상호영향계층분석방법을 이용한 항공기술의 평가에 관한 연구

An Application of the Cross-impact Hierarchy Process to Evaluate Aeronautics Technologies: A Case Study

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Abstract

The Cross-impact Hierarchy Process (CHP), an extended model of the Analytic Hierarchy Process(AHP) which is linked to Cross Impact Analysis(CIA), is a powerful decision making tool to assist in the ranking of large number of dependent technological alternatives. In this paper, we will describe an application of the CHP to the aerospace industry. We here conducted a questionnaire survey for S company that is one of the representative aerospace companies in Korea. A questionnaire was designed to obtain both the priority with dependence (the CHP priority) and the priority with independence (the AHP priority) in order to compare the priority derived by each of two methods. The hierarchy in this case study is concerned with priority setting for R&D area to ensure dependent aerospace design technology of the company. The result shows that there exists the difference hard to neglect between the final priorities gained by two methods.

1. Introduction

A variety of existing research [2][3] 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 [1][4]. 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. We call it the Cross-impact Hierarchy Process (CHP). We will apply our approach to an example which we developed as a case study by eliciting probability judgment from experts in an aerospace company in Korea.

Although the Analytic Network Process (ANP) may also be useful for dealing with dependence, we believe that our probabilistic approach provides a paradigm for that kind of thinking through the ANP. Deriving probabilities as pairwise comparison priorities is often done in the AHP and the ANP [6][7]. However, there is considerable classical knowledge about how to use probabilities. ANP users may find what we have done useful in their work to extend the application of that theory along the lines we have followed in this paper.

2. The Cross-impact Hierarchy Process

The CHP combines the AHP with simulation. The steps of the CHP can be condensed into the 4 stages: hierarchy construction stage, occurrence and nonoccurrence probability estimation stage, cross-impact estimation stage, and priority setting stage[5]

In the CHP, 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.

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.

3. An Application of the CHP

3.1. Framework of Analysis

Sampling and data collection: We conducted a questionnaire survey for company S that is one of the representative aerospace companies in Korea. The reason why we selected this company is that aerospace technology area consists of complex technology systems ranging from conventional technology to advanced high technology. The aerospace technology system is strongly interconnected more than any other industries we know.

A questionnaire was designed to obtain both the priority with dependence (the CHP priority) and the priority with independence (the AHP priority) in order to compare the priority derived by each of two methods. For the additional analysis later, we classify the response group into a management group and a research group, and divide each group into managers and staff. While a management group mainly works at the headquarters of the company on a management function such as forecasting and planning, a research group mostly works at the research laboratory of the company on a research function such as the development of a specific technology. We distributed 40 copies of the questionnaire and received the response from 28. The final questionnaires for analysis after a consistency test were 24. We set a forecasting period of 5 years to help the company to establish a long-term technology plan.

Creating the Hierarchy: The hierarchy in this case study is concerned with priority setting for R&D areas to ensure independent aerospace design technology of the company. Thus, we put it into the focus or the overall objective of this hierarchy. Level 2 is the technology strategy that is composed of an advanced technology strategy, a core technology strategy, and a base technology strategy.

Levels 3 and 4 comprise the criteria and sub-criteria. As common output criteria for the evaluation of R&D projects, the technological and economic factors are mainly used. Each of them has two sub-factors for sub-criteria. While both technological feasibility and technological superiority become sub-factors of the technological

