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Hierarchical Project Difficulty in New Product Development

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Abstract. One core effort of a firm is the successful development of new products to expand its competitive advantage. In general, multiple new product development (NPD) projects are performed in parallel. Therefore, a firm should manage those projects effectively and efficiently through robust strategies and plans. Each project can be classified by various characteristics such as cost, time, materials, processes, vendors, technical risks and teams. The decision maker should consider these characteristics to decide the priority of a project for allocating various resources. One of the criteria to evaluate an NPD project and allocate the resource is the project difficulty. If the difficulty is high, it affects negatively the success probability and requires more effective management. This paper suggests a new framework determine the project difficulty for helping right project management decision and comparing two or more project. Many variables such as design requirements, product complexity, product technology, resource tightness and schedule tightness affect the difficulty. Also, those variables can be classified into major groups, influencing dimensions and actual variables and those are related hierarchical structure. Each actual variable is four criteria for evaluation difficulty. Evaluated value influences a dimension and a major group sequentially from bottom to top. In this paper, the impact degrees and weights of actual variable, dimensions and major group are defined, and the integrated difficulty for the entire project is determined by the weighted sums of major groups, dimensions and actual variables. This framework can be utilized for making a decision on the project life as GO/KILL in each NPD stage.

Keywords: New Product Development(NPD), Hierarchical Approach, Integrated Project Difficulty, Framework

1. Introduction

New product development (NPD) efforts are critical for many companies to survive in competitive markets under various internal and external environmental changes or risks such as new technologies, customer requirements, economic shifts, market and vendors. However, success probability of those efforts is low due to the difficulty of the product development process and unexpected risks and their impact. The success probability of NPD projects in world-wide has been measured as 59% for periods of 1990-2004 and both sales volume and profit have been decreased to 28% in 2004 while they were 32% and 30% respectively in 1995 [1]. Also, two third of the NPD projects have been failed before target date, more than 50% of the NPD efforts have made no returns on the investment of money and time, and more than 40% respondents to a survey answered that the NPD projects required more costs and times than the original plan [2]. To increase the probability, a firm usually launches and manages multiple numbers of NPD projects in parallel. Each project can be classified by difficulties on the basis of technology risks, customer requirements, development procedures, resources, etc. Higher difficulty of a project exists, lower success probability presents. If the difficulty of a project can be determined by a quantitative model, it contributes to make better decision in NPD stages for the project future. The difficulty would be changed in real time. Therefore, resources such as budget, time and people must be allocated effectively and efficiently at each development stage. Few studies focus on determination of the difficulty for a given NPD project. This study develops a quantitative framework to analyze fifty-six actual variables, thirteen influencing dimensions and four major

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groups hierarchically, to define the impact degrees and weights for each variable, dimension and major group and to determine the integrated difficulty of a given project. The difficulty of each variable is determined by the impact degree multiplied by the weight. Therefore, the integrated difficulty of a given project becomes a weighted sum of all major groups, dimensions and actual variables. It should be noted that both the impact degree and weight would be changed at each product development stage. Therefore, the integrated difficulty of a project would be different at each stage, and so the manager can make a decision of GO/KILL for a project at any time.

2. Review of Relevant Studies

Many previous studies does not focus on model development to quantify the project difficulty, but focus on figuring out the influencing dimensions and variables related to product, organization, teams and environment surrounding the NPD projects.

The complexity or innovativeness affects the project performance with lower development speed because it makes higher task difficulty, forecasting difficulty, and communication and teamwork difficulty [3]. Also, the complexity distributes core resources in various functions or processes, and requires more times such as project duration compared to the original development plan [4]. As the complexity increases, especially in developing brand new products, it is difficult to obtain high synergism in the development stages (phases) due to differences between product or process requirements and the available technologies and resources within a firm [5].

The success factors should be defined to determine if the project is successful in terms of project completion date, the amount of budget invested, project performance, etc. [6]. Various success factors along with risks are presented after investigating many NPD projects [7][8][9]. Also, such technical risks as new process, technology, material and vendor are considered to determine how they affect NPD projects and effective responses against the risks are suggested [10].

