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# FUSION OF FUZZY AHP IN SELECTING MATERIAL FOR DRINKING WATER BOTTLE BASED ON CUSTOMER NEEDS

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**ABSTRACT**

In this paper, selection of drinking water bottle material is to be selected. Therefore, to try out decision making tools efficiency, three methods have been used. The methods are fusion of Analytic Hierarchy Process (AHP) with Fuzzy logic with different membership function. The material selected are silicone, polypropylene, HDPE, LDPE and Tin. The criterion that being taken into consideration are price, density, tensile strength, thermal conductivity and electrical resistivity. Three methods have been carried out, and the weightage compared in the form of line graph. The best material gave by traditional AHP and trapezoidal AHP are Polypropylene, however triangular AHP gave LDPE is the best. But all three methods shows that tin is the least desirable when it does not satisfy all criterions.

**Keywords:** traditional AHP, triangular AHP, trapezoidal AHP.

## INTRODUCTION

Decision making is a very crucial action whereby needed in every action in our daily basis routine. Some personal decision made can be determine by just having a proper thinking. However, currently there are proper tools or way which can be used to make decision. Some method such as Analytic Hierarchy Process (AHP), Screening Scoring Method and others is being used. These tools are widely introduced in every field when it comes to decision making. Method such as AHP is used to compare performance of each criterion and justify the best solution for every case study or situation. Fuzzy however is a linguistic judgment where all the uncertainty is taken into account. Fuzzy numbers are subset of real number and they represent of human's confidence interval to place it in which class during their judgment (Wu *et al*. 2009). This is because AHP uses only single round number digit where fuzzy uses more than a single digit and sometimes even decimal. Previous researchers have used both fuzzy and AHP for different framework such as (Shaw *et al.* 2012) supplier selection for developing low carbon supply chain, (Rezaei *et al.* 2014) did supplier selection in the airline retail industry using a funnel methodology, and others which are (Zheng *et al*. 2012; Song *et al.* 2014; Taylan *et al*. 2015; Ugurlu 2015). All of them carried out the same experiment however the method is the same by combine fuzzy into AHP. The problem of this situation is when decision made by experience worker sometimes can be incorrect and without proper discussion. Some workers consult with either expert or experience with the situation. The main purpose of this experiment is to determine the final material selected based on proper evaluation using fusion of Fuzzy and AHP. Some customers also prioritize different criterion such as price, tensile, density and others to be present in bottle. Table-1 is extracted from (Shaw *et al*. 2012) and (Zheng *et al*. 2012). The three types AHP scaling is combined and tweaked to form Table-1. This Table-1 is used for further calculation in this framework. For traditional AHP, the scaling consists of values. Triangular AHP consist of three values and trapezoidal AHP consist of four values.

