A fuzzy approach for projects evaluation and selection: An Iranian auto manufacturer case study

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A Fuzzy Approach for Projects Evaluation and Selection; an Iranian Auto Manufacturer Case Study

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Abstract

Evaluating and selecting alternatives investment projects needs considering all relevant and important aspects. In traditional methods, the focus is just on tangible monetary criteria. Also in the traditional methods, either all the information's about factors must be known precisely or sufficient objective data must be available for applying probability theory. In this paper, a combinative approach is employed to integrate all monetary factors, subjective non monetary factors and also objective non monetary factors in decision making process of project evaluation and selection. In the proposed approach to deal with uncertainty in monetary criteria and also vagueness of human thought in subjective non monetary criteria, fuzzy cash flow analysis and multi criteria decision making method are applied, respectively. As a case study, this methodology has been applied for evaluation of an Iranian auto manufacturer's projects. The results depict that the methodology can vastly help decision makers to evaluate projects under vague and uncertain circumstances considering all important criteria.

Keywords: Project evaluation, Fuzzy cash flow, Fuzzy multi criteria decision making.

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1. Introduction

In economic analysis of the firm's potential projects, the objective is to determine projects acceptability from the economic data available and from managerial standpoint. There are several goals in projects evaluation and selection. Some of them are quantitative and some are qualitative and measured in incommensurable units. There are many different techniques that can be used to estimate, evaluate, and choose project portfolios. In literature there are some papers that have reviewed and categorized the project selection techniques such as R. L. Schmidt and J. R. Freeland [1], R. G. Cooper and et al. [2, 3], D. L. Hall, A. Nauda [4]. Some of these techniques are not widely applied and the following statements have been revealed as the reasons for this rejection: they address only a few of the issues, they are too complex and require too much input data, they may be too difficult for decision makers to understand and use, or they may not be used in the form of an organized process [5]. Project selection methods can usually be placed into one of the following categories:

- Unstructured peer review;
- Scoring;
- Mathematical programming, including integer programming (IP), linear programming (LP), nonlinear programming (NLP), goal programming (GP), and dynamic programming (DP);
- Economic models, such as internal rate of return (IRR), net present value (NPV), return on investment (ROI), cost-benefit analysis, and option pricing theory; [6,7]
- Decision analysis, including multi-attribute utility theory (MAUT), decision trees, risk analysis, and the Analytic hierarchy process (AHP);
- Interactive methods, such as Delphi, Q-sort, Behavioral decision aids (BDA), and Decentralized hierarchical modeling (DHM);
- Artificial intelligence (AI), including expert systems and fuzzy sets;
- Portfolio optimization.

Most of the above techniques consider only the quantitative criteria to evaluate projects. Also the major drawback of the most of the above techniques is the basic assumption of certainty. In all precision based methods for evaluation of projects to invest, certain basic assumptions which are often called "perfect market conditions" are made about the investment projects and the firm. One of the most important assumptions of a perfect market conditions, is the essential assumption of certainty. This assumption means there is a complete certainty about all investment factors such as cash flows, discounting rates, timing, economic lives and etc. However in practice, most economic decision problems involve the uncertainty feature of cash flow modeling.

In uncertainty situation, if sufficient objective data is available, probability theory is commonly used in modeling cash flows and performing decision analysis. Probability theory is only useful when there is sufficient data to estimate the probability function of decision variables. Unfortunately, due to the uniqueness of projects, decision markers rarely have enough information to perform decision analysis using probability theory. Also, decision makers have to concern the intangible factors like flexibility and quality along with the tangible factors, in project selection problems. In this situation, most decision makers rely on experts` knowledge in modeling cash flows when the probability information is not reliable justified. When dealing with uncertainty, decision makers may frequently describe their opinions about the subject by applying linguistic terms such as "low profit" , "around one million", “more than 10%” and so on. Fuzzy set theory introduced by Zadeh [8], is appropriate to deal with the vagueness of human thought. The transition from vagueness to quantification is performed by applying fuzzy set theory.

