An Application of Fuzzy Set Approach for Determining the Appropriate Strategy in Techology Transfer

PAO-LONG CHANG
*YAW-CHU CHEN

Institute of Management Science,
National Chiao Tung University,
4F, 114, Section 1, Chung-Hsiao W. Road,
Taipei, Taiwan, R.O.C.

*Institute of Management Science,
National Chiao Tung University and Department
of International Trade, Ming Chuan College,
250 Chung-Shan N. Road, Sec. 5, Shihlin
Taipei, Taiwan, R.O.C.

ABSTRACT

This paper discusses the potential application of fuzzy set theory to technology transfer strategy selection in the area of technology management. An algorithm for technology transfer strategy selection is proposed. The algorithm is based on the concepts of fuzzy set theory and the hierarchical structure analysis. The linguistic variables and fuzzy numbers are used to aggregate the decision makers' linguistic assessments about criteria weightings and appropriateness of alternative transfer strategies versus selection criteria to obtain fuzzy appropriateness indices. Then rank the fuzzy appropriateness indices to determine the best technology transfer strategy. By using this decision algorithm, the decision makers' subjective assessments with various rating attitudes and the trade-offs among various selection criteria can be taken into account in the aggregation process to assure more convinicing and accurate decision making.

Keywords: Multi-criteria decision making; technology transfer; fuzzy set theory.

1. Introduction

Though application of fuzzy set theory in the fields of artificial intelligence, information processing, engineering, control, and human decision making has proliferated in recent years, effort in analyzing technology transfer strategy selection is lacking.

Brown et al. [1] provide a technique that managers of government-sponsored R&D could use to evaluate innovations during their precommercialization stage in order to indentify an appropriate technology transfer strategy. In their paper, the six types of successful commericalization strategies used by federal agencies are described: contracting R&D to industrial partners, working with industrial consortia, licensing to industry, influencing key decision makers, working with broker organizations, and generating end-user demand. Three sets of criteria for classifying innovations are proposed, including technological criteria, market criteria, and policy criteria. Technological criteria examine the innovations on the nature of science and technology. Market criteria evaluate innovations on the marketplace profiles, while policy criteria refer to the level of government support and the desired time line. Then, they developed a guideline, which links the evaluation criteria and appropriate technology transfer strategy, for selecting a technology transfer strategy, based primarily on the five fully commericialized innovations.

However, the transfer of technology from its source to commercial application is a very complex process. It is a multi-criteria decision making problem in ill-structured situations. We must make a careful analysis between criteria, alternatives, weight, and decision makers before making a decision. Using the conventional crisp decision method, we always have to find precise data. But under many conditions, we cannot get precise data because the data are from the experience and the judgment of decision makers. For example, Brown et al. define the evaluation criterion, "nature of industry" of market criteria, with a crisp concept. They consider that an innovation under that of criterion can be distinguished between "competitive" and "concentrated" in an exact term. And a ternary system (highly/sometimes/not) can be used to represent the possible degree of appropriateness of strategy versus criterion. Two observations are in order at this point: (1) firstly, there is no sharp boundary between "competitive" and "concentrated". The market data like economic data are imprecise and fuzzy by nature due to time, space, measurement error, or uncertain environment [2]. The use of conventional crisp approaches, both deterministic and random process, cut off information if the market concepts are intrinsically imprecise or fuzzy; (2) secondly, a technology transfer strategy versus the evaluation criteria, in some sense, should be taken into account with their admittedly imprecise degree of appropriateness, without too strict and unnatural approximating values. For example, a point system is given to the assessment of degree of appropriateness (highly appropriate=2, sometimes appropriate=1, not=0) of a strategy versus a criterion. The assessments of alternatives versus various criteria and the importance weights of criteria, however, often depend on judgment or approximation. Due to this type of existing fuzziness in decision making problem, we would expect a gradual transition from membership to nonmembership of an innovation's consonance with specified criteria as well as the relative importance weights of criteria.

In this paper the linguistic values are utilized to assess the linguistic ratings given by decision makers as well as the linguistic weights assigned to various criteria. The method proposed in this paper shows how linguistic variable and fuzzy number can be used to describe imprecise measurement and improve our understanding of a technology transfer strategy selection problem.

2. Definition of Criteria and Strategies

The Development Center for Biotechnology (DCB), partially supported by the goverment of Taiwan on a contract basis, is an autonomous nonprofit research and development organization established in March 1984 for the purpose of promoting and upgrading biotechnology industry in Taiwan.

The functions of DCB are carried out along with two directions. Vertically, it will link up the academic sector and the industrial sector through developmental research. It has a pilot plant to develop technologies originated from academic researchers and then transfer them to appropriate manufactures. The Center also provides market research and assessment services for the academy, industry as well as the government. Horizontally, DCB will introduce, purchase and adopt suitable biotechnologies from around the world with a view to transferring them to domestic industries.

