# Evaluating Effects of External Factors on Success of NPD Projects

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***Abstract*—In this study, a framework is suggested to prioritize the handling of external factors or uncontrollable variables that affect the success of new product development (NPD) projects. Many NPD projects fail because of unexpected changes that arise in the environment surrounding a firm. In particular, the success of a project is partly affected by various external factors such as the economic cycle, technological development, customer needs, currency exchange rates, inflation rate, oil price, and stock prices. Therefore, a project manager requires a framework to measure the impacts of these factors scientifically. Here, a multi-response optimization (MRO) method with a loss function is used for developing such a framework. The success factors and external factors of NPD projects are set as the dependent and independent variables, respectively. A priority value generated by this method represents the optimized weight given to a success factor. The difference between the optimized and original weights is then minimized by a given loss function. An illustrative example is described to show how the developed framework can be used to determine the optimized priority with minimum loss. The results of this study may be useful for effective GO/STOP decisions at each phase of the development process for a given NPD project of a firm.**

***Index Terms*—NPD project, success factors, external factors, multi-response optimization, loss function.**

## I. Introduction

The importance of new product development (NPD)to survive the tough competition in the market is recognized by typical firms. Competitive advantages come from a product or service being better in terms of quality, cost, delivery, and technology. However, the failure rate of NPD projects is very high [1]. The Product Development and Management Association (PDMA) reported that about 41% of NPD projects carried out by the top 20% of companies have failed in terms of profitability [2].A typical reason for such failures is an error in decision making under an environment of incomplete information and extreme uncertainty. For an NPD project to be successful, the decision maker must consider factors including the customers' needs, company's strategies, technological opportunities, and company's resources to deduce the goals[3]. Therefore, a project manager must determine the various external factors that impact the project to allocate the firm's resources efficiently. Many external factors are involved in NPD, and these affect a project either positively or negatively. The manager must develop effective and efficient plans to respond to such external factors, which include the economic cycle, technological development, customer needs, currency exchange rates, inflation rate, oil price, and stock prices. The manager should also prepare criteria to evaluate the performance of the project. To make a GO/STOP decision, these evaluation criteria can be applied to each of the five NPD phases: requirement analysis, conceptual design, detailed design, test and verification, and production ramp-up. In this study, such criteria are defined as success factors. The manager can set the success factors—which include customer satisfaction, market share, innovativeness, return-of-investment (ROI), patents, lower cost, and effective management—differently in each phase. That is, he or she can give a different priority or weight to each success factor.

In this study, the success of an NPD project is assumed to be dependent on external factors. This implies that the relationships between external factors and success factors can be quantitatively established. If a project manager gives particular priorities or weights to certain success factors, then he or she can observe the importance of external factors related to those success factors. On the basis of the importance of external factors defined as either priorities or weights, the manager can develop a response plan for the external factors. This study adapts the multi-response optimization (MRO) method to determine the relationships between success factors and external factors. MRO methods have been widely used for cases involving a linear relation between the independent and dependent variables(e.g., regression models). Unlike regression models, however, this method further optimizes the dependent variables by minimizing the differences between nonlinear regression results and target values.

A framework is suggested in this study to determine the importance of external factors in terms of priority or weight under a given set of priorities or weights for

Manuscript received November 15, 2012; revised December 29, 2012.


doi: 10.12720/joams.1.1.118-123

success factors in NPD projects. The framework quantitatively shows the relationship between success factors and external factors in order to improve the management of NPD projects.

## II. Relevant Literature Review

Numerous studies have been conducted in various fields of NPD. In the field of project management, researchers have attempted to identify the number of factors that affect NPD projects. Cooper and Kleinschmidt [4] outlined the uncontrollable variables that are external to firms. Miller [5] suggested multidimensional criteria to classify the uncontrollable variables into uncertainty levels of the environment surrounding firms, and Werner [6] et al. subsequently verified the uncertainty levels to support Miller's results. Kim and Wilemon [7] described project complexity as a combination of task difficulty, forecasting difficulty, communication, and teamwork difficulty, all of which affect the speed of development and performance of NPD projects. Cooper [8] and Polk et al. [9] pointed out various factors that lead to the success of NPD projects as well as disruptive factors that interfere with their progress. Park [10] developed a framework to determine the weights of external factors that affect success factors. As a common theme, these studies also emphasize the importance of GO/STOP decision criteria and efficient resource allocation. The purpose of this study is to specify the most important success factors described in previous studies and to determine their relationships with external factors. If a project manager determines the weights of success factors in a development phase, then he or she can observe which external factors must be controlled in the most significant way.

