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MULTI-CATEGORY AND MULTI-STANDARD PROJECT SELECTION WITH FUZZY VALUE-BASED TIME LIMIT

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Abstract. *This paper proposes a new approach to select projects and their quality-standards corresponding to successively provide new products in the market. The problem involves the situation in which each new product development (NPD) program can be differentiated as multiple categories. Each project has multiple choices of quality/technology standards. Based on this problem, the proposed approach consists of following four components: (1) selecting a project advancement strategy to serve as a scheduling framework for taking into account soft factors in scheduling process, (2) employing the brand-image score of consumers as the objective function for ultimately increasing long-run average profitability, (3) formulating a computable model in which periodical budget constraints are involved and fuzzy value-based time limits are specified, and (4) transforming the objective function into an appropriate form in which the parameters can be estimated more easily and the objective value can be predicated as a clear managerial implication. Also, we simulate 54 items to test the proposed model. The testing results show that one can find the global optimal in a short time for most testing items. That is, the proposed computable model has high feasibility and applicability.*

Keywords: New product development, Project selection and scheduling, Multi-choice of quality-standards, Brand image, Value-based time limit

1. Introduction.

Due to the in-coming new competitors, endless technology innovation and dynamic customer demands have significantly shortened the product life cycle. Thus, enterprises should effectively manage their product development project and bring their products to market as early as possible to maintain the market share. New product development (NPD) is the process by which an organization uses its resources and capabilities to create a new product or improve an existing one [1,2]. It includes the enhancement of the brand image of an enterprise and its marketing position [3]. Restated, capable of influencing overall operational performance during product development, a company continuously attempts to identify important factors in product development.

The success of the NPD is closely associated with the selection of R&D projects under a resource constrained scenario [4,5]. Then the good project selection is extremely important for enterprises to generate competitive advantage in the market. The project selection problem related to an NPD program can be usually expressed as a multi-category and multi-standard project selection problem under a budget- and time-constrained scenario. Indeed, each R&D category involves redesigning or upgrading a specific current product and the effort to redesign/upgrade a specific subsystem of an existing product is treated as a project in a category. In general, each project has usually multiple choices of quality/technology standards and a multiple amount of cost is invested in each period for realizing a specific quality-standard of a project. On the other hand, there are multiple choices of resource-allocation proposals for the realization of a specific quality-standard. Moreover, the contribution of an R&D project/category is limited to a specific time horizon. Such a time horizon is referred to hereinafter as 'the value-based time limit', since a manifest value-loss occurs if a specific product is developed after the major competitor offerings. Therefore, the firm must determine which products to invest how much in at what point in time under funds limited. In other words, they must continuously make decisions concerning the overall portfolio of product development projects that they will execute across time to maximize firm success [6]. This viewpoint shown the multi-project scheduling should be also considered concurrently whenever one attempts to resolve the above multi-standard and multi-allocation project selection problem. Again, the scenario as aforementioned tells us the amount of budget available in each period and value-based time limit constrains the quality-standard and resource-allocation selection of a project. Although aforementioned project selection problem occurs in an actual scenario, most R&D project selections under a constrained budget fail to consider the case in which the budget is periodically needed – resulting in project scheduling delays [7-11]. To conclude, the conventional project selection model cannot respond some NPD actual scenarios as abovementioned.

Except the above NPD practices, most traditional project selection models also fail to consider project the scheduling concurrently. Sun and Ma [12] developed a packing-multiple-boxes model, capable of selecting R&D projects and their associated scheduling. However, they not only fail to consider the NPD actual scenarios as stated-above but also fail to consider intangible factors when scheduling projects. Intangible factors refer to those that are immeasurable by a quantitative method such as the controlling influence of the project leader and the intuitive experience of an engineer. Except for the above works, relevant literature has not examined project selection from the perspective of brand-image creation. In general, the price of a product and the corresponding quality-standard may lead directly to purchase intention and repurchase intention of consumers. "Brand Image" has also been shown as the key factor whether consumers have bought or not [13-15]. Restated, the brand image of consumers obviously influences their purchase intention. Thus, a firm may have a high profitability on average in the long run if its decision makers provide new products by creating brand image in the long-run.

Based on above analysis, we propose an approach to treat the multi-standard and multi-allocation project selection problem. The proposed approach consists of four major components. First, we revise slightly the definition of the four project advancement strategies defined by Chang and Chen [16] in order to benefit the application of our problem. The four strategies are developed to assist decision makers in selecting projects that involve intangible factors. Again, we also discuss simply the major advantages and disadvantages of these strategies. Second, we borrow the concepts of Chang and Yang [17] to establish a measurement of brand-image of a consumer. Indeed, they suggest that consumer perception as to whether the majority of consumers prefer the offerings of a firm should significantly influence the brand image of a consumer about the firm. From this perspective, consumers may determine the brand-image score based on their perception with respect to the perception of market share of one or more products. Third, we provide a computable model in which the selection of quality-standard and resource-allocation proposal of a project under constrained project duration and constrainedly periodical budget are considered. Finally, we transform the objective function into an appropriate form in which the parameters can be estimated more easily and the objective value can be predicated as a clear managerial implication. Consequently, the proposed approach can identify an optimal portfolio of quality standards and resource-allocation proposals for new products, as well as the associated optimal schedule. Such an optimal solution maximizes the expected brand-image score of consumers, which benefits the long-run average profitability. Finally, we simulate 54 items to test the proposed computational model. The testing results show that one can find the global optimal in a short time for most testing items. That is, the proposed computational model has high feasibility and applicability. Consequently, the proposed approach has some special features which show our approach is more general than traditional project selection researches. These include concurrently considering project selection and scheduling, and taking into account the soft factors solving, brand-image score of consumers, periodical budget constraints, fuzzy value-based time limits in the project selection and scheduling process.

2. Choice of Project Advancement Strategy.

R&D project success largely depends on tangible and intangible factors. Tangible factors refer to those that can be measured by a quantitative method such as the number of engineers and the amount of budget invested. Intangible factors refer to those that are immeasurable by a quantitative method such as the controlling influence of the project leader and the intuitive experience of an engineer. Chang and Chen developed four project advancement strategies to assist decision makers in selecting projects that involve intangible factors [16]. In this paper, we revise slightly the definition of the four project advancement strategies to benefit the application of our problem, as described in the following.

Centralized sequential advancement strategy (*CSAS*): A multi-project problem in which each project has multiple choices of quality-standards is given. Again, a non-equal amount of cost must be invested in each period for realizing a specific quality-standard. Accordingly, we redefine CSAS as centralizing the available amount of periodical budget into a R&D project and the remaining budget available from the previous period can be used in the next period. Furthermore, we transfer the periodical budget to another project once the assigned quality standard of this project is achieved. Correspondingly, all projects ultimately achieve their quality standards assigned. Assume there are three projects: A, B and C: A, B and C. Figure 1 displays CSAS.

