World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:1, No:6, 2007

Project Selection by Using Fuzzy AHP and TOPSIS Technique

S. Mahmoodzadeh, J. Shahrabi, M. Pariazar, and M. S. Zaeri

***Abstract*—**In this article, by using fuzzy AHP and TOPSIS technique we propose a new method for project selection problem. After reviewing four common methods of comparing alternatives investment (net present value, rate of return, benefit cost analysis and payback period) we use them as criteria in AHP tree. In this methodology by utilizing improved Analytical Hierarchy Process by Fuzzy set theory, first we try to calculate weight of each criterion. Then by implementing TOPSIS algorithm, assessment of projects has been done. Obtained results have been tested in a numerical example.

***Keywords*—**Fuzzy AHP, Project Selection, TOPSIS Technique.

I. INTRODUCTION

ENGINEERING economics is the application of economic techniques to the evaluation of design and engineering alternatives. The role of engineering economics is to assess the appropriateness of a given project, estimate its value, and justify it from an engineering standpoint. The purpose of engineering economy is to explain the methods which are widely used for evaluation of projects. Engineering economy deals with the methods used in evaluation of projects. The main objective is to determine the "best" project or projects.

There is a large literature dedicated to the project selection problem. It includes several approaches, which take into account various aspects of the problem. Strategic intent of the project, factors for project selection, and various qualitative and quantitative project selection models has been thoroughly discussed by Meredith and Mantle [1].

Danila [2] and Shpak and Zaporojan [3] surveyed some of the project selection methodologies. Various articles discussed application of operation research tools in project selection. Mehrez and Sinuany-Stern [4] used utility function. Khorramshahgole and Steiner [5] and Dey et al. [6] applied Goal programming. Chu et al. [7] demonstrated project selection process using fuzzy theory. Project selection decision and fund allocation problem using 0–1 mathematical modeling was discussed in Lockett and Stratford [8] and Regan and Holtzman [9]. Ghasemzadeh et al. [10] and Ghasemzadeh and Archer [11]. Proposed a 0–1 integer linear programming model for selecting ad scheduling an optimal project portfolio, based on organization's objectives and constraints. AHP has been used by many authors to resolve decision-making issues in project selection (Dey and Gupta, [12]; Mian and Christine, [13]). Project selection issues have been discussed in various management functions like in research and development (Loch and Kavadias, [14]), environmental management (Eugene and Dey, [15]), and quality management (Hariharan et al., [16]). Projects are unique in nature. Hence, each model has its own pros and cons for various applications.

In our methodology first by using improved AHP with fuzzy set theory, the weight of each criterion is calculated. Then this article introduces a model that integrates improved fuzzy AHP with TOPSIS algorithm to support project selection decisions.

The fuzzy AHP is the fuzzy extension of AHP to efficiently handle the fuzziness of the data involved in the decision making. It is easier to understand and it can effectively handle both qualitative and quantitative data in the multi-attribute decision making problems. In this approach triangular fuzzy numbers are used for the preferences of one criterion over another and then by using the extent analysis method, the synthetic extent value of the pairwise comparison is calculated [17].

Other sections of the article are as follows: In section II, Criteria for selection of project have been mentioned. In section III, we have presented our Methodology. In section IV, numerical example has been described. Finally concluding remarks are provided in section V.

II. TIME VALUE OF MONEY

The costs and benefits of an investment occur over an extended period of time rather than at the moment of purchase. Consequently, financial analyses studies must accommodate the future effects of current decisions. According to a concept that economists call the time value of money, all things being equal, it is better to have money now rather than later.

The following are reasons why \$n today is "worth" more than \$n one year from today:
1. Inflation
2. Risk

S. Mahmoodzadeh is with Economic Department, Allameh Tabatabaee University, Tehran, Iran (corresponding author to provide. phone: +98-9122491532, e-mail: soheil.mz@gmail.com).

Dr. J. Shahrabi is with Industrial engineering Department, Amirkabir University of Technology, Tehran, Iran (e-mail: Shahrabi@dal.ca).

M. Pariazar is with Industrial engineering Department, Amirkabir University of Technology, Tehran, Iran (e-mail: m_pariazar@aut.ac.ir).