In this study, the variables affecting the project difficulty are searched first, classified them into a hierarchical structure, evaluate each variable layer by layer, and determine the overall difficulty of a given project. This framework can be utilized for making decisions about allocating budget and time to a given project and GO/KILL at each development stage.

3. New Product Development Project Difficulty

3.1. Definition

The project difficulty is a measure of success when various influencing dimensions and variables affect the complexity of a project and effectiveness of project management in this study. In other words, the difficulty can be defined by two aspects: one is how complex or innovative a new product is to be developed and the other is how difficult the project is to be managed effectively. Each aspect has its own dimensions and variables. Examples of the dimensions related complexity are product complexity and product technology. Program structure, business relationship and team scope are the examples for managing the project effectively.

A variable in the dimension can be measured by four different levels of impact degree, A, B, C and D. The impact degree of a variable is the amount of negative effects to a project, especially an influencing dimension. Each dimension consists of number of actual variables. Therefore, the impact degrees of those variables should be combined together. Also, the weight should be given to a variable because the importance or criticality would be different depending on product development stage under a certain environment surrounding an NPD project. The same concept is applied for influencing dimensions and major groups. Therefore, the integrated project difficulty is a weighted sum of all major groups, dimensions and actual variables.

3.2. Hierarchy of Project Difficulty

The variables affecting the project difficulty have been searched and classified as a hierarchical structure having three layers for major groups, influencing dimensions and actual variables. There are four major

