Optimization of Multi-Criteria Decision Making Analysis for Selection of Suppliers in Supply Chains Using Fuzzy Logic

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Abstract. In today’s business environment, suppliers play key roles in making business strategies successful. Since quality, price, and on-time delivery of the products depend on the supplier’s ability to support the business strategies, choice of the correct providers assumes a key part in any association since it altogether decreases the unit costs and improves corporate value intensity. Supplier selection endures generally a multi-models dynamic issue which incorporates both subjective and quantitative variables. The main objective of this work proposes coordinating the Analytic Hierarchy Process (AHP) and Fuzzy set hypothesis to create assessment models to decide the best suppliers. The project reported here has attempted to integrate and Fuzzy set theory to determine best suppliers. The Fuzzy set hypothesis situated to the sanity of exposure because of imprecision or dubiousness. The Fuzzy set uses semantic elements to sort out rules and sub-rules weight, with a pairwise examination with the Analytical Hierarchy Process (AHP). The fuzzy AHP choice technique, which decides the loads of emotional judgment for logical assessment structure of the provide determination issue. At long last, a provider choice issue was explained utilizing the suggested model in an industrial cleaning machines manufacturing company.

Keywords: Suppliers, Fuzzy - Analytical Hierarchy Process, Fuzzy System, Linguistic Variable.

1 Introduction

The supplier choice cycle is a multi-models issue, which incorporates both subjective and quantitative elements. Buying orders a huge situation in many associations since bought parts, segments, and supplies commonly speak to 40 to 60 percent of the deals of its final results have suggested that supplier determination is a multi-rules dynamic issue which incorporates assessment of variables [1]. The AHP-based specimen is planned and relevant to a genuine contextual analysis to inspect its attainability in choosing a seller for a telecommunication framework [2]. In this paper, the various
levelled dynamic system is introduced where ecological and security guidelines and developing interest for the item quality were additionally considered [3].

It proposed a structure which coordinates the Analytic Hierarchy Process (AHP) and number programming to rate providers presentation with respect to approaching raw materials with regards to supplier board and afterward to dispense periodical purchases [4]. An Outlined mixture strategy, consolidating various strategies into an assessment cycle, so as to choose serious suppliers in a supply chain [5]. This article plot a mixture strategy, which consolidates different methods (i.e., AHP, DEA, and NN) into an assessment cycle, so as to choose serious suppliers in a supply chain. At last, a case of machine device choice is utilized to delineate and approve the proposed approach [6]. Another methodology called "Analytical Hierarchy Process weighted Fuzzy Linear Programming (AHP-FLP)" for supplier determination half breed technique for supplier choice, AHP-FLP is applied to a genuine industry case.

The loads of the different standards, taken as nearby loads from a given judgment framework, are determined Analytical Hierarchy Process (AHP) that are likewise considered as the loads of the fuzzy linear programming model have conferred [7]. The literature, overviewed demonstrated that a precise methodology and assessment technique utilizing AHP and fuzzy-AHP strategies which use the progressive choice structure considering all the connected components can be created and an additionally created numerical model can likewise be planned. It is seen that Analytical Hierarchy Process (AHP) is as a rule dominantly utilized in the provider determination issues. AHP is utilized as an independent instrument in the greater part of the cases. It is a lot of basic to address the issue of complexities emerging out of the coordinated utilizations of AHP and different methods in supplier’s choice issues.

From the literature, we proposed a systematic approach and evaluation method using AHP and fuzzy-AHP methods to consider the hierarchical decision structure considering all the related factors and also we developed mathematical model. Among the issues of supply chain management regarding purchasing decision, supplier selection is the most important activity of a firm’s purchasing department.

2 Methodology of Supplier Selection using AHP in Consumer Product Manufacturing Industries.

The AHP divides a complex decision problem into a hierarchical system of decision elements. A pair wise comparison matrix of these elements is constructed, and then the normalized principal eigenvector is calculated for the priority vector, which provides a measure of the relative importance (weight) of each element.

