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# A Note on New Product Project Selection Model: Empirical Analysis in Japanese Chemical Industry

Kenichi KUWASHIMA
*Graduate School of Business Sciences, University of Tsukuba*
E-mail: kuwa@gssm.otsuka.tsukuba.ac.jp

Abstract: By focusing our attention on one particular scoring method which is used to evaluate R&D projects, this paper seeks to specify empirically the factors that discriminate successful projects from failed projects in the Japanese chemical industry. Our statistical analysis revealed that when projects are evaluated in this industry, three factors, *marketability*, *technology*, and *synergistic potential*, tend to be valued by practitioners approximately in a 3:2:1 ratio. Although the project evaluations in this research were conducted ex-post, the findings suggest that the results may also be applicable in the project selection stage. Built on our findings, we propose a Continuous Improvement Scoring Method (CISM) that contains continuous improvement cycles, which links ex-ante project selection with ex-post project evaluation.

Keyword: product development, project selection, chemical industry

## 1. Introduction

To most firms, the important issue is "how to make more projects a success under severe resource constraints." Generally, mainly two issues could be raised when the firms' management faces this problem. One is "ex-ante project evaluation selection": that is, the firm focuses on how to select a project with high success probability prior to product development project. Another is the "product development process management": that is, the firm focuses on how to manage and lead the selected project to a success. Among these two, this paper intends to focus on the first "project evaluation" and propose a new evaluation method based on empirical analysis.

Studies on project evaluation date back to the

1950s. The mainstream of the earliest studies was something related to project evaluation method (here we call this "evaluation method studies"). Evaluation method studies' concern lay mainly in developing project evaluation criteria and model. Studies began from the most simple scoring method, which developed into economic analysis approach, and then to operations research approach, gradually evolving into more complicated method and model (e.g., Asher 1962; Augood, 1973; Disman, 1962; Hess, 1962; Mottley & Newton, 1959). Studies on evaluation method have been widely popular till the early 1970s, however, in the late 1970s, the mainstream of project evaluation studies shifted to "evaluation process" studies: that is the study on the process through which the method is applied to and evaluated in the actual firms' project evaluation process (here we call this "evaluation process studies"). In evaluation process studies, hierarchical decision system and consensus figuration method applying Delphi method have been presented (e.g., Baker, Souder, Shumway, Maher & Rubenstein, 1976; Presley & Liles, 2000; Schimidt & Freeland, 1992; Souder & Mandakovic, 1986).

Thus, in the early stages of project evaluation studies, "evaluation method studies" gained popularity and then, in the late 1970s, the "evaluation process studies" view has been added. Along this process, a lot of extremely elaborate models and tools have been created to evaluate and select R&D projects. In addition, researches on the processes in order to efficiently utilize these models and tools have been accumulated in plenty. Nevertheless, eyeing the practice (business) side who actually utilize these evaluation models and tools, not much of the fruit of these scholarly researches seemed to be enjoyed. For instance, today, it is said that the most popular evaluation method used in practice is scoring method. However, throughout its half-century history, scoring method does not provide sufficient accuracy and present arbitrariness in practice. Therefore, improvement efforts have been made (e.g., Arikuni, Osawa & Murakami, 1997; Murakami, 1992).

Leading reasons for efforts of scholarly researches not being applied in practice is: 1) Researchers of evaluation studies were mostly concerned in developing precise yet elaborate evaluation methods, on the other hand paying little attention on the fact that the method became complicated and unhandy. 2) From the standpoint of data availability and reasonability, researchers were mainly concerned with ex-post evaluation (ex-post analysis) after the project has ended. On the other hand, practitioners were only interested in ex-ante evaluation of the project sharing little concern in ex-post analysis, therefore, attached little importance in results of scholarly researches based on ex-post analysis.

Consequently, this paper will focus on the "scoring method" which is most popular in business today in regard of the gap between scholarly studies and practical businesses. Based on empirical analyses, we intend to derive "improved scoring method" assuming practical use. Particularly, ex project data from 51 projects of 22 chemical companies in Japan is analyzed empirically to unveil the factors which are weighed in deciding projects' success or failure. And in order to utilize (ex-post) evaluation criteria gained from empirical studies as "ex-ante evaluation criteria," this paper proposes a process which will link ex-post and ex-ante evaluation model by follow-ups and feedback mechanisms. We will name the scoring method containing these series of processes as "Continuous Improvement Scoring Method (CISM)."

