New Product Concept Evaluation Using the AHP

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Abstract

New product concept evaluation is one of the most important activities among many possible evaluation activities involved in the whole new product process. This paper aims at exploring the applicability of the Analytic Hierarchy Process (AHP) to this new product concept evaluation. To this aim, an AHP based concept evaluation model was formulated and explained using an illustrative example. A number of issues were also raised and discussed concerning the applicability of AHP to our problem. Finally, some further research areas were identified.

I. INTRODUCTION

New product process is a stepwise sequence of activities designed to move the product from the initial idea generation stage through to the final launching stage. Each stage of activities is separated from the previous stage by an evaluation or GO/NOGO decision point. Though many different process with varying numbers of distinct stages may be constituted, new product process is essentially a two phase process consisting of an assessment phase followed by an action-oriented implementation phase. A distinctive characteristic of the implementation phase, as compared to the assessment phase, is that the comprizing stages of product development, market planning, prototype testing, test market and market launch require an intensive consumption of expensive resources like test equipments, manufacturing facilities and professional personnels in R&D, manufacturing and marketing departments.

During the assessment phase, two stages of activities are performed, idea screening activities and concept evaluation activities. Since the primary objective of the assessment phase is to determine the boundaries of and the direction for the new product efforts, the corresponding activities are basically intensive screening activities of short-form proposals or more detailed requests. One primary difference between those two stages of activities is that the idea screening stage is focused on generating a number of feasible new product ideas, while the concept evaluation stage is on acute evaluation of those feasible ideas. More precisely, idea screening stage is intended to identify and screen out those ideas that are not compatible with the company's goals, do not match the company's capabilities, or do not appear to have enough market potentials. Meanwhile, the concept evaluation stage ranks the feasible ideas and determines the most suitable concepts to go on to become development projects in the implementation phase.

In decision making point of view, the concept evaluation stage is one of the most important milestone in the whole new product process. Despite the scarcity of reliable informations available to this stage, it involves many difficult activities related to conflict resolution among different evaluation criteria, reduction of uncertainties on market, cost, and the nature of the investment required, and finally optimal trade-off among various project objectives. Furthermore, the decision, once made at this stage, tends to be irrevocable until the whole process turns out to be a complete success or failure. Noting this point, a Booz-Allen and Hamilton study reports that successful U.S. firms spend more money on this kind of pre-development activities, and the Japanese spend even more [5].

Several promising methods and models are available in the literature which can be applied to the new product concept evaluation. They may be categorized into two lines of approaches. One is the mathematical programming approach and the other is scoring models with varying complexities. The most popular approaches belonging to the former category are the well-known goal programming (GP) models. The GP approach, due to its capability to deal effectively with multi-criteria decision making environments, has been attracted much research efforts as a powerful vehicle to attack this kind of evaluation and selection problems. In fact, many GP-based models have been developed for the project selection problems [9,18].

However, the GP model, when applied to our problem, has some drawbacks since it provides no methods for insuring the goals selected reflect adequately the related organizational and environmental factors [11]. Another drawback of it is the lack of a systematic scheme to set priorities and trade-offs among objectives. This shortcoming is even more evident when both tangible and intangible factors need to be considered, when many interests are involved and when a number of people need to participate in the judgment process [10]. In practical situations, few GP-based methods are being utilized by R&D managers as aids to decision making. This practise can be partly ascribed to the fact that most of the proposed methods involve models requiring much quantitative input, not readly available within the company and in the early phase, and in many instances the methods are based on techniques much too elaborate for the R&D manager's routine use [1].

Scoring methods are another class of models which may address the multiple criteria aspect of the concept evaluation. The premise is that there are a number of qualitative variables which are proxies for (or correlated with) new product success and profitability. Several authors have identified different sets of factors that affect concept evaluation, and have described methods for scoring and aggregating to obtain a single-valued evaluation measure [2,12]. An extension of the scoring approach can also be found [8], which utilizes multiattribute utility (MAU) theory to model the unique preferences of the decision maker using utility functions derived in a specific organization context.