As indicated by literature, some supplier determination models are found to shift in various circumstances, and specialists concur that there is nobody most ideal approach to assess and choose suppliers. An investigation did by overviewed purchasers so as to recognize factors they considered in granting agreements to providers. Out of the 23 variables considered, he inferred that quality, conveyance, technical capability, cost, price, and production capacity, reliability, desire for business, geographical location, and reputation, are the ten most important criteria which were extracted [8]. Organizations utilize a wide range of approaches in their assessing measures based upon Brain storming and Likert-Satty’s 1-9 scale The hierarchical structure which is required to be formed according to the AHP is shown in fig 1 as shown select the best supplier from the first level of the Hierarchical structure The second level factors such as (i) Aspect, (ii) Consignment, (iii) Technical Capability, (iv) Cost, (v) Price, (vi) Production Capacity, (vii) Reliability, (viii) Desire for Business, (ix) Geographical Location, (x) Reputation. These are the factors to be concluded for the selection of suppliers. At last, at the third level, we have the choice options that should be assessed through these measures in an extraordinary manner.
3 Fuzzy Set Theory

A fuzzy number A, which indicates a fuzzy set A, addresses if it is triangular Fuzzy number. Let M, be a triangular fuzzy number with a triplet (L, M, and U). The membership function can be characterized as relation 1

\[ \mu(x) = \begin{cases} \frac{x-L}{M-L} & x = M \\ \frac{M-x}{M-L} & L \leq x \leq M \\ \frac{U-M}{U-M} & M \leq x \leq U \\ 0 & \text{otherwise} \end{cases} \] (1)

In the event that a variable can accept words in normal dialects as its worth, it is known as an alliance variable, where the words are portrayed by fuzzy sets characterized known to mankind of talk in which the variable is characterized. Alliance variables are characterized by (Very bad, Bad, Average, Excellent and Outstanding).

Utilizing fuzzy numbers to demonstrate the overall commitment or effect of every option on a measure, a fuzzy judgment vector is then acquired for every model. The fuzzy judgment matrix A is worked with all the fuzzy judgment vectors.

\[ A_{ij} = \begin{bmatrix} G_{11} & G_{12} & \ldots & G_{1n} \\ G_{21} & G_{22} & \ldots & G_{2n} \\ \vdots & \ddots & \ddots & \vdots \\ G_{m1} & G_{m2} & \ldots & G_{mn} \end{bmatrix} \] (2)

A standardization cycle is applied to encourage a coordinating cycle with the weight vector to be determined. Every models in relation 2 is standardized by utilizing relation 3. A fuzzy judgment matrix (A) is gotten as relation subsequent to normalizing.

\[ a_{i1} = \frac{g_{i1}}{\sqrt{g_{i1}^2 + \ldots + g_{im}^2}} \] (3)

\[ A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \ddots & \ddots & \vdots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{bmatrix} \] (4)
Where $a_{ij}$ denotes the judgment score of alternative $(A_i)$ with respect to criteria $j$.

The weight denotes the overall significance among every standards. It tends to be gotten by applying pair-wise examination of the AHP or quickly decided by a decision maker.

$$Ds = \begin{bmatrix} d_{11} & d_{12} & d_{13} & \cdots & d_{1n} \\ d_{21} & d_{22} & d_{23} & \cdots & d_{2n} \\ d_{31} & d_{32} & d_{33} & \cdots & d_{3n} \end{bmatrix}$$

Equation 5 where a score speaks to a decision maker (Ds) gauges the general significance by utilizing Saaty's. At that point a thorough pairwise comparison matrix (Ds) is worked by coordinating all decision maker’s evaluations. Where a far reaching score speaks to the overall significance among every basis with triangular fuzzy numbers.

The significance of every rule is extraordinary. So as to get a weight ($w$) that relates to explicit models these loads of measures altogether make up a fuzzy weight vector ($w$) in relation 6.

$$w = (w_1, w_2, w_3, \ldots, w_n)$$

For deciding the general load between every model, a few decision makers’ assessments are incorporated to improve the basic pairwise correlation of the first AHP and structure a more objective fuzzy weight vector. In the judgment matrix, the general judgment scores of alternative (A) are discovered as for models without thinking about the overall load between every basis. Accordingly, the judgment matrix (A) and the weight vector (w) are combined. Every standards weight ($w$) is taken independently to increase its relating measures and the judgment matrix (H) is appeared in equation 7.