The framework of this paper is as follows: First in Section 2, we will overview major evaluation methods and examine the characteristics and difficulties of the scoring method we take up. Section 3 aims to clarify empirically the evaluation criteria concerning success/failure of the projects in the chemical industry by statistical analysis using data from the industry. Last in Section 4, we will propose the specific process to apply "ex-post evaluation criteria" gained from empirical studies to "ex-ante project evaluation (project selection)."

## 2. Three Types of Evaluation Methods

### 2.1. Scoring Method: Brief Description

Generally, project evaluation method is divided largely into three approaches: "decision theory approach," "economic analysis approach," and "operations research approach" (Baker & Pound, 1964). "Decision theory approach" sets evaluation items and corresponding decision criteria in order to evaluate the ongoing project. For example, it gives scores such as 1 to 5 point (five point method) to each item to rate by total score. The most common evaluation method is the scoring method which is discussed in this paper.

"Economic analysis approach" is a method which value project's performance by contrast of cost and profit from economic point of view. In particular, methods such as "Net Present Value (NPV) method" which evaluate the project's value by present discounted value of future cash flow, or "Internal Rate of Return (IRR) method" which evaluate by internal profit ratio could be named.

The last "operations research approach" utilizes operations research method to represent phenomena which occur in R&D/new product development activities with mathematical models. The method predicts the future by alternating involving factors in a multidimensional and dynamic way to evaluate the project. To name, there are Linear Programming (LP), Dynamic Programming (DP), System Dynamics (SD), and decision tree methods.

The above three evaluation methods have historically developed from decision theory approach to economic analysis approach, and to operations research approach. The accuracies of the evaluations have more or less corresponded to this order as well, in which operations research approach is the most refined. However, today, it is said that the most popular evaluation method used in practice is the scoring method (decision theory approach). That is to say, considering the accuracy of the evaluation alone, it is the operations research approach which is most effective, on the other hand, operations research approach requires detailed and abundant input of information to match the accuracy of evaluation, which cost a lot. For instance, in such cases as in the downstream stages of pharmaceutical product research development, where development costs thousands of million to billion yen at the same time uncertainty is high, it should be a reasonable decision to spend a lot on exhaustive evaluation utilizing operations research approach or economic analysis approach. Nevertheless, not all projects among any industry require such refined evaluation. In that respect, scoring method cost less as it does not need much information for evaluation, and the procedure is quite simple. Moreover, scoring method could take in qualitative factors in the evaluation concerning "strategy" and "technology," which is hard to introduce in operations research approach or economic analysis approach. For these benefits, it is assumed that the scoring method is still very popular in practical use today.

### 2.2. Problems and Points to Improve of Scoring Method

Today, the most popular evaluation method practiced in business is the scoring method, as have been discussed. However, whether practitioners are satisfied with the present scoring method is not a certainty. The most frequently pointed defect of the scoring method is the problem of "rating arbitrariness" and "rating accuracy." The former problem is closely related to the benefits of scoring method. In other words, scoring method, as described before, is based on subjective ratings of the rater hence requires less elaborate data while capable of including un-numeric factors as strategy and technology as rating items. Yet, as a consequence, subjectivity of rating always remains as an issue. The "rating arbitrariness" issue directly reflects the nature of scoring method as an evaluation method, therefore fundamental solution to this problem should not be easily attained.

Meanwhile, the latter "rating accuracy" issue could be given thought for betterment. For we think that one of the largest reasons for the scoring method to have shown poor rating accuracy is that the present scoring method lacked continuous method improvement process; that is, a process which compares and verifies ex-ante and ex-post evaluation results and continuously improve itself. As have been illustrated earlier, the background was that scholarly researches did not pay full attention on applying the results to ex-ante evaluation in practice; while practitioners cared much about ex-ante project evaluation but scarcely eyed on the project afterwards to compare ex-ante and ex-post evaluations. The result must have been the fact that no efforts were made to build handy in practice and highly accurate scoring method.

Thus this paper will attempt to propose a scoring method in which a continuous improvement process is embedded by linking ex-post evaluation model, build upon ex-post data, and ex-ante evaluation using follow-ups and feedbacks. We believe that by continuously improving the evaluation model based on data attained from practical cases we should be able to develop models with higher accuracies.

# 3. Empirical Analysis

## 3.1. Overview of the Analysis

The goal of this paper is to propose an "improved scoring method" by applying ex-post evaluation model attained from empirical analysis to ex-ante project evaluation through follow-ups and feedback cycle. As a first step, we will start by clarifying the "project evaluation criteria" by which the projects' success/failure is decided. Our analysis is based on practical ex-post project data gathered from Japanese chemical companies.

