國立交通大學

工業工程與管理學系

碩士論文

動態專案投資組合管理之架構

A Framework for Dynamic Project Portfolio Management

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指導教授：許錫美 博士

中華民國九十六年六月

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中文摘要

新產品研發專案投資組合決定資金及人力資源的分配，攸關企業新產品研發的方向及其競爭力。本研究建構一個即時回應機制的動態投資組合管理架構，彌補一般企業目前所使用之定期投資組合會議的不足之處，以因應競爭激烈且環境變動快速的時代。

企業目前大多以定期會議方式檢顧新產品研發專案投資組合，此會議必須由企業之高階領導階層主導，藉由大量的評估分析以決定整體投資組合。定期會議需大量的資訊及高階主管許多時間的投入，因此需花費相當高的會議成本。由於定期會議成本高且決策層面在於整體定位而非調整，並不適合作為因應環境變化而即時調整投資組合之決策工具。

因此，本論文定義動態投資組合管理為動態性配合研發內、外在環境的變動，即時檢討新產品研發專案投資組合，將資金及人力資源用在適當的專案上。此一動態管理架構以偵測到的變動資訊發動評估及調整活動，而非僅在固定時間重新檢視投資組合，因此可有較有效因應內、外在環境的變動，將有限資源做最適當的應用。本研究亦提出一決策樹方法以評估專案及投資組合之績效，以支持上述動態投資組合之決策。此方法考慮研發專案高度不確定之特性及專案間複雜的互動關係對績效所造成之影響。本研究將此兩部分結合，期許能幫助企業在投資組合之管理上能更有效、更積極，以達到成功研發並延續企業競爭力的目的。

關鍵字：新產品研發專案、專案投資組合管理、環境變動因素、動態專案投資組合、不確定性、綜效

A Framework for Dynamic Project Portfolio Management

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Abstract

NPD Project portfolio management is important for a firm's resource allocation. Its' role is to lead the firm in spending capital and human resource on the right projects. In today's rapidly changing environments, effective NPD project portfolio should be able to adapt to critical changes. Therefore, in this study we propose a dynamic NPD project portfolio framework that somehow complements the periodical portfolio review meeting in practice. In the periodical portfolio meeting that takes place two to hour times annually, top management is gathered for review, evaluate, and redirect the project portfolio on a strategic viewpoint. Periodical review meetings are not suitable as a tool for real-time adaptation of portfolio due to its original goal and high costs, which rise from the need of huge amount of information and time devoted by top management. Thus, the proposed dynamic portfolio is expected to complement the periodical meeting in facing the changing environments, with lower cost and real-time change detection. This is done through the identified critical change factors that can, if occurs, initiate the evaluation and adjustment actions, and a systematic evaluation procedure that helps to evaluate and identify where adjustments are needed, with a minimum amount of information and management devotion. A subsidiary part of this study is a project evaluation approach that supports the main objective. It takes into concern especially the uncertainty nature of R&D activates, the complex interactions among projects, and the possibility to make control decisions during project development. The two parts together may contribute in an active real-time portfolio management style that leads the firm to do the right projects at the right time.

Keywords: new product development projects, portfolio management, environmental change, dynamic portfolio, uncertainty, synergy.

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Finally, the biggest thanks are given to my beloved family and boyfriend. Without Your loving considerations and great confidence in me all through these years, I would never be able to make it. I love you so much! May the blessings from God be with you always.

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1. Introduction

1.1. Preface

With the rapid change and development in both technology and marketplace, new product development (NPD) becomes essential for firms to maintain competitiveness and even subsistence. In technology intensive firms, NPD activities are often carried out in the form of projects. Great amount of project ideas are proposed in every period, yet only a fraction of them could actually be implemented. This is due to the limitation on capital and human resources that are greatly demanded by NPD projects. The decision process on selecting the “right projects” to effectively allocate resources is called *portfolio management*. An NPD project portfolio is a collection of NPD related projects implemented in a company. Effective portfolio management is vital to successful product innovation (Cooper, Edgett, and Kleinschmidt, 1999) since the selection of NPD projects decides the direction and future capability of a firm.

Firms today are paying increasingly attention to portfolio management. According to the in-depth survey by Cooper, Edgett, and Kleinschmidt (2000a), firms with leading portfolio practices seek to do the right projects while doing the projects right by combining real-time project control gates and periodic portfolio reviews. While project control monitors the progress of individual projects, the periodic portfolio review board overlooks the composition and direction of the portfolio as a whole. The importance of this portfolio review board is that it ensures the right balance, right mix, right strategic alignment, and right priorities among projects, thus directs the firm’s heading. Though having significant importance, portfolio review boards only take place several times a year since it takes many top managers to devote great amount of time. Typically, the portfolio review is held two to four times each year. A portfolio which is renewed periodically is, in this paper, referred to as a *static portfolio*.

In today's rapidly changing environments, drawbacks of static portfolio emerged. With it's periodical review board, a static portfolio is unable to meet the rapidly changing environments caused by the pursue of innovation and improvement. The reason that portfolio reviews are only held several times a year is mainly its high cost rise from the huge amount of information and management devotion required. Due to this high cost, it is impossible for firms to constantly perform the portfolio review to adapt the portfolio to the frequent environmental changes.

Still, the portfolio needs to be efficiently adjusted and re-directed, on a real-time basis, as a response to the dramatic changes in both internal and external business environments in order to reduce detour and maintain competitiveness. In this paper, we propose a *dynamic portfolio framework*, in which, rather than having to wait for periodical adjustments, the portfolio can be adjusted and renewed, with a much lower cost, whenever a new critical piece of change information enters.

While traditional portfolio management (referred in this paper as static portfolio) tries to review the set of R&D projects and re-allocated resource periodically, the idea of dynamic portfolio seeks to do it on an event/information oriented basis. We believe that a set of previously identified change factors will help to quickly detect changes in the environments. These change information then initiates/triggers the actions of evaluation, identification of deviations, and adjustments. Thus, we expect the response actions to be fast and effective. Also, for performance evaluation, we aim to provide a systematic approach that requires less information and can assist decision-making, thus reducing the cost for performing the whole monitoring and adjusting process.

1.2. Problem statement

The main problem dealt in this paper is on the portfolio level, which is the need for R&D project portfolio to be adjusted real-time in order to quickly respond to the frequently rising environmental changes. Portfolio review meetings, the most popular way of making portfolio decision nowadays, is too time-consuming and costly to be performed on a real-time basis. Thus, we hope to find a way to make up for this need.

Another problem is on the project level rising from the attempt to evaluate portfolio. Evaluating portfolio causes the evaluation of all individual projects, bringing the problem down to the project level. Due to the uncertain nature of development project, the performance and outcomes of projects are hard to predict. Moreover, projects in a firm are dependent to each other in certain ways, making it difficult to evaluate its cost and value. We have to address this problem as well in order to provide a better solution our main problem.

1.3. Purpose and value

To complement the drawbacks of periodic portfolio review meetings, we proposed a dynamic portfolio framework for portfolio adjustments in the presence of change. Instead of being performed periodically, adjustments in the dynamic portfolio are initiated at the point when critical changes occur. This provides the advantage of real-time response. In addition, with a systematic evaluation approach that quickly identifies needs for adjustment, through comparison of portfolio goals and performances, the framework requires less information and management devotion. A decision tree approach is also proposed for project and portfolio evaluation under uncertainty and complex interactions. The aim of this study is to provide a framework for dynamic NPD portfolio adjustments in the rapidly changing business environment, thus leads the firm to do the right projects at the right time.