**Table-1.** Fuzzy AHP scaling.

| Categories | Traditional AHP | | Triangular fuzzy AHP | | Trapezoidal fuzzy AHP | |
|---|---|---|---|---|---|---|
| Equally Important | 1 | 1 | 1,1,1 | 1,1,1 | 1,1,1,1 | 1,1,1,1 |
| Intermediate Preference | 2 | $\frac{1}{2}$ | 1,2,3 | $\frac{1}{3},\frac{1}{2},1$ | $1,\frac{3}{2},\frac{5}{2},3$ | $\frac{1}{3},\frac{2}{5},\frac{2}{3},1$ |
| Moderately More Important | 3 | $\frac{1}{3}$ | 2,3,4 | $\frac{1}{4},\frac{1}{3},\frac{1}{2}$ | $2,\frac{5}{2},\frac{7}{2},4$ | $\frac{1}{4},\frac{2}{7},\frac{2}{5},\frac{1}{2}$ |
| Intermediate Preference | 4 | $\frac{1}{4}$ | 3,4,5 | $\frac{1}{5},\frac{1}{4},\frac{1}{3}$ | $3,\frac{7}{2},\frac{9}{2},5$ | $\frac{1}{5},\frac{2}{9},\frac{2}{7},\frac{1}{3}$ |
| Strongly More Important | 5 | $\frac{1}{5}$ | 4,5,6 | $\frac{1}{6},\frac{1}{5},\frac{1}{4}$ | $4,\frac{9}{2},\frac{11}{2},6$ | $\frac{1}{6},\frac{2}{11},\frac{2}{9},\frac{1}{4}$ |
| Intermediate Preference | 6 | $\frac{1}{6}$ | 5,6,7 | $\frac{1}{7},\frac{1}{6},\frac{1}{5}$ | $5,\frac{11}{2},\frac{13}{2},7$ | $\frac{1}{7},\frac{2}{13},\frac{2}{11},\frac{1}{5}$ |
| Very Strong More Important | 7 | $\frac{1}{7}$ | 6,7,8 | $\frac{1}{8},\frac{1}{7},\frac{1}{6}$ | $6,\frac{13}{2},\frac{15}{2},8$ | $\frac{1}{8},\frac{2}{15},\frac{2}{13},\frac{1}{6}$ |
| Intermediate Preference | 8 | $\frac{1}{8}$ | 7,8,9 | $\frac{1}{9},\frac{1}{8},\frac{1}{7}$ | $7,\frac{15}{2},\frac{17}{2},9$ | $\frac{1}{9},\frac{2}{17},\frac{2}{15},\frac{1}{7}$ |
| Extremely More Important | 9 | $\frac{1}{9}$ | 8,9,9 | $\frac{1}{9},\frac{1}{9},\frac{1}{8}$ | $8,\frac{17}{2},9,9$ | $\frac{1}{9},\frac{1}{9},\frac{2}{17},\frac{1}{8}$ |

## METHODOLOGY

Firstly is to place weightage on the criterion. This is being done with a survey. A sample of 30 respondents are required to fill up survey question on which criteria they look into first before they made any purchase to buy drinking water bottle. Next is to evaluate final decision. Three different method of evaluating are being used to determine the final most suitable material. The methods are Traditional AHP, Triangular Fuzzy AHP and Trapezoidal Fuzzy AHP.

### Traditional AHP

**Step 1: Weight scaling**

Place weight according to the scale provided in Table-1 under the column Traditional AHP. Carry out pairwise comparison by placing whole number to superior criterion and reciprocal judgment for least superior.

**Step 2: Weight normalizing**

The weights are sum according to column and divide with every weight under the sum column resulting to obtain a sum of 1.

**Step 3: Weightage calculation**

The weights are added by row where all of the different alternatives are added to obtain one value of final weightage with respect to the row.

**Step 4: Consistency checking**

Calculate the Eigenvalue ($\lambda_{max}$)

$\lambda_{max}$ = Priority Value Criterion 1 (Weight Criterion 1) + Priority Value Criterion 2 (Weight Criterion 2) + …..+ Priority Value Criterion $n$ (Weight Criterion $n$)(Yao *et al*. 2004).

Calculate Consistency Index ($CI$)

$$CI = \frac{\lambda \max - n}{n-1} \quad (1)$$

Calculate Consistency Ratio ($CR$)

The value of $RI$ is referred in Table-2 according to value $n$.

$$CR = \frac{CI}{RI} = < 0.1 \quad (2)$$

**Table-2.** Random consistency index table.

| $n$ | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| $RI$ | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.51 |

**Step 5:** Final decision making

All the values of weightage and criteria are multiply and add to obtain the final value. The biggest value is to be selectedas the best choice or the highest in rank.

### Triangular fuzzy AHP

**Step 1:** Weight scaling

Place weight according to the scale provided in Table-1 refer Triangular Fuzzy AHP column. Carry out pairwise comparison by placing whole number to superior criterion and reciprocal judgment for least superior.

