具有創造新產品名聲能力之專案與品質等級評選模式

Project and Quality-standard Selection Model with Prestige Creation for New Product Development

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摘要：持續性的進行新產品研發是企業維持競爭優勢的重要策略。本文針對新產品研發議題提出一個新的 0-1 混合整數規劃專案評選模型。此模型考慮新產品研發計畫可區分成多重類別。每一研發類別係指一特定現有產品的重新設計或性能的提升計畫，而各類別中另包含幾項研發專案，每項專案係指該產品中某一特定子系統的重新設計或性能的升級。再者，本文假設每項研發專案具有多重品質/技術等級可供研發的選擇，而且對一特定品質/技術等級而言，僅有一項資源配置的方案能達到其要求的標準。此外，本文假設新產品的市占率取決於現有產品的品牌名聲，以及新產品的各子系統品質/技術等級。而消費者對某公司品牌名聲評價則與該公司現有產品的市占率有關。根據上述，我們建構了一個專案與品質等級的評選模型，藉以找出最佳的新產品各子系統的品質等級組合及其執行排程，以極大化消費者對新產品的品牌名聲評價，進而極大化化長期平均利潤。

關鍵字：新產品開發、專案選擇、品質等級選擇、品牌名聲

Abstract: One of the ways by which a firm maintains an advantage over its rivals is by continually developing new products.　This requires a new product development strategy at the core of its

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business efforts. What this paper presents is a mathematical model -- an alternative 0-1 mixed integer programming model -- for selecting projects for new product development (NPD). Such a model considers the situation in which each NPD program can be placed as multiple categories. Each R&D category would refer to a creative project to redesign or upgrade a specific product. A category would involve several projects, each project addressing the redesign or promotion of a specific subsystem of the production process. Each project, moreover, would have a list of quality/technology standards to select from with only single resource-allocation proposals available for realizing a specific quality-standard. It is assumed that the market share of a new product depends on brand-prestige and the portfolio of quality-standards; the brand-image judgment of a consumer would depend on the market share of products offered in a current period. This study proposes a project and quality-standard selection model for finding an optimal portfolio of quality-standard new products and a schedule for maximizing the expected brand-image judgment of consumers. The aim is to achieve long-run average profitability.

Keywords: New Product Development, Project Selection, Quality-standard Selection, Brand Prestige

1. Introduction

In recent years, a harsh competitive environment has pushed companies into developing unique, high quality fashionable products in order to attract customers and sustain competitive advantages. One of the important strategies for doing this is through new product development (NPD) (Brown and Eisenhardt, 1995; Day and Wensley, 1988).

NPD is a process by which an organization transforms data on market opportunities and technical possibilities into information assets for commercial production (Clark and Fujimoto, 1991). It includes the enhancement of the brand image of an enterprise and its marketing position (Robert, 1993). In the course of development, this process can influence the performance of the whole operation. The success of the NPD is closely associated with the selection of R&D Projects under a resource-constrained scenario (Pedro and Francisco, 2009; Robert, 1999; Rutsch et al., 2006).

Meade and Presley (2002) reveal four major topics for R&D project selection which are of interest to scholars. They include: (i) the need to set the related criteria of project selection corresponding to corporate strategies, (ii) the issue of qualitative benefits and risks in producing the new product, (iii) the desire to reconcile and integrate the needs of different stakeholders, and (iv) the need to consider the multi-stage levels of group decision processes. Baker and Freeland (1975), Martino (1995), Henriksen and Traynor (1999) present an excellent survey of these interests.

From a methodological viewpoint, project selection issues may be seen as belonging to four classes: The first is mathematical programming, including integer planning, linear programming and non-linear programming, and selecting the best project association under various kinds of limiting conditions. The second is cognitive emulation models, utilizing linear return, decision tree, and an expert system to develop the operations path. The third is AD HOC methods that include top-down policy, genius award, and systems approach. The fourth is measurement methods for assessing the performance of projects and for choosing the projects (Hall and Nauda, 1990).

Most of the past studies related to R&D project selection under a constrained budget fail to consider the case in which the budget is periodically needed – resulting in project scheduling delays (Asher, 1962; Cooper and Kleinschmidt, 1988; Henriksen and Palocsay, 2008).　Sun and Ma (2005) propose a packing-multiple-boxes model for choosing the R&D projects with a specific time horizon. The authors, however, overlook the situation in which R&D projects may be separated into multiple categories or when there are multiple choices of quality-standards for each project (Nishihara and Ohyama, 2008).　They also fail to consider the case where a manager hopes each R&D project category is completed within a specific time horizon. Indeed, if we treat the attempt of redesigning/upgrading a specific kind of product as a project category and treat the effort of redesigning/upgrading a specific subsystem of an existing product as a project in a category, then the multi-category project selection becomes a central issue.　Furthermore, most traditional investigations neglect the value of a project when the target (or ideal) quality-standard is not realized.

However, in practice, a project may have multiple choices of quality-standards and get a non-zero value regardless of a below-the-ideal quality-standard.　On the other hand, the top-manager usually hopes any new product is launched before a specific time horizon has elapsed because major competitors will put in competitive products in the market after this period.

