

A Fuzzy MCDM Method to Select The Best Company Based on Financial Report Analysis

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Abstract—In this paper, based on financial report analysis, a multi-criteria decision-making approach for supporting decision is presented. There are five companies are evaluated by proposed method. Fuzzy AHP (Analytic Hierarchy Process) is utilized to evaluate weights of criteria for selecting company and fuzzy TOPSIS (technique for order preference by similarity to ideal solution) is used to determine the most suitable alternative with respect to various considered criteria. A numerical example is also included to demonstrate the proposed approach.

Keywords—FAHP, FTOPSIS, Financial report

I. INTRODUCTION

Decision-making problem is a problem that one has to face in life. MCDM (multi-criteria decision-making) problem is the process that chooses the best preferred solution from all considered possible alternatives under evaluation criteria. It has been proved significant to numerous fields such as management science, engineering, education, public administration and military issues. In convention, the ratings of alternatives and the weights of criteria are treated as crisp values when one makes decisions. In real world, however, the used data in MCDM problems are very often imprecise and vague. As one knows, linguistic statements are usually used to evaluate alternatives and criteria. Fuzzy set theory is frequently utilized to deal with uncertainty. Numerous researches have paid attention to fuzzy MCDM problems. Investment issue can be regarded as a FMCDM problem without doubt. Somebody will deposit their money to bank, buy a land, real estate, stock, currency or/and gold for example. In this paper, we focus on how to choose a good stock of company. In addition, financial report is used to analyze the company's performance.

A hybrid model that incorporates FAHP and FTOPSIS methods is employed to solve MCDM problems in a fuzzy environment. According to the proposal model, we have to perform three stages in that the objectives of alternative and criterion will be determined from the investors and practitioners. After that the evaluation will be made by the experts who have much experience in finance fields. We will build hierarchy model include the criteria and alternatives. In next stage, fuzzy AHP is used to determine the preference

weights of alternative. Finally, the fuzzy TOPSIS is employed to find out the best alternative for achieving the aspired/desired levels based on the proposed company

II. LITERATURE REVIEW

In the empirical studies, one of the widely used methods is financial report analysis. Tozum (2009) carried out the measurement of performances by using ratio analysis and performance evaluation of bank. He emphasized that traditional ratio analyses were not sufficient to measure company performance and they should be evaluated in a multilateral way. Another important method used in the measurement of bank performance is data envelopment analysis (DEA). This method is used for measuring the efficiencies of bank's branches. Demir and Astarcioglu (2007) analyzed Turkish commercial banks' performance with DEA by considering their total commercials, interest income and expenses, non-interest income and expense. Ravi *et. al* (2008) suggested some models to estimate banks' financial performances. Mercan *et. al* (2003) examined the impact of ownership and growth of the bank on performance with the selected financial ratios in the period between 1989 and 1999. Thai and Kumar (2008) developed some models for the estimation of banks' financial performances by financial variables and they combined these models with the neural networks and statistical techniques. Beccalli (2007) examined the relation between bank performances and the investment in informatics.

There are so many financial ratios that may be evaluated a company. It makes a difficult problem to evaluate the alternatives. So, I have made a Questionnaire for evaluating the important financial ratios. The aim of this questionnaire reduces a number of financial ratios and support to calculate more easily. This questionnaire has sent to 4 experts who have many experiences in field of finance to get the evaluation opinion. Questionnaire will be fill in the blank to express the important level of each financial ratio based on the linguistic value is presented in table 3.1. After 4 questionnaires have been collected, we have calculated the average value of each ratio (according to Appendix 1). If any average value of each ratio is larger than 7 (very strongly important), they will be

selected. The result of this evaluation is selected 7 important financial ratios

TABLE I. THE IMPORTANT RATIOS

No.	Ratios	Sign	Criteria Direction	Measuring Units
1	Current ratios	S1	Max	Fraction
2	Debt ratio	S2	Min	Fraction
3	Equity/Debt ratio	S3	Max	Fraction
4	Operation profit ratio	S4	Max	Percentage
5	Income before tax ratio	S5	Max	Percentage
6	Net income revenue	S6	Max	Percentage
7	Return on total assets	S7	Max	Percentage