**Step 2:** Using fuzzy analytic hierarchy process

According to (Chang 1996), the basic concepts of triangular fuzzy AHP are shown below. From the Table-1, the triangular fuzzy AHP consist of 3 values represented

by Equation (3). If there is a weaker comparison, Equation (4) will be used.

$$a_{ij} = (l_{ij}, m_{ij}, u_{ij}) \quad (3)$$

$$a_{ij}^{-1} = (\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}) \quad (4)$$

A method of extent analysis was introduced by (Chang 1996) each object was taken analysis were performed for each goal respectively. Hence, $m$ extent analysis values for every object obtained through the following signs:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m, i = 1,2, \ldots, n \quad (5)$$

where all $M_g^j (j = 1,2, \ldots, m)$ represented as triangular fuzzy numbers. Chang's extent analysis can be breakdown into 4 other steps continuing from second step.

**Step 3:** Value of fuzzy synthetic extent with respect to $i$th object defined as:

$$S_i \sum_{j=1}^m M_{gi}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j\right]^{-1} \quad (6)$$

In order to obtain$\sum_{j=1}^m M_{gi}^j$, fuzzy summation operation of $m$ extent analysis value is performed:

$$\sum_{j=1}^m M_{gi}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j\right), i = 1,2,..,n \quad (7)$$

and inverse from the vector in Equation. (6) is computed by:

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i}\right) \quad (8)$$

**Step 4:** Degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as:

$$V(M_2 \geq M_1) = sup\left[\min(\mu_{M_1}(x), \mu_{M_2}(y))\right]_{y \geq x} \quad (9)$$

equivalently expressed to:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d) \quad (10)$$

$$= \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(l_1 - m_1) - (l_2 - m_2)}, & otherwise \end{cases} \quad (11)$$

Figure-1 illustrate Equation. (10) where by $d$ is the coordination with the highest intersection point D between $\mu_{M_1}$and $\mu_{M_2}$. To perform comparison between $M_1$and $M_2$, both values of $V(M \geq M_1)$ and $(M \geq M_2)$ are needed.

**Step 5:** The degree of possibility of convex fuzzy must be greater than $k$ convex fuzzy.

Convex fuzzy must be bigger in value compared to $k$ convex fuzzy $M_i (i = 1,2,3, \ldots, k)$ which can be defined by:

$$V(M \geq M_1, M_2, \ldots, M_k) \quad (12)$$
$$= V(M \geq M_1) \text{and } (M \geq M_2) \ldots \text{ and } (M \geq M_k)$$
$$= \min(M \geq M_i), i = 1,2,3, \ldots, k$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \quad (13)$$

For $k = (1,2,3 \ldots \ldots, n);\ k \neq i$. Then, weight vector is represented by

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \quad (14)$$

Where $A_i (i = 1,2,3, \ldots . n)$ the elements are present after computation.

**Step 6:** Normalization

The last step is to normalize by adding the sum of all elements and divide by each object.

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T \quad (15)$$

Where $W$ is a non - fuzzy number which provides priority weight of alternative or criteria.

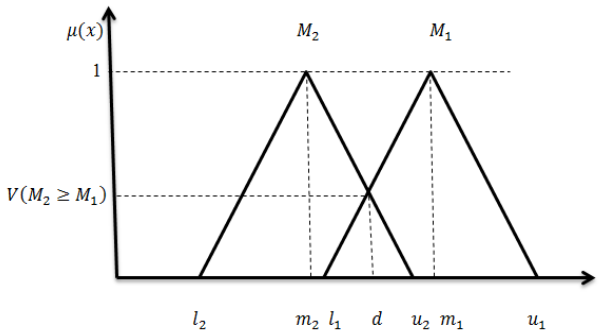



**Figure-1.** The intersection between $M_2$and $M_1$ (Chang 1996).

**Trapezoidal fuzzy AHP**

Trapezoidal fuzzy AHP uses 4 values to classify alternative or attribute. Basically there are four steps to carry out this method.

**Step 1:** Weight scaling

Place weight according to the scale provided in Table-1 under the column of Trapezoidal Fuzzy AHP. Carry out pairwise comparison by placing whole number to superior criterion and reciprocal number for least superior.

