



Computation of Fuzzy Analytic Hierarchy Process (FAHP) Using MATLAB Programming In Sustainable Supply Chain

Ahamad Zaki Mohamed Noor, Muhammad Hafidz Fazli Md Fauadi, Nur Zul Hafiq Zulkifli, Muhamad Naqib Abdul Basit, Fairul Azni Jafar, Nor Rashidah Mohamad

Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia.

Corresponding Author Email: ahamadzaki.mohamednoor@gmail.com.

Abstract

Fuzzy Analytic Hierarchy Process (FAHP) is a well-known method which is currently used by many researchers all around the world. However, the problem lies where the steps are lengthy and consumes time. This paper does the purpose to share a method where Decision Makers (DM) can reduce error or any mistakes while manual compute. A MATLAB programming is develop and field of sustainable supply chain is use as experiment purpose. There is one out of four criteria need to be selected by using FAHP. The criteria are cost, quality, delivery time and supplier distance. Both methods are done simultaneously and the answers were recorded. The percentage accuracy shows 100% for every step showing there is no error and the answers are the same if MATLAB is applied. Final answers for both shows that quality is the highest criterion to be selected based on the weightage.

Keywords: Fuzzy Analytic Hierarchy Process, MATLAB, Decision Makers, Sustainable Supply

1. Introduction

There are numerous decisions need to be made to ensure that a business supply chain is sustainable. Additionally, the management’s ability to produce optimal decisions is critical for the company to be competitive. Consequently, the management needs to consider multiple criteria with some uncertainties to make decision. More often than not, decisions can’t be discriminated at early stage. Fuzzy Logic is one of artificial intelligence (AI) tool other than genetic algorithm, neural network, and other known AI tools [4], [2] .. One of the best techniques to solve uncertainty is to use fuzzy logic. In order to make the final best decision, Fuzzy Analytic Hierarchy Process (FAHP) is utilized. This technique is a combination of two different techniques. The objective of this paper is to develop a MATLAB-based FAHP to compute the decisions need to be made. For the purpose of this report, only four objectives will be discussed. These include product cost, product quality, delivery time and geographical location of the product vendor. This technique has quite lengthy steps to be followed and time consuming [10] . Triangular FAHP is selected after an experiment were conduct by [5] showing Triangular FAHP show near same decision making compared

to Trapezoidal FAHP. The objective is the need to develop a MATLAB programming to compute FAHP. This experiment will be done in sustainable supply chain for multi criteria decision making [8]. Only four criterions will be look into such as product cost, product quality, delivery time and supplier distance of product will be used in this paper.

2. Methodology

This experiment will be conducted by scaling multi – objective criteria. The criteria are equally important. Therefore, the scaling will be done by placing the highest weightage on the product cost. Two methods will be done simultaneously. The first method will be manual computation of FAHP. The second method is to develop MATLAB programming and read the excel file. The MATLAB programming is need of accurate reading from excel file. Therefore, space label from excel such as A1 to M5 column need to be key in properly. If the final answer obtain from both methods are not equal, MATLAB programming will be look into for any mismatch of label. Figure 1 shows the overall methodology of this paper.

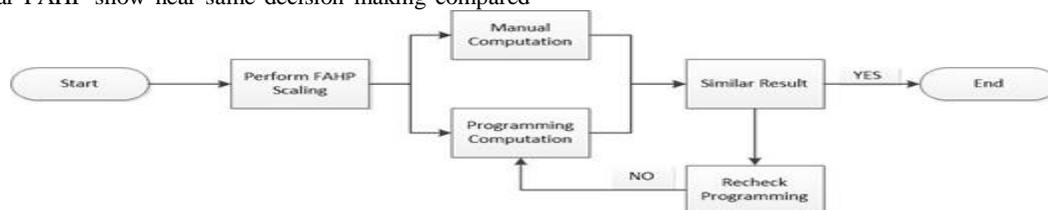


Fig. 1: Overall Methodology

The first step is called weight scaling. This process is done by carrying out comparison in pair by scale a whole number to criterion which is superior and reciprocal judgment for least importance with the help of Table 1 [6].