M. S. Zaeri is with Industrial engineering Department, Amirkabir University of Technology, Tehran, Iran (e-mail: zaeri@aut.ac.ir).

3. Cost of money

Of these, the cost of money is the most predictable, and, hence, it is the essential component of economic analysis. Cost of money is represented by (1) money paid for the use of borrowed money, or (2) return on investment. Cost of money is determined by an interest rate. Time value of money is defined as the time-dependent value of money stemming both from changes in the purchasing power of money (inflation or deflation) and from the real earning potential of alternative investments over time [4].

The economic and financial analysis of the project is based on the comparison of the cash flow of all costs and benefits resulting from the project's activities. There are four common methods of comparing alternative investments: (1) net present value, (2) Rate of Return, (3) Benefit-Cost analysis, and (4) Pay Back Period. Each of these is dependent on a selected interest rate or discount rate to adjust cash flows at different points in time [8].

A. Net Present Value (NPV)

Present worth is the value found by discounting future cash flows to the present or base time. In a present worth comparison of alternatives, the costs associated with each alternative investment are all converted to a present sum of money, and the least of these values represents the best alternative. Annual costs, future payments, and gradients must be brought to the present. Converting all cash flows to present worth is often referred to as discounting. Therefore, the Present Value of a future cash flow represents the amount of money today, which, if invested at a particular interest rate, will grow to the amount of the future cash flow at that time in the future. The process of finding present values is called Discounting and the interest rate used to calculate present values is called the discount rate.

The advantages of the NPV method:

• It is simpler to calculate.
• It takes into account the time value of money
• Varying discount rate (if known) throughout the project can be taken into account
• It can be used to rank alternative investments because it focuses on absolute wealth created by the project.

Limitations of the NPV

• It assumes that income comes or goes in annual bursts
• It's difficult to predict future discount rates and therefore, in many times, it assumes that the discount rate will be constant in the future.
• It is often difficult to predict future cash flows with certainty
• It ignores other factors (than quantifiable financials) that are of importance to project choice. Yet these other non-financially quantifiable factors may include socio responsibility and strategic issues [12].

B. Rate of Return

The internal rate of return (ROR) method of analyzing a major purchase or project allows you to consider the time value of money. Rate of return is, by definition, the interest rate at which the present worth of the net cash flow is zero. Computationally, this method is the most complex method of comparison. If more than one interest factor is involved, the solution is by trial and error. The calculated interest rate may be compared to a discount rate identified as the "minimum attractive rate of return" or to the interest rate yielded by alternatives. Rate-of-return analysis is useful when the selection of a number of projects is to be undertaken within a fixed or limited capital budget. The internal rate of return does not require you to predict future discount rates. That would seem to make the internal rate of return the more useful (or less uncertain) measure.

Limitations of ROR

• It does not help much in ranking projects of differing sizes or levels of investments. (Otherwise, incremental cash flows between investments should be used instead)
• Non-conventional cash flows will produce multiple RORs [15].

C. Benefit-Cost Analysis

Economists traditionally adopt an analytical framework known as cost-benefit analysis (CB) to assess the net benefit of a project. Benefit-cost analysis, also referred to as cost-benefit analysis, is a method of comparison in which the consequences of an investment are evaluated in monetary terms and divided into the separate categories of benefits and costs. The amounts are then converted to annual equivalents or present worth for comparison. The important steps of a benefit-cost analysis are [10]:

1. Identification of relevant benefits and costs
2. Measurement of these benefits and costs
3. Selection of best alternative
4. Treatment of uncertainty

D. Payback Period

Probably the simplest form of financial analysis is the payback period analysis, which simply takes the capital cost of the investment and compares that value to the net annual revenues that investment would generate.

The Payback Period represents the amount of time that it takes for a Capital Budgeting project to recover its initial cost. The use of the Payback Period as a Capital Budgeting decision rule specifies that all independent projects with a Payback Period less than a specified number of years should be accepted. When choosing among mutually exclusive projects, the project with the quickest payback is preferred. Both ROR and NPV employ the notion of Time Value of Money while PBP doesn't. This would ideally mean that the ranking according to PBP is inferior, this may not necessarily always be the case though; Imagine if you are investing in a country where political transition is a huge risk. Here a project that can pay back as quickly as possible would be of priority.