Project evaluation in practice is conducted before (or in the middle of) the project, where projects decided good are called a "go" and projects decided not are called a "no-go." However, in this empirical analysis, the data available are those of already ended projects, therefore we would make the following arrangements. On the concerning project, we asked what evaluation is given ex-post to each evaluation item such as economic achievement, quality, and technology, as in ex-ante project evaluation. At the same time, we asked whether the project as a whole were to be considered a "success (go)" or "failure (no-go)." This will make clear the "weight of evaluation criteria," by which each evaluation item has been valued, in projects considered as success (go) ex-post.

Given that this study samples projects at varied companies in the chemical industry, the criteria attained forthwith should reflect the average evaluation criteria in the Japanese chemical industry. Or else, this study should unveil the evaluation criteria in which the industry would, say, decide success/failure of a certain project by mutual agreement.

## 3.2. Method of Analysis

### (1) Data and Criteria

This paper analyzes 51 product development projects at 22 chemical companies who join Management of Technology Commission of JCII: Japan Chemical Innovation Institute. A questionnaire survey has been conducted from December 1999 to January 2000. We received answers from all 22 companies. Valid response was 47, among which 32 were success projects and 15 were failed projects.

**Table 1.** Items of Project Evaluation

1. amount of sales/market share
2. profit rate
3. man-hour of development/cost
4. development period
5. product cots
6. niche/new market creation
7. product performance and function
8. manufacturing quality (credibility)
9. customer satisfaction/overall quality
10. new technology development
11. new product development
12. development of synergetic technology
13. development of synergetic product
14. building new organizational capability in product development
15. building future project base (e.g., database)

We measured the performances of the projects with two items. One is the performance of the entire project: If an answer is "success," it is rated at one, on the other hand, if an answer is "failure," it is rated at zero. The other item is, as shown in Table 1, 15 specific performances such as economic achievement and quality, by which we measured the success rate by five-point scale (1=failure, 5=success) (Table 1).

**(2) Analysis Framework**

As the framework of our analysis, we use below model of Stahl and Harrel (1983) to bring out the "evaluation criteria" in the sample projects.

$$Z_i = \Sigma\, w_j\, y_{ij} \qquad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$$

$Z_i$: success/failure of the *i*th project (or total score)
$y_{ij}$: the value of factor (item) $j$ which influence the success of the *i*th project
$w_j$: relative weight of factor (item) $j$

$$0 \leqq w_j \leqq 1,\ \Sigma\ w_j = 1 (j = 1, 2, \ldots, n)$$

Here, project "evaluation criteria" corresponds to $w_j$ which is the weight of each evaluation item. This model calculates the overall score ($Z_i$) by the sum of scores of each evaluation item ($y_{ij}$) multiplied by corresponding weights ($w_j$). In this paper, we utilize two kinds of data: ex-post overall evaluation data of success (go) or failure (no-go), and success rates for individual evaluation items. We would treat the former data (success or failure $Z_i$) as explained variable and the latter (success rate $y_{ij}$ of individual evaluation items) as explanatory variable in order to estimate $w_j$ statistically by discriminant analysis.

The model we present here is basically the same as the model routinely used in scoring method. Therefore, the evaluation criteria based on weight attained in our analysis could be applied to ex-ante project evaluation (project selection) as well. In fact, when conducting project evaluation (ex-ante evaluation), scores of each evaluation item ($y_{ij}$) will be assigned to this equation, which is multiplied by preset weights of each item (derived empirically from data attained from observed projects) to gain overall score ($Z_i$). According to the value of this score, the project's go or no-go are decided. In the following Chapter 4, such procedure of applying weights (evaluation criteria) attained from empirical analysis to ex-ante evaluation (project selection) in actual new product development projects are to be discussed.