## III. NPD Project Assessment Factors

### A. Success Factors and Sub-Success Factors

The success of NPD projects has been defined in various ways. In general, financial achievement is the major goal. However, Cooper [11] suggested that financial achievement is only one quantitative measure and is insufficient for defining project success. For example, the creativity resulting from successful projects may be more critical than financial measures. Cooper listed eighteen success factors and showed that several including customer satisfaction, lower cost, and high quality should be considered most significant in evaluating project success after testing them in actual cases. Ernst [12] summarized the success factors obtained from previous studies and classified them into those related to five views: NPD process, organization, culture within process, senior manager's roles and responsibilities, and corporate strategy. Griffin [13] and Page [14] argued that measuring project success is difficult because there are too many variables that affect it in multidimensional ways. They summarized sixteen major factors to measure project performance by investigating various companies and reviewing the relevant literature. Ittner and Larcker [15] studied the relationship between customer satisfaction and financial performance in firms. They showed that higher customer satisfaction leads to higher financial earnings. McCracken [16] divided success factors collected from previous studies into independent and dependent variables, and suggested that project success depends on effective management, product superiority, and marketing budget.

TABLE I. Success Factors and Sub-Success Factors

| Success Factors | Sub-Success Factors |
|---|---|
| PL (Product-Level) | Product superiority |
| | Met performance specification |
| | Met Quality specification |
| | Competitive advantage |
| | Launch on time |
| | Innovativeness |
| CL (Customer-Level) | Customer satisfaction |
| | Customer acceptance |
| | Market share goals |
| | Revenue goals |
| | Revenue growth goals |
| FB (Firm-Based) | Successful launching process |
| | New patents |
| | New technologies |
| | Better strategy |
| FP (Financial-Performance) | Met Profit goals |
| | Margin rate goals |
| | IRR or ROI |
| | Profit/loss break-even point |
| NM (NPD Process Management) | Effective communication through successful IT platforms |
| | Support to NPD from management |
| | Introducing new and innovative opportunities |
| | Improved procedures introduced in the NPD management process |

Five important success factors, as well as the sub-success factors that measure each of their performances, are selected in this study (Table I.).

- PL (Product-Level Measure): project success is based on the product itself, i.e., adequacy of market
- launching time, achievement of quality level and target performance, degree of technological innovation, etc.
- CL (Customer-Level Measure): project success depends on customer satisfaction level, responses to customer requirements, market share rate, firm's growth rate, etc.
- FB (Firm-Based Measure): project success is evaluated by the overall view of a firm. The process of launching new products, intellectual property including patents, developing new technologies, and building better strategies are the measures of success.
- FP (Financial-Performance Measure): project success is evaluated by financial factors such as profit, margin rate, internal rate of return (IRR), ROI, and profit/loss break-even point.
- NM (NPD Process Management Measure): project success depends on either effective or ineffective

NPD process management. Effective communication through successful IT platforms, range of support given to NPD by management, introduction of new and innovative opportunities for the project, and improved procedures introduced into the NPD management process are included in this measure.

### B. External Factors

Project success is hindered by uncontrollable external factors. Cooper and Kleinschmidt [4], Miller [5], Werner et al. [6], Cooper[8], and Polk et al.[9] described various external factors. Table II shows a matrix of success factors and some examples of collected external factors[10]. This matrix can be presented in the form of a three-layer tree, as shown in Fig. 1. This figure is used to obtain the optimal priority or weight of success factors, sub-success factors, and external factors from the MRO method.

