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Applying Fuzzy Logic For New Product Portfolio Selection

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Abstract

Due to limited resources, companies require to strategically allocate resources to a set of projects involving new products. A portfolio management decision is usually made on the basis of product value, project risk and business strategies. Due to both the nature and timing of new product development, portfolio selection is associated with uncertainty and complexity, and conventional evaluation methods cannot handle such decisions suitably and effectively. However, fuzzy logic is well suited for decision making with uncertainty. Thus, a method for portfolio selection decision using fuzzy logic is proposed. As an illustration, a new IT product portfolio selection in Taiwan's company is cited to demonstrate the evaluation procedure that can be used in new product portfolio.

Keywords: New product portfolio management; New product selection; Linguistic multi-criteria decision

Introduction

Currently many companies facing increasing competition have realized that accelerated new product development is crucial for their survival and winning competitive battles. However, resource limitations and consumption that are not uniform over time requires an organization to strategically allocate resources to a subset of possible new product projects. New product portfolio selection is a crucial and vital decision to successful new product innovation. Thus, a large number of new product portfolio selection methods are developed such as mathematical programming, economic models, options pricing theory, strategic approaches, scoring models and checklists, analytical hierarchy approaches (AHP), and mapping approaches (Griff, 1997; Cooper et al., 1999).

The portfolio management is a complex and dynamic decision process. Companies must allocate a limited set of resources to projects to balance risk, reward, and in alignment with its strategies. Complexity, uncertainty and imprecision associated with new product portfolio selection result from the following reasons (Griff, 1997; Martino, 1995; Bard et al., 1988):

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.

To assist managers in making better new product portfolio selections, numerous decision tools have been developed with the hope that managers could make better decisions in an uncertain environment (Cooper et al., 1999). Most of these techniques have both practical and theoretical limitations. The major obstacle is the amount of data required: information on the financial results, resource that needs timing, and probabilities of completion and suspect. Further, these mathematical portfolio approaches historically have provided inadequate treatment of risk and uncertainty unable to handle multiple and interrelated criteria and generally fail to recognize interrelationships with respect to payoffs of combined utilization of resources. In addition, they address only some of the above issues. Finally, managers perceive such techniques to be too difficult to understand and use. Generally, in uncertain situations when the available information is scarce and mechanisms are not clearly defined, managers often react very poorly (Bard et al., 1988). Uncertainty, complexity and scarce or unreliable information become a threat to the effective use of traditional quantitative techniques. However, 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 with 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 (Kao and liu, 1997; Chen and Chiou, 1999; Lin, 2000). 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.

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

Illustrative Case Study

In this section, a new product portfolio selection of an international IT products company in Taiwan is cited to demonstrate the evaluation procedure, which can be used in new product portfolio management.

Subject of Case Study

BIT is one of the top 100 IT companies of 2002 as shown in Business Week, 2002 edition, in which the world's largest technology companies have been listed. BIT focuses its products on networked digital lifestyle devices and categorizes them into four business groups: network display, digital media, imaging network and networking & communications. BIT has annual revenue of $4 billion and invests four percent of its revenues in R&D every year. They have more than 2000 talented researchers working in four R&D centers worldwide. BIT is now strengthening integration both vertically, through the value chain, and horizontally, across their key product lines.

Application of FLNPPSM to the Portfolio Selection

In order to create new platform products to lead to a portable storage device with a built-in wireless display that allows users to both play and record digital information, BIT decides to invest $300-400 million in 3-5 new platform product development in 2003-2004, and nine new network digital products had been proposed from the four business groups of BIT in 2002. For determining the appropriate product and characteristics to be developed, pursuant with previous studies, BIT had set up its architecture for new product portfolio selection, which determined the appropriate new project characteristics to be developed. Based on its architecture and the procedures of FLNPPSM, a decision of new product portfolio selection was reached. The deliberations over how to select the new product projects are summarized below:

1. Form a committee of decision-makers and collect the project related data. For evaluating new products, a new product portfolio selection committee composed of five experts/senior-managers from business planning and global strategy, marketing, engineering/technology, new business project office and finance was organized and led by the Vice President of business planning & marketing.