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{13} & \cdots & h_{1n} \\ h_{21} & h_{22} & h_{23} & \cdots & h_{2n} \\ h_{31} & h_{32} & h_{33} & \cdots & h_{3n} \end{bmatrix}$$

Where $h_{ij}$ signifies the fuzzy exhibition score with alternative (A) compares to measures with triangular fuzzy numbers (L, M and U). By utilizing the relation 8, the fuzzy exhibition scores of every option regarding all measures.

Each fuzzy performance score ($h_{ij}$) is joined $\alpha$-slice to separately from a span $[h_{ijL}, h_{ijR}]$.

$$h_{ijL} = L_{ij} + \alpha(M_{ij} - L_{ij})$$

$$h_{ijR} = U_{ij} - \alpha(U_{ij} - M_{ij})$$

$h_{ijL}$ and $h_{ijR}$ respectively indicate the right point and left point of the scope of the triangular in the wake of utilizing $\alpha$ is somewhere in the range of 0 and 1. Further, the overall span execution matrix (H) with $\alpha$ value can be resolved as equation 11.

$$H^\alpha = \begin{bmatrix} h_{11L}^\alpha & h_{11R}^\alpha \\ h_{21L}^\alpha & h_{21R}^\alpha \\ h_{31L}^\alpha & h_{31R}^\alpha \\ h_{12L}^\alpha & h_{12R}^\alpha \\ h_{22L}^\alpha & h_{22R}^\alpha \\ h_{32L}^\alpha & h_{32R}^\alpha \\ h_{13L}^\alpha & h_{13R}^\alpha \\ h_{23L}^\alpha & h_{23R}^\alpha \\ h_{33L}^\alpha & h_{33R}^\alpha \end{bmatrix}$$

The estimation of $\alpha$ is engaged with the decision makers level of certainty as they individually assess elective scores and standard loads for this MCDM problem.

The risk issues typically go with the dynamic cycle, so a risk-index is considered. The risk index is also applied to be a defuzzifier. Defuzzification is implemented by joining the risk index to produce the final crisp numbers.
The overall crisp performance matrix $H^2_{f}$ is calculated in equation (12) through equation (13)

$$h^c_{ij} = \beta h^e_{ij} + (1-\beta) h^r_{ij}, \quad 0\leq\alpha\leq1; 0\leq\beta\leq1$$

$$H^2_{f} = \begin{bmatrix}
    h^c_{11} & h^c_{12} & \cdots & h^c_{1n}
    h^c_{21} & h^c_{22} & \cdots & h^c_{2n}
    \vdots & \vdots & \ddots & \vdots
    h^c_{m1} & h^c_{m2} & \cdots & h^c_{mn}
\end{bmatrix}$$

Where $h^c_{ij}$ signifies the crisp performance score which every other option (Ai) compares to all standards (Cj) under $\alpha$ level of certainty and $\beta$ hazard level.

In TOPSIS, the ideal arrangement $h^*_{f}$ is characterized as the finest crisp performance score result over all choices on a measure. For example, relation 12 on the opposite the ideal arrangement $h^{-}_{f}$ is resolved as the most exceedingly awful fresh execution score result over all options on standards as shown in equation 13.

$$h^*_{f} = \left\{ \max h^c_{ij}, \quad i = 1,2,...,n \quad j = 1,2,...,m \right\}$$

$$h^{-}_{f} = \left\{ \min h^c_{ij}, \quad i = 1,2,...,n \quad j = 1,2,...,m \right\}$$

By relation 13 and 14 the ideal arrangement and negative ideal arrangement can be discovered for every basis. Subsequent to deciding the ideal arrangement and negative ideal arrangement, the separation between the ideal arrangement and negative ideal solution for every substitute is in that order to determined by relation 15 and 16 as following

$$D^+_{f} = \sqrt{\sum_{i=1}^{n} (h^*_{ij} - h^c_{ij})^2} \quad i = 1,2,...,n$$

$$D^-_{f} = \sqrt{\sum_{i=1}^{n} (h^{-}_{ij} - h^c_{ij})^2} \quad i = 1,2,...,n$$

Where $D^+_{f}$ and $D^-_{f}$ represent the distance between the crisp performance scores.