**Step 2:** Using fuzzy analytic hierarchy process

According to (Wu *et al.* 2004) the basic concept of trapezoidal fuzzy AHP are shown below. From the

Table-1, the trapezoidal fuzzy AHP consist of 4 values represented by Equation (16). If there is a weaker comparison, Equation (17) will be used.

$$x_{ij} = (l_{ij}, m_{ij}, n_{ij}, s_{ij}) \quad (16)$$
$$(x_{ij})^{-1} = (s_{ij}^{-1}, n_{ij}^{-1}, m_{ij}^{-1}, l_{ij}^{-1}) \quad (17)$$

**Step 3:** Calculate weight

Based from the pair wise comparison made referring from Traditional AHP and Table-1, the weight can be calculated as follows:

**Table-3.** Computation of weight, $w$.

| Variable | Product | Sum |
|---|---|---|
| $\alpha$ | $\alpha_j = \left[\prod_{j=1}^{n} l_{ij}\right]^{\frac{1}{n}}$ | $\alpha = \sum_{j=1}^{n} \alpha_j$ |
| $\beta$ | $\beta_j = \left[\prod_{j=1}^{n} m_{ij}\right]^{\frac{1}{n}}$ | $\beta = \sum_{j=1}^{n} \beta_j$ |
| $\gamma$ | $\gamma_j = \left[\prod_{j=1}^{n} n_{ij}\right]^{\frac{1}{n}}$ | $\gamma = \sum_{j=1}^{n} \gamma_j$ |
| $\delta$ | $\delta_j = \left[\prod_{j=1}^{n} s_{ij}\right]^{\frac{1}{n}}$ | $\delta = \sum_{j=1}^{n} \delta_j$ |

Table-3 is gathered from (Wu *et al*. 2004) and it is grouped in a table form. From the computation, the weight can be determined in equation (18).

$$w_j = \left(\alpha_j \delta^{-1}, \beta_j \gamma^{-1}, \gamma_j \beta^{-1}, \delta_j \alpha^{-1}\right) j \in \{1,2,.,n\} \quad (18)$$

Therefore the fuzzy weight vector $W$ can be constructed as:

$$W = [w_1 w_2 w_3 \ldots . w_n \quad (19)$$

**Step 4:** Defuzzification and normalization

The last step is defuzzification where all four values were to substitute from Trapezoidal AHP method into the following equation:

$$N = \frac{b+c}{2} + \frac{[(d-c)-(b-a)]}{6}$$
$$N = \frac{\frac{b+c}{2} + \frac{[(d-c)-(b-a)]}{6}}{} \quad (20)$$
$$N = \frac{a+2b+2c+d}{6}$$

The value will be calculated leaving a crisp value for decision makers to calculate the ranking for all alternatives or attribute. Lastly normalize all the values.

## RESULTS AND DISCUSSIONS

### Survey result

A survey was conducted among students in Universiti Teknikal Malaysia, Malacca (UTeM) where the question required them to give their priority needs in purchasing or using a drinking water bottle. The criteria being look into were price, density, tensile, thermal conductivity and electrical resistivity. Samples of 30 students were asked for their cooperation to fill up by ranking from the entire 5 criterion, which is the most needed and least needed. The data collected is present in a pie chart for easy summarized view.

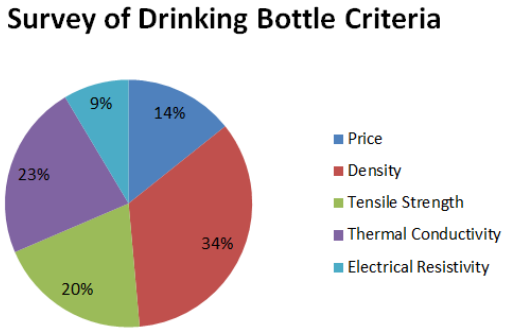



**Figure-2.** Percentage ranking of criterion.

Observe from Figure-2, the most needed criterion is density. When asked, they prefer their bottle to be light so they could travel light. However, the least criterion is much shocking because among these 30 students, only few place first rank in price. The answer received is that expensive drinking bottle last longer and avoids from chemical dangers dissipate from bottle made up of plastics. This percentage will be used to determine the weightage ranking in Fuzzy AHP. The next step is to calculate using three different of fuzzy AHP.