In this paper, an integrated approach is proposed to consider all tangible and intangible factors in project selection decision making, using fuzzy cash flow analysis and fuzzy multi-criteria decision making method. Also in the presented methodology, top decision maker can consider different preference ratings for experts` opinions to rank their opinions` precision level. In section 2, an illustration of fuzzy set theory and fuzzy numbers is proposed. The applied methodology and an illustrative example are proposed in sections 3 and 4.

2. Fuzzy Sets and Numbers

A fuzzy set is a set containing elements that have varying degrees of membership in the set. This idea is in contrast with classical or crisp sets, because members of a crisp set would be not members unless their membership was full or complete in that set. Elements of a Fuzzy set, because their membership need not be complete, can be member of other fuzzy sets on the same universe [9].

If X is some set called a universe of discourse, then a normalized fuzzy subset A of X is defined by membership function, written $\overline{A}(?)$, which produces values in $[0,1]$ for all ? in X. In this situation, we say ? is a member of X with membership function of 0.8 if we have $\overline{A}(?) = 0.8$.

Buckley and Eslami [10] have proposed an understandable definition of fuzzy numbers. The two mostly used fuzzy numbers in the field of decision making are triangular and trapezoidal shaped fuzzy numbers. When there is no difference between a set of numbers' utility in an interval trapezoidal numbers are suitable; but in the cases such as costs and incomes when a small increase or decrease can change the utility, triangular numbers are more appropriate. Therefore, in this paper, triangular fuzzy numbers are used. Triangular fuzzy numbers can be denoted by $\overline{A} = (a,b,c)$ in which $a \le b \le c$. A triangular fuzzy number and its membership function are graphically depicted in figure 1.