Decentralized synchronized advancement strategy (*DSAS*): The scenario same as CSAS is given, DSAS refers to decentralizing the available amount of periodical budget into all R&D projects until all projects achieve their quality standards assigned. Again, the allocated policy for each period may vary since the cost required to invest in each period for any project may vary. Assume there are three projects: A, B and C: A, B and C. Figure 2 displays DSAS.

Types I and II mixed advancement strategies (*Type I, Type II MAS*): While considering projects A, B, C and D, divide the four projects into two categories: {A & B} and {C & D}, which are referred to as "X" and "Y", respectively. Type I MAS refers to deploying CSAS within categories X and Y, while moving ahead between categories X and Y with

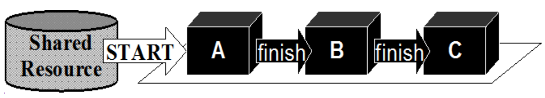

FIGURE 1. CSAS chart

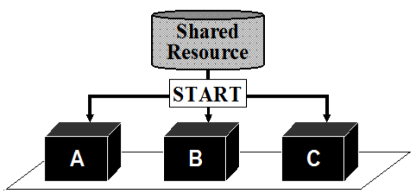

FIGURE 2. DSAS chart

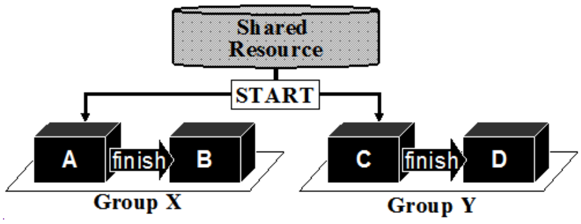

FIGURE 3. The chart of Type I MAS

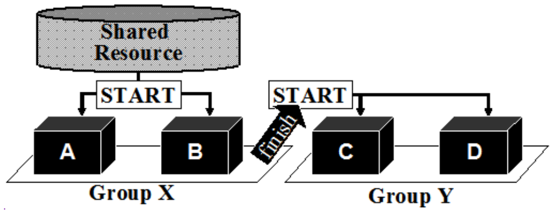

FIGURE 4. The chart of Type II MAS

the DSAS as shown in Figure 3. Whereas Type II MAS refers to deploying the DSAS within categories X and Y, while moving ahead between categories X and Y with CSAS, i.e., transferring the periodical budget onto the projects in category Y for only the assigned quality standards of all projects in category X, as shown in Figure 4.

This work suggests that one should borrow a project advancement strategy for solving some setting problems caused by intangible factors, in order to achieve the highest performance while implementing these projects. DSAS or type I MAS is generally characterized by its resource-utilization efficiency. However, DSAS or type I MAS is limited mainly in the diversification of the managerial skills of a project leader, leading to growth variation of progress and quality. In contrast with DSAS or type I MAS, CSAS or type II MAS is characterized by its emphasis on the project-managerial role of a project leader, subsequently reducing the variation of progress and quality. However, these strategies are less efficient in terms of resource utilization. Additionally, the new product may be developed with an inferior quality standard when the time horizon involving the decision maker has elapsed, subsequently lowering competitiveness. In practice, these strategies are selected based on what has been set up the situation and made actually. This work focuses only on the type II MAS model.

3. **Maximizing the Brand-image Judgements of Consumers.** Consider a (J, K_j) multi-standard project selection problem, where J denotes the number of new product developments, and K_j represents the number of projects for product j, $j = 1, 2, \cdots, J$. Assume there are multiple choices of quality-standards for project k in product j, numbered by levels $0, 1, \cdots, L_{jk}$, where 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} denotes the ideal quality standard. A vehicle industry example is employed to explain the concept of quality-standard more clearly as follows: Supposing a manufacturer would like to increase the quality of a particular car by upgrading the efficiency of the car's engine system. Let us consider that the quality indicators of the engine system are horsepower, torque, and fuel consumption. Table 1 shows the definitions of different quality-standards of this illustrative example. The results of Table 1 tell us that the values of these indicators for current state are respectively 150hp, 19.3kg-m and 12.4km/l. Again, the ideal quality standard of the engine system that the manufacturer hopes to promote is the portfolio of indicator values 155hp, 22.7kg-m and 13.8km/l.

TABLE 1. The level of quality-standards for indicators

Quality-standards Indicators	level 0	level 1	level 2	level 3 (L_{jk})
Horsepower (hp)	150	152	154	155
Torque (kg-m)	19.3	19.9	21.4	22.7
Fuel consumption (km/l)	12.4	12.8	13.2	13.8

Furthermore, as discussed in the introduction, the brand image of consumers obviously influences their purchase intention. Thus, a firm may have a high profitability on average in the long run if its decision makers provide new products by creating brand image in the long-run. Based on this premise, this study employs the expected brand-image scores of consumers as the objective function for ultimately increasing long-run average profitability. Most consumer evaluation studies of a brand image suggested that perceived quality of a consumer should profoundly impact the consumer evaluation of a brand image [18-20,22]. However, the preferences of the majority of consumers may also influence the brand-image score of a consumer. For details, Chang and Yang [17] suggest that consumer perception as to whether the majority of consumers prefer the offerings of a firm should significantly influence the brand image of a consumer about the firm. From this perspective, consumers may determine the brand-image score based on their perception with respect to the perception of market share of one or more products. With this result, two assumptions of consumer behavior can be followed:

A1: The brand-image score of a consumer depends on his/her market share perception of the firm within a target market.

A2: The market share perception of a consumer about a new product depends on the ability to identify the portfolio of quality standards for this new product.

In general, the higher market share perception of a consumer about the offerings of a firm means that he/she perceives the majority of consumers prefer these offerings. Thus, A1 describes that the higher perception of market share of one or more products implies the higher brand image score of a consumer. Moreover, A2 describes that the higher quality of a new product may imply a higher best-selling perception of a consumer (i.e., a higher market share perception).

Corresponding to our assumptions regarding consumer behavior, consumers in a given target market are divided into Groups 1 and 2. The consumers in Group 1 determine their brand-image score of products offered by a particular firm only based on their perception with respect to whether a particular product offered by this firm is popular. Consumers, however, in Group 2 determine the brand-image score based on their perception with respect to whether all products offered by this firm are popular. Based on this premise, further assume that the brand-image score for a consumer is evaluated based on levels 0 and 1. For instance, consider consumers in Group 1 who believe that any product offered by a firm is reliable or give it a brand-image score at level 1 if they feel that a specific new product is going to be best seller. However, these same consumers believe that it is not reliable or give it a brand-image score at level 0 if they feel otherwise. Correspondingly, consider consumers in Group 2 who believe that any product offered by a firm is reliable or give it a brand-image score at level 1 if they feel that all new products are going to be best sellers. However, these same consumers believe that it is not reliable or give it a brand-image score at level 0 if they feel otherwise. Let z_j denote the market share for new product j. Based on the definition of z_j, $V(z_1, \cdots, z_j, \cdots, z_J)$ is further defined as the total anticipated number of consumers who give the new products a brand-image score at level 1 as the portfolio of market shares for all products is at level $(z_1, \cdots, z_j, \cdots, z_J)$. Still, $V_j(z_j)$ refers to the anticipated 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 $\beta(z_1, z_2, \cdots, z_J)$ represents the anticipated number of consumers in Group 2 who perceive that all new products are best sellers once the portfolio of market shares is at level $(z_1, \cdots, z_j, \cdots, z_J)$. Correspondingly, $V(z_1, \cdots, z_j, \cdots, z_J)$ can be derived as the summation of consumers in Group 1 and Group 2 who assign the new products a brand-image score at level 1, indicated as follows:

$$V\left(z_1, z_2, \ldots, z_J\right) = \sum_j V_j(z_j) + \beta(z_1, z_2, \cdots, z_J) \tag{1}$$