Despite their popularity in real world situations, scoring models also have some limitations in determining factor weights and factor scores. Due to the lack of hierarchy, the factors are highly likely to be weighted in an unsystematic way, yielding inconsistent aggregate score values. Also, there are no generally accepted cutoff criteria against which the scores can compared. It requires more knowledge of the evaluator about the product characteristics than might be apparent at his first glance. So, he has to rely on his subjective perception which may not be accurate or even not consistent [3,11]

Motivated by the observations so far, this paper explores the applicability of AHP to the priority setting among new product concepts in the concept evaluation stage. The AHP, originally introduced by T. L. Saaty, provides us with a systematic scheme to decompose our problem into an explicit hierarchy of corporate goal, objectives, evaluation criteria, and new product alternatives. It also enables us to quantify many qualitative factors involved in the evaluation procedure in a consistent way. The organization of this paper is as follows: In the following section, the steps of AHP and the rationale behind it are briefly reviewed. And then, an AHP model for new product concept evaluation is formulated and explained using an illustrative example. In the final section, a number of issues will be raised and discussed concerning the applicability of AHP to our problem. Also, further research areas will be pointed out.

II. DEVELOPMENT OF A NEW PRODUCT CONCEPT EVALUATION MODEL

1. Review of the AHP

The AHP organizes the basic rationality by breaking down a large and complex problem into a multilevel hierarchy of constituents and calls for only simple pairwise comparison judgments to develop priorties in each hierarchy. It requires that the problem structure is decomposed into multilevel hierarchy, where each criterion or alternative on a given level is of the same rough magnitude or importance, and is thought to influence the next higher level [15,19]. Its focus is on determining weights or priorities of a set of criteria in one level of the problem hierarchy to the level just above. The priorities on a given level to each criteria on the next upper level are determined based on a set of pairwise comparisons. By repeating this process level by level, the matrices summarizing the priorities between levels can be multiplied to determine the priorities of the alternatives at the lowest level according to their influence on the overall goal or focus of hierarchy.

Suppose that we have n objects in a given level of hierarchy and also that pairwise comparisons were performed to yield the following n by n square, positive, reciprocal matrix.

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

where $a_{ij} = 1/a_{ji}$ for all $i, j = 1, 2, ..., n$ and measures the strength of alternative i to alternative j in influencing some stated factor.

Table 1. Scale of Measurement for AHP

Numerical Values	Definition
1	Equally important or preferred
3	Slightly more important or preferred
5	Strongly more important or preferrred
7	Very strongly more important and preferred
9	Extremely more important or preferred
2,4,6,8	Intermidiate values to reflect compromise
Reciprocals	Used to reflect dominance of the second alternative as compared with the first.

A 9-point scale is normally used to make such pairwise comparisons since it offers a wide enough range of levels still being within the number of options respondents can handle (7 ± 2). The 9-point scale used in typical analytic hierarchy studies is shown in Table. 1 [7].

Given the pairwise comparison matrix we would like to compute a vector of weights or priorities $w = (w_1, w_2, ..., w_n)$. Note that by using ratio scales, the weights we estimate are unique up to multiplication by positive constant; i.e., w is equivalent to cw where $c > 0$. Thus, we typically will normalize w so that it sums to 1 or 100 for convenience [7].

If we were perfectly consistent; i.e.,

$$a_{ik}a_{kj} = a_{ij} \text{ for all } i, j, k = 1, 2, ..., n,$$

then the entries of the matrix A would contain no errors and could be expressed as

$$a_{ij} = \frac{w_i}{w_j}$$

To see this last result, note that

$$a_{ik}a_{kj} = \frac{w_i}{w_k}\frac{w_k}{w_j} = \frac{w_i}{w_j} \text{ for all } \; i, j, k = 1, 2, ..., n.$$

In this case, one can simply normalize any column j of A to yield the final weights:

$$w_i = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \text{ for all } \; i = 1, 2, ..., n. \qquad (1)$$

However, we typically make errors in judgment and therefore the final result using the column normalization would depend on which column was chosen. In that case, we must solve the following problem to obtain estimates of the weights [15]. This method, called Saaty's eigenvector method, computes w as the principal right eigenvector (or Perron right vector) of the matrix A:

$$Aw = \lambda_{max} w, \tag{2}$$

where λ_{max} is the maximum eigenvalue (Perron root) of the matrix or

$$w_i = \frac{1}{\lambda_{max}} \sum_{j=1}^{n} a_{ij} w_j \quad \text{for all} \quad i = 1, 2, ..., n. \tag{3}$$

The computation of the principal right eigen vector is accomplished by raising the matrix A to increasing powers k and then normalizing the resulting system:

$$w = \lim_{k \to \infty} \frac{A^k e}{e^T A^k e} \tag{4}$$

where $e = (1, 1, ...1)$ [6]. This principal eigenvector is then weighted by priority of the property with respect to which the comparison is made. Those weights are obtained by comparing the properties themselves as to their contribution to the criteria of a still higher level. The weighted eigenvectors can then be added componentwise to obtain an overall weight or priority of contribution of each element to the entire hierarchy [16]. This process of principal eigenvector extraction and hierarchical weighting and composition leads to a unidimensional scale for the priorities of the elements in any level of the hierarchy. The resulting priorities represent the intensities of the respondent's judgmental perception of relative importance of the elements.