Except for the cases mentioned-above, traditional literature has not probed into project selection from the viewpoint of brand-prestige creation.　In general, the price of a product and the corresponding quality-standard may directly influence the consumers' intention to purchase or repurchase (Lichtenstein *et al*., 1993).　"Brand Image" has also been shown as a key factor in sales (Fichter and Jonas, 2008; Kwon and Sharron, 2009; Maxwell *et al*., 2008).　Thus, if the decision makers of a firm present the new products under a policy of creating brand-prestige in the long-run, the firm may be rewarded with a high profitability average in the long-run. In this paper we assume that the market share of a new product depends on the brand recognition of consumers and the portfolio of quality-standards of new products.　However, the brand-image judgment of consumers depends on the market share of products currently in circulation.　Accordingly, we propose a project and quality-standard selection model to find an optimal portfolio of quality-standards of new products and the associated optimal schedule thereby maximizing the expected brand-image judgment of consumers,

which may benefit the market share of the existing products and the future development of new products (Keown *et al*., 1979; Kolisch *et al*., 2005; Kurt and Christian 1999).

2. Choice of Project Advancement Strategy

The success of an R&D project usually depends on both hard and soft factors.   Hard factors are measurable by a quantitative method, i.e. the number of engineers and the amount invested in the project. Soft factors are not measurable by a quantitative method; they refer to intangibles such as the control ability of a project leader and the historical experience of an engineer.   Chang and Chen (2007) propose four types of project advancement strategies to aid decision-maker in selecting projects -- taking soft factors into account.   Such a project advancement strategy is also termed a resource allocation and transfer strategy.   They consist of the following types:

Centralized sequential advancement strategy (*CSAS*): This means centralizing the available amount of a periodic budget into a R&D project; the periodic budget is transferred onto another project once the assigned quality-standard of R&D project has been achieved.   All projects thus achieve their assigned quality-standards. Supposing there are three projects: A, B and C.   Then CSAS would be depicted as Figure 1.

Decentralized synchronized advancement strategy (*DSAS*):   This entails decentralizing the available amount of periodical budget into all R&D projects until all projects achieve their quality-standards assigned.   Supposing there are three projects: A, B and C.   Then DSAS would be depicted as Figure 2.
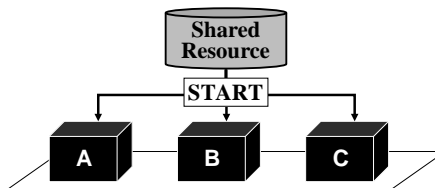

Figure 1   CSAS chart

Figure 2   DSAS chart

Type I and Type Ⅱ mixed advancement strategies (*Type I, Type Ⅱ MAS*): Consider the projects A, B, C and D, and divide the four projects into two categories: {A & B} and {C & D}, which are referred to as "X" and "Y" respectively.　Type I MAS involves deploying the CSAS within the categories X and Y, while going ahead between categories X and Y with the DSAS, as shown in Figure 3.　On the other hand, Type II MAS entails deploying the DSAS within the categories X and Y, while going ahead between categories X and Y with the CSAS; i.e., transferring the periodic budget onto the projects in category Y where only the assigned quality-standards for all projects in category X　are realized, as shown in Figure 4.

This article borrows a specific project advancement strategy for solving some settings caused by soft factors. Clearly, the problem considered in this article fits type I MAS and type II MAS.　In general, the major advantage of type I MAS is the efficiency of resource-utilization.　The major disadvantage is the diversification of the managerial ability of a project-leader, which leads to variation in progress growth and quality.　In contrast to type I MAS, the major advantage of type II is the focus on project-management by a project-leader; this leads to reduced variation in progress and quality. The major disadvantage of this strategy is having less efficient resource-utilization; the new product developed may later slip into a lower quality-standard when the time horizon concerned with the decision-maker has elapsed.　This will lead to a weakening of a firm's competitive advantage.　In practice, the choice of Type I or Type II strategy depends on the actual situation on the ground.　In this paper, we only focus on the model of Type II MAS.
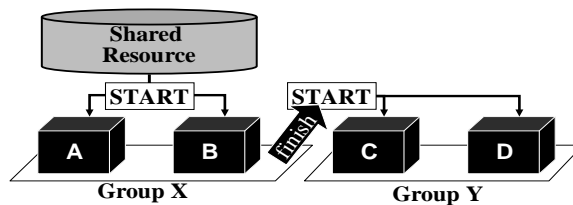
Figure 3　The chart of Type I MAS
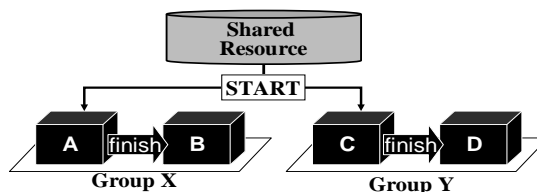
Figure 4　The chart of Type II MAS

3. Type II MAS Based Project Selection Model

3.1 Definition of quality-standard of a particular subsystem

This section first defines the quality-standard of a particular subsystem of a product. This refers to the collection of core quality indicators of the subsystem. To illustrate: in an automobile system, the important indicators of the quality of a vehicle engine would be horsepower, torque, and fuel consumption; let us say that the relevant values of these indicators are 150hp, 19.3kg-m, and 12.4km/l respectively. It is necessary to improve at least one of these indicators if a car manufacturer wants to upgrade the vehicle's systematic efficiency. Suppose torque and fuel consumption are selected for improvement. The indicator of torque is upgraded from 19.3kg-m to 22.7kg-m while fuel consumption is improved from 12.4km/l to 13.2km/l. Thus, the relevant indicators of the engine system become: 150hp, 22.7kg-m, and 13.2km/l. According to this study, the car's quality-standard of engine system is thus upgraded/ redesigned as well.