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

Assume there is a minimum value of market share, e.g., z_j^l, for each new product such that nearly all consumers in Group 2 perceive that all new products are best sellers as $z_j \geq z_j^l$ for all j. According to the definition of $\beta(z_1, z_2, \ldots, z_J)$, $\beta(1, 1, \ldots, 1)$ denotes the maximum number of consumers in Group 2 who assign the new products a brand-image score at level 1. As mentioned earlier, consumers assign the new products a brand-image score at level 1 if they feel that the new products are going to be best sellers. Based on this postulation, the value of $\beta(z_1^l, z_2^l, \ldots, z_J^l)$ should closely approach the value of $\beta(1, 1, \ldots, 1)$. Thus, this study further assumes that

$$\beta\left(1, 1, \ldots, 1\right) - \beta\left(z_1^l, z_2^l, \ldots, z_J^l\right) < \varepsilon \tag{2}$$

where ε is an extremely small number.

Next, 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 intervals must be invested in. Therefore, if P is allowed to be a feasible portfolio of quality standards for all projects that satisfy the resource constraints and the value-based time limit conditions, then the framework of the proposed project selection model can be formulated simply as follows (according to A1-A2):

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

where Ω denotes the set consisting of all feasible portfolios of quality standards for the entire project.

Furthermore, with respect to using (2), the value of $\beta(z_1, z_2, \cdots, z_J)$ can be treated 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 assign the new products a brand-image score at level 1, optimization problem (3) is almost equivalent to the following problem (4).

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

4. A Computable Formulation.

4.1. The requirements of concerned problem.

For the purpose of giving a computable formulation, this section first lists all requirements of our concerned problem as follows:

- Each project in a specific R&D category has multiple choices of quality-standards.
- The amount of budget available in a period constrains the quality-standard selection of a product.
- The remaining budget available from the previous period can be used in the next period.
- A multiple amount of cost is invested in each period for realizing a specific quality-standard of a project in a particular R&D new product.

- It is only permissible that the same amount of cost is invested in each period for realizing a specific quality-standard of a project in a specific R&D category.
- Despite an additional influx of funds for each period, the total cost for conducting all projects is limited to a certain budgetary amount.
- An ambiguous value-based time limit is associated with each R&D category, thus limiting the quality-standard selection of a product as well.

4.2. **Notations.** Again, a list of extra notations is given as follows:

Parameters

j	Index of an 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 an R&D product development. For example, $l = 0, 1, 2, \cdots, L_{jk}$ 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;
M_{jk}	Number of alternatives regarding the amount of cost investing in each period for project k in new product j, $m = 1, 2, \cdots, M_{jk}$, $\forall j$;
R_{jk}^m	Amount of cost corresponding to alternative m of project k in new product j, $m = 1, 2, \cdots, M_{jk}$, $\forall j, k$;
D_{jkl}^m	Period of time required to invest in the cost R_{jk}^m for achieving the goal at assigned quality-standard l for project k in new product j, $l = 0, 1, 2, \cdots, L_{jk}$, $m = 1, 2, \cdots, M_{jk}$, $\forall j, k$;
B_0	Budget available for each period;
T_j	Value-based time limit for each new product j, $j = 1, 2, \cdots, J$;
ACB	Total amount of budget available for conducting all projects;
Δ_j	The remaining budget available once the projects in R&D product j are completed;
c_j^t	The required cost at time t for conducting the projects in new product j.

Decision Variables

y_{jk}^m	Binary variable that takes the value of 1 if periodical budget-alternative m is adopted and 0 if otherwise, $m = 1, 2, \cdots, M_{jk}$, $\forall j, k$;
$\tilde{y}_{jk}^l$	Binary variable that takes the value of 1 if the selected quality-standard is at level l and 0 if otherwise, $l = 0, 1, 2, \cdots, L_{jk}$, $\forall j, k$;
t_j	Period of time required to invest in cost for new product j;
b_j	Average amount of cost invested in each period for new product j;
S_{jk}	Start time of conducting project k in new product j;
f_{jk}	Finish time of conducting project k in new product j;
S_j	Start time of conducting projects in new product j (note that $S_j = t$ refers to new product j is started at the end of period $t - 1$ or at the beginning of period t);
f_j	Finish time of new product j (note that $f_j = t$ refers to new product j is finished at the end of period $t - 1$ or at the beginning of period t).

4.3. **Generating the periodical budget constraints.** The model is further formulated by first determining the sequence of R&D products, while assuming that a larger product-index j implies a longer time horizon of T_j; in addition, a larger value of T_j implies a lower priority for investing in this R&D product. Therefore, it yields that $S_1 = 0$ and $S_j = f_{j-1}$, $j = 2, \cdots, J$. However, assume that R^m_{jk} is non-decreasing in D^m_{jkl}. Based on this premise, this work 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 available once the projects in R&D product j are completed. Given the technical complexity of the proposed problem, this work considers only a schedule in which a project starts at the latest time under a given invariant schedule-duration of the program involving all projects, thus allowing us to formulate a model by using mathematical programming and obtaining a nearly optimal solution. In this case,

$$S_{jk} = f_j - \sum_{l=0}^{L_{jk}} \sum_{m=1}^{M_{jk}} D^m_{jkl} \cdot y^m_{jk} \cdot \tilde{y}^l_{jk}, \quad \forall j, k \tag{5}$$

and

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

Therefore, a feasible project schedule must satisfy the following constraint:

$$\sum_{t=S_j}^{\tilde{t}} c^t_j \le B_0 \cdot (\tilde{t} - S_j + 1) + \Delta_{j-1}, \quad S_j \le \tilde{t} \le f_j - 1 \tag{7}$$

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

Because R^m_{jk} is non-decreasing in D^m_{jkl}, it yields

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

Therefore, for a project schedule that satisfies the condition of $b_j \le B_0$, this solution also satisfies the condition of (7).