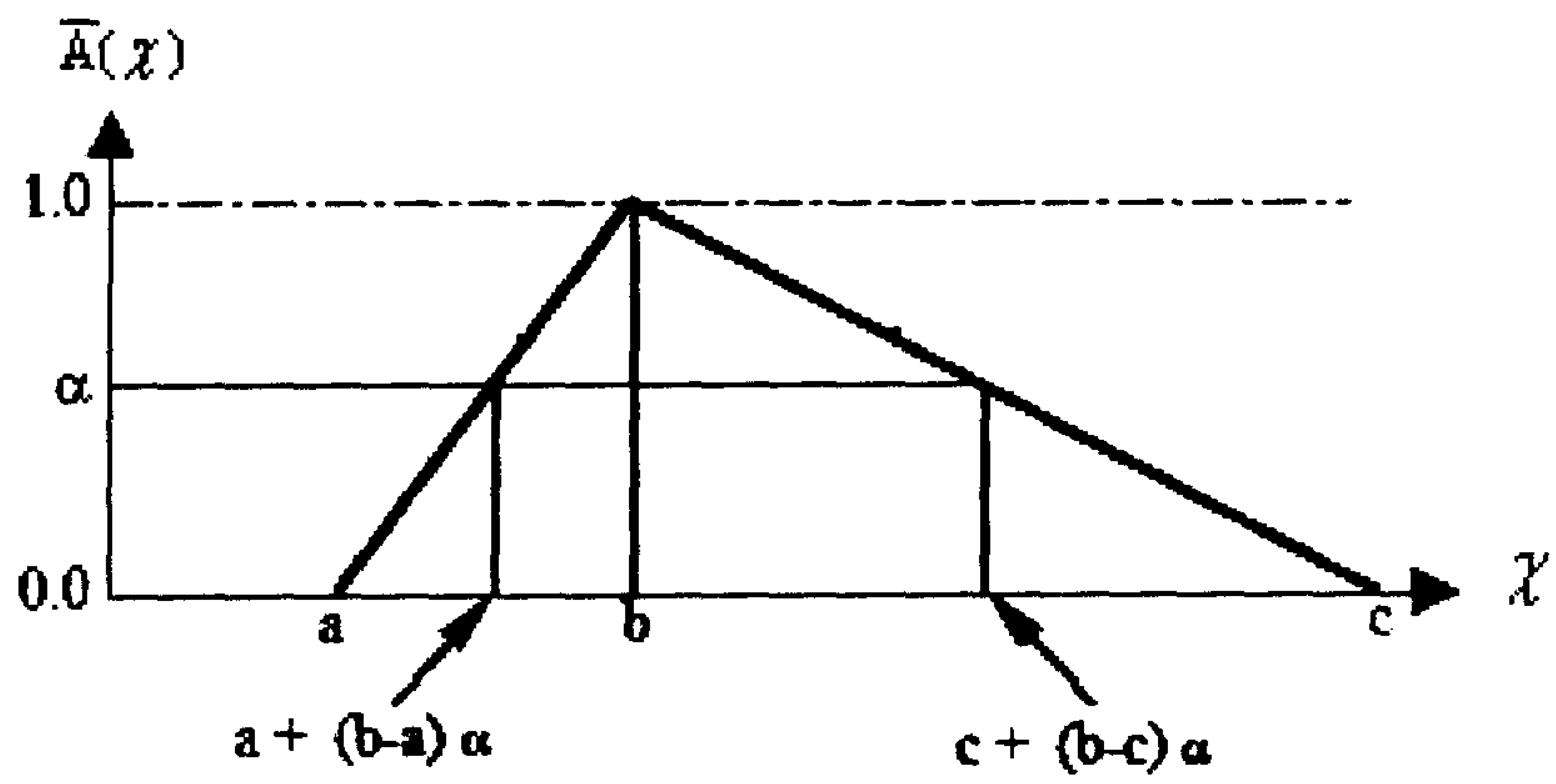

Figure 1. Triangular fuzzy numbers

Trapezoidal fuzzy number will be written by $\overline{A} = (a,b,c,d)$ in which $a \le b \le c \le d$. $\overline{A}$ is a trapezoidal Fuzzy number if is membership function is:

$$\overline{A}(x) = \begin{cases} \dfrac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{x-d}{c-d} & c \le x \le d \\ 0 & \text{otherwise} \end{cases}$$

As can be seen, the membership function of a trapezoidal fuzzy number should be (1) continuous, (2) monotonically increasing on $[a,b]$ and (3) monotonically decreasing on $[c,d]$.

3. Methodology

Figure 2 shows schematically the steps of the methodology. The procedure is somehow similar to the method of selecting facility sites, proposed by Liang and Wang [11]. In this section, the steps of the methodology are illustrated.

Step 1

At first, a committee of qualified experts should be formed. The top decision maker can assign different fuzzy or non fuzzy preference ratings to the experts` opinions due to his knowledge about their opinions precision level. The procedure of assigning fuzzy preference ratings to the experts` opinions is similar to assigning criteria weights and will be illustrated in stage 4.2.1.