1.4. Disposition of the thesis

Figure 1-1 illustrates the thesis outline in a broad context from Chapter 1 to 5.

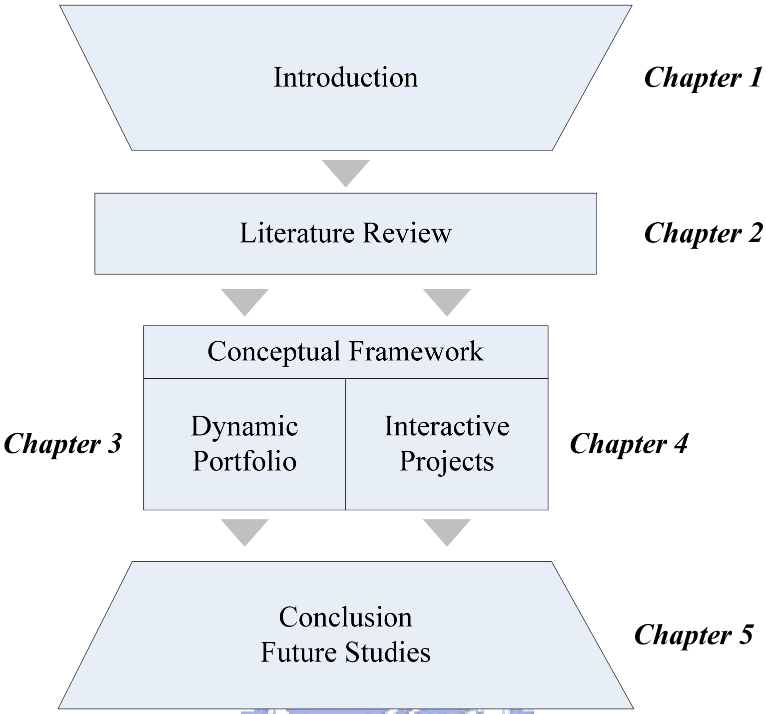

Figure 1-1 Disposition of the thesis

Following the introduction section, a review of former relative studies is done and listed in Chapter two. This chapter will serve as a background introduction to the field of portfolio management and project management.

Chapter 3 and 4 together is the conceptual framework. The two parts, as shown in Figure 1-2, are focusing on different theme but complements each other. The first part describes the idea and procedure of dynamic portfolio control, including the identification of environmental influences, evaluation of portfolio, and possible adjustment actions. The second part digs into the details of project evaluation, which is the basis of portfolio evaluation. With the considerations of development uncertainty and project interaction (synergy), the second part proposes a refined backwards decision tree approach for project value evaluation.

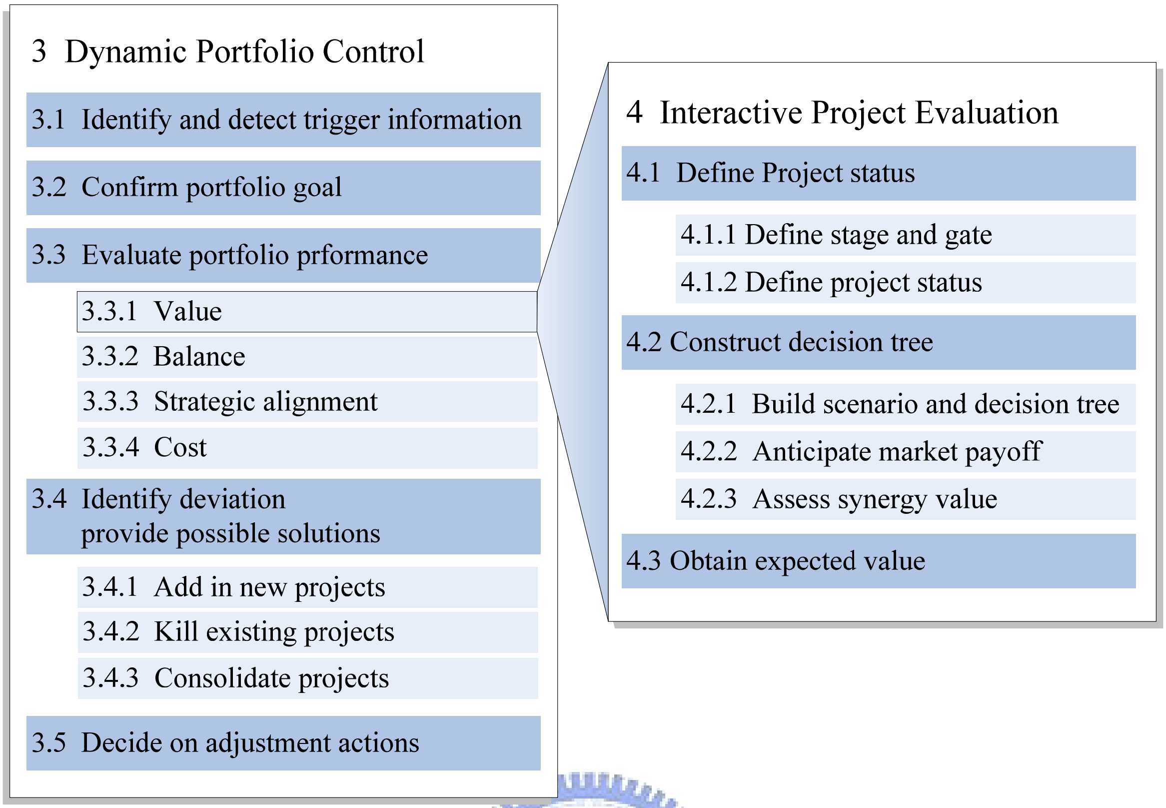

Figure 1-2 Overview of the two-part conceptual framework

Finally, some discussion and conclusion on the purposed concept will be presented in Chapter 5. We will also list some of the possible directions for further investigation and improvement of the research.

2. Literature review

Research and development (R&D) activities, as defined by U.S. National Science Foundation, comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

R&D has been generally perceived as one of the most effective ways for firms to maintain competitiveness and survive in the nowadays fierce competition. R&D activities are mostly carried out in the form of project. With limited resource and too many projects on hand, there is an emerging need for a logical and practical selection. A review of prior related studies can be categorized into the following parts:

- Portfolio management: the importance of portfolio management and available tools/methods
- NPD Project management: how NPD projects are evaluated, selected, and controlled
- Sources of change: what might affect the goals and performance project portfolio

2.1. Portfolio Management

2.1.1. Importance of portfolio management

Due to the limited resource available, not all project proposals could be carried out. Thus, it is important to not only do the projects right, but on the other hand, do the right projects. The right projects are those providing high expected return and market potential, as well as aligning with business strategy and together forming a well balanced portfolio (Cooper, Edgett, and Kleinschmidt, 1997). In the management field, the decision process on selecting the "right projects" to effectively allocate resources is called *Portfolio Management*, which is a term originated from the field of finance and investment.

