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기술대체안의 우선순위 설정을 위한 개량 AHP 모형의 개발

Development of a Methodology for Setting Priority of Technology Alternatives

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Abstract

The Analytic Hierarchy Process (AHP), a decision making model, which is more applicable than other methods to R&D project selection, particularly when it is applied to intangibles. The objective of this paper is to develop an extended model of the AHP which is linked to Cross Impact Analysis to assist in the ranking of a large number of technological alternatives.

In this study, we developed a priority setting algorithm which considers the cross-impact of the future technology alternatives and thus developed an integrated cross-impact hierarchical decision-making model, which sets the priority by considering technological forecasting and technology dependency

1. Introduction

A wide variety of methods and techniques using the theory of management science have been proposed in R&D project selection process [2][3][14][17]. A good many of these are focused on how to evaluate and identify the best subset of projects under some resource constraints. Many practitioners, however, still experience difficulty in applying these methods and techniques to decision making to set priorities for R&D projects [1][9].

To overcome such problems, some of them have viewed the process as a multi-criteria decision making problem within the context of the long-range and strategic planning process of the firm [9] and have utilized the Analytic Hierarchy Process (AHP) [13], a decision making model, which is more applicable than other methods to R&D project selection, particularly when it is applied to intangibles. One of the obvious strengths of the AHP is that it takes into consideration all the relevant elements of the problem, both strategic and tactical, within the model [5]. For emphasis, we note that because the AHP provides a comprehensive framework which incorporates both qualitative and quantitative aspects of human thought, it has been applied to various decision making areas [18][19], particularly to R&D project selection and technology prioritization [8] [9] [10] [12] [16].

Such existing research in application using the AHP for project selection can provide us with useful insights into this issue when R&D projects under consideration are independent. However, in reality, interdependence with respect to such factors as cost, technology, and positive synergy may exist among R&D projects [6][11][15]. For example, a specific R&D project can occur either prior to or after the anticipated time, because it may be affected by the occurrence of other projects. In that case, cross impacts that imply mutual influences among R&D projects need to be considered and evaluated. As a way to capture their cross impacts in this study, we think about the future occurrence probability of each project.

The AHP deals with judgment about preference, importance, and likelihood. Occasionally, these are mixed in a problem. There are numerous decision problems whose likelihood of occurrence in the future determines or should determine the preference for them and their selection at present. However, this preference for one alternative over another is conditional upon the different likelihood of their occurrences. Similar to Bayesian thinking, we will show how best choices need to be made in the present depending on their probabilities of occurrence in the future. Thus, our work will combine the AHP with simulation to develop a methodology. The steps of the methodology can be condensed into the following 4 stages: hierarchy construction stage, occurrence and nonoccurrence probability estimation stage, cross-impact estimation stage, and priority setting stage.

2. Hierarchy Construction Stage

When constructing hierarchies, we must include enough relevant detail to depict the problem as thoroughly as possible. The hierarchy does not need to be complete, but the alternatives which of course are in the bottom level should be thought as interdependent.

3. Occurrence and Nonoccurrence Probability Estimation Stage

Given a decision making problem, to determine the priorities of the interdependent alternatives, we need to estimate two kinds of forecasts for their occurrence probability (initial and conditional probability) with the help of experts, because their relative importance on technology may change according to their occurrence.

Initial probabilities indicate that the alternatives under consideration are estimated without considering any of the other alternatives. This again consists of two kinds of probabilities, those of occurrence and those of nonoccurrence which is [1-P(occurrence of alternative)]. *Conditional probabilities mean that an alternative occurs,* given that some other alternative has occurred. These probabilities portray the impact that the occurrence of any alternative has on the probability that any other alternative will occur. Just as the occurrence of an alternative can affect the probability that another will occur, its nonoccurrence can have a similar impact.

This stage has an estimation procedure of three steps as follows;

Step 1. Forecast the initial occurrence and nonoccurrence probabilities $P_i,\ P_{\bar{i}}\ (i = 1,......,n)$ of the alternatives x_i.

Step 2. Forecast the conditional occurrence probabilities $P(i \mid \mathrm{j})\ (j = 1,.......,n)$ of the alternatives x_i in a situation where a specific alternative is assumed to occur sometime in the future.

Step 3. Forecast the conditional nonoccurrence probabilities $P(i \mid \mathrm{j})$ of the alternatives x_i in a situation where a specific alternative is assumed not to occur sometime in the future.