The best option has a more extended separation to the negative ideal arrangement and a more limited separation to the ideal arrangement simultaneously. Thusly, the overall closeness to the ideal solution for every alternative can be detailed as relation 17

$$P^f_{i} = \frac{D^-_{f}}{D^+_{f} + D^-_{f}} \quad i = 1,2,...,n$$

Where $P^f_{i}$ indicates a final presentation score that contains the decision makers $\alpha$ degree of certainty about their assessments and perspective of risk level $\beta$ for every alternative.

### 4 Result and Discussion

The assessment of Quantitative and Qualitative rules is the initial phase in showing up the fuzzy judgment matrix. In light of the true value (Quantitative information) of every supplier the sub-scores are determined for each substantial measure. The fuzzy judgment matrix for this supplier choice case can be set up by combining all scores.

The scores for every standards are appeared in relation 18 the accompanying matrix

$$A = \begin{bmatrix}
    (5,7,9) & (7,9,5) & (3,5,7) & (8,13,18) \\
    (7,9,2) & (5,7,9) & (5,7,9) & (8,14,18) \\
    (3,5,7) & (3,5,7) & (1,3,5) & (3,5,7) & (8,14,18)
\end{bmatrix}$$
The leftover estimations of standardization were registered utilizing a similar technique. The fuzzy judgment matrix \( A \) built is shown in relation 19

\[
A = \begin{bmatrix}
0.34 & 0.56 & 0.96 & 0.48 & 0.72 & 0.98 & 0.24 & 0.54 & 1.18 & 0.22 & 0.50 & 1.06 & 0.25 & 0.54 & 1.19 \\
0.48 & 0.72 & 0.98 & 0.34 & 0.56 & 0.98 & 0.40 & 0.76 & 1.52 & 0.37 & 0.70 & 0.37 & 0.26 & 0.58 & 1.19 \\
0.20 & 0.40 & 0.76 & 0.20 & 0.40 & 0.76 & 0.05 & 0.32 & 0.84 & 0.22 & 0.50 & 1.06 & 0.32 & 0.61 & 1.19
\end{bmatrix}
\] (20)

The fuzzy weight vector \( W \) is worked by applying a pair wise correlation of the AHP. Yet, it is difficult to keep away from the decision makers’ abstract judgment. Consequently, the cooperative choice with the AHP is utilized to change over into a fuzzy structure. Four decision makers separately analyze relative significance between every model by utilizing Saaty’s nine-point scale.

\[
W = \{(0.3, 0.43, 0.63) (0.16, 0.24, 0.36) (0.05, 0.07, 0.1) (0.12, 0.17, 0.24) \ (0.06, 0.1, 0.14)\}
\] (21)

The fuzzy judgment matrix by the comparing fuzzy weight vector utilizing relation 6. 

\[
H = \begin{bmatrix}
0.10 & 0.24 & 0.61 & 0.07 & 0.17 & 0.35 & 0.01 & 0.03 & 0.11 & 0.02 & 0.08 & 0.25 & 0.01 & 0.05 & 0.16 \\
0.14 & 0.30 & 0.61 & 0.05 & 0.13 & 0.35 & 0.02 & 0.05 & 0.15 & 0.04 & 0.11 & 0.08 & 0.01 & 0.05 & 0.16 \\
0.08 & 0.17 & 0.47 & 0.03 & 0.09 & 0.27 & 0.02 & 0.02 & 0.08 & 0.02 & 0.08 & 0.25 & 0.01 & 0.06 & 0.16
\end{bmatrix}
\] (22)