4.4. **Specifying fuzzy value-based time limit.** For the purpose of giving a computable formulation, this section considers our concerned problem that completion time of new product j is no more than the value-based time limit, i.e., $f_j \le T_j$, and T_j is a fuzzy number. Furthermore, as is generally assumed, the decision-makers treat the parameter of value-based time limit as an ambiguity parameter. Interviewing the decision-maker in charge of process control, the ambiguous value-based time limit is expressed as a fuzzy number. For example, the value-based time limit of new product 1 described with linguistic expression "about 10 time units", e.g., a, can be restricted by a fuzzy number A with the membership function,

$$\mu_A(r) = \max\left(0, 1 - \frac{|r - 10|}{0.6}\right) \tag{9}$$

For simplicity, we deal the problem with symmetric triangular fuzzy numbers. Then, this paper restricts to describing the essence of fuzzy mathematical programming with possibilistic linear programming. A possibilistic linear function value cannot be determined uniquely since its coefficients are ambiguous, i.e., non-deterministic [22].

The fuzzy number A is depicted in Figure 5. As shown in Figure 5, "10" is the most plausible value for fuzzy number A as it takes the highest membership value. The membership value of the fuzzy number A, $\mu_A(r)$, shows the possibility degree of the event

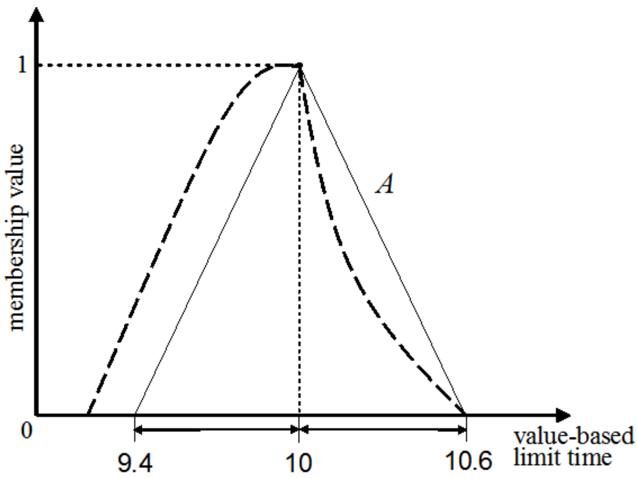

FIGURE 5. A symmetric triangular fuzzy number $\langle 10, 0.6\rangle$

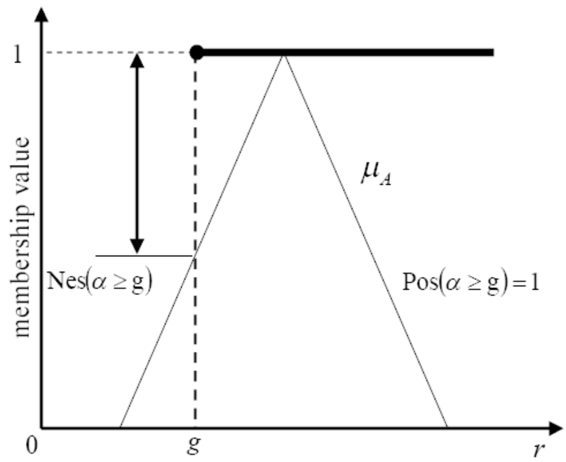

FIGURE 6. Minimum possible degree of $A \geq g$

that the value-based limit time of new product 1 when A is r. In this sense, μ_A can be considered as a possibility distribution of the value-based time limit of new product 1 and r can be regarded as a possibilistic value restricted by the possibility distribution μ_A.

Moreover, the necessity measure of a fuzzy number is defined as follows [23]:

$$\mathrm{Nes}(A \geq g) = 1 - \sup(\mu_A(r) | r < g) \tag{10}$$

where μ_A is the membership function of the fuzzy number A. Thus, $\mathrm{Nes}(A \geq g)$ shows the minimum possible degree to what extent A is bigger than g, as shown in Figure 6.

Moreover, we assume that the value-based time limit T_j obeys a normal distribution $N(m_j, \sigma_j^2)$ with mean m_j and the variance σ_j^2. Thus, the probability density function $f_{T_j}(r)$ is defined by

$$f_{T_j}(r) = \frac{1}{\sqrt{2\pi}\sigma_j} \exp\left(-\frac{(r - m_j)^2}{2\sigma_j^2}\right) \tag{11}$$

As a result, we have normal fuzzy number T_j with the membership function that can be defined as follows:

$$\mu_{T_j}(r) = \exp\left(-\left(\frac{r - T_j^c}{v_j}\right)^2\right) = \exp\left(-\left(\frac{f_j - T_j^c}{v_j}\right)^2\right) \tag{12}$$

This paper wherein considers that T_j is a normal fuzzy number with center value T_j^c and spread value v_j. Note that spread value v_j is equal to $\sqrt{2}\sigma_j$ where σ_j is a standard deviation of the corresponding normal random variable. Another, according to the definition of the necessity measure of a fuzzy number, we can obtain the following constraint of necessity measure.

$$\text{Nes}\{T_j \geq f_j\} \geq h_0, \quad \forall j \tag{13}$$

where $h_0 \in (0, 1]$ is a predetermined value.

Constraint (13) ensures that the minimum possible degree that the value-based time limit is bigger than the finish time of an R&D new product will be greater than h_0, when the value-based time limit is treated as a fuzzy number. Therefore, we can translate to a linear constraint by the constraint (12) and (13), which is in processing as follows:

$$\begin{aligned}
&\text{Nes}\{T_j \geq f_j\} \geq h_0 \Rightarrow 1 - \sup(\mu_{T_j}(r)|r < f_j) \geq h_0 \\
&\Rightarrow 1 - \left[\exp\left(-\left(\tfrac{f_j - T_j^c}{v_j}\right)^2\right)\right] \geq h_0 \Rightarrow \exp\left(-\left(\tfrac{f_j - T_j^c}{v_j}\right)^2\right) \leq 1 - h_0 \\
&\Rightarrow -\left(\tfrac{f_j - T_j^c}{v_j}\right)^2 \leq \ln(1 - h_0) \Rightarrow \left(\tfrac{f_j - T_j^c}{v_j}\right)^2 \geq -\ln(1 - h_0) \\
&\Rightarrow \left|\tfrac{f_j - T_j^c}{v_j}\right| \geq \sqrt{-\ln(1 - h_0)} \Rightarrow -\tfrac{f_j - T_j^c}{v_j} \geq \sqrt{-\ln(1 - h_0)} \\
&\Rightarrow f_j - T_j^c \leq -\sqrt{-\ln(1 - h_0)}v_j \Rightarrow f_j \leq T_j^c - \sqrt{-\ln(1 - h_0)}v_j
\end{aligned}$$

Accordingly, the constraint (13) can be written as

$$f_j \leq T_j^c - \sqrt{-\ln(1 - h_0)}v_j, \quad \forall j \tag{14}$$

Constraint (14) has been transformed into a linear format which is obtained by using the fractile approach.

