SELECTION OF THE BEST SCHOOL FOR THE CHILDREN-
A DECISION MAKING MODEL USING EXTENT ANALYSIS
METHOD ON FUZZY ANALYTIC HIERARCHY PROCESS

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Abstract: Parents have a growing array of options in choosing a school, though the extent of the options varies from
place to place. In this paper, the Extent Analysis Method on Fuzzy Analytic Hierarchy Process (abbreviated as Fuzzy
AHP) is used to develop a decision making model for choosing the best school for the children.

Keywords: Fuzzy Analytic Hierarchy Process, Triangular Fuzzy numbers,Extent analysis Method, Pairwise
Comparison, Fuzzy Synthetic Extent.

I. INTRODUCTION

Decision Making is the act of choosing between two or more courses of action. Decision-making can also be regarded as a problem-solving activity terminated by a solution deemed to be satisfactory among several alternative possibilities. It is, therefore, a reasoning or emotional process which can be rational or irrational and can be based on explicit assumptions or implicit assumption. There are processes and techniques to improve decision-making and the quality of decisions.

Nowadays, decision making is a problem of every common man to take right decision on many routine affairs like education for children, food, transportation, purchase of durables, healthcare, shelter and so on. In this research the authors consider the problem of selecting the best school for the children. Parents have a growing array of options in choosing a school, though the extent of the options varies from place to place. Generally parents consider various factors to select the best school for their children. The researchers identified many such important factors and used the same to develop a mathematical model for decision making regarding the selection of right school for the children using Extent Analysis Method on Fuzzy Analytic Hierarchy Process.

II. BASIC DEFINITIONS

Definition: 1 [2]
A Fuzzy Number $\tilde{A}$ is a convex, normal fuzzy set $A \subset \mathbb{R}$ whose membership function is at least segmentally continuous and has functional value $\mu_A(x) = 1$ at precisely one element.

Definition: 2 [11]
A Triangular Fuzzy Number is a special case of fuzzy number. It is defined by a triplet $\tilde{A} = (a, b, c)$. This representation is interpreted as membership function $\mu_{\tilde{A}}: \mathbb{R} \rightarrow [0,1]$ as follows:
\[ \mu_A(x) = \begin{cases} 
0 & \text{if } x < a \\
\frac{x-a}{b-a} & \text{if } a \leq x \leq b \\
\frac{c-x}{c-b} & \text{if } b \leq x \leq c \\
0 & \text{if } x > c 
\end{cases} \]

**Definition:** 3 [6]

**Algebraic Operations:** Let \( A = (a_1, b_1, c_1) \) and \( B = (a_2, b_2, c_2) \) be two triangular fuzzy numbers.

i) **Addition of Triangular Fuzzy Numbers** \( \oplus \):
\[
A \oplus B = (a_1 + a_2, b_1 + b_2, c_1 + c_2)
\]

ii) **Multiplication of Triangular Fuzzy Numbers** \( \otimes \):
\[
A \otimes B = (\frac{a_1}{c_1', b_1', c_1'}, \frac{b_1}{c_1'}, \frac{c_1}{c_1'})
\]

iii) **Division of Triangular Fuzzy Numbers** \( \oslash \):
\[
A \oslash B = (\frac{a_1}{c_1, b_1, c_1}, \frac{b_1}{c_1, b_1, c_1}, \frac{c_1}{c_1, b_1, c_1})
\]

**Definition 4** [1]

A **Triangular Fuzzy Number Matrix** of order \( n \times m \) is defined as \( A = (\tilde{a}_{ij})_{n \times m} \) where \( \tilde{a}_{ij} \) is a triangular fuzzy number.

