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Application of Fuzzy Logic in Operation Management Research

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***Abstract*-** Decision making is an important aspect of any business entity. In this paper, a new linguistic methodology is suggested in order to express the results obtained by analyzing the situations in a way that can be easily understood by non- experts users through fuzzy logic. The paper will further explain the relationship between variable through the application of fuzzy Logic. The model will be useful to understand better the system as compared to statistical results. It will also allow us to confront both kind of results considering that statistical analysis that are more discriminatory while fuzzy models show a broader vision. The model will let us understand the input variables behavior according to variations in output variables, therefore strategic planning possibilities are increased as no implementation is required. The use of decision support systems (DSS) is increasing and becoming generalized and it actually is the evolution of business computing networking and client/server architectures are impelling utilization of shared information in a decision support context. In addition, an expert system is presented with the information that will act as simulator of output results according to different input conditions controlled by the user

***Index Terms*-** Business Environment, Business Decision, Fuzzy Logic, Fuzzy Rules Based System, Linguistic Modeling, shared information, Operation Management.

I. Introduction

Nowadays, firm managers are becoming aware of the need for information analysis tools in order to support business decisions in the current complex and turbulent business environment. Competition in changing environments due to fast progression of technical advances turns competition on information into the main competitive parameter in order to prevent and anticipate changes in customer needs, technology, industry trends and other competition parameters.

In this context, the use of new DSS techniques has been scarcely applied in the field of operations management. In fact, even though management information systems literature has broadly dealt with tools to assist in managerial decisions, the wide utility these systems generate for specific Operations Management (OM) decisions is not still generalized.

The decision is required to be taken for different areas and in this paper decision making for selection of product portfolio. Companies must take proper decision to allocate a limited set of resources to projects to balance risk, reward, and in alignment with its strategies. The management has to take decision keeping in view the resources available and it has been extremely complex in case of selection of optimum product portfolio mix for the company. The complexity, uncertainty and imprecision associated with new product portfolio selection result due to following reasons:

1. At the time of decision, only uncertain and incomplete information is usually available.
2. The competitive environment is marked by uncertainty and rapid changes in technologies and markets.
3. The criteria for new product portfolio selection are not always quantifiable or comparable; and they may directly conflict or interact with one another.
4. The number of feasible portfolios is often enormous.

Fuzzy logic allows uncertain and imprecise systems of the real world to be captured through the use of linguistic terms so that computers can emulate the human thought processes. Thus, fuzzy logic is a very powerful tool in dealing. The decisions involving complex, ambiguous and vague phenomena that can only be assessed by linguistic values rather than numerical terms. Furthermore, such fuzzy logic has been applied to the evaluation of multi-criteria decision problems. To compensate the ineffective use of traditional quantitative techniques, a method for new product portfolio decision using fuzzy logic is proposed. The criteria ratings and the corresponding importance weights are assessed in linguistic terms, which are described by fuzzy numbers with triangular membership function, and fuzzy weighted average is employed to aggregate these fuzzy numbers into fuzzy value index (FVI), fuzzy risk index (FRI) and fuzzy strategy fitting index (FSFI). Furthermore, under balancing between product value, project risk and business strategies, the FVI, FRI and FSFI are consolidated into a fuzzy project attractive index (FPAI). Finally, the FPAI is ranked for new product selection decision. The fuzzy logic new product portfolio selection model [FLNPPSM] can efficiently aid managers dealing with ambiguity and complexity in achieving relatively realistic and informative results in the evaluation process.