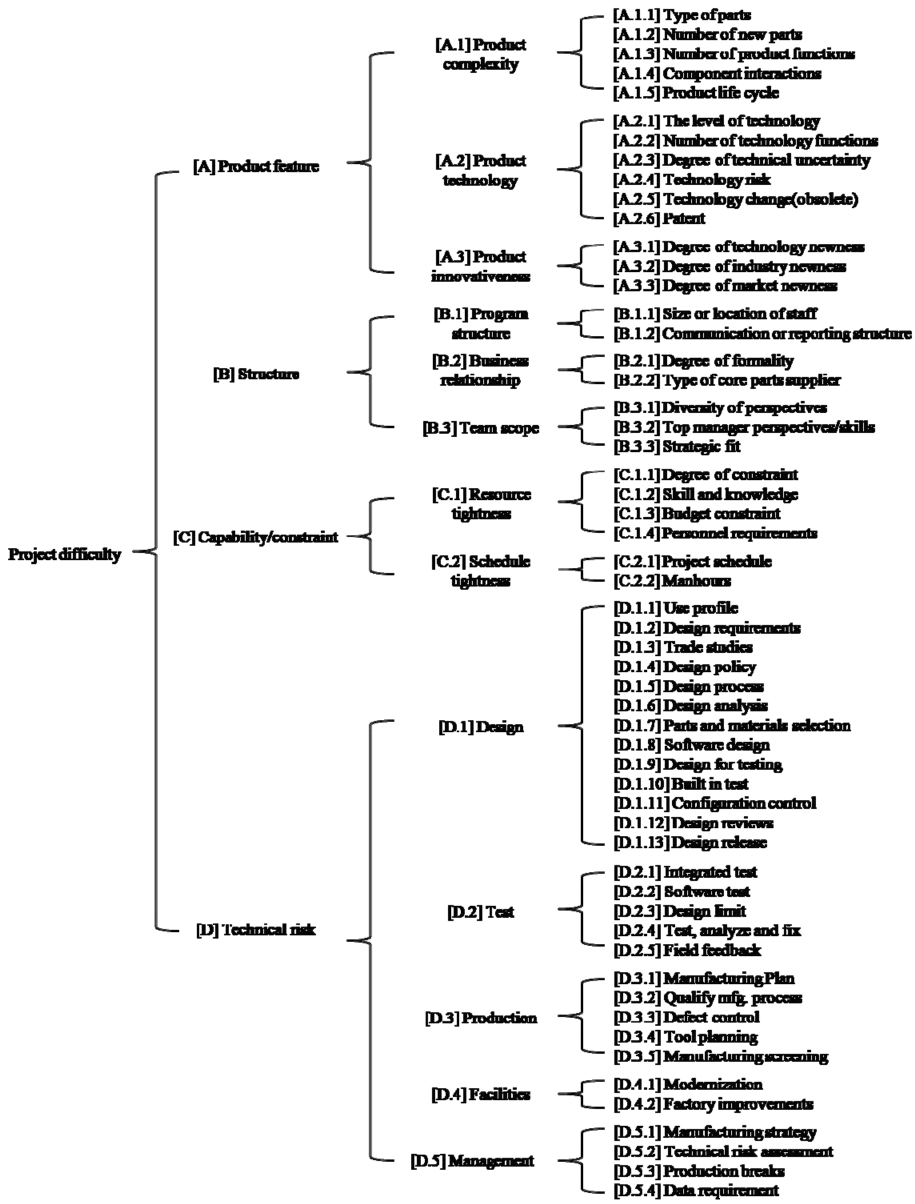

Fig. 1: Hierarchy of variables, influencing dimension, and major groups

group, thirteen dimensions and fifty-six variables. The influencing dimension is defined as a group of the actual variables that influences the project difficulty and effective management. A major group consists of number of influencing dimensions, and each dimension is composed of number of actual variables. Fig. 1 presents the hierarchical structure with fifty-six variables.

1) Measurement of impact degree for a variable: Each variable's impact degree is calssified into four diffferent levels and defined as a numeric value, A for 1, B for 2, C for 3 and D for 4. Higher value means higher impact to a dimension.

- Level A: A variable affects the dimension with minor degree in terms of product complexity and project management. It means that the variable can be easily controlled by visible guidelines and managed under a given NPD environment such as budget and time. No specific resources constraints are required.
- Level B: A variable affects the dimension with low degree in terms of product complexity and project management. It means that the variable can be controlled and managed by the general guidelines established for other projects except NPD projects of a firm. A certain level of resource constraints is to be set.

- Level C: A variable affects the dimension with moderate degree. It means that the variable should be controlled and managed by new guidelines for successful NPD. The performance of the project is dependent upon some critical resource constraints.
- Level D: A variable affects the dimension with high degree. It means that the variable needs tight control and management due to the possibility of its uncertain variation. The specific guidelines for this variable should be visible and every constraint should be considered for better decision making.

Table 1 presents an example of each degree.

2) Hierarchical difficulty computation

When the impact degree of a variable is specified by a grade A, B, C or D or 1, 2, 3 or 4 as shown in Table 1, it is multiplied by a weight given to the variable because the importance or criticality of the same variable would be changed at a different development stage. An influencing dimension's impact degree can be determined by combining the weighted sums of all related actual variables. Like the actual variables, the importance or criticality of a dimension would be changed at a different stage. Therefore, another weight value should be given to each dimension and multiplied by the impact degree. Also, the major group's impact degree is obtained from those weighted sums of all related dimensions. In this paper, all those weights are given by the experts or managers. When all kinds of impact degrees and weights are summed together, the integrated overall difficulty is generated for a given project

As descried before, the integrated difficulty of a given project is sequentially determined by the major groups, influencing dimensions and actual variables with their impact degrees and weights. Especially, four major groups involving dimensions and actual variables are important for characterizing the project. They are product feature, structure, capability/constraint and technical risks.

- Product feature: This group contains three influencing dimensions such as product complexity, product technology and product innovativeness. These dimensions explain the type of a new product(low-cost leadership product or product differentiation) to be developed. If the product feature is complex, in other words, possessing high difficulty in terms of technology, process, market and industry, a firm should develop competitive strategy and plan for allocating core competency resources such as budget, time, personnel, and patent to the project.
- Structure: This group contains three dimensions such as program structure, business relationship and team scope. These dimensions explain the organization or team performing the project. If the