## IV. Multi-response Optimization Method

The purpose of this study is to develop a framework for a project manager to determine which external factors are most critical if he or she gives certain priorities or weight values to success factors in an NPD phase. For this purpose, an MRO method in which five success factors are set as dependent or response variables is adapted. Each success factor has sub-success factors, each of which in turn has a number of external factors. Therefore, the final priority or weight of each success factor is optimized sequentially, i.e., from Layer 3 to Layer 1 in Fig. 2.The MRO method [17] is based on are sponse surface method developed by Box and Wilson [18], in which a single response variable is minimized or maximized by multiple numbers of independent variables or process parameters. However, this method is insufficient for considering multiple response variables under an uncertain environment because the results obtained with a single response variable will be biased.

TABLE II. Success Factors &External Factors

| External Factors | Success Factor Measures | | | | |
|---|---|---|---|---|---|
| | PL | CL | FB | FP | NM |
| Availability of Resource, Raw Materials | O | | O | O | O |
| Competitive Environment | O | O | O | O | |
| Customer Needs/Wants | O | O | | | |
| Client Acceptance | O | O | | O | |
| Employee Ability and Attitude toward NPD | | | O | | O |
| Exchange Rate | | | O | O | |
| Existence of a Potential Demand | | O | | O | O |
| Few Competitors | O | | | O | |
| Government Regulations | O | | O | | O |
| High-Level Management and Support | | | O | | O |
| Inflation Rate | | | O | O | |
| Interest Rate | | | O | O | |
| Internal Competition | O | | | | |
| Newness to Firm | O | | O | | O |
| Political/Social Factors | | O | O | | |
| Potential Interest of Technical Staff | O | | | | O |
| Price Competition | O | O | O | O | |
| Probability of Commercial Success | | O | | O | O |
| Probability of Technological Success | O | | | | O |
| Resources committed to the NPD process | | | O | | O |
| Speed to Market | O | | | O | |
| Life Cycle of Product | O | O | | O | O |
| Patents or Technologies | O | | O | | O |

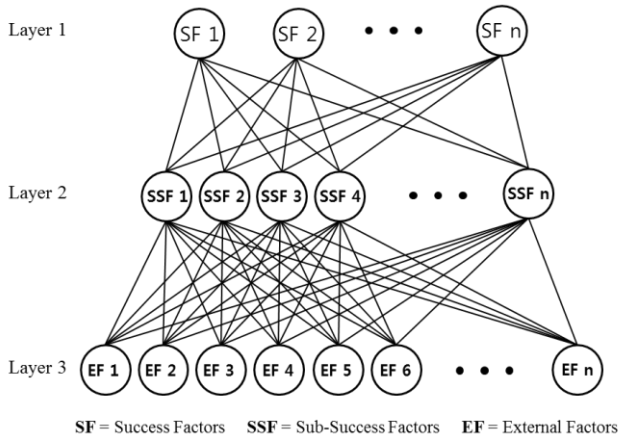


Figure 1. Relations among success factors, sub-success factors, and external factors to determine the optimized priority or weight for each factor

In this study, five success factors are employed as response variables, in addition to multiple sub-success factors and external factors. Two typical methods to optimize the response variables are the desirability function[19] and the loss function[20]. This study adopts the loss function suggested by Pignatiello [20], which is a general form of Taguchi's loss function. The function is shown in(1).

$$L(y(x),\theta) = (y(x)-\theta)^T C(y(x)-\theta) \qquad (1)$$

Here, $L$ is the loss function, $y(x)$ is a vector of response variable $y$ based on independent variable $x$, $\theta$ is a target vector of response variables, and $C$ is an $n \times n$ diagonal cost matrix represented by the difference between $y(x)$ and $\theta$. According to cost matrix $C$, the priority or weight of each response variable is evaluated by minimizing the differences. Subsequently, the priorities or weights of other independent variables such as sub-success factors and external factors are produced as optimal values.

## V. An Illustrative Example

The framework developed in this study maybe described by an example. The following assumptions are made in the example:

The project manager has conducted plenty of NPD projects in the past. This means that he or she can classify the previous projects into various project types. Given that each type is defined by related success factors, he or she can set the priority or weight of each success factor on the basis of his or her experience. The priorities or weights given by the manager have been validated through successful projects.

The project manager is familiar with various external factors that affect success factors and sub-success factors. That is, the manager can establish the relationship between success factors and external factors, as shown in Table I. and Fig. 1.

The project manager can obtain the cost matrix $C$ for the MRO method. In other words, he or she can determine the difference between $\theta$ and the target vector y(x) in terms of costs.