In addition, the AHP contains an intrinsic measure of inconsistency for each matrix and the whole hierarchy. Knowledge of inconsistency enables one to determine those judgments that need to be reassessed. In this sense, the AHP deviates radically from the more traditional decision analytic methods in that the traditional ones have no formal way of dealing with inconsistencies. As shown by Saaty [10], λ_{max} is always greater than or equal to n for positive, reciprocal matrices, and is equal to n if and only if A is a consistent matrix. Thus, $(\lambda_{max} - n)$ provides a useful measure of the degree of inconsistency. Normalizing this measure by the size of the matrix, Saaty defines the consistency index (CI) as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

For each size of matrix n, random matrices may be generated to compute their mean CI value. They, called random index (RI), are shown in Table 2 [15].

Table 2. Random Inconsistency Index

n =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI =	0	0	.58	.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Using these RI values, consistency ratio (CR) can be defined as the CI devided by RI. Or

$$CR = \frac{CI}{RI}$$

The consitency of a hierarchy can also be obtained by simply multiplying each consistency index (CI) by the priority of the corresponding criterion and adding overall such products. The result is then divided by the same type of expression using the random inconsistency index corresponding to the dimensions of each matrix weighted by the priorities as before. The ratio should be normally about 10 % or less for acceptable overall consistency. Otherwise, the quality of the judgmental data should be improved [15,19].

Exhibit 1. Three Objectives

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1) Financial performance
   - profitability: potential for returning adequate profit

2) Competitive Position
   - sales volume
   - market share

3) Opportunity window
   - opportunity window on new categories
   - opportunity window on new market

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2. AHP Model Formulation

The evaluation of new product concepts must be related to the product objectives, which in turn are a consequence of the corporate goal and business strategy. The three objectives which can best achieve the highest level goal of the company, or the well-being of the firm, are listed in Exhibit 1. These product objectives determine the second level criteria to be considered in the evaluation process. The third level criteria and the factors constituting them are listed in Exhibit 2. These criteria shoud be evaluated in view of each product objective.

Exhibit 2. Six Evaluation Criteria

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1) Product advantage
   - unique superiority in the eyes of the customer
   - utility of the product to those who will buy and use it
   - economic advantages to the user
   - high performance-to-cost ratio
   - solved problem: the product solved a problem the customer was having with competing products.

2) Technological sophistication

- high technology
- leading and state-of-the technology
- sophisticated technology

3) Protocol
   - customer needs, wants and preferences were clearly defined?
   - product concept; exactly what the product would be and do; was clearly defined?
   - target market; who the product would be aimed at; was clearly defined?
   - product requirements and specifications were clearly defined?

4) Market attractiveness
   - size of the market (dollar volume)
   - number of potential customers
   - long term potential
   - growth rate
   - number of competitors
   - competences of competitors: fund, marketing, technology, etc
   - entry barrier: patent protection
   - competences of potential competitors

5) Synergy
   - technology: a good fit between the research, engineering, technological and production requirements of the product development and the resources of the firm
   - marketing: a good fit between the selling/marketing requirements of the new product and the resources of the firm
   - management resources and skills
   - facilities and raw materials

6) Risk
   - project risk: risk due to project size

- effect on other business: possibility that introducing new product might hurt existing profitable businesses
- product liability: potential for presently unknown problems to lead to product liabilty claims
- substitutes:possibility that this new development will soon be superceded by even better products and therefore have a very short life-cycle
- possibility that someone out there is trying to do the same thing

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In the lowest level of hierarchy, the product concepts, three in our case example, are located in order to be evaluated with respect to the third level criteria listed before. The resulting AHP model for the new product concept evaluation is summarized in Figure 1.