III. RESEARCH METHOD

MCDM is a well-known method of decision making. It is a branch of a general class of operations research models, which deal with decision problems under the presence of a number of decision criteria. This part presents a Fuzzy MCDM model for criteria selection and evaluation. Fuzzy MCDM model are briefly reviewed combining the general Decision making process. Then Fuzzy sets, weighting method, FMCDM are presented

A. Fuzzy Set Theory

Linguistic expressions are usually used in daily life, and more or less represent some degree of uncertainty of human thought. The fuzzy set theory [1], proposed by Zadeh, is frequently used to treat uncertainty problems. Fuzzy number is a fuzzy subset of real number; they represent the expansion of the idea of a confidence interval. In this paper, we use triangle fuzzy number (TFN) to represent the importance weighting of criterion and rating of alternative. It can be represented by

$$\mu_A(x) = \begin{cases} \frac{(x-a)}{(b-a)}, & a \leq x \leq b \\ \frac{(x-c)}{(b-c)}, & b \leq x \leq c \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Based on the characteristic of TFN and the extension definition proposed by Zadeh [1], given any two TFN and a positive real number r , some algebraic operation of TFN can be described as follow:

Addition of two TFN:

$$A_1 + A_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \quad (2)$$

Multiplication of two TFN

$$A_1 \otimes A_2 = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2) \quad (3)$$

Multiplication of any real number and a TFN:

$$r \otimes A_1 = (ra_1, ra_2, ra_3) \quad (4)$$

Subtraction of two TFNs:

$$A_1 - A_2 = (a_1 - c_2, b_2 - b_1, c_1 - a_2) \quad (5)$$

Division of two TFNs:

$$A_1 / A_2 = (a_1 / c_2, b_2 / b_1, c_1 / a_2) \quad (6)$$

Reciprocal of a TFN:

$$A_1^{-1} = (1/c_1, 1/b_1, 1/a_1) \quad (7)$$

Let two TFNs A_1 and A_2 , then the vertex method is defined to calculate the distance between them [26]

$$d(\tilde{A}_1, \tilde{A}_2) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \quad (8)$$

B. Linguistic Variable

Linguistic variable represents crisp information in a form and precision appropriate for the problem. For example, to answer the question “How do you think about this clothe?” we can answer “it is “not bad” outside. So, “not bad” is linguistic variable. The computational technique is based on the following fuzzy numbers defined by Hsieh *et. al.* We have a table corresponding linguistic variable as follows.

TABLE II. FUZZY PREFERENCE USED IN THE STUDY

Fuzzy number	Linguistic variable	TFN	Reciprocal
$\tilde{9}$	Absolutely Important	(7,9,9)	(1/9,1/9,1/7)
$\tilde{7}$	Very strongly important	(5,7,9)	(1/9,1/7,1/5)
$\tilde{5}$	Essential important	(3,5,7)	(1/7,1/5,1/3)
$\tilde{3}$	Weakly important	(1,3,5)	(1/5,1/3,1)
$\tilde{1}$	Equally important	(1,1,3)	(1/3,1,1)
$\tilde{2}, \tilde{4}, \tilde{6}, \tilde{8}$	Intermediate value between two adjacent judgments		

C. The AHP and Fuzzy AHP method

The AHP method, developed by Saaty (1980), addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem its main characteristic is that it is based on pair-wise comparison judgments. However, the pure AHP model has some problems (Yang & Chen, 2004). They pointed out that the AHP method is mainly used in nearly crisp data applications, creates and deals with a very unbalanced scale of judgment, rather imprecise; and the subjective judgment, selection and preference of decision-makers have much influence on the AHP results. To overcome these problems, several researchers integrate fuzzy theory with AHP to improve the uncertainty.