The Payback Period suffers from several flaws. For instance [1]:

• It ignores the Time Value of Money,
• Does not consider all of the project's cash flows, and
• The accept/reject criterion is arbitrary.

III. Methodology

Four mentioned methods in section Π consider as criteria to evaluate and select projects. Proposed methodology has two steps: in step 1, AHP is improved by fuzzy set theory. By using fuzzy set theory in AHP method the qualitative judgment can be qualified to make comparison more intuitionistic and reduce or eliminate assessment bias in pairwise comparison process. In step 2, obtained results have been used as input weights in TOPSIS algorithm. TOPSIS algorithm by considering ideal and non ideal solution help decision maker to evaluate ranking projects and select the best one.

A. Analytical Hierarchy process (AHP)

The Analytic Hierarchy Process (AHP) is an approach that is suitable for dealing with complex systems related to making a choice from among several alternatives and which provides a comparison of the considered options. This method was first presented by Saaty [17]. The AHP is based on the subdivision of the problem in a hierarchical form. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. By reducing complex decisions to a series of simple comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts to arrive at the best decision, but also provides a clear rationale for the choices made. The objective of using an analytic hierarchy process (AHP) is to identify the preferred alternative and also determine a ranking of the alternatives when all the decision criteria are considered simultaneously [17].

Briefly, the step-by-step procedure in using AHP is the following:

1. Define decision criteria in the form of a hierarchy of objectives. The hierarchy is structured on different levels: from the top (i.e. the goal) through intermediate levels (criteria and sub-criteria on which subsequent levels depend) to the lowest level (i.e. the alternatives);

2. Weight the criteria, sub-criteria and alternatives as a function of their importance for the corresponding element of the higher level. For this purpose, AHP uses simple pair-wise comparisons to determine weights and ratings so that the analyst can concentrate on just two factors at one time.

3. After a judgment matrix has been developed, a priority vector to weight the elements of the matrix is calculated. This is the normalized eigenvector of the matrix.

The use of AHP instead of another multi-criteria technique is due to the following reasons:

1. Quantitative and qualitative criteria can be included in the decision making.
2. A large quantity of criteria can be considered
3. A flexible hierarchy can be constructed according to the problem.

B. Fuzzy Sets Theory and Fuzzy AHP

To deal with vagueness of human thought, Zadeh [18] first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. A tilde "~" will be placed above a symbol if the symbol represents a fuzzy set. Therefore, $\tilde{P}, \tilde{r}, \tilde{n}$ are all fuzzy sets. The membership functions for these fuzzy sets will be denoted by $\mu(x|\tilde{p})$, and $\mu(x|\tilde{n})$ respectively. A triangular fuzzy number (TFN), $\tilde{M}$, is shown in Fig. 1. A TFN is denoted simply as $(\frac{m_1}{m_2}, \frac{m_2}{m_3})$ or (m_1, m_2, m_3). The parameters m_1, m_2 and m_3 respectively denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event[19].

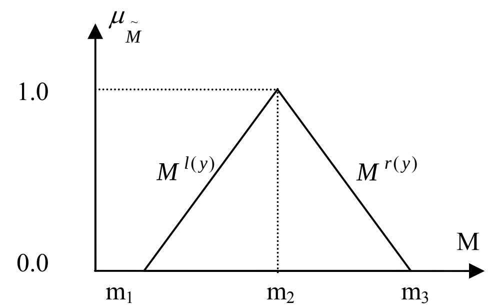

Fig. 1 A triangular fuzzy number

The analytic hierarchy process (AHP) is one of the extensively used multi-criteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pairwise comparisons, and priority vector generation and synthesis.

Though the purpose of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems.

In the fuzzy-AHP procedure, the pairwise comparisons in the judgment matrix are fuzzy numbers that are modified by the designer's emphasis [19].