According to Cooper's definition[1], portfolio management for new products is a dynamic decision process wherein the list of active new products and R&D projects is constantly revised. In this process, new projects are evaluated, selected, and prioritized. Existing projects may be accelerated, killed, or de-prioritized and resources are allocated (or reallocated) to the active projects.

2.1.2. Portfolio reviews

From the field studies by Cooper, Edgett, and Kleinschmidt (2001), portfolio decisions are typically made in a *portfolio review* board, by leadership team of the business. Portfolio review is the periodic review of the portfolio of all projects. It may take place annually, semi annually, or quarterly. Here all projects, both active and even those on hold, are reviewed and compared against each other. The portfolio review often uses portfolio models to display lists or maps of the current portfolio.

This periodic R&D portfolio review, according to Tiggemann, Dworaczyk, and Sabel (1998), provides a routine process for evaluation of progress, priority adjustment, and "reality checks," that is, application of competitive intelligence, reevaluation of market dynamics, R&D findings, business strategic position/direction, and so forth. This routine process also allows for infusion of new ideas, change in strategic direction, and evaluation of new alternatives, as well as identification of new potential business opportunities.

Portfolio review boards and the project control process, though performing on different levels, work together in carrying out the business's strategy. In Figure 2-1, Cooper et al.

[1] Definition of portfolio management found form Stage-Gate Inc. website http://www.stage-gate.com/

demonstrates the how these two work together.

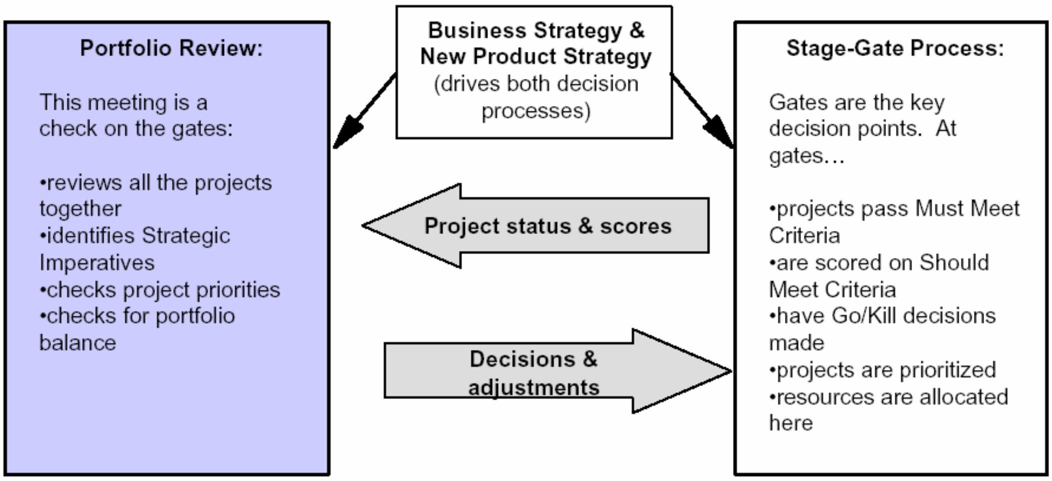

Figure 2-1 Relation between the gating process and portfolio review

Source: Cooper et al., 2000

Tools used for portfolio decisions are introduced in the following section, while the project control (Stage-Gate process) is introduced in section 2.2.

2.1.3. Portfolio review tools

Numerous tools and methods were developed to assist a better portfolio decision. A review made by Henriksen and Traynor (1999) listed eight categories that most portfolio methods can be placed into:

- Unstructured peer review
- Scoring
- Mathematical programming, including integer programming (IP), linear programming (LP), nonlinear programming (NLP), goal programming(GP), and d8namic programming (DP)
- Economic models, such as internal rate of return (IRR), net present value (NPV),

return on investment (ROI), cost-benefit analysis, and option pricing theory

- Decision analysis, including multi-attribute utility theory (MAUT), decision trees, risk analysis, and the analytic hierarchy process (AHP)
- Interactive models, such as Delphi, Q-sort, behavioral decision aids (BDA), and decentralized hierarchical modeling (DHM)
- Artificial intelligence (AI), including expert systems and fuzzy sets
- Portfolio optimization

Through various portfolio tools, Cooper et al. (1997) revealed three main goals have to be achieved by portfolio management. This is through an in depth industry survey that was conducted understand how well performed companies manage their project portfolio. The three goals are: value maximizing, balancing, and strategic aligning. Cooper et al. further described some tools adopted by companies to support portfolio management in order to reach one or several of the above goals.

Goal 1—Value maximizing: Among the tools aiming to maximize the value of the portfolio, they had found expected commercial value (ECV), productivity index, rank ordered list, and scoring models most popular for evaluating the value of projects in the industry. Projects that provide most value to the business are then selected.

Goal 2—Balancing: To achieve the second goal, that is, portfolio balance, bubble diagrams (Figure 2-2) and traditional bar charts are straightforward ways. These Figures visualize the distribution of selected projects on various parameters, allowing managers to easily capture the overall picture. Probability of success vs. expected reward is among of the most popular set of parameters considered by companies.

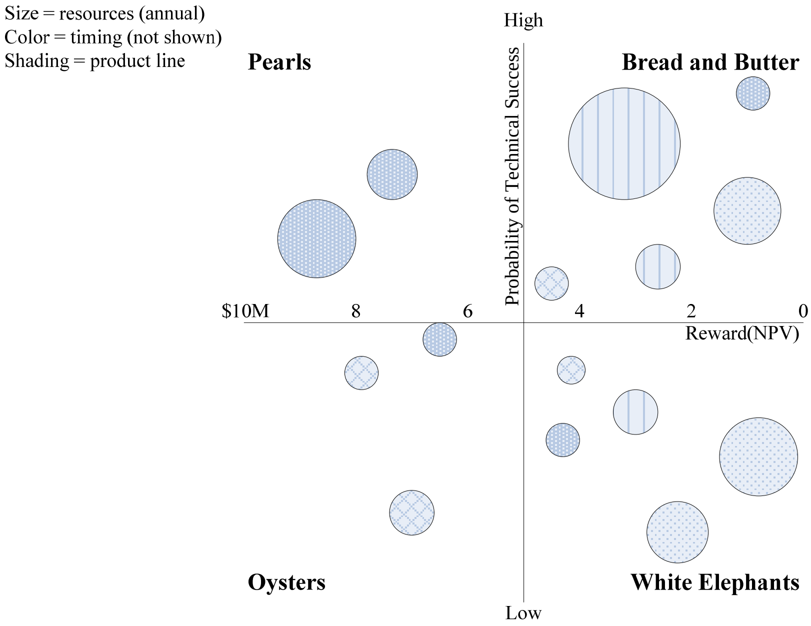

Figure 2-2 A bubble diagram for portfolio balance

Source: Cooper et al. 1997

Goal 3:--Strategic alignment: The third goal of linking portfolio with corporate strategy can be realized by adopting strategic bucket model, top-down spending target method, bottom-up scoring scheme with special emphasis on strategic criteria, and the strategic check, which is a combination of the top-down and bottom-up approach. In the academic field, another strategic bucket approach is presented by McMillan and McGrath (2002). In this approach, projects are categorizes into five types: stepping-stone options, positioning options, scouting options, platform launches, and enhancement launches, according to its technical and market uncertainty (Figure 2-3). A framework developed by Raynor and Leroux (2004) draws upon real options concepts and added scenario-building to help managers formulate and implement strategy in high- commitment, high uncertainty environments. For an existing portfolio, Say et al. (2003) proposed ten alignment dimensions for manager to check whether their portfolio is aligned with business strategy.