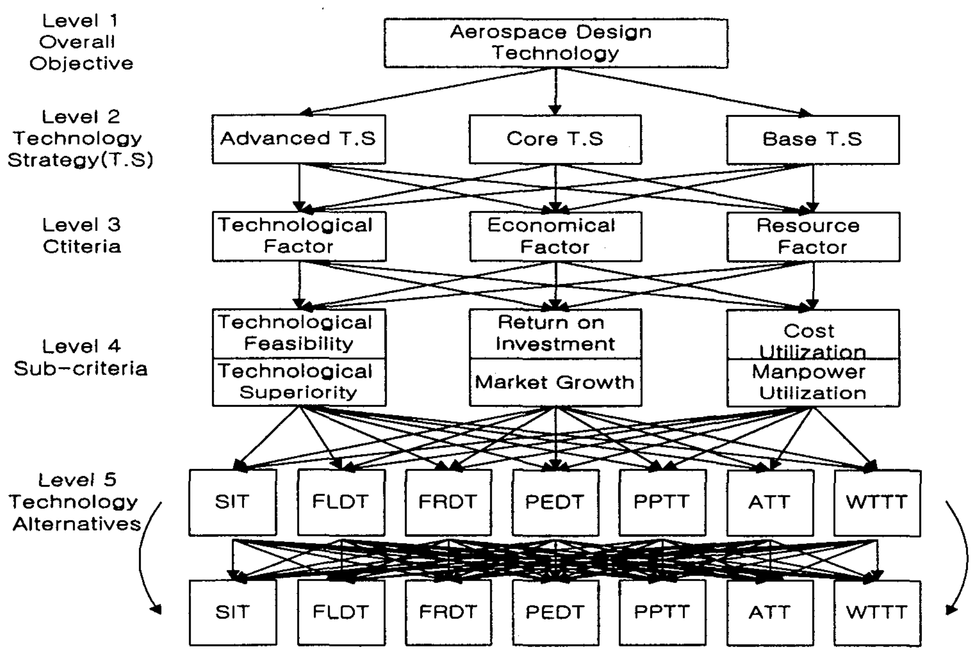

Fig. 1. Cross-impact hierarchy for prioritization of technology alternatives

factor, both return on investment and market growth become sub-factors of the economic factor. 'Resource factor' is used as an input criterion. Its subcriteria are cost utilization and manpower utilization.

The lowest level includes the alternative technologies that would contribute positively or negatively to the main objective through their impact on the intermediate criteria. The alternatives are (1) systems integration technology (SIT), (2) floating design technology (FLDT), (3) frame design technology (FRDT), (4) propelling engine design technology (PEDT), (5) propelling performance test technology (PPTT), (6) aviation test technology (ATT), (7) wind tunnel test technology (WTTT).

Fig. 1 shows the analytic hierarchy for the selection of a technology.

3.2. The results of Analysis

The relative importance of each level: In a level of technology strategy, the outcome indicates that an advanced technology strategy (w = 0.395) has the highest importance with respect to the focus. This result implies the willingness of in-house R&D for the technology on the basis of R&D know-how already possessed by the company.

In a level of criteria and sub-criteria, the results show that the criterion concerning technological characteristics (w = 0.640) is more important than any other criterion and that technological superiority (w = 0.426) has become the dominant criterion among them. In addition, the result indicates that market grow (w = 0.126) is more important than return on investment (w = 0.040) among economical factor. What that means is that the company emphasizes more on the long-term market growth than the short-term profit from investment.

The relative importance of final level: From the result of the overall final priorities for decision alternatives using the CHP as shown in column (1) of Table 1, systems integration technology (w = 0.318) has the highest priority. This result means that systems integration technology, which has more characteristic of an integrated and a systematic technology than of an individual and fragmented design technology, is needed the most for the focus (having a independent design technology) of the hierarchy in this study. As shown in columns (2)(3)(4) of Table 1, the result also indicates that systems integration technology has important meaning in terms of technology strategy.

As shown in columns (5) and (7) of Table 1, however, it is notable that systems integration technology has the lowest priority (w=0.067) with respect to the criterion concerning resource characteristics, which has the lowest weights (w = 0.194) among criteria, while it has the highest priority (w=0.405) with respect to the criterion concerning technological characteristics, which has the highest weights (w = 0.640) among criteria. This means that what is important is not how much money are needed to get the technology, but there is any possibility capable of developing the technology in order for them to ensure interdependent aerospace design technology.

3.3. The comparison of priority obtained from The AHP and the CHP

Here, we want to show an interesting outcome regarding comparison of the final priority rankings obtained from the AHP and the CHP for the case implemented in this study. If there is a difference in the final priority rankings of the decision alternatives obtained from each method, how do we interpret the difference?