II. Fuzzy Rule Based

Fuzzy rule based is developed to relate the input variables to the output variables by if-then rules. Fuzzy rules consist of two parts: an antecedent part stating condition on the input variables, and a consequent part describing the related value of the output variables. A single fuzzy if-then rule assumes as follow:

If x is A then y is B (3)

Where A and B, are linguistic values defined by fuzzy set on the ranges (universes of discourse) X and Y, respectively. The if- part of the rule " x is A " is antecedent or premise, while the then-part of the rule " y is B" is consequent or conclusion. An example such a rule might be If service is good then price of food is average

In this rule, service and price are two fuzzy variables. The fuzzy values in this rule are good and average descriptions. These values are defined on universes of discourse and determine the degree of element x which belongs to the membership functions. In general, the input to an if-then rule is the current value for the input variable (in this case, service) and the output is an entire fuzzy set (in this case, average).

III. Method and Algorithm

The framework of fuzzy logic new product portfolio selection model is composed of three main stages. The first stage is the new-product pre-screening. In this stage, on the basis of business strategy and new product strategy, the managers will set up a set of critical characteristics for the new product must meet to determine a new product is pass or kill. The second stage is the individual new product scoring. In this stage, due to the change in business environment, managerial goals and company's competency, the managers develop a set of criteria that new product should meet to rate the attractiveness of a new product. The third stage prioritizes projects and allocates resources into projects for portfolio selection. A stepwise description is given below:

1. Form a committee of decision-makers and collect the project related data.
2. Select a criteria for scoring project's value, strategy fitting and development risk.
3. Define linguistic variables as well as associated membership functions for measuring the project's value, strategy fitting and development risk.
4. Assess the criteria using linguistic terms and translate them into fuzzy numbers.
5. Aggregate fuzzy numbers to obtain FSFI, FVI and FRI of a new product development project.
6. Alignment of portfolio strategies.
7. Resource allocation and project selection

The fuzzy logic new product portfolio selection model [FLNPPSM] can efficiently aid managers dealing with ambiguity and complexity in achieving relatively realistic and informative results in the evaluation process.

IV. Application of FLNPPSM

Select criteria for scoring project's strategy fitting, value and risk. The next step in the product selection process was to decide the criteria to evaluate the proposed products. A new product selection decision depends not only on the value of the product but also on strategy fitting and development risk. Based

Table 1: Characteristics of high-performance new product arenas:

Major criteria	**Sub criteria**	**Element criteria**
Strategy fit (A)	Business strategy fit (A_1)	Degree of fitting the strategy for the product line and/or business (A_{11})
		Synergy with other product/business within company (A_{12})
	Strategic leverage (A_2)	Proprietary position (A_{21})
		Platform for growth (A_{22})
New product value (B)	Competitive Marketing advantages (B_1)	Matches desired entry timing needed by target segments (B_{11})
		Has unique or special functions to meet and/or special features to attract target segments (B_{12})
		Conforms to our sales force, channels of distribution and logistical strengths (B_{13})
	Market attractiveness (B_2)	Size of the markets (B_{21})
		Long-term potential of markets (B_{22})
		Growth rates of markets (B_{23})
	Technological suitability (B_3)	Allows the company to use very best suppliers (B_{31})
		Degree of fitting R&D skills/resources (B_{32})
		Degree of fitting engineering/design skills/resources (B_{33})

	Potential for gaining product advantage (B_4)	Magnitude of effect for customers (B_{41})
		New products will meet customer needs (B_{42})
		New product differentiated from competitive products (B_{43})
New product development risk (C)	Organizational Risk (C_1)	Lack of resource commitment (C_{11})
		Lack of implementation capability (C_{12})
		Organizational and/or financial impact (C_{13})
	Technical uncertainty risk (C_2)	Technical gap (C_{21})
		Program complexity (C_{22})
		The Project time frame (C_{23})
	Competitive risk (C_3)	Market competitiveness (C_{31})

