient of the j in the i-th bound
x_j: Variable jth decision
b_i: The right hand side corresponding value in bind
d_i^+: Variable deviation of the binding target on the ith.
d_i^-: Variable deviation of binding targets under ith
D_i is the defect rate of the provider i
M is the maximum acceptable defect rate

Both the upper and lower deviation variable deviation variables of a target may not appear at the same time, so one of the two variables must have a value of 0:

$$d_i^+ \times d_i^- = 0 \quad (21)$$

Application

Deploying Fanp: The data related to the mathematic: Criteria in choosing suppliers is presented in Table 5.

Table 5: The criteria for selecting suppliers

Criteria	Sign
Quality	C1
Supplier	C2
Relibility	C3
Cost	C4

FANP Model: FANP models of research are done in Figure 4.

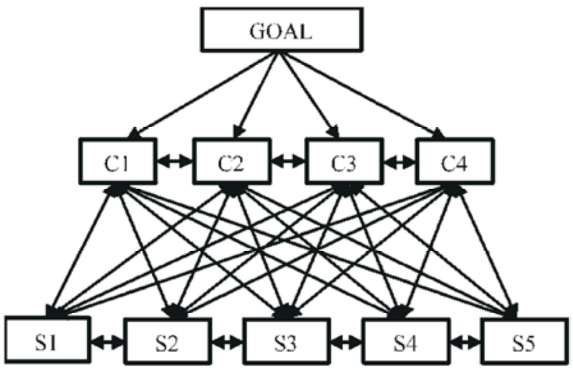

Fig. 4: Schematic structure of research FANP

After evaluation of translucent panel is converted into real numbers using Super Decisions software to solve FANP.

Results obtained after calculating by Super Decisions software is presented as follows:

Table 6: Evaluation results suppliers

Supplier	Supplier evaluation	Rank
S1	0.2732	1
S2	0.2068	3
S3	0.2511	2
S4	0.1191	5
S5	0.1499	4

The results showed that S1 had the highest weight of 0.2732, followed by S3 with a weight of 0.2511, followed by S2 with a weight of 0.2068, fourth with S5 is 0.1499, S4 with 0.1191.
The results of calculations on the software as follows:

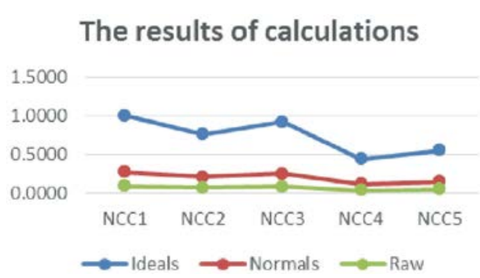

Fig. 5: The results of calculations based on the software Super Decisions

Deployment of GP: After using FANP model to evaluate suppliers, GP model will be developed to allocate orders.

Data Collected: To the distribution order, the number of expected fabric needs is 300 trees fabric. The projected cost is 450.000.000 VND. The maximum acceptable defect rate is 0.5 percent. The remaining information about the vendor is presented in Table 7.

GP Model: After getting the overall score of each supplier in the first stage, Multiple Objective (goal) Programming method provides a solution to allocate the orders among suppliers. Making a decision usually requires consideration of many objectives and certain constraints, such as supplier's capacity and requirement on acceptable defect. The objective functions represented in include, respectively minimum purchase cost of the product, minimum delay in delivery by quantity, minimum quantity of defective product and Optimize order quantity. In constraints, stipulates that supply must satisfy demand requires the order quantity to be smaller than or equal to the supplier's capacity while the last one demands the defect quantity to be smaller than or equal to the maximum accepted defect quantity. The objective functions and constraints of the model are summarized as follows:

X_i Is order quantity from suppliers i.
U_i Is the capacity of supplier i.
D_i Is the defect rate of the provider i.
Q_i Is the delivery rate of the vendor on time i.
C_i Is the purchasing cost of supplier i.
W_i Is the weight of supplier i.
d_j^+ Is the upper bound of the goal i.
d_j^- Is the lower deviation of the goal i.
T Is the demand of the product.
Q Is the maximum acceptable defect rate

Target Function:

$$\text{Min } Z = d_1^+ + d_2^+ + d_3^- + d_4^-$$

Subject to:

- Constraints on suppliers supply capabilities:

$X_i \leq U_i$
$X_1 \leq 150$
$X_2 \leq 100$
$X_3 \leq 145$
$X_4 \leq 100$
$X_5 \leq 80$

- Constraints on the quantity of goods to buy:

$X_1 + X_2 + X_3 + X_4 + X_5 \geq 300$

- Constraints on the maximum acceptable defect rate:

$X_1*0.0029 + X_2*0.0035 + X_3*0.0034 + X_4*0.0043 + X_5*0.005 = 0.005X_1 + 0.005X_2 + 0.005X_3 + 0.005X_3 + 0.005X_4 + 0.005X_5$

- Constraint of homogeneity between upper and lower variables:

$d_j^+ * d_j^- = 0$

- The constraint on the deviation on:

$d_j^+ \geq 0$

- Constraints on lower deviation:

$d_j^- \geq 0$

- Order constraints on purchase quantity:

$X_i \geq 0$

Objective 1: Minimum Purchase Cost:

$X_1*6000000 + X_2*7200000 + X_3*6800000 + X_4*6600000 + X_5*6100000 - d_1^+ + d_1^- = 0$

Objective 2: Minimum Defect Rate:

$X_1*0.0029 + X_2*0.0035 + X_3*0.0034 + X_4*0.0043 + X_5*0.005 - d_2^+ + d_2^- = 0$

Objective 3: Maximum Deliver on Time:

$X_1*0.96 + X_2*0.91 + X_3*0.98 + X_4*0.90 + X_5*0.93 - d_3^+ + d_3^- = 0$

Objective 4: Optimize Order Quantity:

$X_1*0.2732 + X_2*0.2068 + X_3*0.2511 + X_4*0.1191 + X_5*0.1499 - d_4^+ + d_4^- = 0$

After establishing the objective function and the related constraints, we solve the problem using the Lingo Software which results in the optimal order quantity as follows: Supplier 1 is 150 litchi, supplier 4 is 70 litchi and supplier 5 is 80 litchi. The purchase cost is 370,000,000 VND less than the expected cost of 80,000,000 VND and fully meet the demand for necessary fabric.

CONCLUSION

Supplier selection is a multi criteria decision-making problem, which includes both qualitative and quantitative factors. The study concentrated on supplier selection problems. This paper aimed to attain the collection of criteria which have impacts on selecting a reliable supplier. So this study focuses on building a FANP model to rank suppliers by providing pairwise comparison matrices based on the criteria and suppliers set out. Use two Super Decision software to rank suppliers and Lingo to allocate orders. The results of the study suggest that the proposed model is feasible. Specifically, the decision to choose the supplier of the garment used in this study.

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