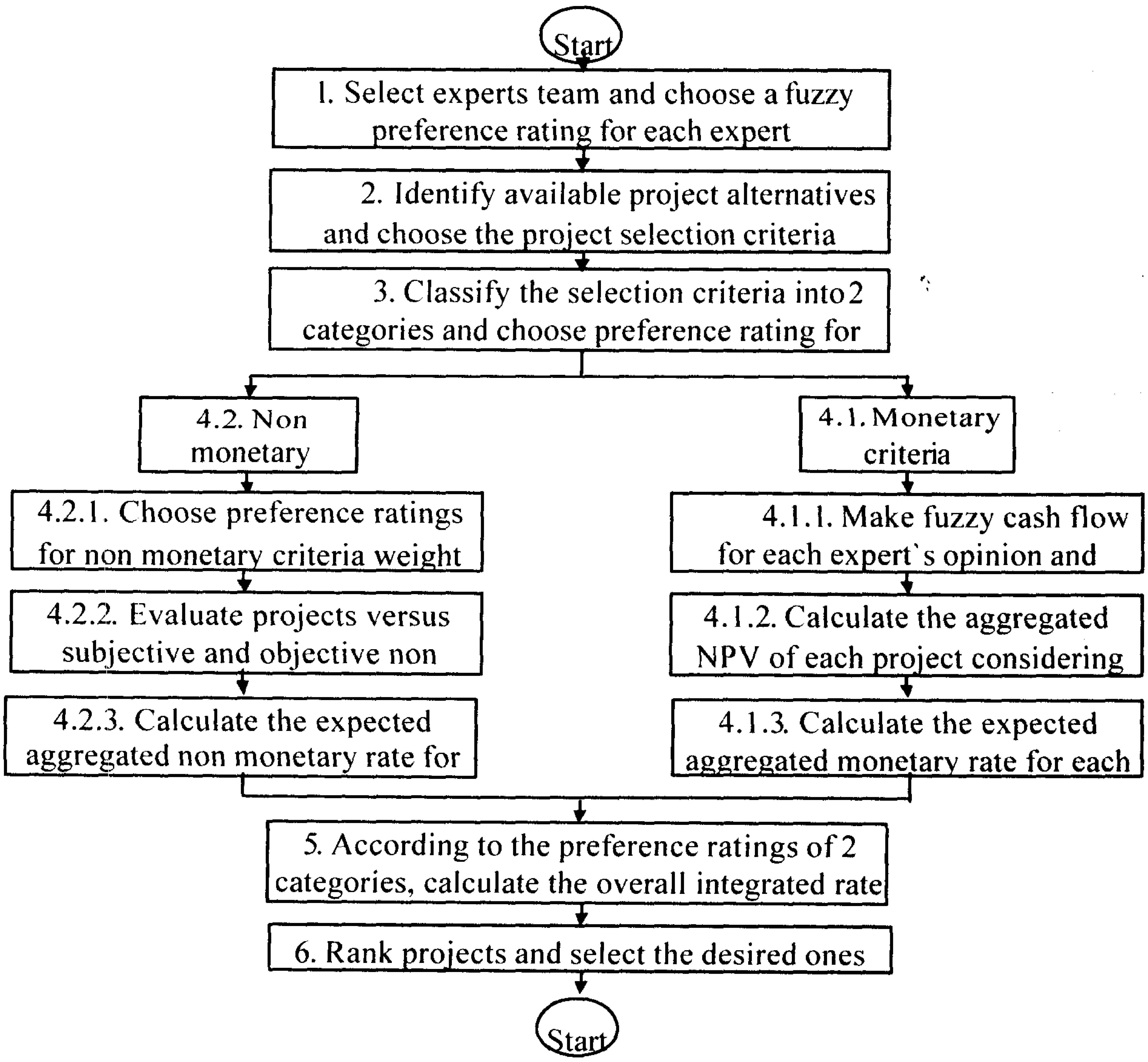

Figure 2: The Project Evaluation and Selection Methodology

Step 2

The experts committee should select the appropriate and suitable project alternatives. Also the most appropriate and important criteria for evaluating projects should be chosen among numerous factors. The chosen criteria should cover all important aspects.

Step 3

After selecting the criteria, they must be grouped into two categories of "monetary" and "non monetary" criteria, and for each group a preference rating should be assigned representing its importance in decision making procedure.

The "monetary" criteria are those which can be treated economically and can be shown as an income or expenditure in the cash flow. Some criteria may appear to be non monetary but we can change them to monetary language by setting up formulas. For instance, in the field of manufacturing projects, flexibility as a criterion for decision making may seem to be non monetary, but there are lots of researches in the last decade in which various aspects of flexibility are made monetary quantifiable. In table 1, some of these aspects which are introduced by Pyoun and Choi [12] are shown.

Table 1: Measuring Flexibility

	Flexibility formula
Flexibility for continuous improvement	$CI_n = S_n \cdot C_n$ where S_n is the average number of parts revisions , and C_n is the average cost required for alteration of tooling and software in the *n*th period .
Flexibility for project abandonment	$PA_n = (1-\gamma) \cdot B_n \cdot P_{an}$ where γ is the rate of salvage value to book value , B_n is the book value at the end of *n*th period , and P_{an} is the occurrence probability of project abandonment in the *n*th period .
Flexibility for changes in product mix	$PM_n = m_n \cdot r$ where m_n is the average number of changes in product mix in the *n*th year and r is the average cost for rescheduling .
Flexibility for work force control	$WC_n = ¢ \cdot J_n \cdot W_n$ where ϕ is the average benefit per job , J_n is the average number of different jobs , and W_n is the average number of operators in the *n*th period .

The suggested idea by most researchers who are dealing with quantification of intangible criteria is trying to quantify all intangible criteria as far as it is possible in monetary terms. One of the examples of these suggestions can be seen in quantifying flexibility in the research done by Beskese et al. [14]. Since some of these criteria can be said in linguistic terms more easily, fuzzy concept would be a good help.