Step 1: AHP uses several small problems to present a complex problem. Thus, the first ace decompose into a hierarchy with a goal at the top, criteria and sub-criteria at level and sub-level and decision alternative at the bottom of the hierarchy (Fig 3)

Step 2: Construct fuzzy pair-wise comparison matrices. Through expert questionnaires, each expert is asked to assign

linguistic terms by TFN (as shown in Table 2 and Fig. 2 to the pair-wise comparisons among all criteria in the dimensions of a hierarchy system

$$D = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_j & \dots & C_m \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_i \\ \vdots \\ C_n \end{matrix} & \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1j} & \dots & \tilde{a}_{1m} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2j} & \dots & \tilde{a}_{2m} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ \tilde{a}_{i1} & \tilde{a}_{i2} & \dots & \tilde{a}_{ij} & \dots & \tilde{a}_{im} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{a}_{nj} & \dots & \tilde{a}_{nm} \end{bmatrix} \end{matrix}$$

The elements a_{ij} can be interpreted as the degree preference of i th criterion over j th criterion. The comparison matrix has to be normalized into the range of $[0, 1]$ by Eq. (13)

$$\tilde{r}_{ij} = \frac{\tilde{a}_{ij}}{\sum_{i=1}^n \tilde{a}_{ij}} \quad (13)$$

$$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1j} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2j} & \dots & r_{2m} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ r_{i1} & r_{i2} & \dots & r_{ij} & \dots & r_{im} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ r_{n1} & r_{n2} & \dots & r_{nj} & \dots & r_{nm} \end{bmatrix}$$

Step 3: Examine the consistency of the fuzzy pair-wise comparison matrices like the AHP method

According to the research of Buckley (1985), it proves that if $A = [a_{ij}]$ is a positive reciprocal matrix then A^{-1} is a fuzzy positive reciprocal matrix. That is, if the result of the comparisons of $A = [a_{ij}]$ is consistent.

Step 4: in the next step, transform the real elements of matrix R into the fuzzy numbers

Step 5: before conducting all the calculation of vector of priorities, the comparison matrix D has to be normalized by Eq. (13)

Step 6: Compute the fuzzy geometric mean for each criterion.

The geometric technique is used to calculate the geometric mean of the fuzzy comparison values of criterion to each criterion, as shown in Eq. (20), where r_i is a fuzzy value of the pair-wise comparison of criterion i to criterion n (Buckley, 1985)

$$r_i = [r_{i1}, r_{i2}, \dots, r_{in}] \quad (14)$$

Step 7: compute the fuzzy weight by normalization. The fuzzy weight of the criterion can be derived as Eq. (15), where $\tilde{w}_i$ denoted as $\tilde{w}_i = (L_{w_i}, M_{w_i}, U_{w_i})$ by a TFN and

$L_{w_i}, M_{w_i}, U_{w_i}$ represent a lower, middle, upper value of the fuzzy weight of the i -th criterion.

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \dots \tilde{r}_n)^{-1} \quad (15)$$

D. Fuzzy Topsis method

Topsis was developed by Hwang and Yoon (1980). Topsis method is based on choosing the best alternative, which has the shortest distance from the positive ideal-solution (PIS) and has the longest from the negative ideal-solution (NIS) for solving problem. In this study, the combination between Topsis and fuzzy number has been applied. The general step-by-step procedure using Fuzzy Topsis method is briefly listed as follow

Step 1: The Fuzzy MCDM can be concisely expressed in the matrix format as follow:

$$X = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_j & \dots & C_m \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{matrix} & \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2j} & \dots & x_{2m} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ x_{i1} & x_{i2} & \dots & x_{ij} & \dots & x_{im} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nj} & \dots & x_{nm} \end{bmatrix} \end{matrix}$$

$$\tilde{w} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)^t$$

If the expert's opinions are evaluated by k th persons, we will calculate the average value as the following Eq. (26)

$$x_{ij} = (1/k)(x_{ij}^1 + x_{ij}^2 + \dots x_{ij}^k) \quad (26)$$

Where A_i denotes by the alternatives, $i=1, 2, \dots, n$; C_j denotes by the criteria, $j=1, 2, \dots, m$. The fuzzy linguistic rating x_{ij} is a fuzzy value indicating the performance rating of the alternative A_i with respect to each criterion C_j . If x_{ij} preserves the property that the range of normalized fuzzy number belong to $[0, 1]$, there is no need for normalization. Decision matrix is normalized as following Eq. (19)

Step 2: calculated the weighted normalization fuzzy decision matrix by multiplying the normalized decision matrix by its association weighted. The weighted normalized value is $\tilde{v}_{ij}$ calculated by (26)

$$\tilde{v}_{ij} = \tilde{w}_i \times \tilde{r}_{ij} \quad (26)$$

$$\tilde{V} = [\tilde{v}_{ij}]_{nm}$$

$$(27)$$

Where $i=1, 2, \dots, n$ and $j=1, 2, \dots, m$.