3.2 The Problem

Let us consider a company that plans to drive a new product program in a bid to maintain/increase its occupation rate of the market. For example, an automaker introduces a new type of car. The NPD program can be divided into several categories with each category reflecting a new product development; for example, in the case of the automobile manufacturer, a sports car. A category would also include several projects, each project referring to redesigning/upgrading a specific subsystem of an existing product. For instance, a project may refer to redesigning/upgrading the engine system of the sports car.

If a top manager hopes that any new product is rendered before a specific time horizon has elapsed, such a time horizon is called "value-based time limit" since there is a manifest value-loss if a specific type of new product is rendered after the major competitor offerings. Simply put, value-based time limit coupled with a new product is the time horizon for the major competitors to produce a competitive product market after the original time horizon has elapsed.

3.3 Assumptions of consumer behavior

From the above problem description we see that each R&D project's contribution value is going along with value-based time limit. Therefore, if each periodic budget is inadequate for realizing the target standards of each R&D project, then we would have to find a portfolio of quality-standards for developing new products. To do this, we have to follow two assumptions of consumer behavior:

A1: The market share of a new product offered in a target market depends on the brand-image judgment of consumers and the portfolio of quality-standards of the new product.

A2: The brand-image judgment of consumers depends on the market share of products offered within a target market.

3.4 Framework of the proposed project selection

Consider a (J, K_j) multi-standard project selection problem, where J denotes the number of new product development (or the number of R&D categories), K_j denotes the number of projects for product $j, j = 1, 2, \cdots, J$. It is assumed there are multiple choices of quality-standards for project k in product j, numbered by levels $0, 1, \cdots, L_{jk}$. wherein level 0 refers to 'do nothing', i.e., the subsystem corresponding to project k in product j is not selected or upgraded. Also, L_{jk} refers to the ideal quality-standard. Corresponding to our assumptions of consumer behavior, we divide consumers in a given target market into Group 1 and Group 2. The consumers in Group 1 decide their brand-image score of products offered by a particular firm only by their perception with regard to the demanding atmosphere of a specific new product offered by this firm. Consumers, however, in Group 2 decide the brand-image score by their perception with regard to demanding atmosphere of all new products. The consumers in Group 1 use their perception of the demanding atmosphere of a particular new product to decide on brand-image of the commodity offered by a firm. The consumers in Group 2, however, apply their perception of demanding atmosphere to all new products. Based on this premise, we further consider that the brand-image score for a consumer is measured by levels 0 and 1. A consumer in Group 1, for example, who believes that the commodity offered by a firm is respectable or gives it brand-image score at level 1 if he feels that a specific new product is going to be best seller. On the other hand, this same consumer believes that it is not respectable or gives it brand-image score at level 0 if he feels otherwise. By the same token, a consumer in Group 2 who believes that the commodity offered by a firm is respectable or gives it brand-image score at level 1 if he feels that all new product are going to be best sellers. On the other hand, this same consumer believes that it is not respectable or gives it brand-image score at level 0 if he feels otherwise. Let z_j denote the market share for new product j. According to the definition of z_j, we further define $V(z_1, \cdots, z_j, \cdots, z_J)$ as the total expected number of consumers who give the new products brand-image score at level 1 as the portfolio of market shares for all products is at level $(z_1, \cdots, z_j, \cdots, z_J)$. Yet, $V_j(z_j)$ refers to the expected number of consumers in Group 1 who perceive that product j is a popular commodity as its market share is at level z_j, and $\beta(z_1, z_2, ..., z_J)$ represents the expected number of consumers in Group 2 who perceive that all new products are best sellers once the portfolio of market shares is at level $(z_1, \cdots, z_j, \cdots, z_J)$. Accordingly, $V(z_1, \cdots, z_j, \cdots, z_J)$ can be computed as the summation of consumers in Group 1 and Group 2 who will give the new products brand-image score at level 1, indicated as follow:

$$V(z_1, z_2, ..., z_J) = \sum_j V_j(z_j) + \beta(z_1, z_2, ..., z_J) \tag{1}$$

Note that the market share of a certain product offered by a firm defined here is measured by the percentage of the number of this product in the current market. Thus, z_j is a real number on interval $[0,1]$ for any product j.

Assuming that there is a minimum value of market share, say z_j^l, for each new product such that almost all of consumers in Group 2 will perceive that all new products are best sellers as $z_j \geq z_j^l$ for all j. According to the definition of $\beta(z_1, z_2, ..., z_J)$, we know that $\beta(1,1,...,1)$ represents the maximum number of consumers in Group 2 who will give the new products brand-image score at level 1. As mentioned above, a consumer who gives the new products brand-image score at level 1 if he feels that the new products are going to be best sellers. Based on this premise, we know that the value of $\beta(z_1^l, z_2^l, ..., z_J^l)$ should extremely approach the value of $\beta(1,1,...,1)$. Thus, this study further assumes that

$$\beta(1,1,...,1) - \beta(z_1^l, z_2^l, ..., z_J^l) \leq \varepsilon \tag{2}$$

where ε is an extremely small number.

Yet, consider a project selection problem with multiple choices of quality-standards for each project. Whenever a quality-standard is assigned to a project of a new product, a specific portfolio of cost and time-periods is required to be invested in. Accordingly, if we let P be a feasible portfolio of quality-standards for all project that satisfies the resource constraints and the value-based time limit conditions, then the framework of the proposed project selection model may be formulated simply as below (according to A1-A2)

$$\underset{P \in \Omega}{\text{maximize}} \; V(z_1, \cdots, z_j, \cdots, z_J) \tag{3}$$

where Ω is the set consisting of all feasible portfolios of quality-standards for all project.