## 3.3. Analysis Results and Validity

**(1) Result of the Analysis**

Commonly, when evaluating a project by scoring method, it is considered that items showing high correlation must be aggregated. It is likely that highly correlated items in fact measure identical matter (construct) by different ways of expression (Cooper, 1981, 1985). We conducted correlation analysis among 15 evaluation items used in our study and found certain items showing high correlation. Therefore, prior to discriminant analysis, we conducted factor analysis in order to aggregate highly correlated items. As a result, three factors

**Table 2.** Factor Analysis on Evaluation Items

| Evaluation items | (Factor 1) *marketability* | (Factor 2) *technology* | (Factor 3) *synergetic potential* |
|---|---|---|---|
| Amount of sales/market share | 0.799 | 0.345 | 0.076 |
| Profit Rate | 0.769 | 0.403 | 0.155 |
| Man-hour of development/cost | 0.775 | 0.154 | 0.417 |
| Development period | 0.609 | 0.071 | 0.136 |
| Product cots | 0.655 | 0.304 | 0.203 |
| Niche/new market creation | 0.680 | 0.402 | 0.194 |
| Product performance and function | 0.584 | 0.504 | 0.324 |
| Manufacturing quality (credibility) | 0.398 | 0.729 | 0.099 |
| Customer satisfaction/overall quality | 0.223 | 0.838 | 0.104 |
| New technology development | 0.353 | 0.619 | 0.293 |
| New product development | 0.438 | 0.494 | 0.308 |
| Development of synergetic technology | 0.171 | 0.052 | 0.883 |
| Development of synergetic product | 0.311 | 0.277 | 0.718 |
| Building new organizational capability in product development | 0.123 | 0.375 | 0.334 |
| Building future project base (e.g., database) | 0.114 | 0.354 | 0.390 |

Note: Factor Loadings are after varimax rotation. Underlines indicate factor loadings over 0.45.

were extracted which eigen values are more than 1 (Table 2).

In Table 2, we will call factor 1 as *marketability* factor since factor loadings of items related to market is high, for example, in economic performance as sales and profit rate, customer satisfaction, and niche creation. As for factor 2, we will call it *technology* factor since factor loading of items related to quality, such as product performance and manufacturing quality, and items related to technical or product novelty are high. Factor 3 is called *synergistic potential* factor because factor loadings of items related to technology and product synergy are high.

After aggregating evaluation items showing high correlation by above procedure, we treat these three factors as explanatory variables and conducted discriminant analysis using aforesaid total performance (success/failure) of the project as explained variables. The result is in Table 3.

From Table 3, we can see that Wilks' Lambda is significant therefore the entire model is statistically

**Table 3.** Result of Discriminant Analysis

| discriminant variable | discriminant coefficient | t value |
|---|---|---|
| *marketability* | 1.592 | 8.458** |
| *technology* | 0.960 | 4.931** |
| *synergistic potential* | 0.447 | 2.311* |
| invariable | 0.615 | 44.915** |
| F value | 37.385** | |
| percent incorrectly classified | 2.1% (1/47) | |

* p<0.05 ** p<0.01

Note: Percent incorrectly classified indicate ratio of mistakenly predicted failure (success) but success (failure) in practice

significant, and that our formula is quite efficient since incorrectly classified rate is low at 2.1%. Moreover, looking at the three discriminant variables, *marketability*, *technology*, and *synergistic potential*, we discovered that each variable is significant at 5% therefore statistically effective on the decision making of the project's success/failure. Besides, comparing the discriminant coefficients for the three variables, 1.592 for marketability, 0.960 for technology, and 0.447 for synergistic potential, we can see that among three factors the most weighed is marketability on deciding success or failure of sample projects. In fact, the ratio of the three factors' weight is approximately 3:2:1.

Fact Finding: In Japanese chemical industry, three factors, *marketability*, *technology*, and *synergistic potential*, are weighed approximately at 3:2:1 ratio upon project evaluation.

This analysis has been conducted as a first step of successive processes aiming application of ex-post evaluation model built on empirical analysis of post project data, to ex-ante project evaluation. Nevertheless, considering the fact that historically in Japan, there scarcely existed empirical studies on project success/failure evaluation criteria in an individual industry. We think that the result of our study has a certain point as fact finding.

### (2) Validation of the Model

Before ending the empirical analysis, we would like to examine the validity of the discriminant formula attained in our analysis. The ultimate verification of the validness of empirically attained model is to substitute samples other than the ones used for analysis. However, most empirical studies deal with data which is hard to gain in addition. Consequently, cross-split-half method becomes useful, which is a hypothetical method of verification (Cooper, 1981). Cross-split half method randomly split the sample data in two to estimate the discriminant formula with half the data and substitute with the other half data to calculate the discriminant score and predict success/failure. This procedure is repeatedly conducted by exchanging the halved data. This procedure makes possible to confirm the validness of the discriminant formula without collecting additional data.