Solutions of fully fuzzy linear system by ranking function

Definition: *The n x n linear system*

$$\begin{cases} (a_{11} \otimes x_1) \oplus (a_{12} \otimes x_2) \oplus \ldots\ldots \oplus (a_{1n} \otimes x_n) = b_1 \\ (a_{21} \otimes x_1) \oplus (a_{22} \otimes x_2) \oplus \ldots\ldots \oplus (a_{2n} \otimes x_n) = b_2 \\ \vdots \\ (a_{n1} \otimes x_1) \oplus (a_{n2} \otimes x_2) \oplus \ldots\ldots \oplus (a_{nn} \otimes x_n) = b_n \end{cases}$$

or in its matrix form,
$A \otimes x = b,$

is called a fully fuzzy linear system of equations (FFLSE) where the coefficient matrix $A = [aij]^n{}_{Ij=}1$ is a fuzzy matrix and $b=[b_1,..., b_n]^T$ is a fuzzy number vector and the fuzzy number vector x is the unknown to be found.

Proposition *Suppose that the matrices B and M* $= \begin{bmatrix} A+ & A- \\ C- & C+ \end{bmatrix}$ *are invertible,*

and $(x_1,..., x_n)^T$ given by $X_j = (x_J, y_J, z_J)$, j = 1,..., n, be the solution of equation

Then this solution is a nonnegative fuzzy exact solution of (3.4) if it satisfies $0 < x_i < y_i < z_i$, i = 1,... , n.

$\{A^+x + A^-z, By, C^-x + C^+z) = b = (d_1, d_2, d_3).$

Numerical example

Consider the following system:

$$\begin{cases} (1, 2, 5) \otimes (x_1, y_1, z_1) \oplus (3, 4, 4) \otimes (x_2, y_2, z_2) \oplus (0,1,2) \otimes (x_3, y_3, z_3) = (19, 68, 115) \\ (2, 3, 5) \otimes (x_1, y_1, z_1) \oplus (0, 1, 11) \otimes (x_2, y_2, z_2) \oplus (4,5,6) \otimes (x_3, y_3, z_3) = (30, 77, 261) \\ (2, 5, 7) \otimes (x_1 y_1, z_1) \oplus (4, 6, 6) \otimes (x_2, y2, z2) \oplus (5,7,10) \otimes (x_3, y3\ z3) = (61, 167, 253) \end{cases}$$

So we must solve two following systems

$$\begin{pmatrix} 1 & 3 & 0 & 0 & 0 & 0 \\ 2 & 0 & 4 & 0 & 0 & 0 \\ 2 & 4 & 5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 5 & 4 & 2 \\ 0 & 0 & 0 & 5 & 11 & 6 \end{pmatrix} \begin{pmatrix} x1 \\ x2 \\ x3 \\ z1 \\ z2 \end{pmatrix} \begin{pmatrix} = \\ = \\ = \\ = \\ = \end{pmatrix} \begin{pmatrix} 19 \\ 30 \\ 61 \\ 115 \\ 261 \end{pmatrix}$$

0 0 0 7 6 10 z3 = 253

$$\begin{bmatrix} 2 & 4 & 1 \\ 3 & 1 & 5 \\ 5 & 6 & 7 \end{bmatrix} \begin{bmatrix} y1 \\ y2 \\ y3 \end{bmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{bmatrix} 68 \\ 77 \\ 167 \end{bmatrix}$$

Using theorem to solve fuzzy linear system:

$$\begin{bmatrix} X1 & y1 & z1 \\ X2 & y2 & z2 \\ X3 & y3 & z3 \end{bmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{bmatrix} 1 & 2 & 7 \\ 6 & 12 & 14 \\ 7 & 10 & 12 \end{bmatrix}$$

Linguistic variables as well as associated membership functions for measuring the project's strategy fitting, value and risk are defined. Finally, the rating scale R= {Worst [W], Very Poor [VP], Poor [P], Fair [F], Good [G], Very Good [VG], Excellent [E]} was chosen for evaluating the rating effect of the different criteria of the project's strategy fitting and value; the rating scale R' = {Extremely High [EH], Very High [VH], High [H], Fairly High [FH], Medium [M], Fairly Low [FL], Low [L]} was used for estimating the possibility of project development risk; the weighting scale W = {Very Low [VL], Low [L], Fairly Low [FL], Fairly High [FH], High [H], Very High [VH]} were used for evaluating the relative importance of the various criteria. All scales and their associated membership functions are listed in