Table. 1: Example of impact degree level

Level 1: Major Group	[A] Product feature					[B] Structure	
Level 2: Dimension	[A.1] Product complexity		[A.2] Product technology			[B.1] Program structure	
Level 3: Actual variable	[A.1.1] Type of parts	[A.1.2] Number of new parts	[A.2.1] The level of technology	[A.2.2] Number of technology functions	[A.2.3] Degree of technical uncertainty	[B.1.1] Size or location of staff	[B.1.2] Communication or reporting structure
A	Catalog items	No core new parts	Available technology	One technology function	No new technology is incorporated	Small staff	Informal communications
B	Mostly common parts, little state of the art	Low number of new parts	New application/custom built	Low number of technology function	Some new technology is used	Moderate size staff	Layered structure
C	State-of-the-art items Sensitive interfaces	Medium number of new parts	New capabilities from core technologies	Medium number of technology function	Integrating new but existing technology	Small or moderate size staff and Multiple locations	Formal communications
D	Pushing the state-of-the-art envelope	High number of new parts	New core technology	High number of technology function	Key technologies do not exist at the start of the project	Large staff, multiple location	Deep reporting structure
Ref.	[12]	[3]	[11][12]	[13]	[11][14]	[12]	[12]

structure is complex in terms of a size of staff, reporting depth, formality, supplier relationship, diversity of perspective, top manager skill required and strategy fits, a firm should develop tight control plan for smooth communication and flexible or permeable decision making procedures.

- Capability/constraint: This group is composed of two dimensions such as resource tightness and schedule tightness. These dimensions present how much budget, time, knowledge and skill are available for a project. If the capability/constraint is highly limited to utilize, a firm requires the visible guidelines to specify how to use its capability, monitors the entire development procedure in real time, and develops the optimal methods to release the critical constraints.
- Technical risk: This group consists of five dimensions such as design, test, production, facilities, and management. These dimensions present how to reduce technical risks and to improve producibility, testability and quality in both design and manufacturing stages. If the technical risk is high in terms of new technology, process, vendor, market and management, a firm should establish a control plan to trace the history of a project from early design stage to production ramp-up stage. As the design maturity is increased, the traceability should be checked and improved.

4. A Framework for Determining Project Difficulty

The following notations are utilized to determine the integrated difficulty for an NPD project:

m_i : the number of influencing dimensions for major group i (i = 1, 2, 3,4)

n_{ij} : the number of actual variables for major group i and dimension j (j= 1, 2, 3 for i=1, j= 1, 2, 3 for i=2, j=1, 2 for i=3, and j=1, 2, 3, 4, 5 for i=4)

d_{ijk} : the impact degree specified for actual variable k for dimension j and major group i (d_{ijk} = 1, 2, 3 or 4)

DL_{ij} : the impact degree for dimension j in major group i ($1 \le DL_{ij} \le 4$)

DL_i : the combined impact degree for major group i ($1 \le DL_i \le 4$)

w_{ijk} : the weight for actual variable k in dimension j of major group i ($0 \le w_{ijk} \le 1$, $\sum_{\text{all k}} w_{ijk} = 1$)

w_{ij} : the weight for dimension j in major group i ($0 \le w_{ij} \le 1$, $\sum_{\text{all j}} w_{ij} = 1$)

w_i : the weight for major group i ($0 \le w_i \le 1$, $\sum_{\text{all i}} w_i = 1$)

ID : the integrated difficulty of an NPD project ($1 \le ID \le 10$)

There are four steps to determine the integrated difficulty.

- Step 1. Assessment of the impact degree (d_{ijk})
- Step 2. Determination of the weights (w_{ijk}, wij and w_i)
- Step 3. Combine the impact degree into the weight:

$$DL_{ij} = \sum_{k=1}^{n_{ij}} (w_{ijk} \times d_{ijk}) \quad (1)$$

$$DL_i = \sum_{j=1}^{m_i} (w_{ij} \times DL_{ij}) \quad (2)$$

Step 4. Determine the integrated project difficulty: In this step, the final difficulty of a project is determined by Eq. (3). It is noted that the difficulty values are scaled by 10 for better visibility even though the impact degree of each actual variable is evaluated by 1 through 4.

$$ID = \frac{10}{4} \times \sum_{i=1}^{5} (DL_i \times w_i) \quad (3)$$

5. An Illustrated Example

The above procedures to obtain the integrated difficulty of a project are applied for an example. All input values such as the impact degree of the actual variable and those weights of the actual variable, influencing dimension and major group are assumed as shown in Tables 2 and 3. Suppose that all the input values are provided at a certain product development stage. Also, suppose that n_1 = 2, n_2 = 1, n_{11} = 2, n_{12} = 3, n_{21} = 2 shown in Table 2.