For two Triangular Fuzzy Number Matrices \( A = (\tilde{a}_{ij})_{n \times m} \) and \( B = (\tilde{b}_{ij})_{n \times m} \) the **Addition** \( A + B \) is defined as
\[
A + B = (\tilde{a}_{ij} \oplus \tilde{b}_{ij})_{n \times m}
\]

**III. EXTENT ANALYSIS METHOD**

The extent analysis method is used to consider the extent to which an object can satisfy the goal, i.e., satisfaction extent. In this method the “extent” is quantified using triangular fuzzy number. On the basis of fuzzy values for the extent analysis of each object, a fuzzy synthetic degree values can be obtained, which is defined as follows:

Let \( X = \{x_1, x_2, ..., x_n\} \) be an object set and \( U = \{u_1, u_2, ..., u_m\} \) be a goal set. Each object is taken and extent analysis for each goal \( g_i \) is performed, respectively. Therefore, \( m \) extent analysis values for each object can be obtained, with the following signs:
\[
M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m \quad i = 1, 2, ..., n
\]
where all \( M_{g_i}^j \) \((j = 1, 2, ..., m)\) are triangular fuzzy numbers.

The steps for extent analysis method on Fuzzy AHP can be given as in the following.

**Step 1:** Construction of the Fuzzy AHP comparison matrix

The first task of the fuzzy AHP method is to decide on the relative importance of each pair of factors in the same hierarchy. The pairwise comparisons are described by values taken from a pre-defined set of ratio scale values as presented in Table 1.

<table>
<thead>
<tr>
<th>Linguistic scale</th>
<th>Triangular fuzzy scale</th>
<th>Triangular fuzzy reciprocal scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equally important</td>
<td>(1/2, 1, 3/2)</td>
<td>(2/3, 1, 2)</td>
</tr>
<tr>
<td>Weakly more important</td>
<td>(1, 3/2, 2)</td>
<td>(1/2, 2/3, 1)</td>
</tr>
<tr>
<td>Strongly more important</td>
<td>(3/2, 2, 5/2)</td>
<td>(2/5, 1/2, 2/3)</td>
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<tr>
<td>Very strongly more important</td>
<td>(2, 5/2, 3)</td>
<td>(1/3, 2/5, 1/2)</td>
</tr>
<tr>
<td>Absolutely more important</td>
<td>(5/2, 3, 7/2)</td>
<td>(2/7, 1/3, 2/5)</td>
</tr>
</tbody>
</table>
Table 1. Triangular Fuzzy Conversion Scale

By using triangular fuzzy numbers, via pairwise comparison, the fuzzy evaluation matrix \( A = (\tilde{a}_{ij})_{n \times m} \) is constructed; where \( \tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) \) is the relative importance of \( i^{th} \) element over \( j^{th} \) element in pairwise comparison and \( l_{ij}, m_{ij}, u_{ij} \) are the lower bound, model, upper bound values of \( \tilde{a}_{ij} \) respectively. Also \( \tilde{a}_{ij} \) are satisfied with

\[
l_{ij} = \frac{1}{l_{ji}}, \quad m_{ij} = \frac{1}{m_{ji}}, \quad u_{ij} = \frac{1}{u_{ji}}
\]

**Step 2: Calculation of the Value of fuzzy synthetic extent**

The value of fuzzy synthetic extent with respect to the \( i^{th} \) object is defined as

\[
S_i = m_{y_i} \bigotimes \left[ \sum_{j=1}^{m} M_{y_j} \right]^{-1}
\]

Here \( S_i \) is defined as the fuzzy synthetic extent and \( \bigotimes \) is the multiplication of Triangular Fuzzy Numbers.

**Step 3: Calculation of the sets of weight values of the Fuzzy AHP**

To obtain the estimates for the sets of weight values under each criterion, it is necessary to consider a principle of comparison for fuzzy numbers.