Table 2: Linguistic variables and the corresponding fuzzy numbers

Performance rate		Risk possibility		Importance weight	
Linguistic variables	Fuzzy number	Linguistic variables	Fuzzy number	Linguistic variables	Fuzzy number
Worst (W)	(0, 0, 0.2)	Low (L)	(0, 0, 0.2)	Very Low (VL)	(0, 0, 0.2)
Very poor (VP)	(0, 0.2, 0.4)	Fairly Low (FL)	(0, 0.2, 0.4)	Low (L)	(0, 0.2, 0.4)
Poor (P)	0.2, 0.35, 0.5	Medium (M)	0.2, 0.35, 0.5	Fairly Low (FL)	0.2, 0.35, 0.5
Fairly (F)	(0.3, 0.5, 0.7)	Fairly High (FH)	(0.3, 0.5, 0.7)	Fairly (F)	(0.3, 0.5, 0.7)
Good (G)	(0.5, 0.65, 0.8)	High (H)	(0.5, 0.65, 0.8)	Fairly High (FH)	(0.5, 0.65, 0.8)
Very Good (VG)	(0.6, 0.8, 1.0)	Very High (VH)	(0.6, 0.8, 1.0)	High (H)	(0.6, 0.8, 1.0)
Excellent (E)	(0.8, 1.0, 1.0)	Extremely High (EH)	(0.8, 1.0, 1.0)	Very High (VH)	(0.8, 1.0, 1.0)

Assess the criteria using linguistic terms and translate them into fuzzy numbers: Once the linguistic variables and associated membership functions for evaluating are defined, the experts use the linguistic terms to directly assess the rating which characterizes the degree of the effect/impact of various factors on the attractiveness of the new product development project as in Table 3. Furthermore, On the basis of Table 2, fuzzy numbers parameterized by quadruples, Table 4 is the linguistic terms approximated by the fuzzy numbers of new product P1 assessed by senior manager of marketing.

Aggregate fuzzy numbers to obtain fuzzy value index (FVI), fuzzy risk index (FRI) and fuzzy strategy fitting index (FSFI) of the new product development project. According to the fuzzy weighted-average definition, the FVI, FRI and FSFI can be obtained by a standard fuzzy operation.

Applying the same processes, the new project P_1 was assessed by the other four seniors managers. Finally, mean operation is used for integrating the FVIs, FRIs and FSFIs under the same project assessed by different senior managers. Furthermore, the senior managers assess the other eight new product projects.

Table 3: Linguistic assessment of new product P_1 given by the senior manager of marketing

Sub criteria	Element criteria	Fuzzy rating	Fuzzy weight of sub criteria	Fuzzy weight of sub criteria
A_1	A11	VG	H	H
	A12	E		VH
A2	A21	G	VH	H
	A22	VG		VH
B_1	B11	G	H	VH
	B12	VG		FH
	B13	E		H
B_2	B21	VG	VH	VH
	B22	G		VH
	B23	G		H
B3	B31	E	FH	FH
	B32	VG		H
	B33	VG		H
B_4	B41	G	H	H
	B42	VG		VH
	B43	G		H
C_1	C11	H	H	FH
	C12	VH		VH
	C13	FL		F
C_2	C21	VH	VH	VH
	C22	H		H
	C23	EH		VH
C3	C31	VH	H	H
	C32	H		FH

Alignment of portfolio strategies: To keep a balance between project's strategy fitting, value and development risk, under the consideration of business environments, company's business strategy and marketing direction, the steering committee of company sets a directive of the weights of project's strategy fitting, value and development risk as "Very High", "High" and "High", respectively.