All necessary data, including the priorities or weights of success factors obtained from past data to use the MRO method, are available.

Fig. 2 shows a flowchart of the procedure for executing the framework. First, the relationships among success factors, sub-success factors, and external factors are defined as shown in Fig. 1. The priorities of the success factors must be initially given by the project manager. Second, these relationships are represented as nonlinear regression models (2). Third, the cost matrix is given. Fourth, the weight values for sub-success factors andexternal factors are optimized sequentially using the MRO method. Finally, the most significant factors among the optimized external factors are specified to satisfy the optimized weights of the success factors.

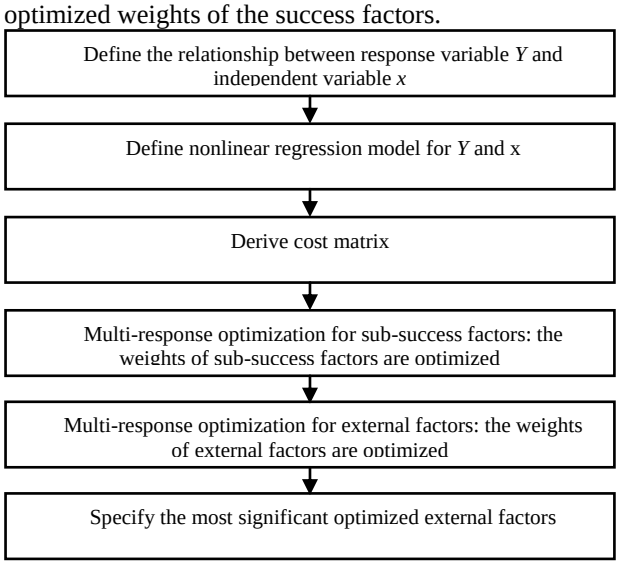


Figure 2. Flowchart of framework procedures for a given example

### A. Defining Response Variables and Independent Variables

For a given example, Table III is used to determine the relationship between success factors and sub-success factors. The success factors and sub-success factors then become the response variables and independent variables, respectively.

TABLE III. Response variables and Independent variables

| Sub-Success Factors (independent variables) | Success Factors (response variables) | | | | |
|---|---|---|---|---|---|
| | CL | PL | FP | FB | NM |
| Customer Satisfaction | O | | | | |
| Market Share Goals | O | | | | |
| Met Performance Specifications | | O | | | O |
| Innovativeness | | O | | | |
| Met Profit Goals | | | O | | |
| IRR or ROI | | | O | | |
| New Patents | | | | O | |
| New Technologies | | O | | O | |
| Support to NPD from management | | | | O | O |
| Improve procedure | | | | | O |

### B. Nonlinear Regression Model

To convert the relationship given in Table III into a quantitative model, the nonlinear regression model shown below is used in this study.

$$Y = \beta_0 + \sum_{i=1}^{p} \beta_i x_i + \sum_{i \le j}^{p} \beta_{ij} x_i x_j \qquad (2)$$

There are $n$ response variables [$Y= (y_1, y_2,\cdots y_n)$] in the form of success factors or sub-success factors,which are affected by $p$ independent variables[$X=(X_1, X_2,\cdots X_p)$]in the form of sub-success factors or external factors. Subsequently, the values of $\beta$ are obtained.

### C. Selection of Cost Matrixand Initial Weights of Success Factors

A cost matrix is used to obtain the optimized priority or weight of each external factor. As mentioned above, the project manager is assumed to have conducted plenty of NPD projects in the past. This implies that all related data including the cost of previous projects are collected and stored in the project data base. If a firm launches many different NPD projects in parallel in a given period, large amounts of data are obtained from the projects. Therefore, clustering algorithms (e.g., k-means algorithm in the area of data mining) are suggested in this study to classify such large amounts of data. In other words, various NPD projects conducted by a firm can be clustered by a data mining algorithm. Each cluster has its own parameters including success factors, sub-success factors, and external factors to group similar NPD projects together. New NPD projects are then grouped into one of the clusters. By using this suggestion, a cost matrix can be generated as a part of the large dataset.