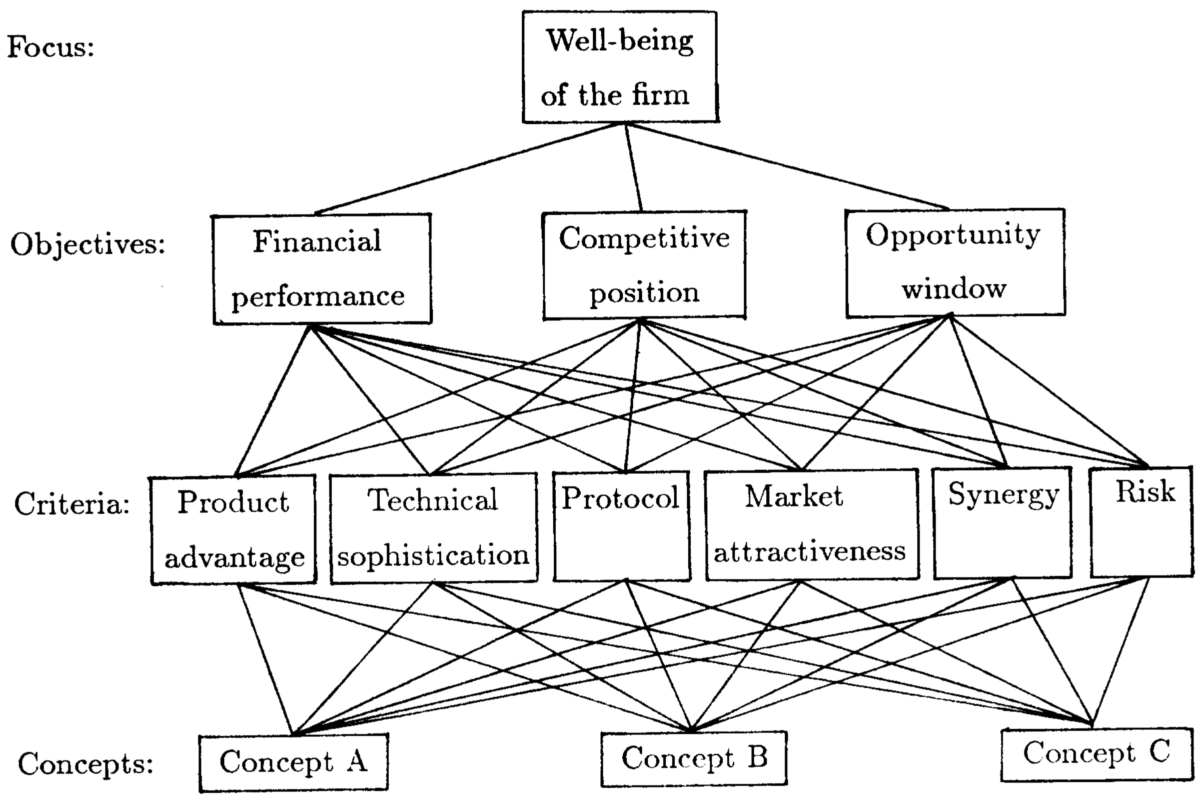

Figure 1. Concept evaluation hierarchy

3. Computation of Priorities - A Case Example

Once the hierarchical structure of the problem has been formulated, the next step is the elicitation of pairwise comparisons using the 9-point scale presented earlier. Two aggregating procedures are available: bottom-up aggregation and top-down assignment. We choose the latter approach just for convenience. For the sake of explanation, the evaluator is assumed to be the marketing vice president of the company.

The first task of top-down assignment procedure is to elicit judgments of the evaluator about the relative importance of the objectives with respect to the highest goal, well-being of the firm. The corresponding evaluation procedure is composed of two sequential questions for each pair of objectives: of the two objectives compared, which is perceived more important and how much more important is it to achieve the goal in the eyes of the evaluator? A total three pairwise comparisons will suffice to give a 3 by 3 reciprocal matrix with all positive entries as shown below:

	O1	O2	03	Priority
O1	1	2	7	0.54
O2	1/2	1	5	0.36
O3	1/7	1/5	1	0.16

$$\lambda_{max} = 3.01 \quad CI = 0.01 \quad CR = 0.02$$

Two entries 7 and 5, for instance, in the upper right corner of the matrix indicate that financial performance, denoted by O1, is perceived very strongly more important than opportunity window, denoted by O3 and competitive position, denoted by O2, is perceived strongly more important than O3. By apply the equation (4) with k=1 to this matrix, we have a principle right eigenvector w=(0.54,0.36,0.16), approximate priorities of the objectives against the goal.

The next step is to apply the same procedure to the third level criteria. Since they have three objectives against which to be evaluated, three 6 by 6 matrices may result. Only one of them is shown below, where the six criteria were evlauated with respect to the compititive position. The corresponding priorities were also computed based on the equation (4).