Table 1: Scaling for FAHP

Categories	Triangular Fuzzy AHP	
Equally Important	1,1,1	$\frac{1}{3}, \frac{1}{2}, 1$
Intermediate Preference	1,2,3	$\frac{1}{4}, \frac{1}{3}, \frac{1}{2}$
Moderately More Important	2,3,4	$\frac{1}{5}, \frac{1}{4}, \frac{1}{3}$
Intermediate Preference	3,4,5	$\frac{1}{6}, \frac{1}{5}, \frac{1}{4}$
Strongly More Important	4,5,6	$\frac{1}{7}, \frac{1}{6}, \frac{1}{5}$
Intermediate Preference	5,6,7	$\frac{1}{8}, \frac{1}{7}, \frac{1}{6}$
Very Strong More Important	6,7,8	$\frac{1}{9}, \frac{1}{8}, \frac{1}{7}$
Intermediate Preference	7,8,9	$\frac{1}{9}, \frac{1}{8}, \frac{1}{7}$
Extremely More Important	8,9,9	$\frac{1}{9}, \frac{1}{9}, \frac{1}{8}$

The second step is to use the FAHP. [1] mention the main concept of triangular fuzzy AHP is shown below. From Table 1, the triangular FAHP consist of 3 values presented in Equation (1). If the alternative compared is weaker, then equation (2) will be used.

$$a_{ij} = (l_{ij}, m_{ij}, u_{ij}) \tag{1}$$

$$a_{ij}^{-1} = (\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}) \tag{2}$$

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		QUALITY			COST			DELIVERY			ORIGIN		
2	QUALITY	1	1	1	2	3	4	4	5	6	6	7	8
3	COST	1/4	1/3	1/2	1	1	1	2	3	4	4	5	6
4	DELIVERY	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1	2	3	4
5	ORIGIN	1/8	1/7	1/6	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1

A = xlsread('Data.xlsx','All','A1:M5')

Fig. 2: Call function in MAT

From figure 2, the file name is “Data” and the sheet name is “All” followed by labelling the space from A1 to M5. An extent analysis is a method introduced by the same author. Each object was analysed and pairwise comparison is carried out to achieve each goal respectively. Hence, *m* which are the extent analysis values for each object were obtained:

$$M_{gi}^1, M_{gi}^2, \dots, M_{gi}^m, i = 1, 2, \dots, n \tag{3}$$

Whereby $M_{gi}^j (j = 1, 2, \dots, m)$ presented as triangular fuzzy numbers. Chang’s extent analysis is further breakdown into another 4 steps continuing from previous step. Third step is to compute the fuzzy synthetic extent value respect to *i*th object as shown in Equation (4):

$$S_i = \sum_{j=1}^m M_{gi}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} \tag{4}$$

In order to calculate $\sum_{j=1}^m M_{gi}^j$, fuzzy summation operation value of *m* extent analysis will be carried out:

$$\sum_{j=1}^m M_{gi}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right), i = 1, 2, \dots, n \tag{5}$$

Inverse from vector in Equation (6) is calculated by:

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right) \tag{6}$$

In MATLAB programming, the total of *l*, *m* and *u* are needed to be identified. To determine *l1*, command “xlsread” is used, recall data in B2, E2, H2 and K2. For *m1*, the same command used but the data used for addition are C2, F2, I2, and L2. This step is done repetitive for *u1* until *l4*, *m4*, and *u4*. This step is equivalent to equation (5). The total of *l*, *m* and *u* and the reciprocal for quality example same as equation (6) are shown in figure 3.

```
l1=xlswread('Data.xlsx','All','B2')+xlswread('Data.xlsx','All','E2')+xlswread
('Data.xlsx','All','H2')+xlswread('Data.xlsx','All','K2')
total_l=l1+l2+l3+l4
total_m=m1+m2+m3+m4
total_u=u1+u2+u3+u4
quality_l=l1/total_u
quality_m=m1/total_m
quality_u=u1/total_l
```

Fig. 3: Representative of Equation (5) and (6)

The l , m and u for cost, delivery time and supplier distance is done the same way for further calculate using equation 9. Figure 4 shows the same as equation 9 but represent in MATLAB. This program need to be run until all pairwise are made. The step in figure 4 is repeated for comparison of quality between cost, delivery time and supplier distance. The fourth step is to use the FAHP rules by identifying the degree of possibility

$M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$. defined as:

$$V(M_2 \geq M_1) = \sup[\min(\mu_{M_1}(x), \mu_{M_2}(y))]_{y \geq x} \quad (7)$$

equivalently expressed to:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d) \quad (8)$$

$$= \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(l_1 - m_1) - (u_2 - m_2)}, & \text{otherwise} \end{cases} \quad (9)$$

```
%comparison quality to cost
if (quality_m >=cost_m)
    w11=1
end
if (cost_l >=quality_u)
    w11=0
end
if (quality_m < cost_m)&&(cost_l < quality_u)
    w11=(cost_l-quality_u)/((cost_l-cost_m)-(quality_u-quality_m))
end
```