### Information acquisition from CES Edupack (Software)

Data presented in Table 3 were gain from CES Edupackwill be used for further ranking in all three methods.

### AHP scaling

Table-4 to 9 below shows the scaling referring to Table-1. The pairwise comparison is made by comparing the value from Table-3. The alternatives and criteria are represented in forms of alphabets. The alternatives or material are represented by alphabet A and numbers. The sample materials are, A1-Silicone, A2-PP, A3-HDPE, A4-LDPE, A5-Tin. For criteria represented with alphabet K. The criterions are K1 - Price, K2 - Density, K3-Tensile Strength, K4-Thermal Conductivity, and K5-Electrical Resistivity. Table-9 shows symbol C which is the criteria. The similar scaling for triangular fuzzy AHP and trapezoidal will be done the same by referring to Table-1. Tables 4 to 9 is the pairwise comparison for all material according to criterion.

**Table-4.** Material properties.

| | **K1 - Price** (RM) | **K2 - Density** ($kg/m^3$) | **K3 - Tensile** (MPa) | **K4 - Thermal conductivity** ($^o$ F) | **K5 - Electrical resistivity** (µohm.cm) |
|---|---|---|---|---|---|
| **A1 - Silicone** | 32.80 – 39 | $1.02e^3 – 1.22e^3$ | 7 – 11.5 | 200 – 250 | $3e^{19} – 5e^{20}$ |
| **A2 - PP** | 8.76 – 11.10 | $1.12e^3 – 1.14e^3$ | 60.4 – 69.2 | 112 – 131 | $1e^{22} – 1e^{24}$ |
| **A3 - HDPE** | 8.39 – 10.30 | $1.18e^3 – 1.28e^3$ | 51.7 – 62.1 | 130 – 150 | $3.3e^{24} – 3e^{25}$ |
| **A4 - LDPE** | 5.55 – 6.17 | 917 – 932 | 13.3 – 26.4 | 81 – 95 | $3.3e^{24} – 3e^{25}$ |
| **A5 - Tin/Foil** | 68.40 – 75.20 | $7.2e3 – 7.3e^3$ | 54 - 66 | -3 – 27 | 11 - 13 |

**Table-5.** Pairwise comparison - price.

| **K1** | **A1** | **A2** | **A3** | **A4** | **A5** |
|---|---|---|---|---|---|
| A1 | 1 | 1/2 | 1/3 | 1/5 | 4 |
| A2 | 2 | 1 | 1/2 | 1/3 | 3 |
| A3 | 3 | 2 | 1 | 1/2 | 4 |
| A4 | 5 | 3 | 2 | 1 | 5 |
| A5 | 1/4 | 1/3 | 1/4 | 1/5 | 1 |

**Table-6.** Pairwise comparison - density.

| **K2** | **A1** | **A2** | **A3** | **A4** | **A5** |
|---|---|---|---|---|---|
| A1 | 1 | 2 | 3 | 1/2 | 3 |
| A2 | 1/2 | 1 | 2 | 1/2 | 3 |
| A3 | 1/3 | 1/2 | 1 | 1/4 | 2 |
| A4 | 2 | 2 | 4 | 1 | 4 |
| A5 | 1/3 | 1/3 | 1/2 | 1/4 | 1 |

**Table-7.** Pairwise comparison - tensile.

| **K3** | **A1** | **A2** | **A3** | **A4** | **A5** |
|---|---|---|---|---|---|
| A1 | 1 | 1/5 | 1/3 | 1/2 | 1/4 |
| A2 | 5 | 1 | 3 | 4 | 2 |
| A3 | 3 | 1/3 | 1 | 2 | 1/3 |
| A4 | 2 | 1/4 | 1/2 | 1 | 1/3 |
| A5 | 4 | 1/2 | 3 | 3 | 1 |