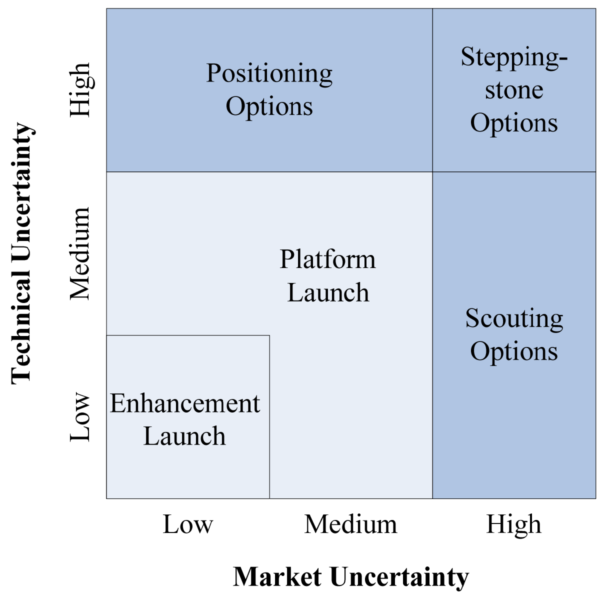

Figure 2-3 Five project types by the level of technical and market uncertainty
Source: McMillan and McGrath, 2002

In order to reach all three goals together, many integrated frameworks had been developed. These frameworks are mostly mathematical programming combined with some other concepts. Some introduced mathematical programming along with the concept of fuzzy logic in order to deal with incomplete information and high uncertainty (Coffin and Taylor, 1996; Lin and Hsieh, 2004). Others may further include decision analysis, for example Analytic Hierarchy Process (AHP) and Analytical Network Process (ANP) (Mohanty, Agarwal, and Choudhury, 2005).

Some other issues have been gradually taken into consideration. One is the interdependency of projects. Projects are not independent incidents as they had been assumed to be, in fact, most of the time they are interdependent. Resource and solutions could be shared among project groups, while additional benefit could be brought in by implementing certain projects together. Sometimes the implementation of one project is dependent on the implementation or progress of other projects. Project interdependency provides valuable cost savings and greater benefits. Santhanam and Kyparisis (1996) formulated a 0-1 programming model for information system (IS) project selection that considers this interdependent nature of projects, and had been proved valid in a real-world IS project. Literature related to project interdependence, or interaction, is further introduced in Section 2.2.2.

2.2. NPD Project Management

2.2.1. NPD project control: the Stage-Gate Process

For controlling the project development process, Cooper (2000b) has proposed a "stage-gate" process. This is a conceptual process for moving new product projects from ideas to launch (Figure 2-4).

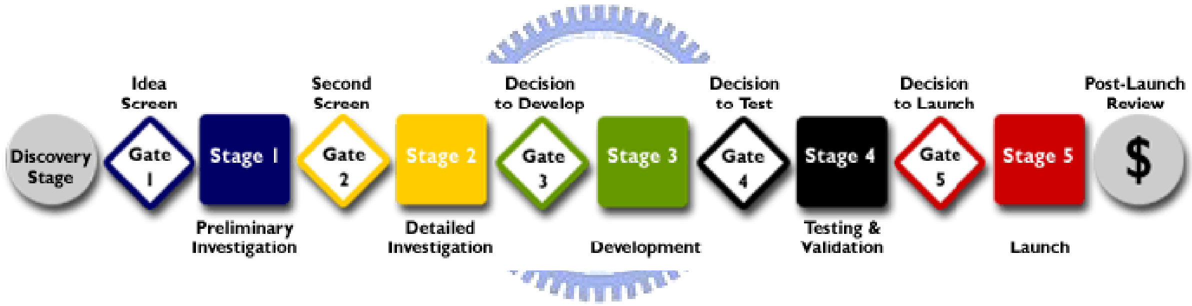

Figure 2-4 Simple map of a typical Stage-Gate process (Cooper, 2000b)

Stages are where actions occur, and gates serve as check and decision points for determining whether the project should enter the next stage. Typical actions and checkpoint criteria for each stage and gate are listed in Figure 2-5. When a project has successfully developed at each stage and passed every gate, the product is ready to be launched to the market and will start generating cash flow. This stage-gate process has been implemented by numerous global firms, and the payoffs have been frequently reported.

IDEA	**Discovery Stage**
Gate 1	**Idea Screen** Does the idea merit any work?
Stage 1	**Preliminary Investigation** Prelim market assessment Prelim technical assessment Prelim financial & business assessment Action plan for Stage 2
Gate 2	**Second Screen** Does the idea justify extensive investigation?
Stage 2	**Detailed Investigation** User needs & wants study Competitive analysis Value proposition defined Technical feasibility assessment Operations assessment Product Definition Financial analysis
Gate 3	**Decision to Develop** Is the business case sound?
Stage 3	**Development** Technical development work Rapid prototypes Initial customer feedback Prototype development In-house product testing Operations process development Full launch & operations plans
Gate 4	**Decision to Test** Should the project be moved to external testing?
Stage 4	**Testing & Validation** Extend in-house testing Customer field trials Acquisition of production equipment Production/operation trials Test market/trial sell Finalized launch and operations plans Post-launch & life cycle plans
Gate 5	**Decision to Launch** Is the product ready for commercial launch?
Stage 5	**Launch** Market launch & roll-out Full production/operations Selling begin Results monitoring Post-Launch & life cycle plans under way

Post-Launch Review
How did we do vs. projections?
What did we learn?

Figure 2-5 From idea to launch: a typical Stage-Gate model

Source: Cooper et al, 2000

At each gate, a scorecard method is recommended by Cooper, Edgett, and Kleinschmidt (2002) in gate meetings to rate the projects. “Must meet” criteria and “should meet” criteria are separated, accounting to its importance, and are evaluated in different ways. A sample scorecard is shown in Figure 2-6. A project has to satisfy all the “must meet” criteria and score high in the “should meet” criteria in order to pass the gate and continue development.

Must Meet Criteria (checklist – Yes/No):
- Strategic Alignment (fits BU’s strategy)
- Reasonable Likelihood of Technical Feasibility
- Meets EH & S and Legal Policies
- Positive Return Vs. Risk
- No Show-Stoppers (killer variables)

Should Meet Criteria (scored on 0-10 scales):

1. **Strategic:**
   - degree to which project aligns with BU’s strategy
   - strategic importance
2. **Product Advantage:**
   - unique benefits
   - meets customer needs better
   - value for money
3. **Market Attractiveness:**
   - market size
   - market growth
   - competitive situation
4. **Synergies (Leverages Core Competencies):**
   - marketing synergies
   - technological synergies
   - manufacturing / processing synergies
5. **Technical Feasibility:**
   - technical gap
   - complexity
   - technical uncertainty
6. **Risk Vs. Return:**
   - expected profitability (magnitude; e.g. NPV)
   - return (e.g. IRR)
   - payback period
   - certainty of return/profit estimates
   - low cost & fast to do

Figure 2-6 “Must Meet” (knock-outs) and “Should Meet” items in gate criteria
Source: Cooper, 2002

2.2.2. Project interactions

While the control of project could be done individually, its evaluation may not be so simple. This is due to the nature of project interactions, that is, active projects are linked, associated, related to each other in one way or another.