First, virtual raw data including the costs and weights of success factors obtained from past projects are randomly generated, solely to describe the procedure of the developed framework. The k-means algorithm is then executed to classify the costs of success factors for all

projects. As a result, the median values of costs for five success factors are clustered into the four groups, A, B, C, and D (Table IV). The median value of CL is 0.218 for cluster A. The median values must sum up to 1 in each cluster after normalization. However, all the values are meaningless because the original data are not real.

Finally, the initial weights for a certain new project at a development phase are assumed for CL, PL, FP, FB, and NM as 0.35, 0.15, 0.20, 0.15, and 0.15, respectively. These weights are used to obtain the optimal weights of sub-success factors, as described in the next section.

### *D. Application of Multi-response Optimization*

In (1), the initial weights of the five success factors (response variables) become the vector *Y*. Table III. presents the sub-success factors related to the success factors. From (1) and Table III., the optimized weights of the sub-success factors are obtained using the MRO method, the results of which are summarized in Table V. Furthermore, the optimized weights of the external factors related to the sub-success factors under success factor CL are shown in Table VI. The CL is affected by the two sub-success factors of "customer satisfaction" and "market share goals."This result may be described as follows:

TABLE IV. COSTS OF SUCCESS FACTORS BY CLUSTERS

| | A | B | C | D |
|---|---|---|---|---|
| **CL** | 0.218 | 0.258 | 0.284 | 0.212 |
| **PL** | 0.204 | 0.325 | 0.275 | 0.153 |
| **FP** | 0.194 | 0.126 | 0.157 | 0.157 |
| **FB** | 0.188 | 0.136 | 0.169 | 0.285 |
| **NM** | 0.196 | 0.155 | 0.116 | 0.193 |

TABLE V. OPTIMIZED WEIGHTS OF SUB-SUCCESS FACTORS UNDER AVERAGE WEIGHTS GIVEN TO SUCCESS FACTORS

| Sub-Success Factors | Optimized Weights |
|---|---|
| Customer Satisfaction | 0.657 |
| Market Share Goals | 0.615 |
| Met Performance Specifications | 0.319 |
| Innovativeness | 0.227 |
| Met Profit Goals | 0.493 |
| IRR or ROI | 0.395 |
| New Patents | 0.254 |
| New Technologies | 0.262 |
| Support to NPD from management | 0.196 |
| Improved Procedures | 0.251 |

TABLE VI. OPTIMIZED WEIGHTS OF EXTERNAL FACTORS UNDER THE OPTIMIZED SUB-SUCCESS FACTORS FOR SUCCESS FACTOR CL

| External Factors | Customer satisfaction | Market Share goals |
|---|---|---|
| | **0.657** | **0.615** |
| Customer Needs/Wants | 0.725 | |
| Competitive Environment | 0.635 | |
| Client Acceptance | 0.711 | |
| Existence of a Potential Demand | 0.528 | |
| Price Competition | 0.517 | |

Under the given weights of the five success factors, the highest weight is optimally given to the sub-success factor of "customer satisfaction."

Under the given optimal weights of the sub-success factors, the most significant external factor that should be managed in the tightest way is the change in customer needs/wants.

## VI. CONCLUSION AND DISCUSSION

The success of NPD projects depends on various controllable and uncontrollable factors. In general, controllable variables are considered internal factors such as product complexity, schedule tightness, and resource tightness, which are defined by the project characteristics. These variables can be handled by smooth communication among a firm's related departments including design. However, uncontrollable variables or external factors are difficult for departments to control. The life of an NPD project is heavily dependent on external factors.

The project manager must make a GO/STOP decision at each phase of the NPD process on the basis of various success factors. If a project cannot satisfy any of thefive success factors owing to internal or external factors, it should be stopped. The manager must consider the appropriate weights for all five success factors for a project. The weights can be changed in each phase of the NPD process.

This study addresses the relationship between success factors and external factors through sub-success factors. The goal is to develop a framework in which the most significant external factors are detected under a given set of weights for the success factors. The major tool to achieve this goal is the MRO method.

One limitation when the framework is used for real-world cases is that all required data must be available. The necessary data are as follows:

Historical weight data for success factors, sub-success factors, and external factors

Loss cost data representing the difference between the actual and target values of the dependent variable (response variable)

Both data are difficult to obtain in real-world situations.

