Research Journal of Applied Sciences, Engineering and Technology 4(20): 3885-3890, 2012
ISSN: 2040-7467

Submitted: December 18, 2011 Accepted: April 20, 2012 Published: October 15, 2012

A New Optimization Model about Enterprise Equipment Investment Project based on Integrated Entropy Weight and Fuzzy Matter Element

Bai Xiaoping and Fan Jia
School of Management, Xi'an University of Architecture and Technology, Xi'an 710055, China

Abstract: The equipment investment scheme evaluation of enterprise is usually multi-objective optimization problem affected by many factors. Among many optimization methods, the common fuzzy matter element is based on the matter-element analysis and combined with the concepts of fuzzy mathematics, which can reflect the subjective fuzzy judgment; the common entropy weight method makes use of the judgment matrix composed of evaluation index value, Weights gotten by the common entropy weight method mainly reflects usefulness of data and can't reflect actual importance of evaluation indexes. Considering this fact, this study integrates engineering economics, reliability theory, fuzzy matter element and entropy theory presents a new optimization model about enterprise equipment investment project and also presents detailed methods and steps of application of integrated model in concrete example, which can offer the reference for project investment activity of practical enterprise equipment.

Keywords: Entropy, equipment investment, fuzzy matter element, multi-objective evaluation, optimization, subjective judgment

INTRODUCTION

Investment activity of enterprise equipment is usually multi-objective optimization decision-making problem affected by many factors. The most optimal investment scheme should be gotten by multi-objective decision-making method. By making use of existed relevant references, integrates engineering economics, reliability theory, fuzzy matter element and entropy theory presents a new optimization model about enterprise equipment investment project.

RELEVANT RESEARCHES

In reference Li *et al.* (2009), a new assessment model, the fuzzy matter-element model, is proposed based on the theory of improved membership degree, the character of water resources carrying capacity and the context of multiple attribute assessment standards (Li *et al.*, 2009). In Zhang *et al*. (2011), a comprehensive evaluation method based on fuzzy matter element analysis is proposed to solve problems of multiple performance and quality evaluation for computer numerical control equipment (Zhang *et al*., 2011). In Luo *et al*. (2009), authors combine the entropy weight theory with fuzzy evaluation method, set up comprehensive evaluation model about construction scheme of roller compacted concrete dam and presents application methods of this model in a real roller compacted concrete dam construction (Luo *et al*., 2009). In Wang (2007), the author makes use of basic ideas of information entropy weight and operational research to build a new entropy weight optimization model in view of particularity of real estate investment project and applies practical data of in real estate investment project in Shanghai to verify validity of the model (Wang, 2007). In Qian and Rao (2009), the author establishes an entropy weight multi-object decision model to evaluate water environmental quality. By contrast with others evaluation methods, the entropy weight multi-object decision evaluation method is found to be proved to be effective (Qian and Rao, 2009). In Wang (2006), the author applies the principle of maximum entropy in risk assessment of real estate investment to study quantitatively risk effect factors of partial real estate investment project and establishes a maximum entropy risk analysis mode combined with the practical example (Wang, 2006) and etc (Lu *et al.*, 2010; Fu *et al.*, 2010; Hsiao *et al.*, 2011; Ahn, 2011; Huynh *et al.*, 2010; Raid, 2010; Kumar *et al.*, 2009; Yager and Ronald, 2009; Tan and Ma, 2009). In summary, entropy weight method has been widely used in many fields. For more effectively being used, the common entropy weight method usually need be improved. Project investment activity of enterprise equipment has the particularity; this study improves the common entropy weight method combined with this particularity and presents detailed

Corresponding Author: Bai Xiaoping, School of Management, Xi'an University of Architecture and Technology, Xi'an 710055, China

Table 1: Some relevant data of three invested equipments

	A equipment	B equipment	C equipment
Purchase cost (unit: ten thousand Yuan)	40	48	78
Estimated service life (unit: years)	8	10	12
Estimated annual make profit (unit: ten thousand Yuan)	20	24	38
The operation cost of the first year (unit: ten thousand Yuan)	5	7	10
The annual increased operation cost after the first year (unit: ten thousand Yuan)	1	1	2

methods and steps evaluating project investment schemes of enterprise equipment according to concrete example.

Analysis on fuzzy matter element and entropy weight method: The common fuzzy matter element is based on the matter-element analysis and combined with the concepts of fuzzy mathematics, which can reflect the subjective fuzzy judgment.