Step 4

4.1. Monetary criteria

4.1.1. Select one of the projects. Ask each member of the experts team to assign a fuzzy or non fuzzy number for factors of the selected project's cash flow, such as operating cash flows, investing cash flows, financing cash flows, interest rate, salvage value, depreciation rate, tax rate, number of periods and so on.

Calculate the fuzzy net cash flow of each period for all the experts' opinions. The fuzzy net cash flow for period t can be calculated as follow:

$$\overline{Y}_t = \left(\overline{G}_t - \overline{C}_t - \overline{B}_t\right)\cdot\left(1 - \overline{T}_e\right) + \overline{D}_t \cdot \overline{T}_e$$

where $\overline{Y}_t$ is the fuzzy net total cash flow at the end of period t, $\overline{G}_t$ is the project's fuzzy gross income, $\overline{C}_t$ is the fuzzy cash outflows during period t, $\overline{B}_t$ is the fuzzy cash interest rate during period t on the borrowed funds, $\overline{T}_e$ is the fuzzy effective income tax rate and $\overline{D}_t$ is the fuzzy depreciation amount in period t.

After calculating all experts' fuzzy net cash flows for the selected project, calculate the fuzzy net present value for each cash flow.

Consider a fuzzy net cash flow, $\overline{A} = \overline{A}_0, \overline{A}_1, \dots, \overline{A}_n$, whose a-cuts are $[a_{t1}(\alpha), a_{t2}(\alpha)]$, with $\overline{i}$ a fuzzy interest rate , then the fuzzy net present value of $\overline{A}$ is:

$$NPV(\overline{A}, n) = \overline{A}_0 + \sum_{t=1}^{n} \overline{A}_t \cdot \left(1 + \overline{i}\right)^{-t}$$

Using the extension principle:

$$NPV(\overline{A}, n) = [npv_{e1}(\alpha), npv_{e2}(\alpha)]$$

Where

$$npv_{e1}(\alpha) = \min\left\{a_0 + \sum_{t=1}^{n} a_t \cdot \left(1+\bar{i}\right)^{-t} \middle| a_t \in \bar{A}_t[\alpha], i \in \bar{I}[\alpha]\right\}$$

$$npv_{e2}(\alpha) = \max\left\{a_0 + \sum_{t=1}^{n} a_t \cdot \left(1+\bar{i}\right)^{-t} \middle| a_t \in \bar{A}_t[\alpha], i \in \bar{I}[\alpha]\right\}$$

4.1.2. Suppose having M members in the experts team. Now we have M net present values for the selected project. The aggregated net present value of these M net present values considering experts` preference ratings (P) can be calculated as below:

$$NPV_j = P_1 \cdot NPV_{j1} + P_2 \cdot NPV_{j2} + \ldots + P_m \cdot NPV_{jm}$$

Where in NPV_{jm} , the first index denotes alternative project j and the second index denotes expert m .

4.1.3. Repeat steps 4.1.1 to 4.1.2 for all the other alternative projects. For calculating the aggregated rate for monetary criteria use:

$$F_j' = \frac{NPV_j}{NPV_1 + \ldots + NPV_k}$$

where k is the number of projects. All the above operations are fuzzy operations.

4.2. Non Monetary Criteria

Non monetary criteria itself can be partitioned into "subjective non monetary" and "objective non monetary". For these both groups use a multi criteria decision making method.

4.2.1. At first, the preference rating for each criterion weight should be determined using either pair-wise comparisons or directly assigning weights. A weighting set W like W = {*very low*, *low*, *medium*, *high*, *very high*} can be employed, and its fuzzy conversion scale must be designed. The importance weights can be obtained by requesting each member of the experts' team to weight the criteria. Using directly assigning weights method, the aggregated fuzzy weight for criterion k can be obtained as follow:

$$w_k = P_1 \cdot w_{k1} + P_2 \cdot w_{k2} + \ldots + P_m \cdot w_{km}$$

Where for example P_1 is the preference rating for first expert and w_{k1} is the assigned weight for criterion k by the first expert.