Table 4: Linguistic terms approximated by fuzzy numbers of new product P_1 given by a senior manager of marketing

Sub criteria	Element criteria	Fuzzy rating	Fuzzy weight of sub criteria	Fuzzy of weight sub criteria
A1	A11	(0.6,0.8,1.0)	(0.6,0.8,1.0)	(0.6,0.8,1.0)
	A12	(0.8,1.0,1.0)		(0.8,1.0,1.0)
A2	A21	(0.5,0.65,0.8)	(0.8,1.0,1.0)	(0.6,0.8,1.0)
	A22	(0.6,0.8,1.0)		(0.8,1.0,1.0)
B1	B11	(0.5,0.65,0.8)	(0.6,0.8,1.0)	(0.8,1.0,1.0)
	B12	(0.6,0.8,1.0)		(0.5,0.65,0.8)
	B13	(0.8,1.0,1.0)		(0.6,0.8,1.0)
B2	B21	(0.6,0.8,1.0)	(0.8,1.0,1.0)	(0.8,1.0,1.0)
	B22	(0.5,0.65,0.8)		(0.8,1.0,1.0)
	B23	(0.5,0.65,0.8)		(0.6,0.8,1.0)
B3	B31	(0.8,1.0,1.0)	(0.5,0.65,0.8)	(0.5,0.65,0.8)
	B32	(0.6,0.8,1.0)		(0.6,0.8,1.0)
	B33	(0.6,0.8,1.0)		(0.6,0.8,1.0)

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B_4	B41	(0.5,0.65,0.8)	(0.6,0.8,1.0)	(0.6,0.8,1.0)
	B42	(0.6,0.8,1.0)		(0.8,1.0,1.0)
	B43	(0.5,0.65,0.8)		(0.6,0.8,1.0)
C1	C11	(0.5,0.65,0.8)	(0.6,0.8,1.0)	(0.5,0.65,0.8)
	C12	(0.6,0.8,1.0)		(0.8,1.0,1.0)
	C13	(0.3,0.5,0.7)		(0.3,0.5,0.7)
C2	C21	(0.6,0.8,1.0)	(0.8,1.0,1.0)	(0.8,1.0,1.0)
	C22	(0.5,0.65,0.8)		(0.6,0.8,1.0)
	C23	(0.8,1.0,1.0)		(0.8,1.0,1.0)
C3	C31)	(0.6,0.8,1.0)	(0.6,0.8,1.0)	(0.6,0.8,1.0)
	C32	(0.5,0.65,0.8)		(0.5,0.65,0.8)

Applying the fuzzy mean and spread method, the mean and variance of each project are calculated. The results are shown in Table 5.

Table 5: The FPAIs of the nine new product projects and their ranking

Product	Cost estimate $ Million	Fuzzy project attractive index (FPAI)	$\mu(M)$	$\sigma(M)$	Ranking
P**1**	85	(0.38, 0.63, 0.83)	0.618	0.0051	8
P2	90	(0.44, 0.69, 0.88)	0.675	0.0049	1
P3	93	(0.39, 0.64, 0.85)	0.63	0.0053	5
P4	84	(0.40, 0.64, 0.84)	0.63	0.0049	4
P$_5$	105	(0.38, 0.63, 0.84)	0.62	0.0053	7
P6	98	(0.43, 0.69, 0.87)	0.67	0.0049	2
P7	86	(0.41, 0.66, 0.86)	0.645	0.0051	3
P**8**	83	(0.39, 0.62, 0.83)	0.615	0.0048	9
P9	97	(0.44, 0.62, 0.83)	0.628	0.0038	6

V. Conclusions

This research has highlighted the decision support system for selection of new product portfolio. Because of complexity, incomplete information and ambiguity in the portfolio selection context, a fuzzy logic-based portfolio selection model, which applies linguistic approximation and fuzzy arithmetic operation, has been developed to address the new product portfolio selection. The method incorporates the multiplicity in meaning and ambiguity of factor measurement while considering important interactions among decision levels and criteria. The company and managers involved in the case study illustrated in this study were generally pleased with the approach.

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