Entropy is originally a thermodynamic property that can be used to determine the energy not available for useful work in a thermodynamic process, such as in energy conversion devices, engines, or machines. Such devices can only be driven by convertible energy and have a theoretical maximum efficiency when converting energy to work. During this work, entropy accumulates in the system, but has to be removed by dissipation in the form of waste heat. In information theory, entropy is a measure of the uncertainty associated with a random variable. In this context, the term usually refers to the Shannon entropy, which quantifies the expected value of the information contained in a message, usually in units such as bits.

Weights gotten by the common entropy mainly reflects usefulness of data.

The concrete case about project investment evaluation of enterprise equipment: A certain enterprise intends to engage in investment activity of equipment because of requirement. There are three kinds of similar equipments, called respectively as equipment A, equipment B and equipment C. By market investigating and material collecting, we can get some relevant data of three invested equipments, shown as Table 1.

Supposing the basic return rate is 10%, the tax rate is 33%; the average service life method is used to calculate the depreciation. The enterprise has determined to select a kind of equipment from equipment A, equipment B and equipment C to invest. The optimal investment decision making scheme need be selected.

SELECTING AND COMPUTING EVALUATION INDEXES

Selecting evaluation indexes: By analyzing actual situation of enterprise, the evaluation index system including 9 indexes selected in this study is shown as Fig. 1.

Computing Evaluation Indexes: This study selects 5 indexes including economic life (C_1), average annual yield (C_2), profitability index

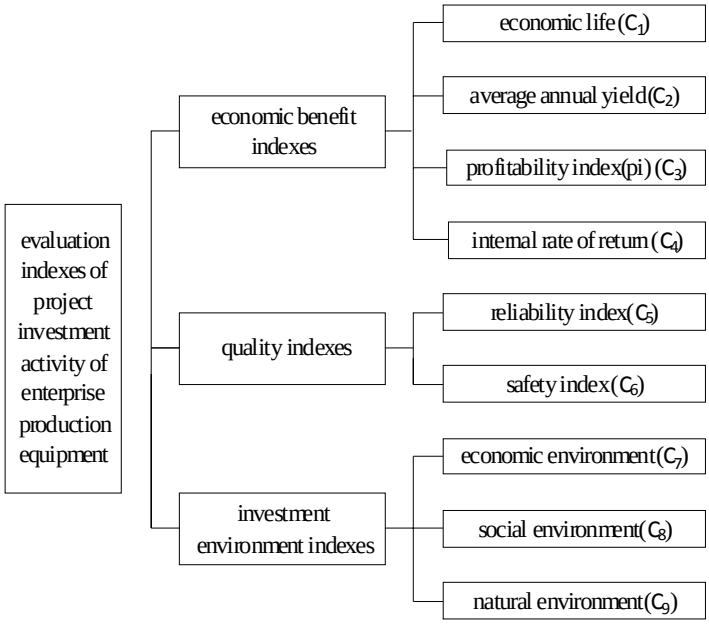

Fig. 1: The evaluation index system of project investment activity of enterprise equipment

(pi) (C_3), internal rate of return (C_4) and reliability index (C_5) as quantitative indexes to calculate their value according to relevant engineering economics and reliability theories.

In addition, this study selects 4 indexes including safety index (C_6), economic environment (C_7), social environment (C_8), natural environment (C_9) to as qualitative indexes calculate their value by expert scoring method. On adopting expert scoring method, virtue or defect degrees of indexes are distinguished as 4 grades, such as good, somewhat good, general, bad, assigned respectively value 1.0, 0.8, 0.6 and 0.4.

Invite experts familiar with investment industry and market situation to estimate score value of safety index (C_6), economic environment (C_7), social environment (C_8), natural environment (C_9) of equipment A, equipment B and equipment C, by many times opinions statistics, analysis, summary and feedback , score value of four indexes can be gotten, shown as Table 2.

In sum, authors integrate engineering economics and reliability theories with expert scoring method to get value of all nine indexes, shown as Table 3.

ESTABLISHING OPTIMIZATION MODEL BASED ON INTEGRATED ENTROPY WEIGHT AND FUZZY MATTER ELEMENT

Building fuzzy matter element model: Supposing there is an optimization problem that has m investment schemes and n evaluation indexes in the enterprise.