4. Cross-impact Estimation Stage

This stage involves making pairwise comparisons of the elements taken in pairs against a given criterion. The same procedure as in the AHP is applied to all the elements in the levels above that of the decision alternatives at the bottom level of a hierarchy. A different procedure is needed to make the pairwise comparisons for the alternatives. The alternatives may enhance or inhibit each other. As a result, their relative importance may change according to their future occurrence or nonoccurrence. Therefore, we must deal with this dual situation and estimate relative weights for the alternatives, depending on whether an alternative occur or does not occur.

When each specific alternative is assumed to occur with respect to a certain criterion, the pairwise comparison matrix that indicates relative importance among the alternatives, called the 'Occurrence Pairwise Comparison Matrix', is estimated. Also when each specific alternative is assumed not to occur with respect a certain criterion, the pairwise comparison matrix of relative importance among the alternatives, called the 'Nonoccurrence Pairwise Comparison Matrix', is estimated

Importance weights of the alternatives are obtained by using the eigenvalue method for the two estimated matrices respectively. The results are called the 'Occurrence Weight Vector' and the 'Nonoccurrence Weight Vector' respectively. The number of the occurrence and nonoccurrence weight vectors is equal to the number of the alternatives. Each set of occurrence weight vectors and nonoccurrence weight vectors forms a single matrix called the 'Merged Occurrence Weight Matrix' and the 'Merged Nonoccurrence Weight Matrix' respectively.

5. Priority Setting Stage

Setting of the priorities which are the weights set for the alternatives can be made by incorporating the merged occurrence and nonoccurrence weight matrices with the initial and conditional probabilities. A computer-based Monte Carlo simulation can be used to do this. When we select one alternative at a time randomly, it is assumed that this selection follows the uniform distribution. There have been attempts to use the Bayesian approach even when no prior information is available [4]. What is needed in such situation is a noninformative prior. For example, in testing between two simple hypotheses, the prior which gives probability ½ to each of the hypotheses is clearly noninformative. That is why we assume the uniform distribution.

After each round of simulation, we determine the sets of occurrence and nonoccurrence weights matrices of the alternatives according to the combinations of their occurrence and nonoccurrence. Then, we compute their arithmetic mean to obtain the weights of the alternatives that are the outcome of that simulation. We iterate the simulation procedure numerous times and seek the mean value for the final weights. Finally, we synthesize by weighting the final priorities of the interdependent alternatives by the priorities of these covering criteria in the hierarchy.

The simulation algorithm to determine final priorities is as follows:

Step 1. Select one of the n alternatives $x_i\ (i = 1,.......,n)$ under consideration randomly (n : number of alternative).

Step 2. Generate a random number R_i between 0 and 1.

Step 3. Compare the random number generated in *Step 2* with the initial probability of an alternative selected in *Step 1*, to determine if it occurs. The principle of comparison is that if R_i is greater than $P(i)$, then alternative x_i occurs; otherwise, it does not occur.

Step 4. According to the results of *Step 3*, the initial probability of each remaining alternative is replaced by its conditional probability, given that the alternative in Step 3 occurs or does not occur.

Step 5. Iterate *Step 1* through *Step 4* for the remaining alternatives. Note that we should compare a random number generated newly with an initial probability changed in *Step 4* and determine whether an alternative occurs or does not occur.

Step 6. The process described in *Step 1* through *Step 5* is repeated until all n alternatives have been selected. The simulation is replayed, typically 1,000 or more times.

Step 7. In every round of simulation, the combination of the column vectors $x_i w$ $(i = 1, \ldots\ldots, n)$ of the occurrence weight matrix XW with the column vectors $x_i w$ of nonoccurrence weight matrix XW is developed, and then the row vector of the combination is averaged arithmetically. The outcome is the weights set of interdependent alternatives after each simulation. Finally, we average the weight sets obtained from every simulation and derive the final weights of the alternatives.

Step 8. We synthesize the weights of elements in the hierarchy to obtain the overall priorities of the alternatives.

6. Conclusion

This study presented a methodology as a decision aid model necessary in setting priorities for technological alternatives involving cross impact relationships among them. It is designed to capture cross impacts through simulation, a generally accepted method for modeling and analyzing complex stochastic systems that change over time. It may be viewed as a forecasting model that is capable of reflecting future changes of technological alternatives.

The major contribution of this research is to combine decision theory and technological forecasting theory in the selection of interdependent technological alternatives to decision making involving a forecasting function.

We foresee that the methodology itself can be extended further. For example, we can expand the first-order conditional probability to more a second-order conditional probability of each alternative. In the simulation stage to obtain the changed weight of the elements, we considered only the conditional probability of an alternative occurring given one other alternative. We need to consider the conditional probability of an alternative occurring given two or more other alternatives.

Despite this limitation, the analysts using the methodology will certainly gain insight, by using it in the manner it is used here regarding the significance of future technologies that would not be possible without the use of the probabilistic approach.

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