Furthermore, with the use of (2), we can treat the value of $\beta(z_1, z_2, ..., z_J)$ as a constant once the value of z_j is limited to the condition of more than the value of z_j^l. Because such a constant also denotes the maximum number of consumers in Group 2 who will give the new products brand-image score at level 1, optimization problem (3) almost is equivalent to following Problem (4).

$$\underset{\substack{P \in \Omega \\ z_j \geq z_j^l, \forall j}}{\text{Maximize}} \; \widetilde{V}(z_1, z_2, ..., z_J) = \sum_{j=1} V_j(z_j) \tag{4}$$

3.5 Multi-standard and single-resource-allocation model

For the purpose of this research, this article defines such a model as one which has the following characteristics:

- There exist multiple choices of quality-standards for each project in a specific R&D category.
- It is necessary to invest in a certain amount of cost for each period.
- It is permissible that the non-equal amount of cost is invested in each period for realizing a specific quality-standard of a project in a specific R&D category.
- The remaining available budget of previous period can be used in the next period.
- There exists only a portfolio of the cost and period to realize a specific quality-standard of a project in a specific R&D category.
- There is an extra influx of fund for each period but the total cost for conducting all projects is limited to a certain amount of budget.
- A specific value-based time limit associates with each R&D category, which limits the finish time of all projects in this category.

In order to formulate such a model, a list of extra notations is given as follows:

Parameters

j Index of a R&D product, $j = 1,2,\cdots,J$;

k Index of a project related to a new product development. For example, $k = 1,2,\cdots,K_j$ corresponding to R&D product j ;

l Index of a quality-standard related to a project in a R&D product development. For example, $l = 0,1,2,...,L_{jk}$ corresponding to project k in R&D product j ;

w_{jkl} Weight with regard to project k contributing to the market share of new product j when project k's quality- standard is at level l ;

D_{jkl} Time period required to invest in cost for achieving the goal at assigned quality-standard l of project k in R&D product j , $l = 0,1,2,...,L_{jk}$;

R_{jkl}^{d} Amount of cost required to invest in th-d period for achieving the goal at assigned quality-standard l for project k in R&D product j ,

$l = 0,1,2,...,L_{jk}$, $d = 1,2,\cdots,D_{jkl}$;

B Budget available for each period;

T_j The value-based time limit for each R&D product j , $j = 1,2,\cdots,J$;

ACB Total budget limitation for conducting all projects;

Decision Variables

I_{jkl} Binary variable that takes value 1 if the assigned quality-standard is at level l for project k in R&D product j , and 0 if otherwise.

t_j Time period required to invest in cost for R&D product j ;

b_j Average amount of cost invested in each period for R&D product j ;

S_{jk} Start time of conducting project k in R&D product j ;

f_{jk}　　　Finish time of conducting project k in R&D product j;

S_j　　　Start time of conducting projects in product j (note that $S_j = t$ refers to R&D product

　　　　　j is started at the end of time $t-1$ or at the beginning of time t);

f_j　　　Finish time of R&D product j (note that $f_j = t$ refers to R&D product j is finished

　　　　　at the end of time $t-1$ or at the beginning of time t).

For further formulating the model, we first decide the sequence of R&D products by designating that the larger product-index j implies the longer time horizon of T_j, and the bigger value of T_j implies the lower priority for investing in this R&D product. Accordingly, it yields that $S_1 = 0$ and $S_j = f_{j-1}, j = 2, \cdots, J$. Yet, assuming that R_{jkl}^d is non-decreasing in d. Based on this premise, this study further defines Δ_j as follows:

$$\Delta_j = B_0 t_j + \Delta_{j-1} - b_j t_j, \quad j = 1, \cdots, J$$

and

$$\Delta_0 = 0$$

The value of Δ_j refers to the remaining budget which is available once the projects in R&D product j are finished. Subject to the technical complexity of the proposed problem, in this study we only consider the schedule that any project starts at the latest time under a given invariant schedule-duration of the program (involving all projects), which allows us to formulate a model by using mathematical programming and find a near-optimal solution. In this case, we know

$$S_{jk} = f_{jk} - \sum_{l=0}^{L_{jk}} D_{jkl} \cdot I_{jkl}, \forall j, k. \tag{5}$$

and

$$f_{jk} = f_j, \forall j, k \tag{6}$$

Accordingly, we know that any feasible project schedule has to satisfy the following constraint:

$$\sum_{t=S_j}^{\tilde{t}} c_j^t \le B \cdot (\tilde{t} - S_j + 1) + \Delta_{j-1}, \quad S_j \le \tilde{t} \le f_j - 1 \tag{7}$$

where c_j^t denotes the required cost at time t for conducting the projects in category j.