4.5. **The proposed computable model.** Therefore, the multi-standard and multiple-resource-allocation project selection problem can be formulated as follows:

Objective Function:

$$\text{Maximize } \tilde{V} = \sum V_j(z_j) \tag{15}$$

Subject to

$$z_j = \sum_{l=1}^{L_{jk}} \sum_{k=1}^{K_j} \sum_{m=1}^{M_{jk}} w_{jkl} \cdot \tilde{y}_{jk}^l \cdot y_{jk}^m + w_{jk0} \cdot \tilde{y}_{jk}^0, \quad \forall j \tag{15.1}$$

$$z_j \geq z_j^l, \quad \forall j \tag{15.2}$$

$$f_j \leq T_j^c - \sqrt{-\ln(1 - h_0)}v_j, \quad \forall j \tag{15.3}$$

$$\sum_{k=1}^{K_j} \sum_{l=1}^{L_{jk}} \sum_{m=1}^{M_{jk}} R_{jk}^m \cdot D_{jk}^m \cdot y_{jk}^m \cdot \tilde{y}_{jk}^l = b_j \cdot t_j \quad \forall j \tag{15.4}$$

$$t_j \geq \sum_{l=1}^{L_{jk}} \sum_{m=1}^{M_{jk}} D_{jkl}^m \cdot y_{jk}^m \cdot \tilde{y}_{jk}^l, \quad \forall j, k \tag{15.5}$$

$$\sum_{j=1}^{J} b_j \cdot t_j \leq ACB \tag{15.6}$$

$$b_j \leq B_0, \quad \forall j \tag{15.7}$$

$$S_{jk} = f_j - \sum_{l=1}^{L_{jk}} \sum_{m=1}^{M_{jk}} D_{jkl}^m \cdot y_{jk}^m \cdot \tilde{y}_{jk}^l, \quad \forall j, k \tag{15.8}$$

$$f_{jk} = f_j, \ \ \forall j, k \tag{15.9}$$

$$f_j = \sum_{i=1}^{j} t_i, \ \ \forall j \tag{15.10}$$

$$S_1 = 0 \tag{15.11}$$

$$S_j = f_{j-1}, \ \ \forall j \geq 2 \tag{15.12}$$

$$\sum_{l=0}^{L_{jk}} \tilde{y}_{jk}^{l} = 1, \ \ \forall j, k \tag{15.13}$$

$$\sum_{m=1}^{M_{jk}} y_{jk}^{m} \leq 1, \ \ \forall j, k \tag{15.14}$$

$$y_{jk}^{m} = 0, 1, \ \ m = 1, 2, \cdots, M_{jk}, \ \ \forall j, k \tag{15.15}$$

$$\tilde{y}_{jk}^{l} = 0, 1, \ \ d = 1, 2, \cdots, M_{jk}, \ \ \forall j, k \tag{15.16}$$

$$b_j \geq 0, \ \ \forall j \tag{15.17}$$

$$t_j \geq 0, \ \ \forall j \tag{15.18}$$

where (15.1) warrants the consistency of the definitions regarding the market share of a new product, (15.2) ensures that the market share z_j^l is expected realized at very least, (15.3) denotes that the finish time to new product j has to less than the value-based time limit associated with this new product, (15.4) warrants the consistency of the definitions regarding the amount of cost invested in a new product, (15.5) ensures that the time period invested in a specific new product satisfies the requirements of each project in this new product, (15.6) ensures that the amount of cost invested in all R&D new products is not more than the total budget available, (15.7) ensures that the average amount of cost invested in each period for new product j is not more than the amount of budget available for each period, (15.8)-(15.12) warrants the consistency of the definitions regarding the start time and finish time of a project, (15.13) ensures just a level of quality-standard is assigned to a project and (15.14) ensures that at most only a proposal about invested cost for project k in new product j can be selected.

Notably, the result of $\tilde{y}_{jk}^{0} = 1$ means that project k in new product j is not selected and the subsystem k of product j is not developed or upgraded as well. Therefore, after the above model is derived, our results indicate the projects selected in each new product, the quality standards assigned each project in a particular new product, and the baseline schedule for implementing the chosen projects.

5. **Further Consideration of Objective Function.** The function form of $V_j(z_j)$ must be determined first to derive the proposed problem. For simplicity, $w_{jk,L_{jk}}$ is replaced with w_{jk}. Again, a situation is considered in which there exists a strictly increasing function, e.g., u_{jkl}, such that $w_{jkl} = w_{jk} u_{jkl}$, where $0 \leq u_{jkl} \leq 1$ and $u_{jk0} = 0$, $u_{jk,L_{jk}} = 1$. Notably, the target market share of new product j is the value of $\sum\limits_{k} w_{jk}$.

Additionally, introducing parameter u_{jkl} may help decision-makers to understand the percentage of realizing w_{jk}.

Furthermore, let $\tilde{w}_{jk}$ denote the normalized weight so that

$$\tilde{w}_{jk} = \frac{w_{jk}}{\sum\limits_{m} w_{jm}} \tag{16}$$

According to (16), constraint (15.1) can be rewritten as

$$\tilde{z}_j = \sum_{l=0}^{L_{jk}} \sum_{k=1}^{K_j} \sum_{m=1}^{M_{jk}} \tilde{w}_{jk} u_{jkl} \cdot \tilde{y}_{jk}^l \cdot y_{jk}^m + \tilde{w}_{jk} u_{jk0} \cdot \tilde{y}_{jk}^0, \ \ \forall j \tag{17}$$

Notably, $\tilde{z}_j$ can be predicated as the percentage of achieving the target market share of new product j (i.e., $\sum_k w_{jk}$). Similarly, constraint (15.2) can be rewritten as

$$\tilde{z}_j \geq \frac{z_j^l}{\sum_k w_{jk}}, \ \ j = 1, 2, \ldots, J \tag{18}$$

Let w_j denote the anticipated percentage of consumer population in Group 1 for giving the brand-image score at level 1 as the market share is at the value of $z_j = \sum_k w_{jk}$ about product j. Therefore, $\sum_j w_j$ denotes the target performance of brand-image creation. However, as is generally assumed, there exists a continuous and strictly increasing function, e.g., $U_j(z_j)$. Therefore, the objective functions have the following equivalent relationships:

$$\text{Maximize } \sum V_j(z_j) \cong \text{ Maximize } \sum w_j U_j(z_j) \tag{19}$$

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

Notably, that $U_j(z_j)$ can be predicated as the percentage of realizing the value of w_j given the value of z_j. Moreover, this study suggests using the following function to evaluate $U_j(z_j)$.

$$U_j(z_j) = z_j^{\beta_j}, \ \ \beta_j > 0, \ \ \forall j \tag{20}$$

The above function is characterized by its ability not only to easily evaluate parameter β_j by using log-transform and linear regression method, but also to accurately represent the strictly increasing linear, concave and convex functions. For the latter, it is strictly increasing linear if $\beta_j = 1$, strictly increasing concave if $0 < \beta_j < 1$, and strictly increasing convex if $\beta_j > 1$. Owing to the technique complexity, this work does not examine situations in which $U_j(z_j)$ is strictly increasing convex. However, if $U_j(z_j)$ is strictly increasing concave then the proposed model is a separable convex programming problem. Thus, several effective methods such as a piecewise-linear approximation can be adopted to derive the model.