Possible interactions among R&D projects are characterized by Gear and Cowie in 1980. They distinguished interactions caused by internal and external factors. External interactions arise over time from overall social and economic changes which have effects that cut across many subsets of a project set. Internal interactions, which is more emphasized in this study, includes (1) cost or resource utilization interaction, (2) outcome, probability, or technical interaction, and (3) benefit, payoff, or effect interaction. (Fox, Baker, and Bryant, 1984)

These interactions lead to an influenced outcome of project performance, making the evaluation of projects complicated. However, the influence of interaction might be strong and should not be ignored. Thus, the evaluation of project interaction becomes an important issue.

2.2.3. Risk management

Besides interaction, projects are difficult to evaluate and predict due to the uncertain nature of innovative activities. Risk management has been practiced since the mid 1980s. According to Artto (1997), risk management consists of four distinct elements: risk identification, risk quantification, response development, and risk control.

The *project risk matrix* provided by Printo (2002) is a simple way to quantify risk (see Figure 2-7). It allows a project team to brainstorm and evaluate possible risks and identify those with strong impacts to the development process.

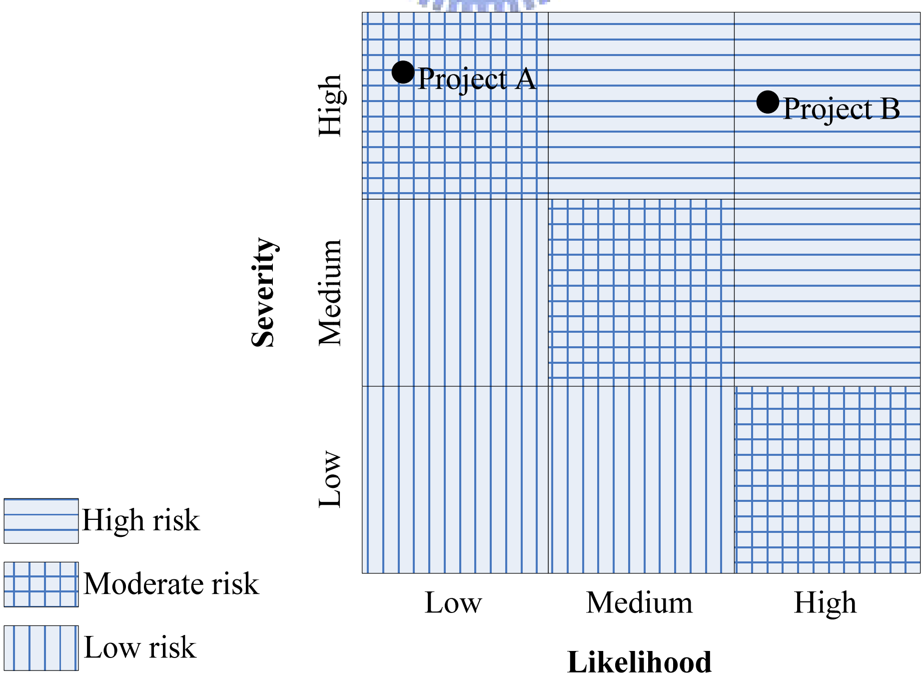

Figure 2-7 Project risk matrix
Source: Printo, 2002

Huchzermeier and Loch (2001) proposed a decision tree approach for making optimal policy at each project stage under risk and uncertainties, as show in Figure 2-8. The uncertainties addressed include uncertainty of performance, development cost, development time, market requirement, and market payoff. It adopts the real option concept and dynamic programming for evaluating the project value, and make decisions at control gates during development.

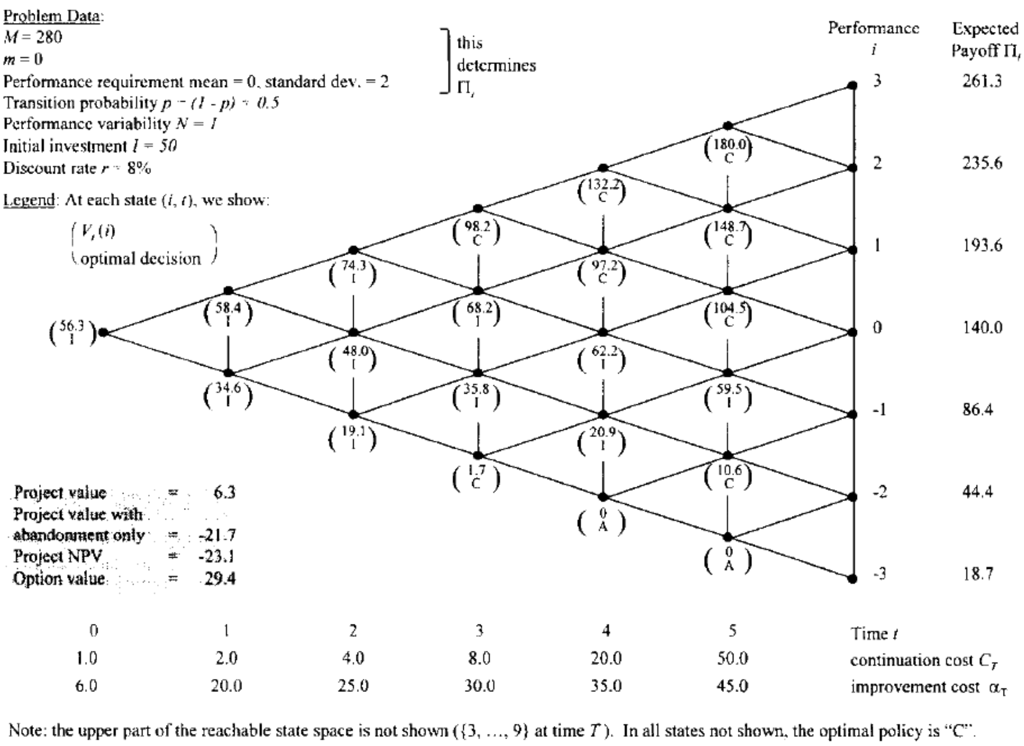

Figure 2-8 Obtained optimal policy from decision tree

Source: Huchzermeier and Loch, 2001

2.2. Sources of change

To identify changes in the business environment, it is good to first identify the possible source of change. From a case study focusing on organizational change, Bamford and Forrester (2003) revealed that a realistic interpretation of the change process had to take into account multiple and varied forces which interacted over time and which exerted varying influences. These forces of change, classified into external and internal, are identified in Figure 2-9.