We checked the validness of the discriminant formula attained in our analysis by using cross-split-half method. The result was 4.3% (2

**Table 4.** Discriminant Results of Cross-Split-Half Method

| | | predicted by cross-split-half method | | total |
|---|---|---|---|---|
| | | predicted success | predicted failure | |
| actual data | actual success | 32 | 0 | 32 |
| | actual failure | 2 | 13 | 15 |
| total | | 34 (incorrectly classified case: 2) | 13 (incorrectly classified case: 0) | 47 (incorrectly classified case: 2) |

Note: Shaded cells indicate incorrectly classified case.

incorrect classification among 47 projects), which was approximately at the equivalent level to the rate gained through the analysis using full sample data (Table 4). By this we can say that the validity of the empirically gained discriminant formula has been confirmed by cross-split-half method.

## 4. Discussion: Proposal of "Continuous Improvement Scoring Method (CISM)"

The model attained by empirical analysis in Chapter 3 is based on ex-post project data. Such evaluation criteria (model) built on ex-post data does not reflect the firms' present strategies and evaluation criteria thus, when used in practice, it is not much effective. However, if we can link "ex-post evaluation model" built on empirical analysis of post project data and "ex-ante evaluation model" by continuous improvement cycle of "follow-ups" and "feedback," we could possibly build an effective scoring method for practitioners with updated strategies and evaluations. We would like to call this scoring method in which a continuous improvement cycle is built in as "Continuous Improvement Scoring Method (CISM)."

In particular, the CISM proposed in this paper takes the following steps. The first step is to prepare a list of items or measures to be considered when conducting project evaluation using scoring method. With these items and measures we select several or preferably several dozens of terminated projects (which have been released within six to twelve months) and conduct ex-post evaluation (Step 1). Next, utilizing the evaluated data, we statistically estimate the ex-post evaluation criteria (Step 2). Our analysis has gone as far as step 2 in this paper.

Then, we use the attained evaluation criteria (ex-post evaluation model) to conduct ex-post "variance analysis" (Step 3). That is, deviation between ex-ante and ex-post evaluation concerning overall evaluation of a project can be decomposed to deviation between ex-ante and ex-post "evaluation weight," and deviation between ex-ante and ex-post evaluation scores of "each item." The former deviation (in evaluation weight) should be made clear by comparing the weight system presently used and the weight system of statistically estimated "ex-post evaluation model." On the other hand, the latter deviation (in evaluation score of each item) should be made clear by comparing the ex-ante evaluation score and the ex-post evaluation score attained in this study. In both cases, if there is a significant deviation between ex-ante and ex-post results, we shall make close investigation for the causes.

Now, based on the outcome of above variance analysis, we consider improvement of the present evaluation system (Step 4). First, we consider modification of variables (evaluation items). If a variable turns out to be peculiarly unfit for ex-ante evaluation, it is an option to eliminate the item from the model. On the contrary, we may add new items if considered more preferable. Next, we consider modification of each item's weight. We shall add strategic view in order to revise the model at the same time referring to scores of empirically analyzed discriminant model. These improvements are conducted across divisions lead by research management division. When strategic decision making is required, top management may have to intervene as necessary.

Last, we get back to the beginning to conduct ex-post and ex-ante evaluation under the new evaluation system for next term constructing an improvement cycle (Step 5).

By repeating these five steps in a cycle, ex-ante and ex-post project evaluation become linked. And by continuously repeating such cycle, we could activate the process of theme evaluation hypothesis verification by ongoing ex-ante and ex-post deviation analysis (variance analysis) thus improve scoring method. As a result we believe that we can enhance the accuracy of ex-ante evaluation.

## 5. Conclusion

This paper focuses on the scoring method, which is one of the methods of product development projects evaluation. We analyzed statistically the evaluation criteria on projects' success/failure by using data from the chemical industry. Results of the analysis show that, in Japanese chemical industry, three factors, namely *marketability*, *technology*, and *synergistic potential*," are weighed at 3:2:1 ratio at projects' success/failure evaluation.

The result of the analysis is at any rate ex-post based on data from already terminated projects. Yet there is a possibility that we could apply it to ex-ante evaluation (project selection). Based on the results of the analysis, we proposed a new method of improving the evaluation method itself as "Continuously Improved Scoring Method (CISM)," which links projects' ex-post evaluation and ex-ante evaluation to build an ongoing improvement cycle. We believe that the proposal we made for improved process shall in any way fill the existing gap between academic research and practical businesses at the same time make certain contribution to scholarly researches on "evaluation process."

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