In addition, letting $\tilde{w}_j = \frac{w_j}{\sum_m w_m}$, then one may employ the pair-wise comparison method like proposed one by AHP to evaluate $\tilde{w}_j$. Based on the above, the proposed objective function (15), and constraint (15.1)-(15.2) can be rewritten as follows:

$$\text{Maximize } \sum \tilde{w}_j z_j^{\beta_j} = \text{ Maximize } \sum \tilde{w}_j \cdot \left(\sum_k w_{jk} \right)^{\beta_j} \tilde{z}_j^{\beta_j} \tag{21}$$

Subject to

$$\tilde{z}_j = \sum_{l=1}^{L_{jk}} \sum_{k=1}^{K_j} \sum_{m=1}^{M_{jk}} \tilde{w}_{jk} u_{jkl} \cdot \tilde{y}_{jk}^l \cdot y_{jk}^m + \tilde{w}_{jk} u_{jk0} \cdot \tilde{y}_{jk}^0, \ \ \forall j \tag{21.1}$$

$$\tilde{z}_j \geq \frac{z_j^l}{\sum_k w_{jk}}, \ \ j = 1, 2, \ldots, J \tag{21.2}$$

Moreover, if we take Q_j breaking points from interval $(0,1]$, noted by $r_{j(q)}$, $q = 0,1,\cdots,Q_j$, then there exist some $a_{j(q)}$, $0 \le a_{j(q)} \le r_{j(q)} - r_{j(q-1)}$, so that

$$\tilde{z}_j = r_{j(0)} + \sum_{q=1}^{Q_j} a_{j(q)}, \text{ for } \tilde{z}_j \in [0,1] \tag{22}$$

$$\tilde{z}_j^{\beta_j} \approx r_{j(0)} + \sum_{q=1}^{Q_j} \rho_{j(q)} \cdot a_{j(q)}, \quad \forall j \tag{23}$$

where $r_{j(0)} = 0$, $r_{j(Q_j)} = 1$ and $\rho_{j(q)} = \frac{r_{j(q)}^{\beta_j} - r_{j(q-1)}^{\beta_j}}{r_{j(q)} - r_{j(q-1)}}$.

With above results, objective function (19) can be repressed as a linear form as follows:

$$\text{Maximize } \sum \tilde{w}_j \cdot \left(\sum_k w_{jk}\right)^{\beta_j} \left(\sum_{q=1}^{Q_j} \rho_{j(q)} \cdot a_{j(q)}\right) \tag{24}$$

Therefore, the constraints (21.1) and (21.2) also can be rewritten as follows:

$$\sum_{q=1}^{Q_j} a_{j(q)} = \sum_{l=1}^{L_{jk}} \sum_{k=1}^{K_j} \sum_{m=1}^{M_{jk}} \tilde{w}_{jk} u_{jkl} \cdot \tilde{y}_{jk}^{l} \cdot y_{jk}^{m} + \tilde{w}_{jk} u_{jk0} \cdot \tilde{y}_{jk}^{0}, \quad \forall j \tag{24.1}$$

$$\sum_{q=1}^{Q_j} a_{j(q)} \ge \frac{z_j^l}{\sum_k w_{jk}}, \quad j = 1,2,\ldots,J \tag{24.2}$$

$$0 \le a_{j(q)} \le r_{j(q)} - r_{j(q-1)} \tag{24.3}$$

6. **Model Testing.**

6.1. **An example (describing example and designing parameter).** In this section, we present an example of new car development and test the proposed model using this example. 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 owing 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 products. They are Sedans (NP 1), Hatchbacks (NP 2), SUVs (NP 3), Minivans (NP 4) and Coupes (NP 5). In order to test the proposed model, three and four projects are respectively included in each product (note that each project represents resigning/upgrading a specific subsystem of cars). The values of parameters are obtained with two methods (i.e., arbitrarily settings and simulating method). We first describe the parameters of arbitrarily settings. The values of $\tilde{w}_j$ and w_{jk} are depicted in Table 2.

Beside, the designing parameters of this model are given by $h_0 = 0.9$, $ACB = 106$, $B_0 = 11$, and the T_j^c form NP 1 to NP 5 are 12, 16, 20, 23 and 27. The percentage of realization of w_{jk} (i.e., u_{jkl}) is depicted in Table 3. Table 4 shows the periodical costs and the period required to invest in a project in order to achieve a specific assignment of a quality standard. The values of above parameters are arbitrarily settings.

Furthermore, we test our model which focuses on the main parameters to z_j^l, σ_j and β_j. For doing so, we conduct a uniform simulation to generate three values for each of these parameters. For details, z_j^l values are simulated between 0.1∼0.2, σ_j between 1∼2.5,

TABLE 2. Projects of the new product of car types

New product j	Sedans	Hatchbacks	SUVs	Minivans	Coupes
$\tilde{w}_j$	0.13	0.25	0.2	0.2	0.22
P_{jk} Projects (w_{jk})	*P11* Engine system (0.7)	*P21* Suspension system (0.5)	*P31* Engine system (0.55)	*P41* Engine system (0.6)	*P51* Suspension system (0.4)
	P12 Body & dimension (0.35)	*P22* Engine system (0.75)	*P32* Suspension system (0.5)	*P42* Transmission system (0.6)	*P52* Engine system (0.6)
	P13 Transmission system (0.35)	*P23* Safety system (0.4)	*P33* Body & dimension (0.35)	*P43* Body & dimension (0.5)	*P53* Body & dimension (0.5)
	P14 Suspension system (0.35)	*P24* Transmission system (0.4)	*P34* Safety system (0.35)	*P44* Suspension system (0.5)	*P54* Safety system (0.5)

TABLE 3. Percentage of realization of w_{jk}

l	New product 1				New product 2				New product 3				New product 4				New product 5			
	P11	P12	P13	P14	P21	P22	P23	P24	P31	P32	P33	P34	P41	P42	P43	P44	P51	P52	P53	P54
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.4	0.5	0.6	0.5	0.4	0.5	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.5	0.4	0.3	0.5	0.4	0.5	0.5
2	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.8	0.7	0.8	0.8	0.6	0.7	0.7
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

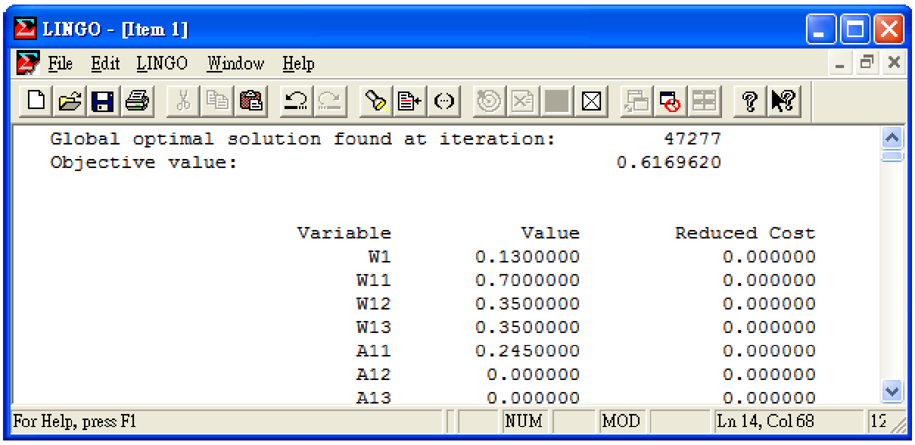

FIGURE 7. The results of testing item 1

and β_j between 0.7∼0.9 (by using MS-Excel). Table 5 shows the values of these three parameters.