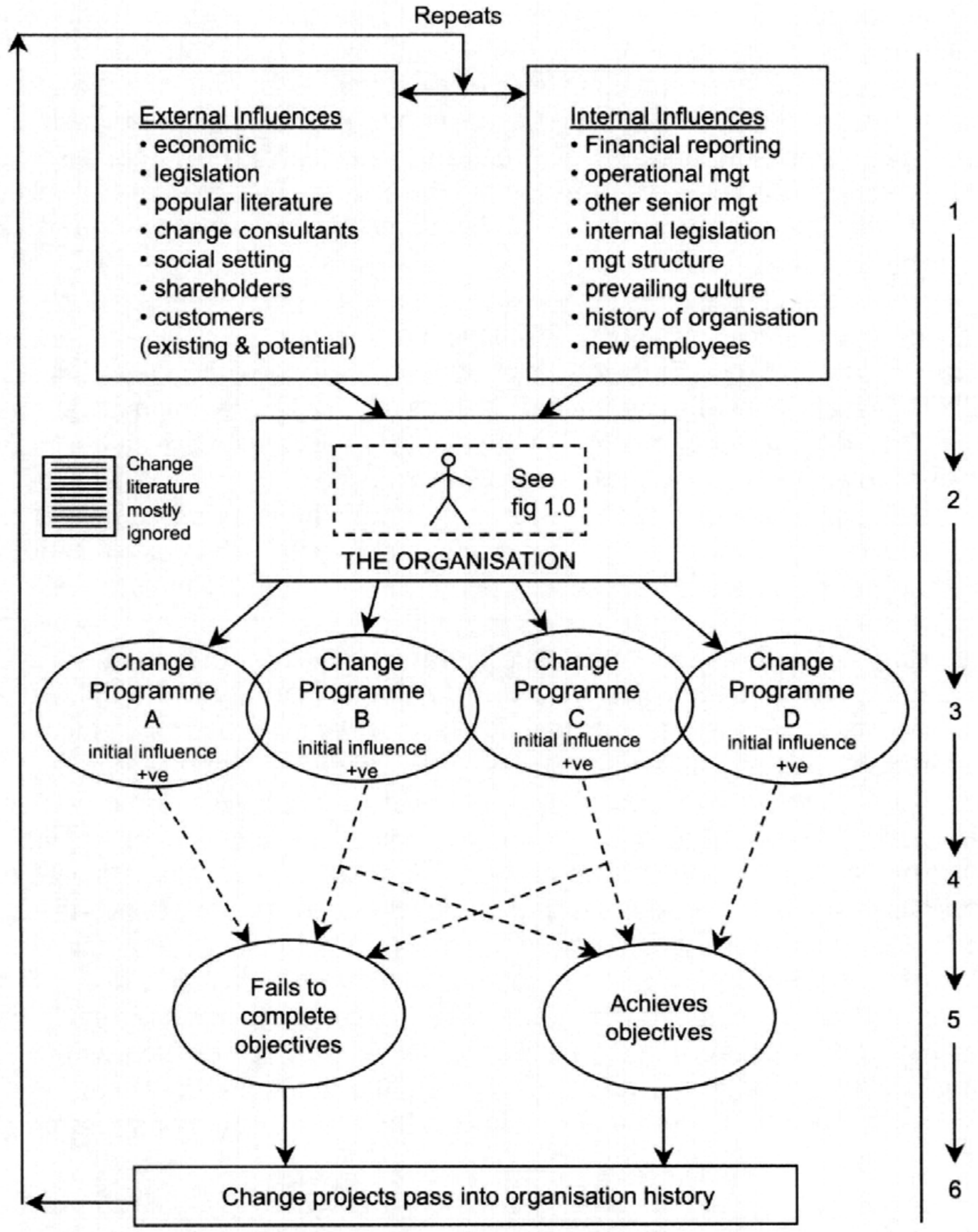

Figure 2-9 The emergent influences and aspects of change (EIAC) model
Source: Bamford and Forrester, 2003

3. Dynamic portfolio

3.1. Introduction to dynamic portfolio

A traditional static portfolio is one which is renewed periodically by portfolio review board. Dynamic portfolio, on the other hand, is one with not only the periodical review but also a real-time response mechanism to deal with changes in the environment. Changes occur when the projects are taking place. These changes include internal and external factors. External factors are from outside the firm and cannot be controlled by the firm’s management, for example, market demand change and legislative issues. Internal factors, on the other hand, raises within the firm and can be partially controlled through management. The controllable part includes strategic directions, management decisions, and so on, while uncertain factors also play a great role in the development process as uncontrollable factors.

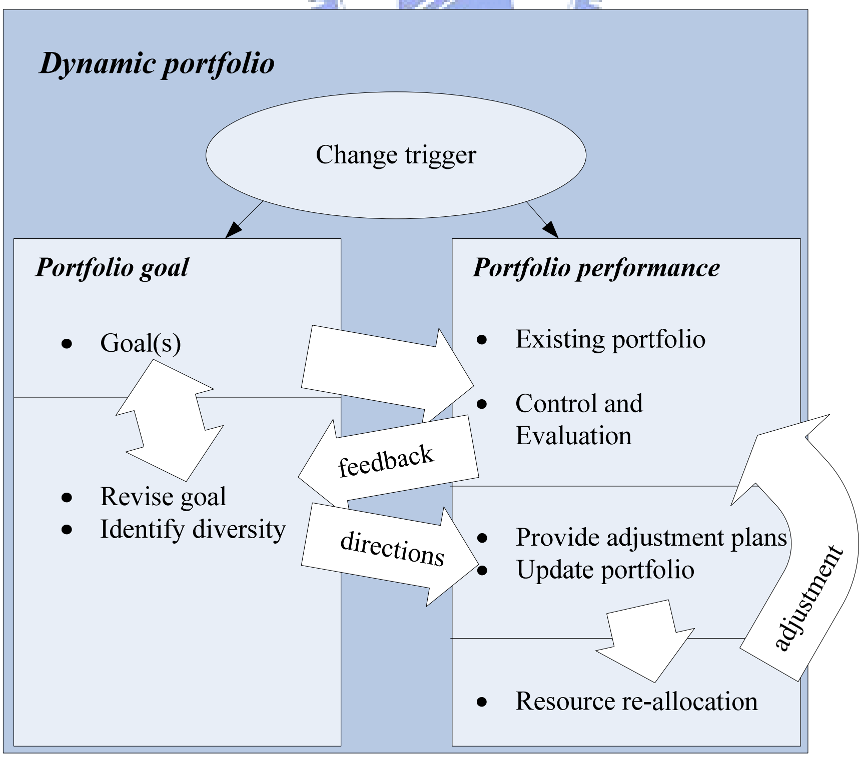

Figure 3-1 Conceptualization of a dynamic portfolio

In a traditional static portfolio mode, the portfolio is evaluated and adjusted periodically. The time interval between every portfolio review board may be different in different firms. A typical practice is a three-month (seasonal) review meeting. Although projects in the portfolio are controlled in a real-time manner, there remains a lack of overall sight between portfolio reviews. During this period, environmental changes may have influence on the original settled goals or have impact on existing portfolio performances. Control solely on project level may lead to inefficient management results.

The idea of dynamic portfolio rises from the sight of this need. The aim is to build a dynamic portfolio framework that has real-time response to changes in the environments. Instead of a time-interval-based portfolio review, the desire is to let change information *trigger* the dynamics within the portfolio. Thus, when a trigger enters, immediate adjustments can be made on the portfolio level: either goals or composition of the portfolio, and will continue to influence one another. This series of changes and adjustments, as shown in Figure 3-1, are here called the dynamics in project portfolio.