**Definition 5 [5]**

The degree of possibility of

\[
M_1 = (l_1, m_1, u_1) \geq M_2 = (l_2, m_2, u_2)
\]

is defined as

\[
V(M_1 \geq M_2) = \sup_{x \geq y} \left[ \min(\mu_{M_1}(x), \mu_{M_2}(x)) \right]
\]

When a pair \((x, y)\) exists such that \( x \geq y \) and \( \mu_{M_1}(x) = \mu_{M_2}(x) \), then we have \( V(M_1 \geq M_2) = 1 \). Since \( M_1 \) and \( M_2 \) are convex fuzzy numbers we have that

\[
V(M_1 \geq M_2) = 1 \quad \text{iff} \quad m_1 \geq m_2
\]

\[
V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d)
\]

where \( d \) is the ordinate of the highest intersection point \( D \) between \( \mu_{M_1}(d) \) and \( \mu_{M_2}(d) \). Also the above equation can be equivalently expressed as follows:

\[
V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d)
\]

\[
= \begin{cases} 
1 & \text{if } m_2 \geq m_1 \\
0 & \text{if } l_1 \geq u_2 \\
\frac{m_2 - u_2}{m_2 - u_2 - (m_1 - l_1)} & \text{otherwise}
\end{cases}
\]

The following figure illustrates Equation (2)
To compare \( M_1 \) and \( M_2 \), we need both the values of \( V(M_1 \geq M_2) \) and \( V(M_2 \geq M_1) \).

**Definition 6 [5]**

The degree of possibility for a convex fuzzy number to be greater than \( k \) convex fuzzy numbers \( M_i \) (\( i = 1, \ldots, k \)) can be defined by

\[
V(M \geq M_1, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots \text{ and } (M \geq M_k)]
\]

\[
= \min V(M \geq M_i) \quad i = 1, \ldots, k
\]

Assume that

\[
d'(A_i) = \min V(S_i \geq S_k)
\]

For \( k = 1, 2, \ldots, n \); \( k \neq i \).

Then the weight vector is given by

\[
W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T
\]

where \( A_i \) (\( i = 1, \ldots, n \)) are \( n \) elements.

Via normalization, the normalized weight vectors are

\[
W = (d(A_1), d(A_2), \ldots, d(A_n))^T
\]

where \( W \) is a non fuzzy number.

**Step 4: Aggregate the relative weights of decision elements to obtain an overall rating for the alternatives.**

Finally the alternative with highest weight is chosen as the best alternative.

**IV. APPLICATION OF EXTENT ANALYSIS METHOD ON FUZZY AHP**

Based on the pilot study, the researchers identified five major criteria for developing a model for the selection of the best school by the parents for their children. Further, care was taken to enlist possible sub criteria for each major criteria, which are considered by them as vital for achieving the objective. The details are presented below.

1) **\( C_1 \): Distance and Transport**
   - Sub Criteria
     - \( C_{11} \): Transportation Offered
     - \( C_{12} \): Location of the School

2) **\( C_2 \): Cost**
   - Sub Criteria
     - \( C_{21} \): Admission Fees
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C₂₂ : Fees Structure
3) C₃ : Staff and Curriculum
   Sub Criteria
   C₃₁ : Competent Staff
   C₃₂ : Teaching and coaching
   C₃₃ : Extra Curricular Activities
4) C₄ : Atmosphere
   Sub Criteria
   C₄₁ : Infrastructure
   C₄₂ : Campus Discipline
   C₄₃ : Facilities and Security
5) C₅ : Administration
   Sub Criteria
   C₅₁ : Academic Performance
   C₅₂ : Staff and Student Welfare
   C₅₃ : Reporting to parents

After the initial screening, three schools listed below were considered as alternatives and an attempt has been made by the researchers to develop a model to select the best one based on the above criteria.

1) A₁ : P.M.G HIGHER SECONDARY SCHOOL, COLLEGE ROAD, PALAKKAD
2) A₂ : BHARATH MATHA HIGHER SECONDARY SCHOOL, CHANDRANAGAR, PALAKKAD
3) A₃ : VYASA VIDYA PEETHOM SCHOOL, KALLEKAD, PALAKKAD.