Consequently, we test 54 ($3 \times 3 \times 3 \times 2$) items to demonstrate the feasibility of our model.

6.2. **Computational results.** In this section, we display the computing results for all our tests. The 54 portfolio items are resolved by using LINGO 8.0. The testing computer facility is the Pentium 4, CPU 2.8 GHz and RAM 1.74 GB. Table 6 shows the computational results.

As shown in Table 6, the values of global optimal and local optimal solutions are respectively 39 and 15 (i.e., the percentages are respectively 72.22% and 27.78%). Moreover, the average run time is 28.8 seconds. As a result, it has high reliability and feasibility for resolving the proposed model. Furthermore, we also show a numerical result for our model with Item 1. The computational result of Item 1 is a global optimal solution as shown in Figure 7.

TABLE 4. Periodical cost and the period required to invest in a project for achieving a specific assignment of quality-standard

Standards	New product 1											
	P11			P12			P13			P14		
	Budget amount											
Period	**3**	**4**	**5**	**4**	**5**	**6**	**5**	**6**	**7**	**4**	**5**	**6**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	0	0	0	1	0	0	0
3	0	1	1	0	1	1	0	1	1	0	1	1
4	1	1	2	1	1	1	1	1	1	1	1	1
5	1	1	2	1	2	2	1	1	1	1	2	2
6	1	2	2	1	2	2	1	1	2	1	2	2
7	2	2	2	2	2	2	1	2	2	2	2	2
8	2	2	3	2	2	3	2	2	3	2	2	3
9	2	3	3	3	3	3	2	3	3	3	3	3
10	3	3	3	3	3	3	3	3	3	3	3	3

Standards	New product 2											
	P21			P22			P23			P24		
	Budget amount											
Period	**3**	**4**	**5**	**3**	**4**	**6**	**5**	**6**	**7**	**5**	**6**	**7**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	1	0	0	1
3	0	0	1	0	0	1	1	1	1	1	1	1
4	1	1	1	1	1	2	1	1	1	1	1	1
5	1	1	1	1	1	2	1	2	2	1	2	2
6	1	2	2	1	2	2	2	2	2	2	2	2
7	2	2	2	2	2	2	2	2	2	2	2	2
8	2	2	2	2	2	3	2	2	3	2	2	3
9	2	3	3	2	3	3	2	3	3	2	3	3
10	3	3	3	3	3	3	3	3	3	3	3	3

Standards	New product 3											
	P31			P32			P33			P34		
	Budget amount											
Period	**4**	**5**	**6**	**3**	**5**	**6**	**3**	**4**	**6**	**3**	**5**	**6**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	1	0	0	1	0	0	1
3	0	1	1	0	1	1	0	1	2	0	1	1
4	1	1	1	0	1	2	1	1	2	0	1	2
5	1	1	2	1	1	2	1	2	2	1	1	2
6	1	2	2	1	2	2	2	2	3	1	2	2
7	2	2	3	1	2	2	2	2	3	1	2	2
8	2	3	3	2	2	3	2	3	3	2	2	3
9	3	3	3	2	3	3	3	3	3	2	3	3
10	3	3	3	3	3	3	3	3	3	3	3	3

Standards	New product 4											
	P41			P42			P43			P44		
	Budget amount											
Period	**3**	**4**	**5**	**2**	**3**	**5**	**5**	**6**	**7**	**3**	**4**	**5**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	1	1	1	1	0	0	1
3	1	1	1	0	1	1	1	2	2	1	1	1
4	1	1	2	1	1	2	2	2	2	1	1	2
5	1	2	2	1	1	2	2	2	2	1	2	2
6	2	2	2	2	2	2	2	2	3	2	2	2
7	2	2	3	2	2	3	2	3	3	2	2	3
8	3	3	3	2	3	3	3	3	3	3	3	3
9	3	3	3	3	3	3	3	3	3	3	3	3
10	3	3	3	3	3	3	3	3	3	3	3	3

Standards	New product 5											
	P51			P52			P53			P54		
	Budget amount											
Period	**2**	**4**	**5**	**4**	**6**	**7**	**3**	**4**	**5**	**3**	**4**	**5**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	1	0	0	1	0	0	1
3	0	1	1	0	1	2	1	1	1	1	1	1
4	1	1	2	1	1	2	1	1	2	1	1	2
5	1	2	2	1	2	2	1	2	2	1	2	2
6	2	2	3	2	2	2	2	2	2	2	2	2
7	2	3	3	2	2	3	2	2	2	2	2	2
8	2	3	3	2	3	3	2	3	3	2	3	3
9	3	3	3	3	3	3	3	3	3	3	3	3
10	3	3	3	3	3	3	3	3	3	3	3	3

Table 5. The random values of parameters z_j^l, σ_j and β_j

	New product 1			New product 2			New product 3			New product 4			New product 5		
Parameters	item1	item2	item3	item1	item2	item3	item1	item2	item3	item1	item2	item3	item1	item2	item3
z_j^l	**0.17**	0.18	0.15	**0.10**	0.19	0.18	**0.18**	0.14	0.16	**0.10**	0.18	0.20	**0.19**	0.13	0.12
σ_j	**2.02**	1.87	2.12	**1.21**	1.29	1.60	**1.01**	1.33	2.07	**2.21**	1.81	2.24	**2.01**	2.31	1.17
β_j	**0.90**	0.75	0.85	**0.91**	0.77	0.85	**0.89**	0.76	0.79	**0.81**	0.81	0.80	**0.79**	0.71	0.85