Because R_{jkl}^d is non-decreasing in d, it yields

$$\sum_{t=S_j}^{\tilde{t}} c_j^t \le b_j \cdot (\tilde{t} - S_j + 1) + \Delta_{j-1}, \quad S_j \le \tilde{t} \le f_j - 1 \tag{8}$$

Therefore, any project schedule satisfies the condition of $b_j \le B_0$, this solution will also satisfy the condition of

$$\sum_{t=S_j}^{\tilde{t}} c_j^t \leq B \cdot (\tilde{t} - S_j + 1) + \Delta_{j-1}, \quad S_j \leq \tilde{t} \leq f_j - 1 \qquad (9)$$

Accordingly, the multi-standard and single-resource-allocation model may be approximately formulated as below:

Objective Function:

$$\text{maximize} \quad \tilde{V} = \sum V_j(z_j) \qquad (10)$$

Subject to

$$Z_j = \sum_{l=0}^{L_{jk}} \sum_{k=1}^{K_j} w_{jkl} \cdot I_{jkl}, \forall j \qquad (10.1)$$

$$z_j \geq z_j^l , \forall j \qquad (10.2)$$

$$\sum_{k=1}^{K_j} \sum_{d=1}^{D_{jkl}} \sum_{l=0}^{L_{jk}} R_{jkl}^d \cdot I_{jkl} = b_j \cdot t_j, \forall j \qquad (10.3)$$

$$t_j \geq \sum_{l=0}^{L_{jk}} D_{jkl} \cdot I_{jkl}, \forall \ j,k \qquad (10.4)$$

$$\sum_{j=1}^{J} b_j \cdot t_j \leq ACB \qquad (10.5)$$

$$b_j \leq B, \forall j \qquad (10.6)$$

$$S_{jk} = f_{jk} - \sum_{l=0}^{L_{jk}} D_{jkl} \cdot I_{jkl}, \forall j,k \qquad (10.7)$$

$$f_{jk} = f_j, \forall j,k \qquad (10.8)$$

$$f_j = \sum_{i=1}^{j} t_i, \forall j \qquad (10.9)$$

$$S_1 = 0 \qquad (10.10)$$

$$S_j = f_{j-1}, \forall j \geq 2 \qquad (10.11)$$

$$f_j \leq T_j, \forall j \qquad (10.12)$$

$$\sum_{l=0}^{L_{jk}} I_{jkl} = 1 , \ \forall j , k \qquad (10.13)$$

$$I_{jkl} = 0,1, \forall j, k, l \qquad (10.14)$$

$$b_j \geq 0, \forall j \qquad (10.15)$$

$$t_j \geq 0, \forall j \qquad (10.16)$$

where (10.1) warrants the consistency of the definitions regarding the market share of a new product, (10.2) ensures that the market share z_j^l is expected realized at very least, (10.3) warrants the consistency of the definitions regarding the amount of cost invested in a R&D product, (10.4) ensures that the time period invested in a specific R&D product satisfies the requirements of each project in

this R&D product, (10.5) ensures that the amount of cost invested in all R&D products is not more than the total budget available, (10.6) ensures that the average amount of cost invested in each period for R&D product j is not more than the amount of budget available for each period, (10.7)-(10.11) warrants the consistency of the definitions regarding the start time and finish time of a project, (10.12) ensures that the finish time of a R&D product is not more than the value-based time limit associated with it, and (10.13) ensures just a level of quality-standard is assigned to a project.

Note that the result of $I_{jk0} = 1$ means that project k in R&D product j is not selected and the subsystem k of product j is not developed or upgraded as well. Therefore, after solving problem (10)-(10.16), one can find (1) the projects selected in each R&D product, (2) the quality-standards assigned to each project in a specific R&D product, and (3) the baseline schedule for implementing the chosen projects.

3.6 Further consideration

To solve the proposed model, the form of value function has to be decided. For simplicity, replacing $w_{jk,L_{jk}}$ by w_{jk} and considering the case in which there exists a strictly increasing function, say u_{jkl}, such that $w_{jkl} = w_{jk}u_{jkl}$, where $0 \le u_{jkl} \le 1$ and $u_{jk0} = 0, u_{jk,L_{jk}} = 1$. Note that the target market share of new product j is the value of $\sum_k w_{jk}$ and the introduction of parameter u_{jkl} may help the decision-makers to understand the percentage of realizing w_{jk}.

Furthermore, letting $\widetilde{w}_{jk}$ denote the normalized weight so that

$$\widetilde{w}_{jk} = \frac{w_{jk}}{\sum_m w_{jm}} \tag{11}$$

According to (12), Constraint (10.1) may be rewritten as

$$\widetilde{z}_j = \sum_{l=0}^{L_{jk}} \sum_{k=1}^{K_j} \widetilde{w}_{jk} u_{jkl} \cdot I_{jkl}, \, j = 1,2,\ldots,J \tag{12}$$

Notice that the value of $\widetilde{z}_j$ may be predicated as the percentage of realizing the target market share of new product j (i.e., $\sum_k w_{jk}$). Similarly, Constraint (10.2) may be rewritten as

$$\widetilde{z}_j \ge \frac{z_j^l}{\sum_k w_{jk}}, \, j = 1,2,\ldots,J \tag{13}$$

By letting α_j denote the expected consumer population in Group 1 (defined in section 3.3) for giving the brand-image score at level 1 as $\widetilde{z}_j = 1$. Then, this article defines that the value of $\sum_j \alpha_j$ is the target performance of brand-prestige creation. Yet, it is assumed that there exists a continuous

and strictly increasing function, say $U_j(\tilde{z}_j)$, such that the value function have following equivalent relationships:

$$\text{maximize } \sum V_j(z_j) \cong \text{maximize } \sum \alpha_j U_j(\tilde{z}_j) \tag{14}$$

where $0 \leq U_j(z_j) \leq 1$, and $U_j(1) = 1, U_j(0) = 0$.