Biotechnology is a strategic industry in Taiwan. According to the current domestic technological capacity and industrial demand, the DCB has chosen pharmaceutical, agricultural, specialty chemicals and environmental protection as impending research task. However, DCB faces the problem of choosing the appropriate transfer strategy to insure the innovation against unsuccessful commercialization.

With the help of senior managers in DCB and business units, by means of personal interviews, the respondents were asked to list the criteria and commonly used strategies that are successful in transferring government-sponsored innovations. A committee of four decision makers, i.e., D_1, D_2, D_3, *and* D_4, has been formed to determine the most appropriate technology transfer strategy. After screening, four selection criteria are considered: Technological availability (C_1), Market potential (C_2), Policy support (C_3), and Management ability (C_4). The following are the descripitions of the criteria.

(1). *Technological availability*: This criterion describes the technology R&D by reflecting its likely rate of diffusion, including: the process or product innovation, generic research or applied research, simplicity or complexity, proprietary or nonproprietary, low or high technological uncertainty, desired time of tranfer, and transfer cost.

(2). *Market potential*: This criterion includes the considerations of the breadth of possible applicaitons, competitive or concentrated market, size of market, and product life cylcle.

(3). *Policy support*: This refers to the level of government support, including: tax incentives or subsidies, infrastructure projects required for years to implement the R&D.

(4). *Management ability*: This reflects whether the managerial and business functions of the recipient (firm) is effective or not, including: manufacturing capability, financial and human resources, and marketing skills.

The four commonly used strategies that are successful in transferring government-sponsored R&D in the case studies are described as follow:

A_1 = *Purchasing* (firms just buy R&D from research bodies).

A_2 = *Working with industrial partner* (like joint venture strategy, but do not set up an individual firm, both share (50-50) the required resources).

A_3 = *Licensing* (the licensee has rights to produce and market the product).

A_4 = *Cooperative R&D* (the company's cost sharing are 100 percent; the company is committed to the commercialization process and as a way of enhancing the R&D effort).

3. A fuzzy algorithm for technology transfer strategy selection

The concepts of hierarchical structure analysis with two distinct levels are used in this paper. The first level is to evaluate fuzzy importance of the decision criteria (including: technological innovations, market potential, policy support, and management ability) and the second level is to assign ratings to various strategies under each evaluation criterion.

The triangular fuzzy number [4] and the linguistic variable [6] are the two main concepts used in this paper to assess the preference ratings of linguistic variables, "importance" and "appropriateness". The decision makers can employ a weight set W ={Very Low, Low, Medium, High, Very High}, to assess the relative importance of various criteria. And use the linguistic rating set S= {Very Poor, Poor, Fair, Good, Very Good}, to evaluate the appropriateness of the alternatives versus various criteria. Without a loss of generality, the membership functions of the linguistic values in the weighting set W and linguistic rating set S can be represented by the approximate reasoning of triangular fuzzy numbers, as shown in the following:

Linguistic values		*Fuzzy numbers*
Very Low Very Poor	:	(0,0,0.25)
Low Poor	:	(0,0.25,0.5)
Medium Fair	:	(0.25,0.5,0.75)
High Good	:	(0.5,0.75,1)
Very High Very Good	:	(0.75,1,1)

The reason of using triangular fuzzy number is that it is intuitively easy to be used by the decision makers.

An algorithm of the multi-persons multi-criteria technology transfer strategy selection with fuzzy set approach is given in the following:

Step 1. Form a committee of decision makers, then identify the selection criteria and list the prospective technology transfer alternative strategies.

Step 2. Choose the appropriate preference ratings for the importance weight of the selection criteria and the preference ratings for alternatives versus criteria.

Step 3. Evaluate the importance weight of each criterion and the fuzzy ratings for the appropriateness of alternatives versus criteria.

Step 4. Aggregate the weightings of criteria to get the aggregated weighting W_t; pool the decision makers' opinions to get the aggregated fuzzy rating S_{it} of alternative A_i under criterion C_t; then aggregate S_{it} and W_t with respect to each criterion to obtain the fuzzy appropriateness indices F_i for all alternatives.

Step 5. Calculate the ranking value $(U_T(F_i))$ associated with each alternative's fuzzy appropriateness index F_i.

Step 6. Choose the technology transfer strategy with the maximal ranking value.

4. An application – numerical treatment of the problem

The following example discusses the hepatitis B vaccine technology transfer strategy selection through the observation and survey of DCB and company.

Step 1. From Section 2, we know that the four decision makers (D_1, D_2, D_3, and D_4) are based on the four selected criteria (C_1, C_2, C_3, and C_4) in choosing the most appropriate strategy among the four alternative strategies (A_1, A_2, A_3, and A_4). The definition of evaluation criteria and alternative strategies are described in Section 2.

Step 2. Importance weighting set W and appropriateness ratings set S are described the same as in Section 3., i.e., W={Very Low, Low, Medium, High, Very High}, S={Very Poor, Poor, Fair, Good, Very Good}.

Step 3. The weight assigned to the four criteria given by decision makers is presented in Table 1. The appropriateness of alternatives versus criteria given by decision makers are presented in Table 2, 3, 4 and 5.