Step 3: calculate the distance of each alternative from A^* and A^- using the following equation:

$$D_j^* = \sum_j^m d(\tilde{v}_{ij}, \tilde{v}_i^*) \quad (28)$$

$$D_j^- = \sum_j^m d(\tilde{v}_{ij}, \tilde{v}_i^-) \quad (29)$$

where $j=1, 2, \dots, m$.

Step 4: Identify positive ideal A^* and negative ideal solution A^- . The fuzzy positive ideal and fuzzy negative ideal solution are shown in the following Equation.

$$A^* = \{\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_i^*\} = \{(max_j v_{ij} \mid i \in B), (min_j v_{ij} \mid i \in C)\} \quad (30)$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_i^-\} = \{(min_j v_{ij} \mid i \in B), (max_j v_{ij} \mid i \in C)\} \quad (31)$$

where $i=1, 2, \dots, i$ and $j=1, 2, \dots, j$.

Where B is associated with benefit criteria and C is associated with cost criteria.

Step 5: calculate the relative closeness to the ideal solution

$$CC_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad j=1, 2, \dots, m. \quad (32)$$

Step 6: Rank preference order. Rank alternatives according to CC_j in descending order.

IV. A NUMERICAL APPLICATION FROM THE TAIWAN STOCK EXCHANGE

In this research, we first base on the criteria and ratios of the financial statement to prepare a list of performance evaluation indicators, and then have a survey with the experts in related financial areas in Taiwan. A questionnaire is designed using the AHP and TOPSIS questionnaire format, the criteria and ratios of the financial statement and the selected companies are included. The results can provide some suggestions and orientation to investors in developing their investment strategies in the future.

For selecting operation system, four main criteria and seven sub-criteria are used in application. Regarding the evaluation of the firm's financial statement, three experts were invited to survey five alternatives. After the construction of hierarchy, the different priority weights of each criterion attribute and alternatives are calculated using the fuzzy AHP and Fuzzy TOPSIS approaches. The comparison of the importance or preference of one criterion, attribute or alternative over another can be done with the help of the survey questionnaire. The method of calculating priority

weights of the difference decision alternatives is presented below.

We transfer the linguistic scales to the corresponding fuzzy numbers (as Appendix A). Computing the elements of synthetic pair-wise comparison matrix by using the geometric mean method suggested by Buckley (1985) that is:

$$\begin{aligned} \tilde{a}_{ij} &= (\tilde{a}_{ij}^1 \otimes \tilde{a}_{ij}^2 \otimes \tilde{a}_{ij}^3)^{1/3} \tilde{a}_{12} \\ &= [(5,6,7) \otimes (6,7,8) \otimes (2,3,4)]^{1/3} \\ &= (3.91, 5.01, 6.07) \end{aligned}$$

TABLE III. WEIGHT OF DIMENSIONS

No.	Criteria	Weights	BNP	Rank
S1	Current ratio	(0.185, 0.284, 0.372)	0.281	1
S2	Debt ratio	(0.185, 0.234, 0.299)	0.239	2
S3	Equity/Debt ratio	(0.091, 0.123, 0.165)	0.126	4
S4	Operation profit ratio	(0.091, 0.122, 0.167)	0.127	3
S5	Income before tax ratio	(0.095, 0.115, 0.153)	0.121	5
S6	Net income revenue	(0.058, 0.072, 0.094)	0.075	6
S7	Return on total asset ratio	(0.054, 0.051, 0.068)	0.058	7

It can be obtained the other matrix elements by the same computational procedure; therefore, the synthetic pair-wise comparison matrix of the five representatives will be constructed as follows matrix D

To apply the COA method to compare the BNP value of the fuzzy weights of each dimension: to take the BNP value of the weight of S1 (current ratio) as an example, the calculation process is as follows:

$$\begin{aligned} BNP_{S1} &= \frac{[(U_{w1} - L_{w1}) + (M_{w1} - L_{w1})]}{3} + L_{w1} \\ &= \frac{[(0.372 - 0.185) + (0.284 - 0.185)]}{3} \\ &\quad + 0.185 = 0.281 \end{aligned}$$

Then, the weights for the remaining dimensions can be found as shown in table 4. This table shows the relative weight of eight dimensions of the evaluation of the companies, which obtained by Fuzzy AHP method.