**Table-8.** Pairwise comparison - thermal.

| **K4** | **A1** | **A2** | **A3** | **A4** | **A5** |
|---|---|---|---|---|---|
| A1 | 1 | 3 | 2 | 4 | 5 |
| A2 | 1/3 | 1 | 1/2 | 3 | 4 |
| A3 | 1/2 | 2 | 1 | 3 | 4 |
| A4 | 1/4 | 1/3 | 1/3 | 1 | 2 |
| A5 | 1/5 | 1/4 | 1/4 | 1/2 | 1 |

**Table-9.** Pairwise comparison - electrical.

| **K5** | **A1** | **A2** | **A3** | **A4** | **A5** |
|---|---|---|---|---|---|
| A1 | 1 | 2 | 1/2 | 1/3 | 3 |
| A2 | 1/2 | 1 | 1/3 | 1/4 | 2 |
| A3 | 2 | 3 | 1 | 1/2 | 3 |
| A4 | 3 | 4 | 2 | 1 | 4 |
| A5 | 1/3 | 1/2 | 1/3 | 1/4 | 1 |

**Table-10.** Pairwise comparison - criteria.

| **C** | **K1** | **K2** | **K3** | **K4** | **K5** |
|---|---|---|---|---|---|
| K1 | 1 | 1/4 | 1/2 | 1/3 | 4 |
| K2 | 4 | 1 | 3 | 2 | 4 |
| K3 | 2 | 1/3 | 1 | 1/2 | 3 |
| K4 | 3 | 1/2 | 2 | 1 | 3 |
| K5 | 1/4 | 1/4 | 1/3 | 1/3 | 1 |

## RESULT

From the traditional AHP scaling in Tables 4 to 9, the exact values were used to construct triangular AHP and trapezoidal AHP. For Triangular AHP, after the scaling have been done, the equation (3) until equation (15) will be used to determine final weightage and the best material for this experiment. For Trapezoidal AHP, the equation will be used to determine the weightage are from equation (16) to (28). Figures 3 to 8 is the weightage comparison after all equation has been applied. The answer is presented in line graph. Three different line colors have been applied. For traditional AHP presented by blue line, but for triangular and trapezoidal are represented using red and green line respectively.

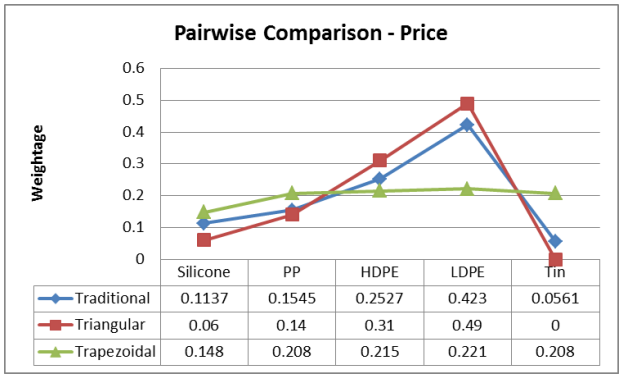
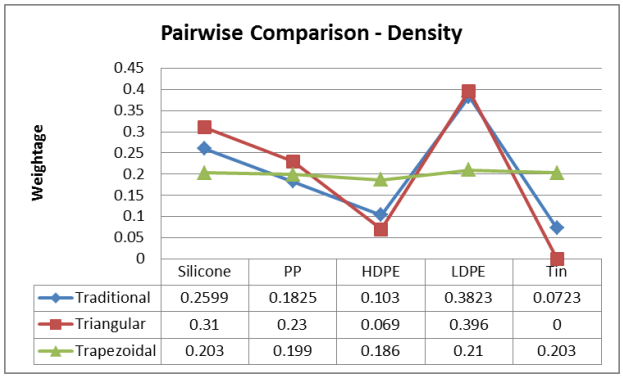
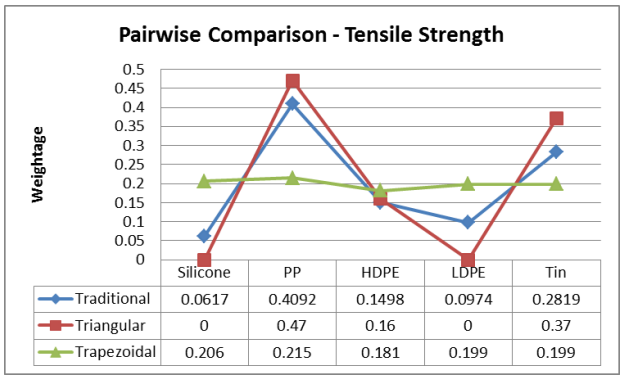