The fuzzy matter element evaluation index matrix: The m investment schemes can be looked as m elements, among them every one can be described by n-dimensional fuzzy matter elements. So the fuzzy matter element evaluation index matrix of investment projects is:

$$R = \begin{bmatrix} x_{11} & x_{21} & \cdots & x_{m1} \\ x_{12} & x_{22} & \cdots & x_{m2} \\ \vdots & \vdots & & \vdots \\ x_{1n} & x_{2n} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

The optimal subordinate degree: The corresponding fuzzy value of each evaluation index is subject to the corresponding fuzzy value of each evaluation index in standard case, which subordinate degree is called as optimal subordinate degree, which can be shown as u_{ij}(i = 1, 2, …, m; j = 1, 2, …, n)

For bigger-more-optimal evaluation index, u_{ji} can be calculated by:

$$U_{ij} = x_{ij} / max\ x_{ij} \quad (2)$$

For less-more-optimal evaluation index, u_{ji} can be calculated by:

Table 2: Score value of four qualitative indexes

	A equipment	B equipment	C equipment
Safety index (C_6)	0.9	0.85	0.93
Economic environment (C_7)	0.95	0.8	0.85
Social environment (C_8)	0.85	0.75	0.8
Natural environment (C_9)	0.85	0.87	0.82

Table 3: Calculate value of all 9 indexes

	Equipment A	Equipment B	Equipment C
Economic life (C_1) (year)	7.00	10.00	7.00
Average annual yield (C_2)(C_2) (ten thousand Yuan)	2.19	2.66	3.58
Profitability index (pi) (C_3)	1.29	1.34	1.31
Internal rate of return (C_4) (%)	18.53	18.58	17.71
Reliability (C_5)	0.93	0.90	0.86
Safety (C_6)	0.90	0.85	0.93
Economic environment (C_7)	0.95	0.80	0.85
Social environment (C_8)	0.85	0.75	0.80
Natural environment (C_9)	0.85	0.87	0.82

$$U_{ij} = \min x_{ij}/x_{ij} \quad (3)$$

So the fuzzy matter element of composite optimal subordinate degree can be calculated by:

$$\tilde{R}_{mn} \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & u_{11} & u_{21} & \cdots & u_{m1} \\ C_2 & u_{12} & u_{22} & \cdots & u_{m2} \\ \vdots & \vdots & \vdots & & \vdots \\ C_n & u_{1n} & u_{2n} & \cdots & u_{mn} \end{bmatrix} \quad (4)$$

The difference square composite fuzzy matter element: Standard fuzzy matter element R_{0n} is maximum value or minimum value of the preferred membership grade of evaluating samples. In this study, the maximum value is selected.

If Δ_{ij} is used to indicate the absolute of differences of the corresponding values between standard fuzzy matter element and compound fuzzy matter-element of optimal subordinate degree, then the difference square composite fuzzy matter element R_Δ can be calculated by:

$$R_\Delta = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & \Delta_{11} & \Delta_{21} & \cdots & \Delta_{m1} \\ C_2 & \Delta_{12} & \Delta_{22} & \cdots & \Delta_{m2} \\ \vdots & \vdots & \vdots & & \vdots \\ C_1 & \Delta_{1n} & \Delta_{2n} & \cdots & \Delta_{mn} \end{bmatrix} \quad (5)$$

where, $\Delta_{i9} = (u_{0n}\text{----}u_{in})^2$

Detailed computing steps of entropy weight: Regarding a multi-objective decision making problem that has m selected schemes and n evaluation indexes, detailed computing steps of Entropy weight are as follows.

- Establishes evaluation index matrix including each evaluation index and corresponding evaluation value:

$$A = (a_{ij})_{m\times n} \tag{6}$$

- Standardizes evaluation index matrix by following formula.

For the index that bigger is always better, the standardized value r_{ij} of the evaluation index can be calculated by:

$$r_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}} \tag{7}$$

For the index that smaller is always better, the standardized value rij of the evaluation index can be calculated by:

$$r_{ij} = \frac{\max a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}} \tag{8}$$

So the standardized decision-making matrix ($R = (r_{ij})_{m\times n}$, $r_{ij}\in[0, 1]$) can be gotten.