4.2.2. Set up a linguistic variable set like S = {*very poor, poor, fair, good, very good*} and design a fuzzy conversion scale for its linguistic values. Experts use these linguistic values to evaluate the suitability of alternatives versus subjective non monetary criteria. For each objective non monetary criterion, in order to ensure compatibility between these fuzzy objective criteria and subjective non monetary criteria, use the method of calculating aggregated rate for monetary criteria.

For both subjective and objective non monetary criteria, both methods of pair-wise comparisons and directly assigning rates can be used by experts to evaluate the suitability of an alternative versus non monetary criteria.

Suppose S_{ijk} is the rate assigned to project alternative j by decision maker i for criterion k, then:

$$f_{jk} = P_1 \cdot S_{1jk} + P_2 \cdot S_{2jk} + \ldots + P_m \cdot S_{mjk}$$

and the aggregated rate of non monetary criteria for alternative j would be:

$$F_j'' = f_{j1} \cdot w_1 + f_{j2} \cdot w_2 + \ldots + f_{jk} \cdot w_k$$

Step 5

In this stage the overall integrated rate (OIR) should be calculated by considering the preference ratings for monetary and non monetary criteria.

$$OIR_j = PR_{F'} \cdot F_j' + PR_{F''} \cdot F_j''$$

Where $PR_{F'}$ and $PR_{F''}$ are preference ratings for monetary and non monetary criteria, respectively.

Step 6

Use one of the fuzzy ranking methods to rank alternatives from best to worst. Buckely [15] has proposed some methods for ranking alternatives using fuzzy numbers. Also, you can use defuzzified overall integrated rate for projects to rank them. If projects are mutually exclusive select the best ranking alternative. If projects are not mutually exclusive according to the investment costs and the budget make a bundle of alternatives.

5. Case Study

As a case study we selected three company projects of an Iranian auto manufacturer company in the field of "SUV", "Truck" and "Pickup" This Company is one of the holding corporations in Tehran stock exchange which is active 4 business area: manufacturing automobiles and are spare parts, bicycles and motorcycles financing investments and IT. The first two projects are about launching production lines, but the third project was about increasing production volume by adding a new production line. To evaluate these three investing projects, we applied the proposed methodology. The applied procedure in this case study is illustrated as below.

Step1

3 members were chosen for the experts team. The top decision maker assigned 0.35, 0.15 and 0.5 as preference ratings of experts due to his knowledge about their idea, respectively.

Step2

The following evaluation criteria were considered:

C1: Net present value

C2: Competency with similar type domestic products

C3: Flexibility for project abandonment

C4: Products export chance

C5: Meeting public regulations for pollution

Step 3

The experts team decided to group C1 as monetary criteria and the others as non monetary criteria. Also preference ratings for monetary and non monetary criteria were assigned 0.65 and 0.35 respectively.

Step 4.1

The experts assigned their evaluations for the cash flow factors. Then, in accordance with each expert's opinion a fuzzy net cash flow was calculated as shown in table 2. Also, the fuzzy net present value and the aggregated net present value of projects are represented in table 3.

Table 2: Fuzzy Net Cash Flow

Alternative	Expert \ Period	0	1	2	3	4	5
Pickup	1	(-78,-79,-80)	(-117,-114,-110)	(-271,-265,-260)	(204,209,210)	(450,455,452)	(420,426,430)
	2	(-77,-78,-79)	(-120,-116,-114)	(-280,-276,-272)	(195,200,205)	(470,473,476)	(415,420,425)
	3	(-75,-79,-80)	(-113,-112,-111)	(-280,-280,-280)	(200,205,207)	(470,475,480)	(415,425,435)
Truck	1	(-80,-79,-77)	(18,20,22)	(23,24,27)	(43,45,47)	(60,65,67)	(60,65,67)
	2	(-77,-75,-73)	(16,17,19)	(25,26,28)	(40,45,48)	(64,65,66)	(64,65,66)
	3	(-80,-75,-72)	(18,18,18)	(28,29,30)	(39,42,44)	(63,66,69)	(63,66,69)
SUV	1	(-47,-44,-40)	(-185,-183,-180)	(-200,-198,-194)	(195,198,203)	(275,285,290)	(400,410,417)
	2	(-45,-42,-38)	(-190,-185,-180)	(-198,-194,-190)	(190,195,200)	(282,282,282)	(410,415,420)
	3	(-42,-42,-42)	(-183,-178,-172)	(-195,-187,-185)	(193,195,197)	(270,275,277)	(410,415,420)