After building the hierarchy, the pairwise comparison of the importance of one criterion over the others, one sub criterion over the others and one alternative over the others were estimated with the help of a pre-tested questionnaire. A sample of 100 parents in Palakkad city was selected by adopting convenient sampling technique and the questionnaire was administered to the parents. The data collected were edited and tabulated for further analysis. Five point scaling technique (Equally Important, Weakly More Important, Strongly More Important, Very Strongly More Important, Absolutely More Important) was adopted to assess the degree of importance of one criterion, sub criterion, or alternative over another. Using Triangular Fuzzy Conversion Scale given in Table 1, the pairwise comparison matrices (Triangular Fuzzy Number Matrices Aᵢ, i = 1, .. 100) for 100 respondents are constructed. By using the definition of addition of Triangular Fuzzy Number Matrices a new matrix \( D = A_1 + A_2 + \cdots + A_{100} \) is arrived. Then by taking average of each element in the matrix \( D \) (the average is based only on the number of responses) the aggregated fuzzy evaluation matrix is constructed (Table 2).

\[
\begin{pmatrix}
C_1 & (1,1,1) & (1.08,1.58,2.08) & (0.86,1.36,1.86) & (0.93,1.43,1.93) & (1.38,1.87,2.36) \\
C_2 & (0.48,0.63,0.93) & (1,1,1) & (1.06,1.56,2.06) & (1.17,1.67,2.17) & (1.65,2.15,2.65) \\
C_3 & (0.54,0.74,1.16) & (0.49,0.64,0.94) & (1,1,1) & (1.13,1.63,2.13) & (1.88,2.38,2.88) \\
C_4 & (0.52,0.71,1.08) & (0.46,0.6,0.85) & (0.47,0.61,0.88) & (1,1,1) & (1.97,2.47,2.97) \\
C_5 & (0.42,0.53,0.72) & (0.38,0.47,0.61) & (0.35,0.42,0.53) & (0.34,0.4,0.51) & (1,1,1)
\end{pmatrix}
\]

**Table 2.** Fuzzy Evaluation Matrix with respect to the goal

Then applying formula (1),
Using formula (2),

\[ V(S_1 \geq S_2) = V(S_1 \geq S_3) = V(S_1 \geq S_4) = V(S_1 \geq S_5) = 1 \]

\[ V(S_2 \geq S_1) = \frac{0.14 - 0.39}{(0.24 - 0.39) - (0.25 - 0.14)} = 0.96 \]

\[ V(S_2 \geq S_3) = V(S_2 \geq S_4) = V(S_2 \geq S_5) = 1 \]

\[ V(S_3 \geq S_1) = \frac{0.14 - 0.36}{(0.22 - 0.36) - (0.25 - 0.14)} = 0.88 \]

\[ V(S_3 \geq S_2) = \frac{0.147 - 0.36}{(0.22 - 0.36) - (0.24 - 0.147)} = 0.91 \]

\[ V(S_3 \geq S_4) = V(S_3 \geq S_5) = 1 \]

\[ V(S_4 \geq S_1) = \frac{0.14 - 0.3}{(0.19 - 0.3) - (0.25 - 0.14)} = 0.73 \]

\[ V(S_4 \geq S_2) = \frac{0.147 - 0.3}{(0.19 - 0.3) - (0.24 - 0.14)} = 0.75 \]

\[ V(S_4 \geq S_3) = \frac{0.139 - 0.3}{(0.19 - 0.3) - (0.22 - 0.139)} = 0.84 \]

\[ V(S_4 \geq S_5) = 1 \]

\[ V(S_5 \geq S_1) = \frac{0.14 - 0.15}{(0.1 - 0.15) - (0.25 - 0.14)} = 0.063 \]

\[ V(S_5 \geq S_2) = \frac{0.147 - 0.15}{(0.1 - 0.15) - (0.24 - 0.147)} = 0.021 \]