Fig. 4: Representative of Equation (9)

The fifth step is to make sure the possible degree of convex fuzzy stands higher than k convex fuzzy. Convex fuzzy must have greater value compared to k convex fuzzy $M_i (i = 1, 2, 3, \dots, k)$ this can be defined by ([7],[9]):

$$V(M \geq M_1, M_2, \dots, M_k) = V(M \geq M_1) \text{ And } (M \geq M_2) \dots \text{ and } (M \geq M_k) = \min(M \geq M_i), i = 1, 2, 3, \dots, k \quad (10)$$

$$\text{Assume that } d'(A_i) = \min V(S_i \geq S_k) \quad (11)$$

```
a=[w1 w12 w13];
b=[w21 w22 w23];
c=[w31 w32 w33];
d=[w41 w42 w43];

quality=min(a)
cost=min(b)
delivery=min(c)
supplier=min(d)
```

Fig. 5: Representative of Equation (11)

```
weight_quality=quality/(quality+cost+delivery+supplier)
weight_cost=cost/(quality+cost+delivery+supplier)
weight_delivery=delivery/(quality+cost+delivery+supplier)
weight_supplier=origin/(quality+cost+delivery+supplier)
```

Fig. 6: Representative of Equation (13)

From figure 5, the answers are grouped in matrix form consist of four criterion. Assume “a” is quality, “b” is product cost, “c” is delivery time and “d” is supplier distance. The minimum value among each variable is identified.

For $k = (1, 2, 3 \dots \dots, n); k \neq i$. Then, weight vector is presented as:

$$W' = (d'(A_1), d'(A_2), \dots \dots, d'(A_n))^T \quad (12)$$

Whereby $A_i (i = 1, 2, 3, \dots \dots, n)$ are elements obtained after computation. The final step, sixth step is to make sure summation equal to 1 through adding elements and divide using each object [11].

$$W = (d(A_1), d(A_2), \dots \dots, d(A_n))^T \quad (13)$$

Whereby W , is no longer fuzzy number provides priority weight for alternative or a criterion. Figure 6 is method of using MATLAB program to perform normalization.

3. Results

Refer to table 2, the scaling is done and same scaling is used in Microsoft Excel in order for MATLAB to recall the same file. Assume in this experiment, the quality is look into as highest priority. These 3 parameters are adapt from [3] and the origin parameter added by the authors for experiment purpose. Thus scaling process is carried

out and the scaling should show highest score in quality.

Table 2: Data Scaling Using FAHP

	Quality			Cost			Delivery			Origin		
Quality	1	1	1	2	3	4	4	5	6	6	7	8
Cost	1/4	1/3	1/2	1	1	1	2	3	4	4	5	6
Delivery	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1	2	3	4
Origin	1/8	1/7	1/6	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1

After manual and programming computation were done, the answers are recorded and compared.

Table 3: Comparison between Manual and MATLAB Programming Answers

Steps	Manual Computation	MATLAB Programming	Percentage Accuracy (%)								
Equation (5)	= (25.208, 31.543, 38.167)	<table border="0"> <tr><td>total_l</td><td>25.2083</td></tr> <tr><td>total_m</td><td>31.5429</td></tr> <tr><td>total_u</td><td>38.1667</td></tr> </table>	total_l	25.2083	total_m	31.5429	total_u	38.1667	100%		
total_l	25.2083										
total_m	31.5429										
total_u	38.1667										
Equation (6)	Quality = (13, 16, 19) Cost = (7.250, 9.333, 11.50) Delivery= (3.417, 4.533, 5.750) Supplier = (1.542, 1.676, 1.917)	Quality = (13, 16, 19) Cost = (7.250, 9.333, 11.50) Delivery= (3.4167, 4.533, 5.750) Supplier = (1.5417, 1.6762, 1.917)	100%								
Equation (9)	Quality = (0.341, 0.507, 0.754) Cost = (0.190, 0.296, 0.456) Delivery= (0.090, 0.144, 0.228) Supplier = (0.040, 0.053, 0.076)	Quality = (0.3406, 0.5072, 0.7537) Cost = (0.1900, 0.2959, 0.4562) Delivery= (0.0895, 0.1437, 0.2281) Supplier = (0.0404, 0.0531, 0.0760)	100%								
Equation (11)	a = (1, 1, 1) b = (0.3535, 1, 1) c = (0, 0.7282, 1) d = (0, 0, 0)	a = (1, 1, 1) b = (0.3535, 1, 1) c = (0, 0.7282, 1) d = (0, 0, 0)	100%								
Min Equation (11)	a = 1 b = 0.3535 c = 0 d = 0	a = 1 b = 0.3535 c = 0 d = 0	100%								
Equation (13)	Normalize (0.7388, 0.2612, 0, 0)	<table border="0"> <tr><td>weight_cost</td><td>0.2612</td></tr> <tr><td>weight_delivery</td><td>0</td></tr> <tr><td>weight_origin</td><td>0</td></tr> <tr><td>weight_quality</td><td>0.7388</td></tr> </table>	weight_cost	0.2612	weight_delivery	0	weight_origin	0	weight_quality	0.7388	100%
weight_cost	0.2612										
weight_delivery	0										
weight_origin	0										
weight_quality	0.7388										