C. Extent Analysis Method on Fuzzy AHP

In the following, first the outlines of the extent analysis method on fuzzy AHP are given and then the method is applied to a supplier selection problem. Let

$$X = \{x_1, x_2, ..., x_n\} \tag{1}$$

be an object set, and

$$U = \{u_1, u_2, ..., u_m\} \tag{2}$$

be a goal set.

According to the method of Chang's [20], extent analysis, each object is taken and extent analysis for each goal is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m \quad i = 1,2,...,n \tag{3}$$

where all the $M_{g_i}^j (j = 1,2,...,m)$ are triangular fuzzy numbers. The value of fuzzy synthetic extent with respect to the i_{th} object is defined as:

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

The degree of possibility of $M_1 \geq M_2$ is defined as:

$$V(M_1 \geq M_2) = \underset{x \geq y}{SUP} \left[\min(\mu M_1(x), \mu M_2(y) \right] \tag{5}$$

When a pair (x,y) exists such that $x \geq y$ and $\mu M_1(x) = \mu M_2(y)$, then we have $V(M_1 \geq M_2) = 1$. Since M1 and M2 are convex fuzzy numbers we have that:

$$V(M_1 \geq M_2) = 1 \quad if \quad m_1 \geq m_2 \tag{6}$$

$$\begin{aligned} V(M_1 \geq M_2) &= hgt(M_1 \cap M_2) \\ &= \mu M_1(d) \end{aligned} \tag{7}$$

where d is the ordinate of the highest intersection point D between μM_1 and μM_2.

When $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, the ordinate of D is given by equation (8):

$$\begin{aligned} V(M_2 \geq M_1) &= hgt(M_1 \cap M_2) \\ &= \frac{l_1 - u_1}{(m_2 - u_2) - (m_1 - u_1)} \end{aligned} \tag{8}$$

To compare M1 and M2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1,2,...,k)$ can be defined by:

$$\begin{aligned} V(M \geq M_1, M_2, ..., M_k) &= V[(M \geq M_1) \\ and\ (M \geq M_2)\ and\ ...\ and V\ (M \geq M_k) \\ &= \min V(M \geq M_i), i = 1,2,...,k \end{aligned} \tag{9}$$

Assume that:

$$d'(A_i) = \min V(S_i \geq S_k) \tag{10}$$

For $k = 1,2,...,n;\ k \neq i$. Then the weight vector is given by:

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \tag{11}$$

where $A_i (i = 1,2,...,n)$ are n elements. Via normalization, the normalized weight vectors are:

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \tag{12}$$

where W is a nonfuzzy number.

D. TOPSIS

General Topsis process with six activities is listed below [21]:

Activity 1

Establish a decision matrix for the ranking. The structure of the matrix can be expressed as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & \cdots & F_n \end{array} \\ \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} \end{array} \tag{13}$$

where A_i denotes the alternatives i, i = 1, . . . ,m; F_j represents j^{th} attribute or criterion, j = 1, . . . , n, related to i^{th} alternative; and f_{ij} is a crisp value indicating the performance rating of each alternative A_i with respect to each criterion F_j.

Activity 2

Calculate the normalized decision matrix R(=[r_{ij}]). The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \tag{14}$$

Where j = 1. . . n; i = 1, . . . ,m.

Activity 3

Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value Vij is calculated as:

$$v_{ij} = w_{ij} r_{ij}, \tag{15}$$

where w_j represents the weight of the j^{th} attribute or criterion.

Activity 4

Determine the PIS and NIS, respectively:

$$\begin{aligned} V^+ &= \{v_1^+, ..., v_n^+\} = \\ &\{(Max\, v_{ij} \mid j \in J), (Min\, v_{ij} \mid j \in J')\} \end{aligned} \tag{16}$$

$$\begin{aligned} V^+ &= \{v_1^-, ..., v_n^-\} = \\ &\{(Min\, v_{ij} \mid j \in J), (Max\, v_{ij} \mid j \in J')\} \end{aligned} \tag{17}$$

where J is associated with the positive criteria and J` is associated with the Negative criteria.