(1,1,1)	(3.91,5.01,6.07)	(4.64,5.65,6.65)	(2.88,4.12,5.24)	(1.49,1.82,2.19)	(0.79,1.17,1.55)	(1.10,1.44,1.82)
(0.25,0.20,0.26)	(1,1,1)	(3.78,4.82,5.85)	(5.19,6.21,7.23)	(1.67,1.69,2.08)	(1.91,1.71,1.98)	(4.31,5.31,6.32)
(0.26,0.18,0.22)	(0.28,0.21,0.26)	(1,1,1)	(2.62,3.83,4.93)	(0.83,1.49,2.08)	(1.14,1.33,1.59)	(2.62,3.63,4.64)
(0.150,0.24,0.35)	(0.24,0.16,0.19)	(0.30,0.26,0.38)	(1,1,1)	(3.91,5.01,6.07)	(3.63,4.72,5.77)	(2.88,4.12,5.24)
(0.48,0.55,0.67)	(0.48,0.59,0.75)	(0.48,0.67,1.00)	(0.31,0.20,0.26)	(1,1,1)	(6.21,7.23,8.24)	(2.88,2.00,2.38)
(0.61,0.85,1.26)	(0.51,0.58,0.69)	(0.63,0.75,0.94)	(0.26,0.21,0.28)	(0.22,0.14,0.16)	(1,1,1)	(1.82,2.11,2.43)
(0.87,0.69,0.91)	(0.29,0.19,0.23)	(0.37,0.28,0.38)	(0.35,0.24,0.35)	(0.42,0.50,0.60)	(0.85,0.47,0.55)	(1,1,1)

In order to calculate the closeness coefficients of each of the alternatives. The values d_1^+ and d_1^- can be calculated as a follows:

$$d_1^+ = \sum \sqrt{[(0.074 - 1)^2 + (0.170 - 1)^2 + (0.289 - 1)^2]} \frac{1}{3} + \dots$$

$$+ \sqrt{[(0.021 - 1)^2 + (0.030 - 1)^2 + (0.055 - 1)^2]} \frac{1}{3}$$

$$= 6.281$$

$$d_1^- = \sum \sqrt{[(0.074 - 0)^2 + (0.170 - 0)^2 + (0.289 - 0)^2]} \frac{1}{3} + \dots$$

$$+ \sqrt{[(0.021 - 0)^2 + (0.030 - 0)^2 + (0.055 - 0)^2]} \frac{1}{3} = 0.799$$

Once the distances from FPIS and FNIS are determined, the closeness coefficient can be obtained with (32). The index CC_1 of first alternative is calculated as:

$$CC_1 = \frac{0.799}{0.799 + 6.281} = 0.113$$

The other results are shown in table 5.

TABLE IV. CLOSNESS COEFFICIENTS AMONG DIFFERENT COMPANIES

Company	d+	d-	Satisfaction of CC_1^-	Rank
China Steel	6.281	0.799	0.113	5
Cathay	6.277	0.805	0.114	4
TSMC	6.225	0.855	0.121	2
Acer	6.208	0.869	0.123	1
Asus	6.256	0.821	0.116	3

V. CONCLUSION

The result of this study can offer us the way to select the best company among the company group. It help the people to invest the best one based on analyzing the information from financial report and applying fuzzy MCDM method. The new point of this study is that the user only needs some basic knowledge of finance to construct the criteria hierarchy, and the necessary result will be obtained. This method used in the study can also be applied to other industries only the considered criteria may be different. For example, solvency ratios are very important with banks. However, they are less

important than with manufacturing company. In the future, we will try to develop or use the fuzzy MCDM method to solve the decision problems.

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