Step 1: Assessment of the impact degree such as $d_{111} = 1$, $d_{112} = 2$, $d_{121} = 1$, $d_{122} = 1$, $d_{123} = 4$, $d_{211} = 3$, and $d_{212} = 2$.

Table. 2: Evaluation of impact degree of actual variable

Actual Variables	Impact Degree			
	A	*B*	*C*	*D*
[A.1.1] Type of parts	○			
[A.1.2] Number of new parts		○		
[A.2.1] The level of technology	○			
[A.2.2] Number of technology functions	○			
[A.2.3] Degree of technical uncertainty				○
[B.1.1] Size of location of staff			○	
[B.1.2] Communication or reporting structure		○		

Step 2: Determination of the weights as shown in Table 3.

Table. 3: The weights of each layer

Major Group	w_i	Dimension	w_{ij}	Actual Variable	w_{ijk}	w
[A]	0.5	[A.1]	0.2	[A.1.1]	0.1	0.01
				[A.1.2]	0.9	0.09
		[A.2]	0.8	[A.2.1]	0.5	0.20
				[A.2.2]	0.3	0.12
				[A.2.3]	0.2	0.08
[B]	0.5	[B.1]	1	[B.1.1]	0.7	0.35
				[B.1.2]	0.3	0.15

Step 3: Combine the impact degree into the weight as shown in Eqs. 4-8.

$$DL_{11} = \sum_{k=1}^{2} (w_{11k} \times d_{11k}) = 0.1 \times 1 + 0.9 \times 2 = 1.9 \quad (4)$$

$$DL_{12} = \sum_{k=1}^{3} (w_{12k} \times d_{12k}) = 0.5 \times 1 + 0.3 \times 1 + 0.2 \times 4 = 1.6 \quad (5)$$

$$DL_{21} = \sum_{k=1}^{2} (w_{21k} \times d_{21k}) = 0.7 \times 3 + 0.3 \times 2 = 2.7 \quad (6)$$

$$DL_{1} = \sum_{j=1}^{2} (w_{ij} \times DL_{ij}) = 0.2 \times 1.9 + 0.8 \times 1.6 = 1.66 \quad (7)$$

$$DL_{2} = \sum_{j=1}^{1} (w_{ij} \times DL_{ij}) = 1 \times 2.7 = 2.7 \quad (8)$$

Step 4: Determine the integrated project difficulty: The final difficulty at a given product development is shown in Eq. (9).

$$ID = \frac{10}{4} \times (1.66 \times 0.5 + 2.7 \times 0.5) = 5.45 \quad (9)$$

As described the previous section, the obtained integrated difficulty means nothing. However, this paper suggests that this value should be compared to other difficulty values of other projects for project managers to make a decision with respect to the following views:

1. The value is accurately obtained through the exact variables, dimensions and major groups.
2. The integrated value obtained is acceptable on the basis of past successful projects.

3. The given project should be continued or killed in the current product development stage.
4. The integrated difficulty would be expected to have lower value in next development stage.
5. Availability of any effective and efficient responses to reduce the value from management strategy and plans.

6. Conclusion

This study suggests a simple framework to determine the project difficulty easily. The variables that affect the success probability of a project have been collected from many previous studies and classified as a hierarchical structure.

The framework suggested by this paper has some pros and cons as follows:

Advantages:

- inclusive collection of variables, dimensions and major groups.
- simple quantification for difficulty.
- new difficulty determination at any development stages.

Disadvantages:

- subjectivity depending on experts or managers.
- difficult to collect historical data related to variables, dimensions and major groups.
- time consuming determination for impact degree and weight for variable, dimension and major group.

The integrated difficulty would be an index to decide whether an NPD project is continued or killed at any development stage. Also, the index would provide decision criteria to allocate resources effectively and efficiently to low difficulty projects and to decide the control level in project management. However, further studies are necessary for realizing the reality of the developed procedure. In general, most of NPD projects fail due to lack of control, lack of specific guidelines for design, manufacturing, and management, uncertainties or risks existing in environment, etc. Still, just few quantitative approaches are available in these days. Therefore, many tools such as H/W and S/W, methodologies, models, and algorithms should be developed for building better strategy and plan.

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