Note that $U_j(\tilde{z}_j)$ may be predicated as the percentage of realizing the value of α_j given the value of $\tilde{z}_j$. This study only examines the special case in which $U_j(\tilde{z}_j) = \tilde{z}_j$. Based on above, if $\tilde{w}_j$ means the normalized value of α_j then project selection model (10)-(10.16) is equivalent to the following problem:

$$\text{maximize } \sum_{j=1}^{J} \tilde{w}_j U(\tilde{z}_j) = \sum_{j=1}^{J} \tilde{w}_j \tilde{z}_j \tag{15}$$

Subject to

$$\tilde{z}_j = \sum_{l=0}^{L_{jk}} \sum_{k=1}^{K_j} \tilde{w}_{jk} u_{jkl} \cdot I_{jkl}, j = 1, 2, \ldots, J \tag{15.1}$$

$$\tilde{z}_j \geq \frac{z_j^l}{\sum_k w_{jk}}, j = 1, 2, \ldots, J \tag{15.2}$$

$$\sum_{k=1}^{K_j} \sum_{d=1}^{D_{jkl}} \sum_{l=0}^{L_{jk}} R_{jkl}^d \cdot I_{jkl} = b_j \cdot t_j, \forall j \tag{15.3}$$

$$t_j \geq \sum_{l=0}^{L_{jk}} D_{jkl} \cdot I_{jkl}, \forall\ j, k \tag{15.4}$$

$$\sum_{j=1}^{J} b_j \cdot t_j \leq ACB \tag{15.5}$$

$$b_j \leq B, \forall j \tag{15.6}$$

$$S_{jk} = f_{jk} - \sum_{l=0}^{L_{jk}} D_{jkl} \cdot I_{jkl}, \forall j, k \tag{15.7}$$

$$f_{jk} = f_j, \forall j, k \tag{15.8}$$

$$f_j = \sum_{i=1}^{j} t_i, \forall j \tag{15.9}$$

$$S_1 = 0 \tag{15.10}$$

$$S_j = f_{j-1}, \forall j \geq 2 \tag{15.11}$$

$$f_j \leq T_j, \forall j \tag{15.12}$$

$$\sum_{l=0}^{L_{jk}} I_{jkl} = 1, \forall j, k \tag{15.13}$$

$$I_{jkl} = 0,1, \forall j, k, l \tag{15.14}$$

$$b_j \geq 0, \forall j \tag{15.15}$$

$$t_j \geq 0, \forall j \tag{15.16}$$

Because the quantity of $\sum \tilde{w}_j U_j(\tilde{z}_j)$ may be explained as the percentage of achieving the ideal performance of brand-prestige creation which is defined as the value of $\sum w_j$. And the evaluation of parameter $\tilde{w}_j$ is easier than the evaluation of parameter α_j, the parameters transform for α_j to $\tilde{w}_j$ and z_j to $\tilde{z}_j$ not only transform original model (10)-(10.16) into a real solvable form (i.e., (15)-(15.16)) but also provide the objective value a clear managerial implication.

3.7 Evaluation of model parameter

Letting N_j denote the expected consumer population for purchasing product j in a target market, N_{jk} denote the expected consumer population for making decision of purchasing product j and depending on the quality-standard of subsystem k. Furthermore, let N_{jk}^e denote the expected consumer population for making a decision to buy product j, offered in the firm, given the assigned quality-standard of subsystem k is at the level l $(l=1,2,\cdots,L_{jk})$. Then, one may obtain the value of w_{jkl} by the following formula:

$$w_{jkl} = \frac{N_{jk}}{N_j} \cdot \frac{N_{jk}^e}{N_{jk}} = \frac{N_{jkl}^e}{N_j} \tag{16}$$

After obtaining the value of parameter w_{jkl}, one can further obtain the value of parameter u_{jkl} by computing the value of w_{jkl}/w_{jk}. Note that obtaining the individual actual values of N_j and N_{jkl}^e may be difficult; however, one may easily employ a questionnaire method to evaluate the value of $\frac{N_{jkl}^e}{N_j}$.

For the evaluations of $\tilde{w}_j$ and z_j^l, one can design a questionnaire to obtain the information in relation to the consumers in Group 1or Group 2. For example, consider two new products A and B. One may request a consumer to answer the problem: "what is the situation that will influence his/her brand-image?" If a certain consumer claims that the popular new products A or B will be, then this consumer can be classified into Group 1. On the other hand, if this consumer claims that the popular new products A and B will be, then this consumer can be classified into Group 2. Moreover, a second problem can request a consumer to answer for obtaining $\tilde{w}_j$ and z_j^l. This problem is "what is the minimum size of market share of a particular new product for enabling him/her to believe that this new product is popular?" After obtaining the information in relation to the two problems mentioned-above, one may evaluate the value of z_j^l by some methods. Because the too big estimated

value of z_j^l may imply no solution in resolving (15)-(15.16), this study suggests that the median or average value of observed samples is a feasible selection. Despite such suggestion may not confirm the requirement of Equation (2); however, this method allows us to formulate an approximated model like (10)-(10.16) to resolve the dilemma of Equation (1).

Furthermore, letting n_j denotes the number of respondents who belong to Group 1 and believe that product j will influence their brand-image under $z_j \leq \sum_k w_{jk}$. Then, one can estimate the value of value of $\tilde{w}_j$ by computing value of $\dfrac{n_j}{\sum n_i}$.