Activity 5

Calculate the separation measures, using the m-dimensional Euclidean distance. The separation measure D_i^+ of each alternative from the PIS is given as:

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2}\ ,\ i = 1,\ldots,m \tag{18}$$

Similarly, the separation measure D_i^- of each alternative from the NIS is as follows:

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2}\ ,\ i = 1,\ldots,m \tag{19}$$

Activity 6

Calculate the relative closeness to the idea solution and rank the alternatives in descending order. The relative closeness of the alternative A_i with respect to PIS V^+ can be expressed as:

$$\overline{C}_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{20}$$

Where the index value of $\overline{C}_i$ lies between 0 and 1. The larger the index value, the better the performance of the Alternatives.

IV. Numerical Example

Assume that the management wants to choose the best project amongst all proposed projects. Based on proposed methodology, 2 steps are applied for assessment and selection of project.

In step 1, for assessment of suppliers with the help of improved AHP by fuzzy set theory, the procedure is as follows: first we should make hierarchy structure. Proposed tree shows in Table I, II.

In Step 2, According to TOPSIS algorithm's Activities, below results are obtained. Obtained results have been brought in Table III, IV, V and VI.

TABLE I
EVALUATION MATRIX

	ROR	PB	NPV	BC
ROR	1	2	1	1
PB	0.5	1	0.5	0.75
NPV	1	2	1	2
BC	1	1.33	0.5	1

TABLE II
FUZZY EVALUATION MATRIX

	ROR	PB	NPV	BC
ROR	(1,1,1)	(1,2,3)	(0.75,1,1.25)	(0.75,1,1.25)
PB	(0.33,0.5,1)	(1,1,1)	(0.25,0.5,0.75)	(0.5,0.75,1)
NPV	(0.8,1,1.33)	(1.33,2,4)	(1,1,1)	(1,2,3)
BC	(0.8,1,1.33)	(1,1.33,2)	(0.33,0.5,1)	(1,1,1)

From Table II the following values are obtained:

$S_{ROR} = (3.5,5,6.5) \otimes (0.04,0.057,0.078) = (0.14,0.28,0.51)$

$S_{PB} = (2.08,2.75,3.75) \otimes (0.04,0.057,0.078) = (0.08,0.16,0.29)$

$S_{NPV} = (4.13,6,9.33) \otimes (0.04,0.057,0.078) = (0.17,0.34,0.73)$

$S_{BC} = (3.13,3.83,5.33) \otimes (0.04,0.057,0.078) = (0.13,0.22,0.42)$

Using these vectors:

$V(S_{ROR} \ge S_{PB}) = 1, V(S_{ROR} \ge S_{NPV}) = 0.86,\ V(S_{ROR} \ge S_{BC}) = 1$
$V(S_{PB} \ge S_{ROR}) = 0.54, V(S_{PB} \ge S_{NPV}) = 0.41,\ V(S_{PB} \ge S_{BC}) = 0.73$
$V(S_{NPV} \ge S_{PB}) = 1, V(S_{NPV} \ge S_{ROR}) = 1,\ V(S_{NPV} \ge S_{BC}) = 1$
$V(S_{BC} \ge S_{ROR}) = 0.81, V(S_{BC} \ge S_{PB}) = 1,\ V(S_{BC} \ge S_{NPV}) = 0.67$

The weight vector from Table II is calculated as:

$$W' = (0.86,0.41,1,0.67)^T$$
$$W = (0.29,0.14,0.34,0.23)^T$$

TABLE III
DECISION MATRIX

	ROR	PP	NPV	BC
project 1	24	4	71340	1.6
project 2	25	5	84475	1.7
project 3	20	3	87275	1.6
project 4	21	4	82320	1.7
project 5	20	3	91548	1.5
project 6	24	3	73805	2

TABLE IV
SEPARATION MEASURE D_i^+ OF EACH ALTERNATIVE

D_1^+	0.043839
D_2^+	0.036796
D_3^+	0.035247
D_4^+	0.034644
D_5^+	0.038312
D_6^+	0.030457

TABLE V
SEPARATION MEASURE D_i^+ OF EACH ALTERNATIVE

D_1^-	0.026647
D_2^-	0.036237
D_3^-	0.041108
D_4^-	0.027003
D_5^-	0.045831
D_6^-	0.046559

TABLE VI
SCORE OF EACH PROJECT

project 1	0.378043
project 2	0.496176
project 3	0.538381
project 4	0.438027
project 5	0.54468
project 6	0.604535

As it is shown in Table VI, project 6 can gain the best score among all projects.