\[ V(S_5 \geq S_3) = \frac{0.139 - 0.15}{(0.1 - 0.15) - (0.22 - 0.139)} = 0.084 \]

\[ V(S_5 \geq S_4) = \frac{0.12 - 0.15}{(0.1 - 0.15) - (0.19 - 0.12)} = 0.25 \]
Thus,

\[
d'(C_1) = \min V(S_1 \geq S_2, S_3, S_4, S_5) = \min(1,1,1,1) = 1
\]

\[
d'(C_2) = \min V(S_2 \geq S_1, S_3, S_4, S_5) = \min(0.96,1,1,1) = 0.96
\]

\[
d'(C_3) = \min V(S_3 \geq S_1, S_2, S_4, S_5) = \min(0.88,0.91,1,1) = 0.88
\]

\[
d'(C_4) = \min V(S_4 \geq S_1, S_2, S_3, S_5) = \min(0.73,0.75,0.84,1) = 0.73
\]

\[
d'(C_5) = \min V(S_5 \geq S_1, S_2, S_3, S_4) = \min(0.063,0.021,0.084,0.25) = 0.021
\]

Therefore,

\[
W' = (1.096,0.88,0.73,0.021)^T
\]

Via normalization, the weight vectors with respect to the decision criteria \( C_1, C_2, C_3, C_4, C_5 \) are obtained as

\[
W = (0.28,0.27,0.25,0.2,0.006)^T
\]

In a similar manner the aggregated pairwise comparison matrices for sub criteria with respect to each criteria are constructed, as shown below.

\[
\begin{array}{ccc}
C_{11} & & C_{12} \\
(1,1,1) & (1.27,1.77,2.27) \\
(0.44,0.56,0.79) & (1,1,1)
\end{array}
\]

**Table 3.** Sub-criteria matrix with respect to \( C_1 \)

The weight vector from Table 3 is calculated as \( W_1 = (0.91,0.088)^T \)

\[
\begin{array}{ccc}
C_{21} & & C_{22} \\
(1,1,1) & (1.03,1.53,2.03) \\
(0.49,0.65,0.97) & (1,1,1)
\end{array}
\]

**Table 4.** Sub-criteria matrix with respect to \( C_2 \)

The weight vector from Table 4 is calculated as \( W_2 = (0.71,0.29)^T \)

\[
\begin{array}{ccc}
C_{31} & & C_{32} & & C_{33} \\
(1,1,1) & (0.69,1.18,1.68) & (1.38,1.88,2.38) \\
(0.6,0.85,1.45) & (1,1,1) & (2.18,2.68,3.18) \\
(0.42,0.53,0.72) & (0.31,0.37,0.46) & (1,1,1)
\end{array}
\]

**Table 5.** Sub-criteria matrix with respect to \( C_3 \)

The weight vector from Table 5 is calculated as \( W_3 = (0.22,0.24,0.54)^T \)

\[
\begin{array}{ccc}
C_{41} & & C_{42} & & C_{43} \\
(1,1,1) & (0.74,1.24,1.74) & (0.58,1.08,1.58) \\
(0.57,0.81,1.35) & (1,1,1) & (0.62,1.12,1.62) \\
(0.63,0.93,1.72) & (0.62,0.89,1.61) & (1,1,1)
\end{array}
\]

**Table 6.** Sub-criteria matrix with respect to \( C_4 \)
The weight vector from Table 6 is calculated as \( W_4 = (0.36,0.32,0.317)^T \)

\[
\begin{pmatrix}
C_{51} & C_{52} & C_{53} \\
C_{51} & (1,1,1) & (0.7,1.2,1.7) & (1.07,1.57,2.07) \\
C_{52} & (0.59,0.83,1.4) & (1,1,1) & (1.15,1.65,2.15) \\
C_{53} & (0.48,0.64,0.93) & (0.47,0.61,0.87) & (1,1,1)
\end{pmatrix}
\]