4. Illustrative Example

In this section, we present an example of new car development to demonstrate the proposed model. The aim of the decision maker is to select the most appropriate projects and their quality standards so as to maximize the expected brand-image judgment of consumers. In general, consumer's criteria for buying a car may differ owning to the individual preference of consumers. For instance, the criteria of a consumer towards buying a specific type of car may include power engine system, body and dimension, and security system etc. In this case, we take common car styles as an example and divide these cars into five categories. They are Sedans, Hatchbacks, SUVs, Minivans, and Coupes. Each category includes three projects with regard to the attempt of resigning/upgrading a specific subsystem of the car; this can be seen in Table 2. The parameters of $\tilde{w}_j$ and $\tilde{w}_{jk}$ are shown in Table 1 as well. Yet, the value-based time limits for R&D categories 1 through 5 are respectively 16, 15, 18, 23, and 29 time-units. The value of z_j^l for $j = 1,2,\ldots,5$, is given by 0.17, 0.1, 0.18, 0.1, and 0.19.

Table 1　Projects of the category of car types

Category j ($\tilde{w}_j$)	Sedans (C1) 0.2	Hatchbacks (C2) 0.3	SUVs (C3) 0.25	Minivans (C4) 0.15	Coupes (C5) 0.1
Project k ($\tilde{w}_{jk}$)	Engine system (P11) (0.5)	Suspension system (P21) (0.3)	Engine system (P31) (0.4)	Engine system (P41) (0.35)	Transmission system (P51) (0.26)
	Body & dimension (P12) (0.25)	Engine system (P22) (0.45)	Suspension system (P32) (0.35)	Transmission system (P42) (0.35)	Suspension system (P52) (0.4)
	Transmission system (P13) (0.25)	Safety system (P23) (0.25)	Body & dimension (P33) (0.25)	Body & dimension (P43) (0.3)	Engine system (P53) (0.34)

Table 2　Percentage of realization of w_{jk} **(i.e.,** u_{jkl} **)**

l	Category 1			Category 2			Category 3			Category 4			Category 5		
	P11	P12	P13	P21	P22	P23	P31	P32	P33	P41	P42	P43	P51	P52	P53
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.4	0.5	0.6	0.4	0.5	0.7	0.5	0.5	0.5	0.3	0.5	0.4	0.5	0.4	0.5
2	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.7	0.8	0.6	0.7
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The data listed in Table 2 indicate the values of u_{jkl}.　The data listed in Table 3 indicate the periodical cost and the period required to invest in a project for achieving a specific assignment of quality-standard.

Given $B_0 = 9$, $ACB = 186$ and based on the data of Tables 1 through 3, we can fined the values of (I_{jkl}, t_j, b_j, S_{jk}, f_{jk}, S_j, f_j) by resolving (15)-(15.16).　The results are exhibited in Table 4 (resolved by employing LINGO 8.0 software tool).

The results of Table 4 are depicted in Figure 5.　To illustrate: the chosen projects in category 2 (i.e., Hatchbacks) are project 2 (the improvement of the engine system) and project 3 (the improvement of safety system).　The quality-standards assigned to these two projects are respectively at level 2 and 1. Yet, the period invested in Sedans, Hatchbacks, SUVs, Minivans and Coupes are respectively 4, 5, 7, 7 and 6 units of time.　Finally, the total cost required for achieving the assigned quality-standards of these two projects is 40 units that are obtained by computing the value of $b_2 \cdot t_2$.

5. Discussion and Conclusion

The problem of new product development under a constrained budget may be formulated as a R&D project selection problem. Traditional budget-constrained R&D project selection problems failed to consider the situations in which the quality-standard assigned for each project are at multiple levels available; the amount of cost for achieving a specific quality-standard of a project is needed periodically; and the contribution of a project declines over time.　In addition to hard factors mention-above, previous studies regarding a R&D project selection problem also failed to consider the soft factors influencing the project performance such as the managerial and control ability of decision-makers.　Clearly, such a study cannot completely respond to all practical events.　In this paper we have proposed a project selection model for a new product development program taking above factors into account.　Assume that the decision-makers of a manufacturer adopts type Ⅱ mixed advancement strategy (MAS) after considering soft factors related to this R&D program.
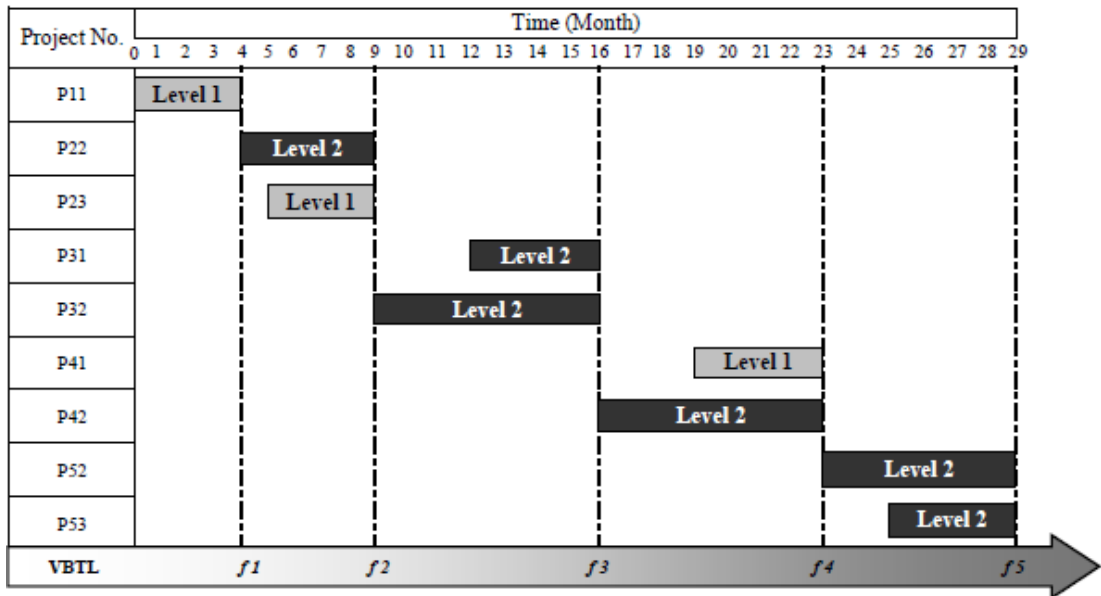
Tables 3   Periodical cost and the period required to invest in a project for achieving a specific assignment of quality-standard