The defuzzification process is executed by deciding the span execution matrix with \( \alpha \)-cut and considering the risk index. The estimation of \( \alpha \) can be fixed by the decision maker’s level of certainty when they emotionally assess elective scores and measures loads. The higher worth \( \alpha \) esteem communicates the further extent of certainty and the closer to the conceivable estimation of the triangular numbers. In this supplier determination issue, the decision makers set up \( \alpha = 0.85 \), to beat vulnerability in their assessments. The stretch \( [h_{ij}^a, h_{ij}^b] \) can be sequentially solved using relation 13 and 14. This is shown below.

\[
h_{11}^{0.85} = 0.10 + 0.85 (0.24 - 0.10) = 0.219
\]

\[
h_{12}^{0.85} = 0.16 - 0.85(0.61 - 0.24) = 0.290
\]

\[
[h_{11}^{0.85}, h_{12}^{0.85}] = (0.219, 0.290)
\]

Likewise, the remaining stretches were determined like the equations 13 and equation 14 with \( \alpha = 0.85 \) built is shown below

\[
H^{0.85} = \begin{bmatrix}
0.21 & 0.29 & 0.15 & 0.19 & 0.02 & 0.04 & 0.07 & 0.10 & 0.49 & 0.63 \\
0.27 & 0.34 & 0.11 & 0.16 & 0.04 & 0.06 & 0.10 & 0.11 & 0.49 & 0.63 \\
0.15 & 0.21 & 0.08 & 0.11 & 0.01 & 0.01 & 0.07 & 0.10 & 0.56 & 0.69
\end{bmatrix}
\] (23)

The potential dynamic risk problems envelop the supplier determination issues inside a supply chain. In the proposed approach, the decision makers of key buying change hazard record \( \beta \) alongside buying diverse raw materials attributes in the connected market.

\[
h_{11,2}^{0.85} = 0.2 \cdot 0.219 + 0.85 \cdot 0.290 = 0.27
\]

\[
h_{12,2}^{0.85} = 0.2 \cdot 0.27 + 0.85 \cdot 0.34 = 0.32
\]

\[
h_{11,3}^{0.85} = 0.2 \cdot 0.15 + 0.85 \cdot 0.215 = 0.19
\]

\[
H_{62}^{0.85} = \begin{bmatrix}
0.32 & 0.15 & 0.65 & 0.11 & 0.60 \\
0.19 & 0.10 & 0.01 & 0.09 & 0.66
\end{bmatrix}
\]

To adjust these crisp exhibition scores and execute final positioning, TOPSIS (Techniques of request inclination by similitude to ideal framework) strategy is utilized [10]. The final presentation score \( (p_{1,62}^{0.85}) \)
speaks to the general closeness to the ideal arrangement. The final exhibition score with $\alpha = 0.85$ and $\beta = 0.2$ are understood utilizing relation 17.

$$P_{0.85} = \frac{d_{0.85}}{d_{0.85} + d_{0.2}} = 0.521$$

$$P_{0.05} = \frac{d_{0.05}}{d_{0.05} + d_{0.2}} = 0.624$$

$$P_{0.25} = \frac{d_{0.25}}{d_{0.25} + d_{0.2}} = 0.287$$

The execution of the proposed model dependent on Fuzzy AHP for selection suppliers of manufacturing industry has been portrayed. The calculation procedure is detailed understand the use of the proposed model.

5 Conclusion

From the result proposed it is evident that Fuzzy-AHP method can be applied to any supplier selection problem of a manufacturing company. In the two cases, the choices came to by utilizing the model as harmonized with those acquired by utilizing the prior supplier choice cycle. This may be because of the set number of suppliers and choice standards. When there are more number of suppliers and determination models, the current strategy won't be feasible because of the tedious calculations involved and the possibilities of mathematical errors. Whereas, in the Fuzzy-AHP model, quite a few standards for suppliers determination and alternatives can be incorporated. This helps the decision makers to assess the quality and shortcoming of suppliers systems by contrasting them with deference with the rules. The proposed system can likewise decrease the time and exertion in dynamic huge.

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