V. CONCLUSION

The evaluation and selection of industrial projects before investment decision is customarily done using, technical and financial information.

In this article, Authors proposed a new methodology to provide a simple approach to assess alternative projects and help decision maker to select the best one. By using improved AHP with fuzzy set theory the qualitative judgment can be qualified to make comparison more intuitionitic and reduce or eliminate assessment bias in pairwise comparison process. Finally this article introduces an approach that integrates Improved AHP with TOPSIS algorithm to support project selection decisions.

REFERENCES

[1] J. Meredith, S. Mantle, " Project Management: A Managerial Approach", *fourth ed. Wiley, New York*, 2000.
[2] N. Danila, "Strategic evaluation and solution of R&D projects", *R&D Management* 19, 47–62, 1999.
[3] A. Shpak, D. Zaporojan, "Working out R&D program via multicriteria analysis", *Computer Science of Moldova* 4 (2 (11)), 239–259, 1996.
[4] A. Mehrez, Z. Sinuany-Stern, "An interactive approach to project selection", *Journal of Operational Research Society* 34, 621–626, 1983.
[5] R. Khorramshahgole, H. M. Steiner, "Resource analysis in project evaluation", *A multicriteria approach. Journal of Operational Research Society* 95 (2), 795–803, 1998.
[6] P. K. Dey, M. T. Tabucanon, S. O. Ogunlana, "Hierarchical approach to project planning", *Applied Mathematical Modelling* 20, 683–698, 1996.
[7] P. Chu, Y. Hsu, M. Fehling, "A decision support system for project portfolio selection", *Computer in Industry* 32 (2), 141–149, 1996.
[8] G. Lockett, M. Stratford, "Ranking of research projects, experiments with two methods", *Omega* 15, 395–400, 1987.
[9] P. Regan, S. Holtzman, "R&D decision advisor: An interactive approach to normative decision system model construction", *European Journal of Operational Research* 84 (1), 1995.
[10] F. Ghasemzadeh, N. P. Archer, P. Iyogun, "A zero-one model for project portfolio selection and scheduling", *Journal of Operational Research Society* 50 (7), 745–755, 1999.
[11] F. Ghasemzadeh, N. P. Archer, "Project portfolio selection through decision support", *Decision Support Systems* 29, 73–88, 2000.
[12] P. K. Dey, S. S. Gupta, "Feasibility analysis of crosscountry pipeline projects: A quantitative approach", *Project Management Journal* 32 (4), 50–58, 2001.
[13] Mian, S. A., Christine, N.D., 1999. Decision-making over the project life cycle: An analytical hierarchy approach. Project Management Journal 30 (1), 40–52.
[14] C. H. Loch, S. Kavadias, "Dynamic portfolio selection of NPD programs using marginal returns", *Management Science* 48 (10), 1227–1241, 2002.
[15] R. Eugene, P. K. Dey, "The role of environmental factors in industrial site selection activities: A case of limestone quarry expansion in Barbados", *Impact Assessment and Project Appraisal* 23 (2), 2005.
[16] S. Hariharan, P. K. Dey, A. Y. Kumar, H. Moseley, " A new tool for measurement of process-based performance of multispecialty tertiary care hospital", *International Journal of Health Care Quality Assurance* 17 (6), 302–312. 116–133, 2004.
[17] T. L. Saaty, "The analytic hierarchy process", *New York: McGraw-Hill;* 1980.
[18] L. Zadeh, "Fuzzy sets", information control, vol 8, pp.338-53, 1965.
[19] C. Kahraman, U. Cebeci, Z. Ulukan "Multi-criteria supplier selection using fuzzy AHP", Logistic information Management. Volume 16. Number 6. pp. 382-394, 2003.
[20] D. Y. Chang,d, "Extent analysis and synthetic decision", Optimization Techniques and Application, vol (1) . p. 352, 1992.
[21] D. L. Olson, "Comparison of weights in TOPSIS models", *Mathematical and Computer Modeling*, 40, (7) 21-727, 2004.