Nonetheless, this study is still significant in suggesting a framework to determine the most significant external factors for the success of NPD projects.

## ACKNOWLEDGMENT

This work was supported by National Research Foundation of Korea(NRF) grants funded by the Korea government(MEST) (Nos. 2012-0272 and 2012-1168).

## REFERENCES

[1] T. M. Yeh, F. Y. Pai, and C. C. Yang, "Performance improvement in new product development with effective tools and techniques adoption for high-tech industries," *Quality and Quantity*, vol. 44, no. 1, pp. 131-152, Jan. 2010.

[2] T-A. Chiang and Z. H. Che, "A fuzzy robust evaluation model for selecting and ranking NPD projectsusing Bayesian belief network

and weight-restricted DEA," *Expert Systems with Applications*, vol. 37, no. 11, pp. 7408-7418, Nov. 2010.
[3] B. G. Gulcin and F. Orhan, "A fuzzy-logic-based decision-making approach for new product development," *International Journal of Production Economics*, vol. 90, no. 1, pp. 27-45, Jul. 2004.
[4] R. G. Cooper and E. J. Kleinschmidt, "New products: What separates winners from losers?" *Journal of Product Innovation Management*, vol. 4, pp. 169-184, Sep. 1987.
[5] K. D. Miller, "Industry and country effects on managers perceptions of environmental uncertainties," *Journal of International Business Studies*, vol. 24, no. 4, pp. 693-714, 1993.
[6] S. Werner, L. E. Brouthers, and K. D. Brouthers, "International risk and perceived environmental uncertainty: The dimensionality and internal consistency of Miller's measure," *Journal of International Business Studies*, vol. 27, pp. 571-587, 1996.
[7] J. Kim and D. Wilemon, "Sources and assessment of complexity in NPD projects," *R&D Management*, vol. 33, pp. 15-30, Jan. 2003.
[8] R. G. Cooper, "The invisible success factors in product innovation," *Journal of Product Innovation Management*, vol. 16, pp. 115-133, Mar. 1999.
[9] R. Polk, R.E. Plank, and D.A. Reid, "Technical risk and new product success: An empirical test in high technology business markets," *Industrial Marketing Management*, vol. 25, pp. 531-543, Nov. 1996.
[10] S-Muk Park, "Determination of impact degrees from uncontrollable external factors to new product development by using fuzzy or grey system theory," Industrial Engineering, Sungkyunkwan Univ., Republic of Korea, 2011.
[11] R. G. Cooper, "How to identify potential new product winners," *Research Management*, vol. 18, pp. 10-19. 1980.
[12] H. Ernst, "Success factors of new product development: A review of the empirical literature," *International Journal of Management Reviews*, vol. 4, no. 1, pp. 1-40, Mar. 2002.
[13] A. Griffin and A. L. Page, "An interim report on measuring product development success and failure," *Journal of Product Innovation Management*, vol. 10, pp. 291-308, Sep. 1993.
[14] A. Griffin and A. L. Page, "PDMA success measurement project: recommended measures for product development success and failure," *Journal of Product Innovation Management*, vol. 13, pp. 478–496, Nov. 1996.
[15] C. D. Ittner and D. F. Larcker, "Total quality management and the choice of information and reward system," *Journal of Accounting Research*, vol. 33, pp. 1-34, 1995.
[16] K. Mc Cracken, "A study of the factors influencing new product development success in the South African investment sector," Business Management, Stellenbosch Univ., South Africa, 2011.
[17] R. H. Myers and D. C. Montgomery, *Response Surface Methodology: Process and Product Improvement with Designed Experiments* 2nd ed. John Wiley & Sons, New York, 2002.
[18] G. E. P Box and K. B. Wilson, "On the experimental attainment of optimum conditions," *Journal of Royal Statistical Society-Series B*, vol. 13, pp. 1-45, 1951.
[19] G. C. Derringer and R. Suich, "Simultaneous optimization of several response variables," *Journal of Quality Technology*, vol. 12, no. 4, pp. 214-219, 1980
[20] J. Pignatiello, "Strategies for robust to multiresponse quality engineering," *IIE Transactions*, vol. 25, pp. 5-15, 1993

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