Calculates the entropy value of each evaluation index:

$$H_j = -k\sum_{i=1}^{m} f_{ij} 1n\, f_{ij} \text{ (j = 1… n)}$$

$$(f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}, k = \frac{1}{1nm}) \tag{9}$$

Calculates objective weight ω_j of each evaluation index:

$$\omega_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{10}$$

Improvements of common entropy weight method: Because the information Entropy weight main reflect data usefulness, combined weights integrated by the information Entropy weight with subjective importance weight given by experts of each evaluation index can obtain more scientifically rational result. The subjective importance weight of each evaluation index can be given by Delphi method, Analysis Hierarchy Process (AHP), fuzzy evaluation method or other correlative methods Supposed the subjective importance weight vector is:

$$V = (v_1, v_2\ldots v_m) \tag{11}$$

Combined weights λ_j can be calculated by:

$$\theta_j = \frac{\omega_j v_j}{\sum_{j=1}^{n} \omega_j v_j} \tag{12}$$

The integrated optimization model based on entropy weight and fuzzy matter element: Supposes Euclid approach degree composite fuzzy matter element is $R_{\rho h}$, which can be calculated by:

$$R_{\rho h} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ \rho h_i & \rho h_1 & \rho h_2 & \cdots & \rho h_m \end{bmatrix} \tag{13}$$

where,

$$\rho h_i = 1 - \sqrt{\sum_{j=1}^{n} (\theta_j \cdot \Delta_{ij})} (i = 1, 2, \ldots, m)$$

The evaluation schemes can be ordered by their Euclid approach degree ρh_i, the one whose Euclid approach degree is biggest is thought as the optimal scheme because it is most close to the standard scheme.

Detailed case computing of integrated model:

- Computing composite fuzzy matter element $R_{9\times3}$ including 3 investment schemes and 9 evaluation indexes by Table 3:

$$R_{9\times3} = \begin{bmatrix} & M_1 & M_2 & M_3 \\ C_1 & 7.00 & 10.00 & 7.00 \\ C_2 & 2.19 & 2.66 & 3.58 \\ C_3 & 1.29 & 1.34 & 1.31 \\ C_4 & 18.53 & 18.58 & 17.71 \\ C_5 & 0.93 & 0.90 & 0.86 \\ C_6 & 0.90 & 0.85 & 0.93 \\ C_7 & 0.95 & 0.80 & 0.85 \\ C_8 & 0.85 & 0.75 & 0.80 \\ C_9 & 0.85 & 0.87 & 0.82 \end{bmatrix}$$

- **Computing optimal subordinate degree fuzzy matter element:** The 9 evaluation indexes including economic life (C_1), average annual yield (C_2), profitability index (pi) (C_3), internal rate of return (C_4), reliability index (C_5), safety index (C_6), economic environment (C_7), social environment (C_8) and natural environment (C_9) all belong to bigger-more-optimal evaluation ones, so the optimal

subordinate degree fuzzy matter element can be calculated by the formula (2) and (4), the result is:

$$\tilde{R}_{9\times 3} = \begin{bmatrix} & M_1 & M_2 & M_3 \\ C_1 & 0.378 & 0.538 & 0.395 \\ C_2 & 0.118 & 0.143 & 0.202 \\ C_3 & 0.070 & 0.072 & 0.074 \\ C_4 & 1.000 & 1.000 & 1.000 \\ C_5 & 0.050 & 0.048 & 0.049 \\ C_6 & 0.049 & 0.046 & 0.053 \\ C_7 & 0.051 & 0.043 & 0.048 \\ C_8 & 0.046 & 0.040 & 0.045 \\ C_9 & 0.046 & 0.047 & 0.046 \end{bmatrix}$$

- **Computing the difference square composite fuzzy matter element R_Δ:** The difference square composite fuzzy matter element R_Δ can be calculated by the formula (5), for practical case, the computing result is:

$$R_\Delta = \begin{bmatrix} & M_1 & M_2 & M_3 \\ C_1 & 0.387 & 0.213 & 0.366 \\ C_2 & 0.778 & 0.734 & 0.637 \\ C_3 & 0.866 & 0.861 & 0.858 \\ C_4 & 0.000 & 0.000 & 0.000 \\ C_5 & 0.902 & 0.905 & 0.905 \\ C_6 & 0.905 & 0.911 & 0.898 \\ C_7 & 0.900 & 0.916 & 0.906 \\ C_8 & 0.910 & 0.921 & 0.912 \\ C_9 & 0.910 & 0.909 & 0.910 \end{bmatrix}$$