Step 4. Compute the final score F_i of each A_i, as shown in Table 6, by using the following equation.

$$F_i = \sum_{t=1}^{4} W_t \, S_{it} \ , \ i=1,2,3,4.$$

Where W_t is the average weight of each criterion C_t, S_{it} is the aggregate fuzzy rating of alternative A_i under criterion C_t across the decision makers' opinions. F_i are approximately triangular fuzzy numbers, due to W_t and S_{it} are triangular fuzzy numbers.

Step 5. There are many methods for ranking fuzzy numbers. Here, we use the combination of Chen [3] and Kim and Park [5] methods. Let $F_i=(c_i, a_i, b_i)$, $i=1,\dots,4$, be four triangular fuzzy numbers, then the ranking values of these triangular fuzzy numbers are

$$U_T(F_i) = [(b_i-x_i)/(x_2-x_1-a_i+b_i) + 1-(x_2-c_i)/(x_2-x_1+a_i-c_i]/2 \qquad (1)$$

where $x_1=\min\{c_1, c_2, c_4, c_4\}$ and $x_2=\max\{b_1, b_2, b_3, b_4\}$. By using equation (1) we obtain the ranking values of F_i as shown in Table 7.

Step 6. The ranking order of fuzzy appropriateness for four alternatives is A_2, A_3, A_1 *and* A_4. Therefore, it is obvious that the best selection is A_2, *i.e. ,working with industrial partner* strategy. Now, the committee can recommend that the alternative A_2 is the most appropriate technology

5. Discussion and Conclusion

In this paper, a decision algorithm based on the fuzzy set theory is proposed to solve the technology transfer strategy selection problem under fuzzy environment.

The main concepts of fuzzy set theory used in this paper are the linguistic variable and fuzzy number, because they can be easily used to describe the assessments of alternatives versus criteria and the importance weights of criteria. The conventional approaches, both deterministic and random process, tend to be less effective in conveying the imprecision or vagueness nature of the linguistic assessment. This approach is still very much in the preliminary stages of development, but it gives us a promising means to handle the intangible and nonquantitative factors inherent in technology transfer strategy selection.

There are many research issues remaining in the development of this approach. Among these are following:

(1) The definition of the appropriate fuzzy linguistic variables, their numbers, their values, and their universe of discourse for a general use in the algorithm.

(2) A procedure for collecting raw data and estimating the proper membership functions for the base linguistic variable values.

(3) The criteria tree of technological availability, market potential, policy support and management ability can be decomposed into more levels of hierarchical structure, i.e., down to the subcriteria. Then the evaluation task is performed on the level of subcriteria. The decision algorithm proprosed in this paper can be also used to find the best technology transfer strategy.

(4) The relative importance of each decision maker is not considered in this paper. In many multi-judge decision problems, the weight W not only determined by decision maker and criterion, but also can be varied by the decision environment and structure.

Although the decision algorithm presented in this paper is primarily designed for the technology transfer strategy selection, however, it can be applied to the problems such as project management, foreign market entry mode selection, and many other areas of management decision problems.

	Decision makers			
Criteria	D_1	D_2	D_3	D_4
C_1	H	VH	M	H
C_2	H	VH	VH	M
C_3	VH	VH	H	VH
C_4	H	H	H	VH

Table 1. The importance of the criteria by using set in scale set W.

	Decision makers			
Alternatives	D_1	D_2	D_3	D_4
A_1	F	P	F	F
A_2	G	VG	G	G
A_3	G	G	F	VG
A_4	F	F	G	G

Table 2. The decision makers' evaluation of the four alternatives under criterion C_1.

	Decision makers			
Alternatives	D_1	D_2	D_3	D_4
A_1	G	VG	G	G
A_2	F	F	G	F
A_3	G	G	F	G
A_4	F	P	P	G

Table 3. The decision makers' evaluation of the four alternatives under criterion C_2.

	Decision makers			
Alternatives	D_1	D_2	D_3	D_4
A_1	F	G	G	G
A_2	F	G	G	VG
A_3	P	F	F	F
A_4	P	F	F	P

Table 4. The decision makers' evaluation of the four alternatives under criterion C_3.

Alternatives	Decision makers			
	D_1	D_2	D_3	D_4
A_1	G	G	F	F
A_2	G	G	G	VG
A_3	VG	G	VG	G
A_4	F	F	F	F

Table 5. The decision makers' evaluation of the four alternatives under criterion C_4.

Alternatives	Fuzzy appropriateness index
A_1	(0.2305, 0.5352, 0.8486)
A_2	(0.2793, 0.6074, 0.9092)
A_3	(0.2441, 0.5605, 0.8613)
A_4	(0.1299, 0.3955, 0.7100)

Table 6. The fuzzy appropriateness indices of the four alternatives.

Alternatives	A_1	A_2	A_3	A_4
Ranking values	0.5158	0.5760	0.5351	0.3923

Table 7. The ranking values of the fuzzy appropriateness indices for alternatives.

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