Table 6. Testing results of these 54 items

	Optimal Solutions	Run Time		Optimal Solutions	Run Time		Optimal Solutions	Run Time
Item 1	**Global**	**6″**	Item 19	Global	11″	Item 37	Local	42″
Item 2	Global	17″	Item 20	Local	9″	Item 38	Global	45″
Item 3	Local	8″	Item 21	Local	3″	Item 39	Global	26″
Item 4	Local	8″	Item 22	Global	15″	Item 40	Local	28″
Item 5	Global	26″	Item 23	Local	9″	Item 41	Global	59″
Item 6	Local	8″	Item 24	Global	28″	Item 42	Global	58″
Item 7	Global	22″	Item 25	Global	35″	Item 43	Global	36″
Item 8	Global	23″	Item 26	Global	17″	Item 44	Global	22″
Item 9	Local	40″	Item 27	Local	3″	Item 45	Global	36″
Item 10	Global	26″	Item 28	Global	41″	Item 46	Global	35″
Item 11	Global	1′06″	Item 29	Global	51″	Item 47	Global	30″
Item 12	Global	48″	Item 30	Local	19″	Item 48	Local	52″
Item 13	Global	46″	Item 31	Global	54″	Item 49	Global	20″
Item 14	Local	8″	Item 32	Global	46″	Item 50	Global	58″
Item 15	Local	8″	Item 33	Global	43″	Item 51	Global	40″
Item 16	Global	34″	Item 34	Global	25″	Item 52	Global	20″
Item 17	Global	10″	Item 35	Global	41″	Item 53	Global	3″
Item 18	Global	27″	Item 36	Global	28″	Item 54	Local	23″

Table 7. The values of decision variables to item 1

	New product 1	New product 2	New product 3	New product 4	New product 5
Project selected (level)	P11(1)	P22(2)	P31(1)	P41(1), P42(1) P43(1)	P52(1), P52(2) P53(1)
b_j	5	4	6	6.75	10.6
t_j	2	6	2	4	3
S_{jk} (project)	0(P11)	2(P22)	8(P31)	11(P41) 10(P42) 12(P43)	14(P51) 14(P52) 15(P53)
f_{jk} (project)	2(P11)	8(P22)	10(P31)	14(P41) 14(P42) 14(P43)	17(P51) 17(P52) 17(P53)
S_j	0	2	8	10	14
f_j	2	8	10	14	17

The values of decision variables I_{jkl}, t_j, b_j, S_{jk}, f_{jk}, S_j, f_j of Item 1 are shown in Table 7.

The results of Table 7 can also be depicted as Figure 8. To illustrate, the execution order of each new product (NP) is NP 1→NP 2→NP 3→NP 4→NP 5. However, the

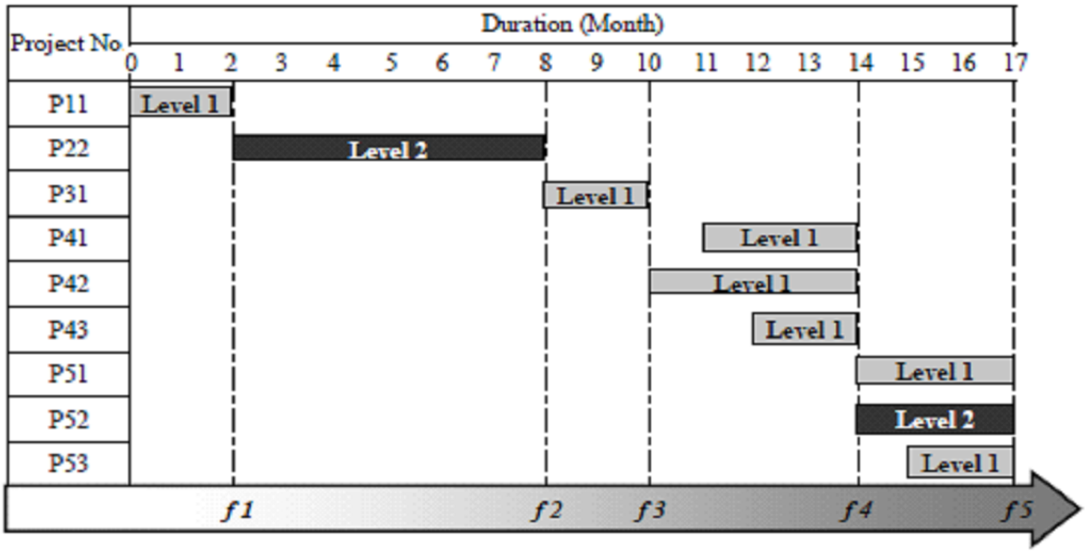

FIGURE 8. Project schedule of item 1

time period of time invested in Sedans, Hatchbacks, SUVs, Minivans and Coupes are respectively 2, 6, 2, 4 and 3 units, respectively. In addition, the chosen projects in new product 5 (i.e., Coupes) are all selected, and the quality-standard assigned for these three projects are respectively at level 1, level 2 and level 1. Finally, the total cost required to achieve the assigned quality standards of these three projects is 32 units, which are obtained by calculating the value of $b_5 \cdot t_5$.

7. **Discussion and Conclusion.** The project selection problem relating to an NPD program is expressed as a multi-category and multi-standard R&D project selection problem under a budget- and time-constrained context in this work. Almost conventional project selection model cannot respond some NPD actual scenarios, in which the quality standards assigned for each project are at multiple levels; 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 the above mentioned tangible factors, previous studies regarding an R&D project selection problem have also failed to consider intangible factors that influence the project performance such as the managerial and control capabilities of decision makers. Obviously, such a study cannot respond entirely to all practical elements. While taking the above factors into account, this work has developed a four component approach to select and schedule projects for an NPD program. We release four issues that involve the theoretical and practical contributions of the proposed approach to discuss as follows:

First, most consumer evaluation studies of a brand image suggested that perceived quality of a consumer should profoundly impact the consumer evaluation of a brand image. However, individual consumption of a consumer and the preferences of the majority of consumers largely influence perceived quality. Therefore, this work assumes that consumer perception as to whether the majority of consumers prefer the offerings of a new product can significantly influence the brand image of a consumer. From this view, consumers may determine the brand-image score based on their perception with respect to the perception of market share of one or more products. Moreover, this work considers two consumer types (i.e., Group 1 and Group 2), and the results of the proposed model significantly contribute to new product development literature.

Second, past studies on project selection model normally consider only total budget constraints during the duration of all projects. In contrast with above, this model considers the selection of quality-standard and resource-allocation proposal of a project under constrained project duration and constrainedly periodical budget. Subject to technique complexity, this work considers only the schedule solution in which a project starts at the latest time under the invariant schedule duration. Therefore, the schedule solution derived by the proposed model may fail to provide buffer time for each project. However, our results provide a valuable reference for future research efforts that consider the above factors.

Third, most project selection studies fail to concurrently consider the scheduling problem. In contrast, in this project selection model, we not only proposed the scheduling problem but involved the factors such as the quality standard assigned for each project, in which multiple grades are available and the resource-allocation and time limited considerations to achieve a specific quality-standard of a project are multiple proposals available.

Finally, we transform the objective function into an appropriate form in which the parameters can be estimated more easily and the objective value can be predicated as a clear managerial implication. Therefore, the proposed four component approach is obviously useful in terms of project selection practices, especially for new product development.

In conclusion, the proposed model can find the portfolio of quality standards for new products and their associated optimal schedule, which maximizes the expected brand-image score of consumers, which benefits the long-run average profitability. Therefore, the refinement of this study may increase long-run average profitability. Since this work does not consider a case in which type I mixed advancement strategy serves as a project scheduling framework and buffer time for projects, future research should more closely examine this issue.

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