Before proceeding with the assessment, the evaluators studied the data and information related to the new product project. The project managers were asked to hold a briefing session to introduce both market and technical data, as well as to present a cursory financial forecast. Despite the availability of both technical and market data, the "first cut" homework was still marked by ambiguity and uncertainty. The reported data might have been obtained in a specific environment, such as a developed country, and, therefore may not have been valid for other environments, particularly in developing countries like China and the Association of Southeast Asian Nations. Much of the information is simply not available in developing countries, and it is not reliable if they have the information. Since the attributes of the new product project may not exactly satisfy the firms' ideal, the decision-makers had to deal with the critical issue of integrating and balancing different criteria. Since experts can easily differentiate between high, medium, and low, but find it difficult to judge whether a value, e.g. 0.2, is low, or another value, e.g. 0.3, is also low, they find it easier to use linguistic terms to measure ambiguous events. Furthermore, linguistic variables contain ambiguity and multiplicity of meanings and the information obtained can be expressed as a range in fuzzy set, instead of a single value in traditional methods, thus fuzzy logic was suggested to apply to this decision making context.

2. 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 on their experience and referring to the assessment factors proposed in previous studies (Cooper et al., 2002), the selection committee developed a selection architecture and criteria as shown in Table 1 (Table 1 merely presents what they assess to be the most prevalent and meaningful factors for this case study).

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})
		Magnitude of defend from competitors (C_{32})

3. Define linguistic variables as well as associated membership functions for measuring the project's strategy fitting, value and risk. For the sake of convenience, instead of eliciting linguistic terms and the corresponding membership functions from the experts, some were obtained directly from past data (Chen and Hwang, 1992) and others were modified to incorporate BIT situations. 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.

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)

4. 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 P_1 assessed by senior manager of marketing.

5. 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. For example: fuzzy business strategy fit (FA_1) and fuzzy strategy fitting index (FSFI) is defined as:

$$FA_1 = \sum_{j=1}^{2}(A_{1j} \otimes W_{1j}) \Big/ \sum_{j=1}^{2} W_{1j} \quad \text{FSFI} = \sum_{i=1}^{2}(FA_i \otimes W_i) \Big/ \sum_{j=1}^{2} W_i$$

Table 5 shows the results of FVI, FRI and FSFI of new product project P_1 assessed by a senior manager of marketing.

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	A_{11}	VG	H	H
	A_{12}	E		VH
A_2	A_{21}	G	VH	H
	A_{22}	VG		VH
B_1	B_{11}	G	H	VH
	B_{12}	VG		FH
	B_{13}	E		H
B_2	B_{21}	VG	VH	VH
	B_{22}	G		VH
	B_{23}	G		H
B_3	B_{31}	E	FH	FH
	B_{32}	VG		H
	B_{33}	VG		H
B_4	B_{41}	G	H	H
	B_{42}	VG		VH
	B_{43}	G		H
C_1	C_{11}	H	H	FH
	C_{12}	VH		VH
	C_{13}	FL		F
C_2	C_{21}	VH	VH	VH
	C_{22}	H		H
	C_{23}	EH		VH
C_3	C_{31}	VH	H	H
	C_{32}	H		FH

6. 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. Since the project's development risk impacts the success of a project, the fuzzy project attractive index (FPAI) of a project is defined as:

$$\text{FPAI} = \left(FSFI \otimes W_A \oplus FVI \otimes W_B \oplus FRI' \otimes W_C\right) / \sum_{i=A}^{C} W_i$$

where W_i, i = A, B, C, are the weights of project's strategy fitting, value and development risk, and FRI' = (1, 1, 1) Θ FRI. Applying this definition, the FPAI of the new product project P_1 assessed by a senior manager of marketing is obtained as listed in Table 5. Applying the same process, the nine FPAIs of new product projects obtained are as listed in Table 6.