Budget amount	Category 1									Category 2									Category 3									Category 4									Category 5								
	P11			P12			P13			P21			P22			P23			P31			P32			P33			P41			P42			P43			P51			P52			P53		
	Standards									Standards									Standards									Standards									Standards								
Period	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	3	3	3	3	3	3	3	4	4	3	4	4	4	4	4	4	4	4	4	4	5	3	3	4	5	5	5	4	4	4	3	3	3	4	5	5	4	5	4	3	3	3	4	5	6
2	4	3	4	3	3	3	4	4	4	4	4	4	4	4	5	4	4	4	4	5	5	3	3	4	5	5	5	4	4	4	3	3	3	4	5	5	4	5	4	3	3	3	4	5	6
3	4	4	4	3	3	4	4	5	5	4	4	4	4	4	5	5	4	5	5	5	5	4	3	5	4	5	5	4	4	5	3	3	4	4	5	5	4	5	4	4	4	4	4	5	6
4	5	4	4	3	4	4	5	5	5	5	4	5	4	5	5	5	5	5	5	5	5	4	4	5	4	5	5	4	5	5	4	4	4	4	5	6	5	5	5	4	4	4	4	5	6
5				4	5	4	4	4	5	5	5		4	5	5	5	5					5	5	4	5	5	5	5	5	4	4	4			6		5	5	4	4					
6						4				5	5				6		5						4	5			5	5			4	4					6				4	5			
7												5											5	6							5	5													

Table 4   The values of decision variables to propose model

Project selected (level)	Category 1 P11(1)	Category 2 P22(2), P23(1)	Category 3 P31(2), P32(2)	Category 4 P41(1), P42(2)	Category 5 P52(2) , P53(2)
t_i	4	5	5	7	6
b_i	4	8	9	6	7
S_{jk} (project)	0	4 (P22) 5 (P23)	12 (P31) 9 (P32)	19 (P41) 16 (P42)	23 (P52) 25 (P53)
f_{jk} (project)	4	9 (P22) 9 (P23)	16 (P31) 16 (P32)	23 (P41) 23 (P42)	29 (P52) 29 (P53)
S_i	0	4	9	16	23
f_i	4	9	16	23	29

Figure 5   Project schedule of this example

Under type Ⅱ MAS, this paper models a project selection problem by considering a linear value function.   Furthermore, some discussions are presented as follows in order to highlight the contributions of this paper.

First, in past studies on the subject of consumer evaluation for brand image were discussions. Most studies in this issue believe that perceived quality of a consumer is the core factor to influence the consumer evaluation for brand image (Colleen and Tara, 2003; Timothy, 1997).   Yet, the individual

consuming experience of a consumer and the liking of majority are usually the core factors to influence perceived quality.　Accordingly, this paper assumes that the perception of a consumer for whether a new product is the liking of majority is a critical factor to influence the consumer's brand-image. From this viewpoint, consumers may decide the brand-image score by their perception with regard to the perception of market size of one or more than one products.　Despite this paper only consider two types of consumers (i.e., Group 1and Group 2), the results of the proposed model really contribute the literature in new product development.

Second, conventional studies in the project selection issues usually only consider the constraints of total budget in the duration of all projects.　This study considers the amount of cost for achieving a specific quality-standard of a project is needed periodically and budget available is also limited periodically. Subject to technique complexity we only consider the schedule solution that any project starts at the latest time under the invariant schedule duration.　In view of this, the schedule solution resolved by our proposed model may fail to provide any buffer time for each of projects.　In view of this, the duration of all projects may be delayed whenever a project's progress is delayed.　However, the results of this study will benefit the future researches in taking into account above factors.

Third, most studies related project selection fail to concurrently consider the scheduling problem. Even though the scheduling problem has found in a conventional project selection model, it also fails to take into account the factors such as the quality-standard assigned for each project are multiple grades available and the resource-allocation to realize a specific quality-standard of a project are multiple proposals available.　In view of this, traditional models related to project selection usually are the linear program ones; however, our proposed model is a nonlinearly mixed 0-1 integer program one.　Of course, our proposed model is more useful than traditional ones in project selection practices; specially, in the issues of new product development.

To conclude, the proposed model is capable of finding the portfolio of quality-standards of new products and their associated optimal schedule, which maximize the expected brand-image judgment of consumers.　Doing so may benefit the long-run average profitability.　The presented model does not consider the case where value function is nonlinear.　Therefore, further research can focus on the examination of this issue.

The model presented here does not consider the case where the amount of cost required to invest in each period for achieving a specific quality-standard of a project is also that presents multiple choices. Thus, an enhanced model recuperating this available variation should be made in the near future.

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