Table 7. Sub-criteria matrix with respect to \( C_3 \)

The weight vector from Table 7 is calculated as \( W_5 = (0.41,0.39,0.204)^T \)

In the next step of the decision procedure, the alternatives under each sub criteria are compared. The results are shown below.

\[
\begin{pmatrix}
A_1 & A_2 & A_3 \\
A_1 & (1,1,1) & (0.99,1.49,1.99) & (0.97,1.47,1.97) \\
A_2 & (0.5,0.67,1.01) & (1,1,1) & (1.21,1.71,2.21) \\
A_3 & (0.51,0.68,1.03) & (0.45,0.58,0.83) & (1,1,1)
\end{pmatrix}
\]

Table 8. Alternative matrix with respect to \( C_{11} \)

The weight vector from Table 8 is calculated as \( W_{11} = (0.45,0.37,0.18)^T \)

\[
\begin{pmatrix}
A_1 & A_2 & A_3 \\
A_1 & (1,1,1) & (1.25,1.75,2.25) & (1.24,1.74,2.24) \\
A_2 & (0.44,0.57,0.8) & (1,1,1) & (1.18,1.68,2.18) \\
A_3 & (0.45,0.574,0.81) & (0.46,0.6,0.85) & (1,1,1)
\end{pmatrix}
\]

Table 9. Alternative matrix with respect to \( C_{12} \)

The weight vector from Table 9 is calculated as \( W_{12} = (0.47,0.3,0.23)^T \)

Using similar calculations, the weight vectors of the alternatives with respect to

- the sub-criteria \( C_{21} \) is calculated as \( W_{21} = (0.58,0.32,0.098)^T \)
- the sub-criteria \( C_{22} \) is calculated as \( W_{22} = (0.59,0.37,0.044)^T \)
- the sub-criteria \( C_{31} \) is calculated as \( W_{31} = (0.62,0.36,0.025)^T \)
- the sub-criteria \( C_{32} \) is calculated as \( W_{32} = (0.47,0.43,0.11)^T \)
- the sub-criteria \( C_{33} \) is calculated as \( W_{33} = (0.52,0.46,0.022)^T \)
the sub-criteria $C_{41}$ is calculated as $W_{41} = (0.46, 0.39, 0.15)^T$
the sub-criteria $C_{42}$ is calculated as $W_{42} = (0.46, 0.38, 0.16)^T$
the sub-criteria $C_{43}$ is calculated as $W_{43} = (0.48, 0.4, 0.12)^T$
the sub-criteria $C_{51}$ is calculated as $W_{51} = (0.54, 0.44, 0.022)^T$
the sub-criteria $C_{52}$ is calculated as $W_{52} = (0.52, 0.4, 0.08)^T$
the sub-criteria $C_{53}$ is calculated as $W_{53} = (0.47, 0.39, 0.14)^T$

<table>
<thead>
<tr>
<th>Sub-criterias of $C_1$</th>
<th>$C_{11}$</th>
<th>$C_{12}$</th>
<th>Alternative Priority Weight</th>
</tr>
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<tbody>
<tr>
<td>Weight</td>
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<td>0.088</td>
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<th>$C_3$</th>
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The combination of priority weights for criteria, sub criteria and alternatives to determine the priority weight for the best school are shown in Table 10. Based on this result alternative 1(P.M.G Higher Secondary School, College Road, Palakkad) which has the highest alternative priority weight 0.51 is found to be the best school.

V. CONCLUSION

People often find it hard to make decisions in a complex, subjective situation with more than a few realistic options. So we need a systematic, organized mathematical way to evaluate our choices and figure out which one offers the best solution to our problem. Application of the Extent Analysis Method on Fuzzy AHP in real life problems helps the people to take a correct decision from the available alternatives.

REFERENCES


Table 10. Obtained Results

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<th>Weight</th>
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