Competitive position

	C1	C2	C3	C4	C5	C6	Priority
C1	1	6	5	3	7	9	0.448
C2	1/6	1	1/4	1/5	4	3	0.076
C3	1/5	4	1	1/3	3	4	0.135
C4	1/3	5	3	1	6	7	0.257
C5	1/7	1/4	1/3	1/6	1	1/5	0.031
C6	1/9	1/3	1/4	1/7	1/5	1	0.052

$\lambda_{max} = 6.79 \quad CI = 0.16 \quad CR = 0.13$

The third step is to perform pairwise comparisons among concepts against each of the six evaluation criteria. Though six 3 by 3 matrices result, the matrix evaluated with respect to the protocol only is demonstrated.

Protocol

	Concept A	Concept B	Concept C	Priority
Concept A	1	6	4	0.70
Concept B	1/6	1	3	0.19
Concept C	1/4	1/3	1	0.11

$\lambda_{max} = 3.26 \quad CI = 0.07 \quad CR = 0.12$

Having one, three and six matrices at each level of hierarchy and the respective sets of priorities, there remains the step of aggregating those priorities systematically to yield the global priorities of concepts. Table 3 and 4 show the aggregating procedure performed in the second and third levels of hierarchy respectively.

Table 3. Composite Priorities of the Criteria

Objectives / Criteria	O1 (0.54)	O2 (0.30)	O3 (0.16)	Composite priority
C1	0.32	0.45	0.09	0.32
C2	0.14	0.08	0.41	0.16
C3	0.03	0.13	0.24	0.09
C4	0.13	0.26	0.17	0.19
C5	0.24	0.03	0.06	0.15
C6	0.14	0.05	0.03	0.09
CI	0.10	0.16	0.17	0.129

Table 4. Composite Priorities of the Concepts

Criteria / Concepts	C1 (0.32)	C2 (0.16)	C3 (0.09)	C4 (0.19)	C5 (0.15)	C6 (0.09)	Composite priority
Concept A	0.58	0.36	0.70	0.46	0.11	0.27	0.43
Concept B	0.35	0.59	0.19	0.46	0.26	0.10	0.36
Concept C	0.07	0.05	0.11	0.08	0.64	0.63	0.21
CI	0.02	0.02	0.07	0.00	0.02	0.06	0.023

The figures in Table 4 provide us with an explicit rule for choosing the new product concepts. In our case, the marketing vice president appears to have a strong preference for product concept A. Besides, the other figures in Table 3 and 4 give us additional valuable informations like:

- The relative contribution of the three objectives are:

  financial performance: 54%

  competitive position: 36%

  opportunity window: 16%

- The relative importance of the six criteria are:

  product advantage: 32%

  technology sophistication: 16%

  protocol: 9%

  market attractiveness: 19%

  synergy: 15%

  risk: 9%

- The relative ranking of the three concepts are:

  concept A: 0.43

  concept B: 0.36

  concept C: 0.21

Our final comment is on the consistency of the evaluator's judgements made in the AHP procedure. Using the consistency indices computed for each matrix, the overall consistency was computed following the procedure described before. An acceptable but marginal level of consistency, 0.14, was obtained.

III. DISCUSSION

The applicability of the AHP to the new product concept evaluation problem was explored in this paper. To this aim, a four level hierarchy of goal, objectives, evaluation criteria and product concepts was carefully built and the priority setting procedure was described via a case example. The framework suggested in this paper is valid in a sense that almost all factors were chosen from the related literature and carefully arranged in their appropriate levels in the hierarchy. But it is also true that such normative model as suggested in this paper often lacks in its empirical evidence.

In this sense, there remains much room for further research and extension. The first might be the choice of the decision point at which our AHP model is applied. In practical situations, different types of products are likely to have different processes, thus having different decision points at which the application of our AHP model is most effective. The second might arise from the fact that the view point of our model is primarily restricted to the inside of the firm but that success/failure factors reported in real world situations include many market factors related with the comsumers' perceptions or preferences. Unfortunately, however, these factors involve too many evaluators to be incorporated into our AHP model effectively. The development of a wise and efficient scheme to integrate those consumers' view or perceptions into our model is one of fruitful further research areas. An idea in this direction is to include the compititor's products or some potential substitutes in our model.

There are also much room for further research in the inherent technical side of the AHP model itself. They include priority estimation with partial information, development of an effective procedure to find and correct the most inconsistent comparisons, and finally modification of AHP to fit to the nonhierarchical arrangement of objectives, criteria and alternatives.

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