Table 3: Aggregated Net present Value

Alternative	Expert	NPV_{jk}	NPV_j
Pickup	1	(63.48,74.53,80.93)	(64.03,73.64,80.65)
	2	(59.31,69.06,79.13)	
	3	(65.84,74.39,80.91)	
Truck	1	(12.30,18.66,25.07)	(14.14,20.93,26.70)
	2	(15.57,20.96,26.69)	
	3	(14.99,22.50,28.00)	
SUV	1	(16.44,28.27,40.96)	(20.79,32.11,42.15)
	2	(18.73,29.74,41.55)	
	3	(24.45,35.51,43.16)	

Thus:

$\tilde{F} = (0.43, 0.58, 0.81)$

$F_2' = (0.1, 0.17, 0.27)$

$F_3' = (0.14, 0.25, 0.43)$

Step 4.2

C2, C3, C4 and C5 are subjective non monetary criteria. For assigning criteria weight, the linguistic weighting set, *W= {very low (VL), low (L), medium (M), high (H), very high (VH)}*, can be employed. The fuzzy conversion scale for linguistic values of *W* is shown in table 5.

Table 4: Fuzzy Conversion Scale for Linguistic Values

Linguistic value	Fuzzy scale
VL,VP	(0,0,0.3)
L,P	(0,0.3,0.5)
M,F	(0.2,0.5,0.8)
H,G	(0.5,0.7,1)
VH,VG	(0.7,1,1)

Experts' opinions about weights of non monetary criteria are as table 5.

Table 5: Weights of non Monetary Criteria

	Experts		
Criteria	E1	E2	E3
C2	M	VH	H
C3	H	H	VH
C4	VH	M	VH
C5	L	M	H

Considering experts' preference ratings:

$W_{C2} = (0.425, 0.675, 0.93)$

$W_{C3} = (0.6, 0.85, 1)$

$W_{C4} = (0.625, 0.925, 0.97)$

$W_{C5} = (0.28, 0.53, 0.795)$

For evaluating alternatives versus subjective non monetary criteria, the linguistic set, S = {*very poor (VP), poor (P), fair (F), well (G), very good (VG)*} is employed. The fuzzy conversion scale for linguistic values of S is also shown in table 4. Table 6 shows experts' evaluation of non monetary criteria.

Table 6: Experts' Evaluation of non Monetary Criteria

		Expert			
Alternative	**Criteria**	**E1**	**E2**	**E3**	f_{jk}
A1	C3	F	G	G	(0.395,0.63,0.93)
	C4	G	G	G	(0.5,0.7,1)
	C5	G	VG	VG	(0.63,0.895,1)
	C6	F	F	P	(0.1,0.4,0.65)
A2	C3	F	F	F	(0.2,0.5,0.8)
	C4	P	F	P	(0.03,0.33,0.545)
	C5	F	G	G	(0.395,0.63,0.93)
	C6	G	F	F	(0.305,0.57,0.87)
A3	C3	G	G	F	(0.35,0.6,0.9)
	C4	VG	G	G	(0.57,0.805,1)
	C5	F	G	F	(0.245,0.53,0.83)
	C6	G	G	VG	(0.6,0.85,1)

The aggregated rate of non monetary criteria for alternative j would be:

$F_1'' = (0.88, 2.06, 3.35)$

$F_2'' = (0.44, 1.50, 2.88)$

$F_3'' = (0.81, 2.03, 3.44)$

Step 5

$OIR_1 = (0.588, 1.098, 1.699)$

$OIR_2 = (0.219, 0.636, 1.184)$

$OIR_3 = (0.375, 0.873, 1.484)$

Step 6

Figure 3 graphically shows the three overall integrated rates for three alternatives. Using Jain's method, results the following ranking for alternatives:

Rank 1: Pickup

Rank 2: SUV

Rank 3: Truck

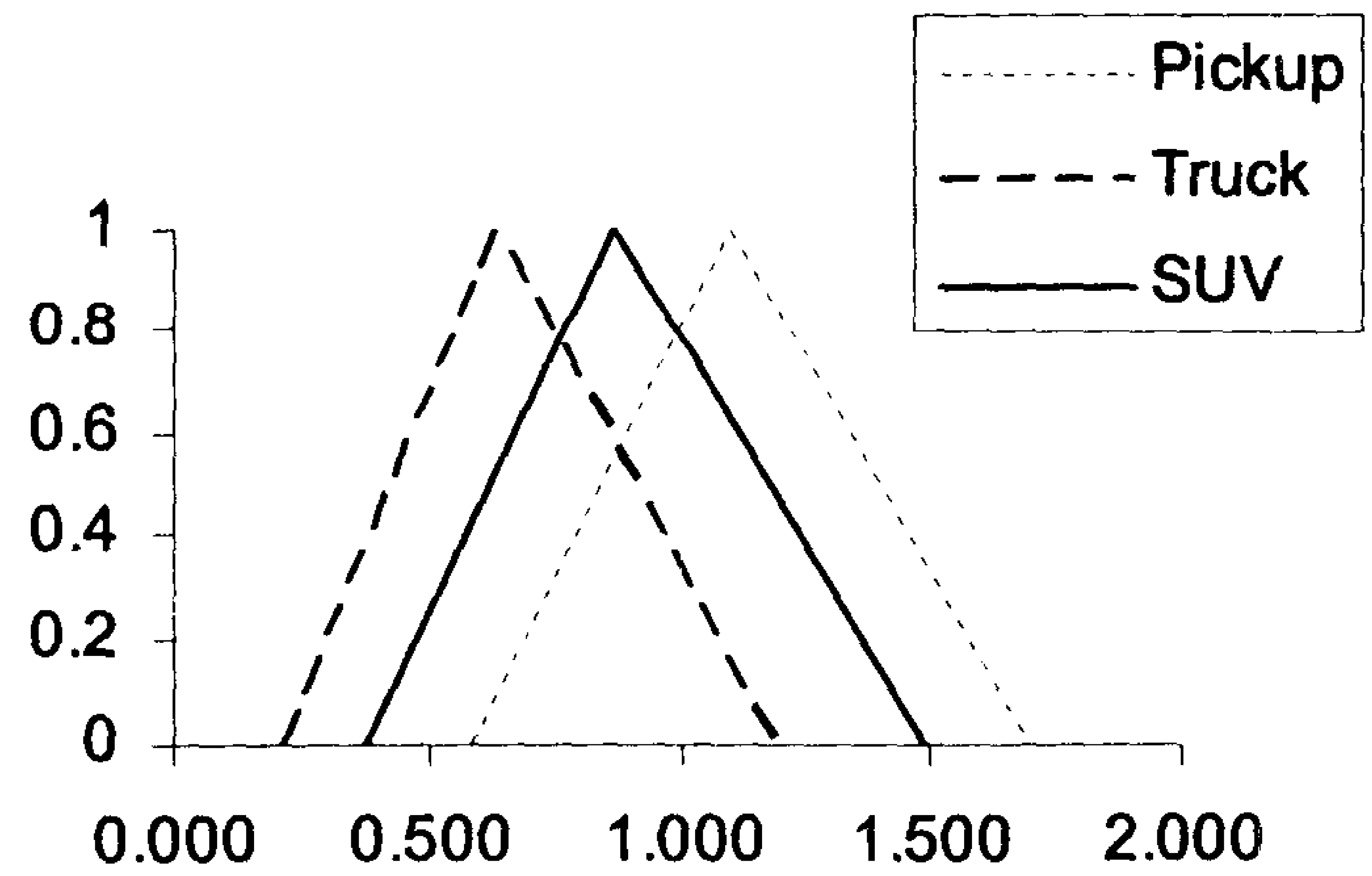

Figure 3: Overall Integrated Rates

6. Conclusion

Rarely, exact and enough information is ready in process of project evaluation and selection to invest. Also along with monetary criteria, there are some other important non monetary factors which should be considered. In this paper, a methodology which helps decision makers to consider monetary and non monetary criteria in vague and uncertain situation is proposed. Fuzzy cash flow is illustrated for evaluation of monetary criteria and for non monetary criteria fuzzy multi criteria decision making is employed. The results of monetary and non monetary evaluation are integrated by overall integrated rates index.

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