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 weight of sub criteria
A_1	A_{11}	(0.6,0.8,1.0)	(0.6,0.8,1.0)	(0.6,0.8,1.0)
	A_{12}	(0.8,1.0,1.0)		(0.8,1.0,1.0)
A_2	A_{21}	(0.5,0.65,0.8)	(0.8,1.0,1.0)	(0.6,0.8,1.0)
	A_{22}	(0.6,0.8,1.0)		(0.8,1.0,1.0)
B_1	B_{11}	(0.5,0.65,0.8)	(0.6,0.8,1.0)	(0.8,1.0,1.0)
	B_{12}	(0.6,0.8,1.0)		(0.5,0.65,0.8)
	B_{13}	(0.8,1.0,1.0)		(0.6,0.8,1.0)
B_2	B_{21}	(0.6,0.8,1.0)	(0.8,1.0,1.0)	(0.8,1.0,1.0)
	B_{22}	(0.5,0.65,0.8)		(0.8,1.0,1.0)
	B_{23}	(0.5,0.65,0.8)		(0.6,0.8,1.0)
B_3	B_{31}	(0.8,1.0,1.0)	(0.5,0.65,0.8)	(0.5,0.65,0.8)
	B_{32}	(0.6,0.8,1.0)		(0.6,0.8,1.0)
	B_{33}	(0.6,0.8,1.0)		(0.6,0.8,1.0)
B_4	B_{41}	(0.5,0.65,0.8)	(0.6,0.8,1.0)	(0.6,0.8,1.0)
	B_{42}	(0.6,0.8,1.0)		(0.8,1.0,1.0)
	B_{43}	(0.5,0.65,0.8)		(0.6,0.8,1.0)
C_1	C_{11}	(0.5,0.65,0.8)	(0.6,0.8,1.0)	(0.5,0.65,0.8)
	C_{12}	(0.6,0.8,1.0)		(0.8,1.0,1.0)
	C_{13}	(0.3,0.5,0.7)		(0.3,0.5,0.7)
C_2	C_{21}	(0.6,0.8,1.0)	(0.8,1.0,1.0)	(0.8,1.0,1.0)
	C_{22}	(0.5,0.65,0.8)		(0.6,0.8,1.0)
	C_{23}	(0.8,1.0,1.0)		(0.8,1.0,1.0)
C_3	C_{31})	(0.6,0.8,1.0)	(0.6,0.8,1.0)	(0.6,0.8,1.0)
	C_{32}	(0.5,0.65,0.8)		(0.5,0.65,0.8)

Table 5: FVI, FRI, FSFI and FPAI of a new product P_1 given by a senior manager of marketing

Fuzzy project attractive index (FPAI)	Main criteria (FVI, FRI, FSFI)	Sub criteria
(0.37,0.62,0.83)	(0.60,0.81,0.97)	(0.69,0.91,1.0)
		(0.54,0.73,0.93)
	(0.57,0.76,0.92)	(0.61,0.81,0.94)
		(0.53,0.70,0.88)
		(0.64,0.86,1.0)
		(0.53,0.71,0.89)
	(0.55,0.75,0.93)	(0.47,0.67,0.89)
		(0.66,0.83,0.95)
		(0.54,0.73,0.93)

7. Resource allocation and projects selection

Finally, for allocating the resources into projects, FPAIs are ranked for new product selection decision. According to the fuzzy mean and spread method, a triangular fuzzy number M = (l, m, u), and let $\mu(M)$ and $\sigma(M)$ be the mean and variance of M. Then $\mu(M)$ and $\sigma(M)$ can be computed as:

$$\mu(M) = \frac{1}{4}(l + 2m + u) \quad \text{……(1)}$$

$$\sigma(M) = \frac{1}{80}(3l^2 + 4m^2 + 3u^2 - 2ul - 4lm - 4mu) \quad \text{……(2)}$$

Suppose that the mean values and spreads are calculated for the fuzzy numbers M_i and M_j. The rules for ranking are:

If $\mu(M_i) > \mu(M_j)$, then $M_i > M_j$
If $\mu(M_i) = \mu(M_j)$ and $\sigma(M_i) > \sigma(M_j)$, then $M_i > M_j$

Applying the fuzzy mean and spread method, the mean and variance of each project are calculated. The results are shown in Table 6.

Since the total investment is set up to $300-400 million, and the total cost estimation of the four most attractive projects, P2, P6, P7, and P4, is $358 million, the committee suggests selecting the projects P2, P6, P7 and P4 as the new product portfolio.

Table 6: 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
P_2	90	(0.44, 0.69, 0.88)	0.675	0.0049	1
P_3	93	(0.39, 0.64, 0.85)	0.63	0.0053	5
P_4	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
P_6	98	(0.43, 0.69, 0.87)	0.67	0.0049	2
P_7	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
P_9	97	(0.44, 0.62, 0.83)	0.628	0.0038	6

Conclusions

This research has highlighted the importance of new product portfolio selection. 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. This study has provided potential value to practitioners by offering a rational structure for reflecting imprecise phenomena common in many business environments and has taken into account the uncertainty of each factor to assure a relatively realistic and informative evaluation, and demonstrated another application of fuzzy logic for the researchers.

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