4. Discussion

Both manual and programming computation provides the same answer. The answer given is same in weightage. The computation using MATLAB run in shorter time compared to manual computation. Mistakes or error can occur if the decision maker did not really focus while perform manual calculation. However, for programming, once the sample space is determined, the scaling can just be placed in Excel and automatic run. To conclude the results, quality criterion shows the first in rank with the weightage of 0.7388 highest among the rest. This program can also be applied in other related field as long the purpose is to make decision. Future work is to use this program and combine with neural network fitting to be applied in sustainable field. This is to identify the accuracy if the program combines with human like thinking algorithm. To conclude the results, quality criterion shows the first in rank with the weightage of 0.7388 highest among the rest.

Acknowledgement

We would like to thank Mybrain 15 by Malaysian Ministry of Higher Education for financial support throughout this research.

References

- [1] Chang, D.-Y. "Applications of the extent analysis method on fuzzy AHP", European Journal of Operational Research, vol. 95, Issue. 95, pp. 649–655, 1996
- [2] Fauadi, H. F., Nordin, M. H., & Zainon, Z. M., 2007. Frontal obstacle avoidance of an autonomous subsurface vehicle (ASV) using fuzzy logic method. In Intelligent and Advanced Systems, 2007. ICIAS 2007. International Conference on (pp. 125-128). IEEE.
- [3] González, M. E., Quesada, G., & Monge, C. a. M. "Determining the importance of the supplier selection process in manufacturing: a case study." International Journal of Physical Distribution & Logistics Management, vol. 34, pp. 492–504, 2004
- [4] Hosseini Ezzabadi, J., Dehghani Saryazdi, M., & Mostafaeipour, A. "Implementing Fuzzy Logic and AHP into the EFQM model for

- performance improvement: A case study", *Applied Soft Computing*, vol. 36, pp. 165–176, 2015
- [5] Noor, A. Z. M., Fauadi, M. H. F. M., Jafar, F. A., & Zainudin, S. F. "Fusion Of Fuzzy AHP in selecting material for drinking water bottle based on customer needs.", *ARNP Journal of Engineering and Applied Sciences*, vol.12, Issue. 14, pp. 4243–4249, 2017
- [6] Saaty, T. L., & Tran, L. T. "On the invalidity of fuzzifying numerical judgments in the Analytic Hierarchy Process", *Mathematical and Computer Modelling*, vol. 46, pp. 962–975, 2007
- [7] Sahu, A. K., Datta, S., & Mahapatra, S. S. "Evaluation and selection of resilient suppliers in fuzzy environment: Exploration of fuzzy-VIKOR", *Benchmarking*, vol. 23, Issue. 3, pp. 651–673, 2016
- [8] Shaw, K., Shankar, R., Yadav, S. S., & Thakur, L. S. "Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain", *Expert Systems with Applications*, vol. 39, Issue. 9, pp.8182–8192, 2012
- [9] Song, Z., Zhu, H., Jia, G., & He, C. "Comprehensive evaluation on self-ignition risks of coal stockpiles using fuzzy AHP approaches", *Journal of Loss Prevention in the Process Industries*, vol. 32, pp. 78–94, 2014
- [10] Taha, Z., & Rostam, S. "A hybrid fuzzy AHP-PROMETHEE decision support system for machine tool selection in flexible manufacturing cell", *Journal of Intelligent Manufacturing*, vol. 23, Issue. 6, pp. 2137–2149, 2012
- [11] Yeap, J. A. L., Ignatius, J., & Ramayah, T. "Determining consumers' most preferred eWOM platform for movie reviews: A fuzzy analytic hierarchy process approach", *Computers in Human Behavior*, vol. 31, Issue. 1, pp. 250–258, 2014