This chapter aims to construct a dynamic portfolio framework as a complement to the traditional periodical portfolio review, in order to provide quick response to changes in the environment.

3.2. Identify trigger factors

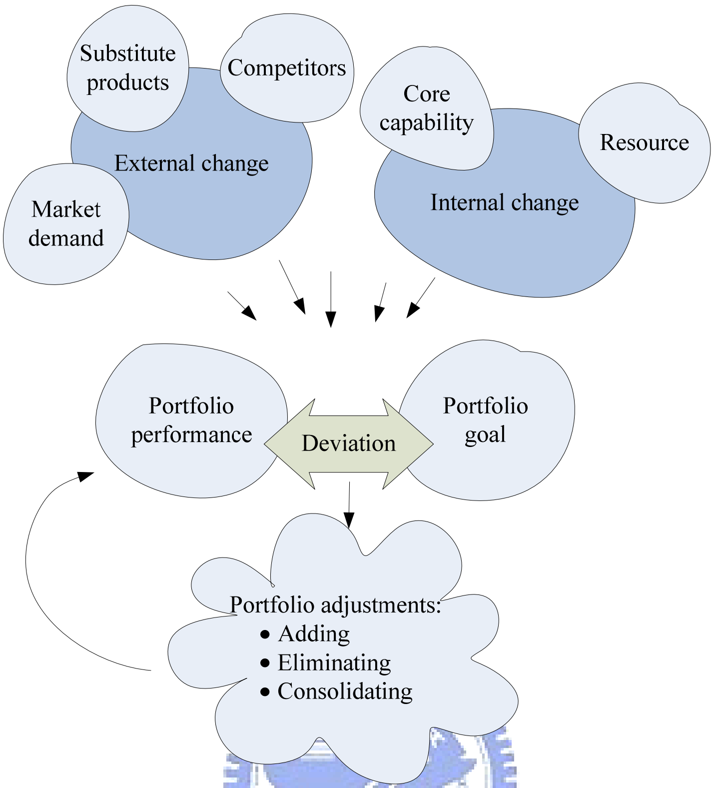

Figure 3-2 Environmental changes trigger the portfolio dynamics

Changes in the business environment, both internal and external, create deviations between the firm's portfolio goals and performances (see Figure 3-2). Portfolio goals are targets on different criteria reflecting the firm's strategic directions which are to be fulfilled through the implementation of R&D projects. Portfolio performance, on the other hand, is the expected level of contribution provided by the actual set of project portfolio. Theoretically, the performance of a portfolio is the realization of its goals. When changes occur, both goals and performances may be affected. The result is a deviation between goals and performances, that is, the portfolio's contribution may no longer be able to fulfill its goals.

In order to effectively adjust the portfolio goals and contents, changes in the environment have to be detected efficiently. Thus, the firm has to generate a list of trigger factors, that is, the drivers of possible changes in the future that may influence its portfolio. A list of trigger factors is a result of environmental analysis and brainstorming, which determines the most important factors that will decide the future environment which the firm operates.

Bamford et al. (2003) have identified some trigger factors and categorized in the table below:

Table 3-1 Sources of change

External Influences	***Internal Influences***
• Economics	• Financial reporting
• Legislation	• Operational management
• Popular literature	• Other senior management
• Change consultants	• Internal legislation
• Social setting	• Management structure
• Shareholders	• Prevailing culture
• Customers (existing and potential)	• History of organization
	• New employees

Source: Bamford and Forrester, 2003

Based on the nature of its business or industry, a firm should identify its specific triggering influences thus effectively detect their occurrences.

3.3. Confirm portfolio goals

When new information of change detected, management has to identify its influence on both portfolio goals and performances. The first thing to do is to check if the new information has affected the original goals.

- Do the original goals still factually reflect the firm's direction in the changed business environment?
- If not, how could the goals be revised?

Evaluation criteria for portfolio lie in where the goals are set. The goal of a good portfolio is to maximize value, balance, and to align with strategy (Cooper et al., 1997). Therefore, we consider the three goals as the three categories of portfolio targets and evaluation criteria:

1. *Value maximization goal:* Portfolio value can be defined in many ways, depending on the decision-maker's preferences. A popular definition for NPD portfolio (or project) value is the expected market payoff of the project deliveries. Portfolio value may also include technical performance, synergy, or other values defined by management. Thus, the goal could be set as the amount of market payoff in a certain period, return on investment level, the performance level of a certain technical attribute, and so on.

2. *Balance goal:* according to Cooper et al. (1997), the second major goal sought by some firms is a balanced portfolio—a balanced set of development projects in terms a number of key parameters. These parameters could be the number of project in different risk levels, project cost and rewards, and projects across various markets, technologies, product types, and project types. An ideal balance of portfolio is set by top management according to the firm's strategy and capability. Certain parameters are selected and given ideal numbers or percentages regarding different types or categories of projects, and will become one of the basis in allocating resource.

3. *Strategic alignment goal:* The third major goal is that all project directions should be aligned to the firm's vision and strategy. Many strategic goals set by the firm management have to be met through the implement of project portfolio. For clear evaluation, strategic goals should be converted into quantitative goals. Take the strategic bucket approach for example, if the firm wants to focus on certain

technologies or markets, it could be transferred to a target number (or percentage) of project or a lower-bound of resource level for projects focusing on that area.

4. *Resource availability constraint:* To ensure resource availability for any adjustment actions, an additional consideration of resource constraint is taken as a monitor criterion. Resource includes capital budget, human workforce, facilities and other critical resources for project development.

Under each criterion, a target value should be set as goal for performance evaluation. The unit used on each criterion for setting target value and evaluating performance should be identical.

3.4. Evaluate portfolio performance

Since a portfolio is made up by a group of projects, the evaluation of portfolio should be based on the evaluation of projects. Here we assume that the expected portfolio performance is the summation of all expected project performances. A simple weighting technique is used to obtain an overall performance grade of the portfolio under evaluation. Table below shows how the overall performance grade is calculated.

Table 3-2 Portfolio performance evaluation criteria

Criteria	***Weight*** w_i	***Portfolio goals*** g_i	***Portfolio Performance*** p_i	***% Achievement*** $\frac{p_i}{g_i}$	***Grade*** $\frac{p_i w_i}{g_i}$
Criterion 1					
Criterion 2					
Criterion 3					
…					
Criterion I					
Portfolio performance/achievement grade (total) $\sum_{i=1}^{I} \frac{p_i w_i}{g_i}$					

Notations:

i criteria index, $i = 1, 2, \ldots, I$

w_i weight of criterion i, $\sum_{i=1}^{I} w_i = 1$

g_i portfolio goal/target value of criterion i

p_i expected portfolio performance value of criterion i

Weight of each criterion is given according to management perception of the relative importance of each criterion. Decision support tools such as Analytic Hierarchy Process (AHP) may provide satisfying results in weight setting.

The portfolio achievement grade $\sum_{i=1}^{I} \frac{p_i w_i}{g_i}$ represents the overall goal achievement of the current portfolio. The maximum value of this indicator is 1, meaning that the goal can be fully achieved by the portfolio within resource limitation.