**Figure-3.** Pairwise comparison - price.



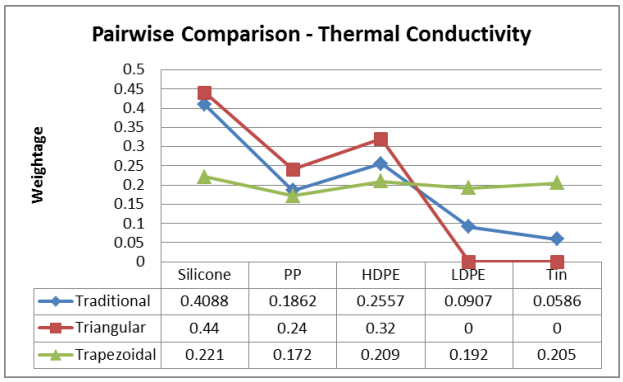

| | Silicone | PP | HDPE | LDPE | Tin |
|---|---|---|---|---|---|
| Traditional | 0.2599 | 0.1825 | 0.103 | 0.3823 | 0.0723 |
| Triangular | 0.31 | 0.23 | 0.069 | 0.396 | 0 |
| Trapezoidal | 0.203 | 0.199 | 0.186 | 0.21 | 0.203 |

**Figure-4.** Pairwise comparison - density.



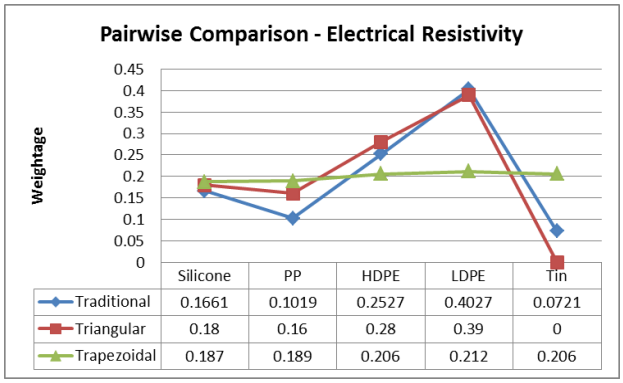

| | Silicone | PP | HDPE | LDPE | Tin |
|---|---|---|---|---|---|
| Traditional | 0.0617 | 0.4092 | 0.1498 | 0.0974 | 0.2819 |
| Triangular | 0 | 0.47 | 0.16 | 0 | 0.37 |
| Trapezoidal | 0.206 | 0.215 | 0.181 | 0.199 | 0.199 |

**Figure-5.** Pairwise comparison - tensile strength.



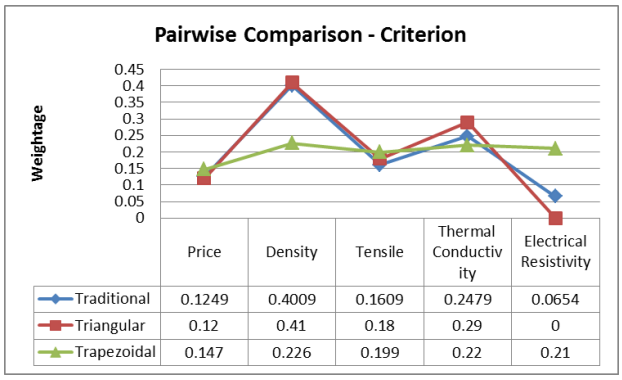

| | Silicone | PP | HDPE | LDPE | Tin |
|---|---|---|---|---|---|
| Traditional | 0.4088 | 0.1862 | 0.2557 | 0.0907 | 0.0586 |
| Triangular | 0.44 | 0.24 | 0.32 | 0 | 0 |
| Trapezoidal | 0.221 | 0.172 | 0.209 | 0.192 | 0.205 |