For this, we asked the survey group to answer the questionnaires for both the AHP and the CHP. As expected, we see in Table 2 that the final priorities involving dependence of technological alternatives and their rankings are somewhat different from what we obtained in the case of independence using the AHP. For example, frame design technology (FRDT) and propellant engine design technology (PEDT) ranked third and fourth in

Table 1 Relative importance weights of each alternative

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
T1	.318	.350	.320	.268	.405	.273	.067	.407	.405	.292	.267	.080	.055
T2	.143	.140	.143	.147	.136	.156	.154	.139	.135	.171	.151	.205	.105
T3	.134	.130	.134	.140	.123	.146	.160	.120	.125	.150	.145	.212	.110
T4	.138	.137	.138	.140	.134	.140	.148	.133	.135	.157	.134	.179	.119
T5	.090	.083	.090	.102	.069	.093	.158	.075	.066	.078	.098	.132	.183
T6	.085	.076	.084	.099	.060	.096	.156	.060	.060	.078	.102	.107	.203
T7	.092	.085	.092	.104	.072	.097	.156	.066	.075	.074	.104	.086	.225

T1:SIT, T2:FLDT, T3:FRDT, T4:PEDT, T5:WTTT, T6:ATT, T7:PPTT.

(1) Aerospace Design Technology (2) Advanced Technology Strategy (3) Core Technology Strategy (4) Base Technology Strategy (5) Technological factor (6) Economical factor (7) Resource factor (8) Technological Feasibility (9) Technological Superiority (10) Return on Investment (11) Market Growth (12) Cost Utilization (13) Manpower Utilization

Table 2 Final priorities for the alternatives by the AHP and the CHP

Priorities	The AHP	The CHP
1	SIT (0.312)	SIT (0.318)
2	FLDT (0.157)	FLDT (0.143)
3	FRDT (0.138)	PEDT (0.138)
4	PEDT (0.124)	FRDT (0.134)
5	PPTT (0.095)	ATT (0.092)
6	ATT (0.092)	WTTT (0.090)
7	WTTT(0.084)	PPTT (0.085)

priorities by the AHP changed to fourth and third ranks by the CHP, respectively. In addition, propellant performance test technology (PPTT), aviation test technology (ATT), and wind tunnel test technology (WTTT) which ranked as 5th, 6th, 7th by the AHP changed to 7th, 5th, 6th ranks by the CHP, respectively. That is, the ranks of five of the seven alternatives have changed.

Thus, the degree of difference in the final priority rankings obtained by the two models, the AHP and the CHP, indicates 71%, where we define the degree of difference as (the number of alternatives whose priority changed / the number of all alternatives)×100%. It is undeniable that there exists the difference hard to neglect between the final priorities gained by two methods.

From the above comparison, we may insist that the CHP could become a powerful method with a unique concept and/or idea necessary for dealing with dependent technological alternatives like dependent R&D projects as decision alternatives.

4. Discussion and Conclusion

The CHP is designed to capture cross impacts through simulation, a generally accepted method for modeling and analyzing complex stochastic systems that change over time. Thus, the CHP may be viewed as a forecasting model that is capable of reflecting future changes of technological alternatives.

Therefore, we propose using the CHP in situations where the decision making problem involves dependent decision alternatives that have properties of future technologies to capture interaction between the alternatives, because of the above difference in the final priority rankings obtained from two methods.

We may have practical difficulty in applying the CHP in the business world, due to problems arising from the requirement of a number of input data. Such data should include the estimation of probabilities subject to uncertainty. To remove these difficulties that hamper the practicality of the CHP, we have used two approaches. One is attributable to a substantial reduction of input data estimated through the use of Bayes' rule and the laws of joint and conditional probability. In this manner, the number of conditional probabilities estimated by experts was substantially decreased. Despite such efforts to minimize the requirement of input data, there are still many estimates (survey questions) needed from each evaluator. Thus, the other approach is to reduce the number of survey samples by identifying who should be sent a questionnaire. That is, an alternative way to decrease the quantity of required input data is to seek a so-called 'focus group', who could provide more consistent and reliable answers within their group than any other group can within that group. We anticipate that these approaches would improve the practicality of the CHP.

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

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