Detailed computing steps of concrete case about project investment evaluation of enterprise equipment are shown as follows:

- Establishes evaluation index matrix including 9 evaluation index and 3 selected schemes and their corresponding evaluation value by the formula (6):

$$\alpha_{3\times 9} \begin{bmatrix} 7.00 & 2.19 & 1.29 & 18.53 & 0.93 & 0.90 & 0.95 & 0.85 & 0.85 \\ 10.00 & 2.66 & 0.34 & 18.58 & 0.90 & 0.85 & 0.80 & 0.75 & 0.87 \\ 7.00 & 3.58 & 0.31 & 17.71 & 0.86 & 0.93 & 0.85 & 0.80 & 0.82 \end{bmatrix}$$

- **Standardization of evaluation index matrix:** Nine indexes are all positive indexes, that is, the better the index value is bigger. Standardization value of indexes can be gotten by the formula (7), so the whole standardization decision matrix is shown as follows:

$$\dot{R}_{3\times 9} \begin{bmatrix} 0.000 & 0.000 & 0.000 & 0.943 & 1.000 & 0.625 & 1.000 & 1.000 & 0.600 \\ 1.000 & 0.338 & 1.000 & 1.000 & 0.571 & 0.000 & 0.000 & 0.000 & 1.000 \\ 0.000 & 1.000 & 0.400 & 0.000 & 0.000 & 1.000 & 0.333 & 0.500 & 0.000 \end{bmatrix}$$

- **Computing the entropy value of each evaluation index:** By the formula (9), the computing result of entropy value of evaluation indexes is:

$k = 1/1n3 = 0.91$

$(f_{11}, f_{21}, f_{31}) = (0, 1, 0)$
$(H_1, H_2, H_3, H_4, H_5, H_6, H_7, H_8, H_9)$
$= (0, 0.515, 0.545, 0.630, 0.597, 0.606, 0.512, 0.579, 0.602)$

- **Computing combined weights:** By the formula (9) and (10)

$$\sum_{j=1}^{9} H_j = (0.000 + 0.515 + 0.545 + 0.630 + 0.597 + 0.606 + 0.512 + 0.579 + 0.602) = 4.586$$

$$\omega_1 = \frac{1 - H_1}{9 - \sum_{j=1}^{9} H_j} = \frac{1 - 0.000}{9 - 4.586} = 0.227$$

Similarly, $\omega_2 = 0.110$, $\omega_3 = 0.103$, $\omega_4 = 0.084$, $\omega_5 = 0.091$, $\omega_6 = 0.089$, $\omega_7 = 0.111$, $\omega_8 = 0.095$, $\omega_9 = 0.090$. By detailed investigation and analysis, subjective weights of nine indexes can be gotten, such as:

$\upsilon_1 = 0.95$, $\upsilon_2 = 0.95$, $\upsilon_3 = 0.85$, $\upsilon_4 = 0.85$, $\upsilon_5 = 0.90$, $\upsilon_6 = 0.85$, $\upsilon_7 = 0.80$, $\upsilon_8 = 0.75$, $\upsilon_9 = 0.70$

Therefore,

$$\sum_{j=1}^{9} \omega_j \upsilon_j = (0.227 \times 0.95 + 0.110 \times 0.95 + 0.103 \times 0.85 + 0.084 \times 0.85 + 0.091 \times 0.90 + 0.089 \times 0.85 + 0.111 \times 0.80 + 0.095 \times 0.75 + 0.090 \times 0.70) = 0.860$$

$$\theta_1 = \frac{\omega_1 \upsilon_1}{\sum_{i=1}^{9} \omega_1 \upsilon_1} = \frac{0.227 \times 0.95}{0.860} = 0.255$$

Similarly, $\theta_2 = 0.124$, $\theta_3 = 0.104$, $\theta_4 = 0.084$, $\theta_5 = 0.097$, $\theta_6 = 0.090$, $\theta_7 = 0.105$, $\theta_8 = 0.085$, $\theta_9 = 0.075$ So combined weights of evaluation indexes are:

$$\theta_j = (\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7, \theta_8, \theta_9)$$
$$= (0.255, 0.1\ 24, 0.104, 0.084, 0.097\ \ 0.090, 0.1\ \ 05, 0.085, 0\ \ 0.75)$$

- Computing Euclid approach degree composite fuzzy matter element $R_{\rho h}$ by the formula (5), (12) and (13), shown as:

$$R_{\rho h} = \begin{bmatrix} & M_1 & M_2 & M_3 \\ \rho h_i & 0.167 & 0.196 & 0.181 \end{bmatrix}$$

- **The optimization evaluation of investment schemes:** The scheme whose Euclid approach degree is biggest is thought as the optimal scheme because it is most close to the standard scheme, so the scheme 2, that is, the investment of equipment B is the optimum scheme.