**Figure-6.** Pairwise comparison - thermal conductivity.




| | Silicone | PP | HDPE | LDPE | Tin |
|---|---|---|---|---|---|
| Traditional | 0.1661 | 0.1019 | 0.2527 | 0.4027 | 0.0721 |
| Triangular | 0.18 | 0.16 | 0.28 | 0.39 | 0 |
| Trapezoidal | 0.187 | 0.189 | 0.206 | 0.212 | 0.206 |

**Figure-7.** Pairwise comparison - electrical resistivity.




| | Price | Density | Tensile | Thermal Conductivity | Electrical Resistivity |
|---|---|---|---|---|---|
| Traditional | 0.1249 | 0.4009 | 0.1609 | 0.2479 | 0.0654 |
| Triangular | 0.12 | 0.41 | 0.18 | 0.29 | 0 |
| Trapezoidal | 0.147 | 0.226 | 0.199 | 0.22 | 0.21 |

**Figure-8.** Pairwise comparison - criterion.

## DISCUSSIONS

From Figure 3 to 8 shows the final weight after computation being made. The result shows weightage of each material. The green line present trapezoidal AHP whereby follows the up and down of the other two methods. The difference the gradient is less noticeable, but it follows every peak point and low point in triangular and traditional. This is due to inconsistency from scaling resulting in sudden high weightage. As for blue and red line representing other two methods shows a result after being normalize. Table-11 shows the most desired until least desired material after using all three methods.

**Table-11.** Summary final result.

| Methods | Ranking |
|---|---|
| Traditional AHP | A4>A1>A2>A3>A5 |
| Triangular AHP | A2>A1>A4>A3>A5 |
| Trapezoidal AHP | A4>A5>A3>A1>A2 |

Observe that 2 out of 3 methods show that LDPE (A4) is selected to be the best material for drinking water bottle. Sample respondent chooses to have light weight drinking water bottle. Two method shows that LDPE is the best material since it has lightest density compared to other four materials. Triangular method show material PP (A2) is to be selected. Even though this material is not the lightest but PP is a material having the best tensile strength and intermediate weightage in other criteria. The least preferred material is tin (A5) because it has the heaviest material $7.2e^3$ - $7.3e^3 kg/m^3$. Therefore the result shows 2 method gave A5 is the least desired material for drinking bottle. This is due to the methods are fused with fuzzy. Therefore, some weightage are manipulated due to linguistic judgement. The scaling use three values in triangular and four values in trapezoidal however overlap with other class of scaling. To conclude different results is due to scaling whereby overlaps with other class.

## CONCLUSIONS

Analytic Hierarchy Process involves uncertainty to solve on selecting which alternative is the best. This process is suitable when there are multi - criteria decision

making in any field required. However, to make it more accurate, fuzzy logic is the key to determine the best selection due to its membership function. Membership function will take into consideration when the value between 0 and 1 is counted compared to traditional AHP will test on only single digit. Traditional and Triangular AHP show about the same curve of slope but final calculation made some tweaks in the result.

This is due to linguistic judgement made in triangular tends to give slightly different answer. In future research, consistency analysis needs to be carried out to achieve consistent weight value. The best material can be PP or LDPE. LDPE is chosen to be the best because two out of three methods gave the same answer. The least preferable material for drinking water bottle which can be observed from Table-4 is Tin material where it dissatisfied each and every criterion. Tin was proven to be least desired when both Traditional and Triangular AHP gave the same answer. To conclude, the material selected would be LDPE (A4) and least desired would be Tin (A5). Consequently, three methods are able to solve material selection problems and therefore suitable according to user requirements.

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