CONCLUSION

By above calculation result, three project schemes including equipment A, equipment B and equipment C can be selected according to such sequence: B scheme>C scheme>A scheme. Generally, project investment of enterprise equipment is usually multi-objective optimization decision-making problem affected by many factors. This study integrates engineering economics, reliability theory, fuzzy matter element and entropy theory presents a new optimization model about enterprise equipment investment project and also presents detailed methods and steps of application of integrated model in practical case, which can offer the reference for project investment activity of practical enterprise equipment.

ACKNOWLEDGMENT

This research study was supported by Shanxi Province Natural Science Basic Foundation (2010JM7004) and Shanxi Province Key Discipline Construction Special Fund subsidized project.

REFERENCES

Ahn , B.S., 2011. Compatible weighting method with rank order centroid: Maximum entropy ordered weighted averaging approach. Europ. J. Oper. Res., 212(3): 552- 559.

Fu , Z.Q., Q.Y. Ou and C.L. Ma, 20 10. A study on scheme choice for the communications safety equipment based on fuzzy theory and entropy weights. Comput. Digital Eng., 38(5): 92- 95.

Huynh , V. N., L. Tri Thanh and A. L. Cuong, 2010. Adaptively entropy- based weighting classifiers in combinatio n using Dempster- Shafer theory for word sense disambiguation. Comput. Speech Language, 24(3): 461- 473.

Hsiao , B., C.C. Chern and C.R. Chiu, 2011. Performance evaluation with the entropy- based weighted Russell measure in data envelopment analysis. Exp. Syst. Appli., 38(8): 9965- 9972.

Kumar , C., P. Prasad and V. Vasudeva, 2009. A light-weight summarizer based on language model with relative entropy. Proceedings of the ACM Symposium on Applied Computing, pp: 1752- 1753.

Li , J .Q., X.H. Yang and G.H. Lu, 2009. Fu zzy matter-element model based on improved membership degree for comprehensive assessment of water resources carrying capacity in river basins. J. Hydroel. Eng., 28 (1): 78 - 83 .

L uo , W., Z.G. H u , W.H. P eng , Q. L iu , X. W u and J.H. W en , 2009. Construction plan of roller compacted concrete dam based on entropy weight multi- objective decision. Eng. J. Wuhan U., 42 (2): 201- 204.

Lu , S.B., Q. Huang, X.Y. Sun and C.G. Wu, 2010. The applied research of entropy proportion in the tendering procedures. J. Hydroel. Eng., 29(3): 221-224.

Q ian , Q .S. and Q.H. R ao , 2009. Application of multi-object decision model based on entropy weight to evaluate the water environmental quality. Env. Sci. Surv., 44 (3): 90- 92.

Raid , A. A., 2010. A combined ahp- entropy method for deriving subjective and objective criteria weights. Int. J. Ind. Eng. Theor. Appl. Pract., 17 (1): 12- 24.

Tan , X.C. and Y.S. Ma, 2009. Applicat ion of fuzzy matter- element for water quality evaluation. J. Sichuan U., 41(2): 368- 372.

Yager and R. Ronald, 2009. Weighted maximum entropy OWA aggregation with applications to decision making under risk. IEEE Trans. Syst. Man Cy. A, 39 (3): 555- 564.

Wang , Y.T., 2006. Study on Application of entropy-weight method to investment decision in real estate. MA. Thesis, Wuhan University of Technology, pp: 18- 26.

Wang , J.W., 2007. Study of investment risk evaluation in real estate based on entropy weight. MA. Thes is, Qingdao University, pp: 21- 28.

Zhang , G.B., J.H. Pang, G.H. Chen and H.Y. Ge, 2011. A comprehensive evaluation method of fuzzy matter element for CNC equipment quality. J. Chongqing U., 34(1): 36- 41.