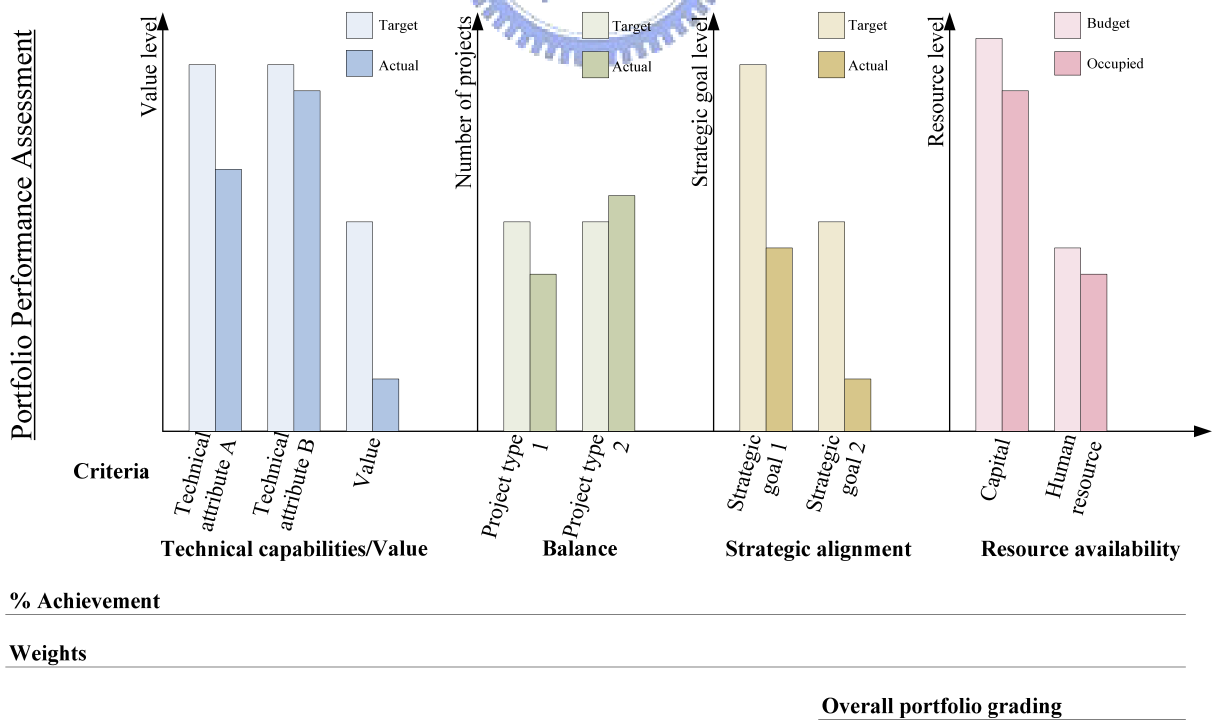

Figure 3-3 Portfolio performance evaluation presented in bar chart

We believe that the value of projects is tough and complicated due to the uncertain and interactive nature of NPD projects. To avoid losing focus on portfolio perspective, a separate chapter is created from a project point of view to deal with the definition and evaluation of projects, with the consideration of uncertainty and interaction/synergy. Please see Chapter 4 for *interactive project evaluation.* With the method proposed in Chapter 4, the portfolio value is then the summation of values for individual projects in the portfolio.

3.5. Identify deviation and provide adjustment plan

With the revised goals and evaluated performances, the deviation in between can be identified. Deviation exists in where adjustments are needed, thus is the accordance for generating adjustment plans.

The aim of adjustment actions is to improve the overall portfolio performance grade. Thus, a good adjustment action/solution is one that provides big improvement on portfolio performance grading. Typical actions on portfolio adjustment include:

- Add in completely new projects
- Hold existing projects
- Consolidate several new or existing projects and form a new project
- Modify existing project plans

In Figure 3-4, a yes-no procedure is proposed as a suggestion for deciding the add-ins, holds, and other plans.

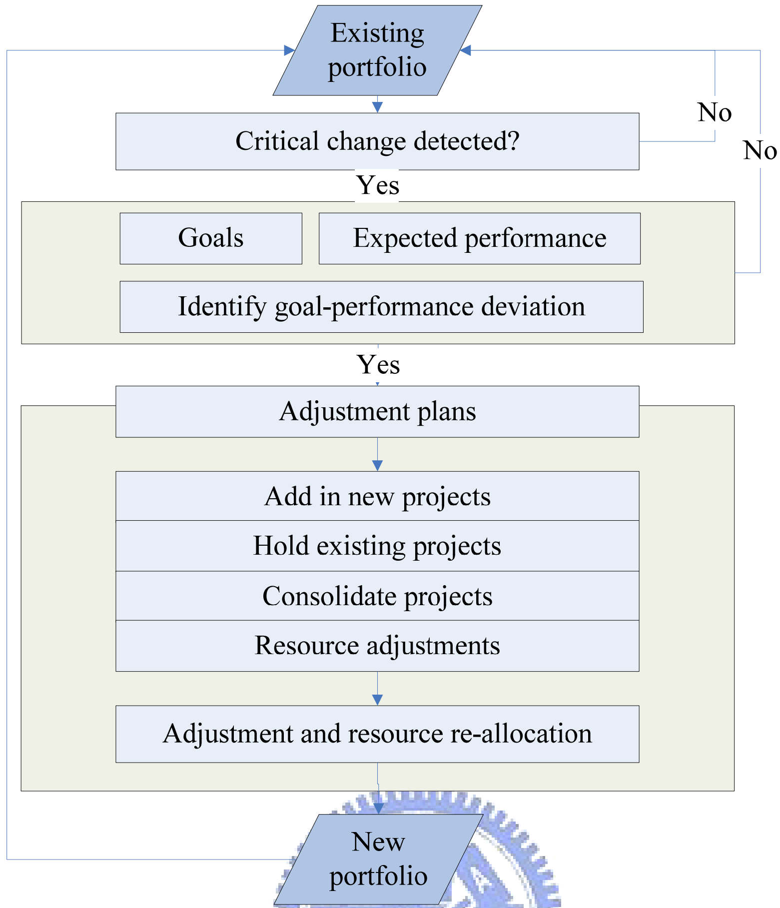

Figure 3-4 Yes-no procedure for dynamic portfolio control

Finally, we describe the evaluation process for add in new projects and hold existing projects.

3.5.1. Add in new project

Adding in a new project means to create a project as a response to the needs (or deviation) of existing portfolio. Here, a new project may come from a completely new idea, or an existing project with several adjustments. A simple suitability evaluation is provided to ensure its suitability and contribution to the portfolio. The evaluation is very similar to the way portfolio is evaluated. The difference is that "portfolio goal" has been changed onto "*portfolio deviation*", which demonstrates the unfulfilled part of portfolio goal. The portfolio deviation then becomes the goal to be fulfilled by the new project. Table presents how the project suitability grade is obtained.

Table 3-4 *New project suitability: delivery vs. deviation*

Criteria	***Weight*** w_i	***Portfolio deviation*** d_i	***Project delivery*** p_i^x	***% Fulfillment*** $\frac{p_i^x}{d_i}$	***Grade*** $\frac{p_i^x w_i}{d_i}$
Criterion 1					
Criterion 2					
Criterion 3					
…					
Criterion I					
New project suitability grade (total) $\sum_{i=1}^{I} \frac{p_i^x w_i}{d_i}$					

Notations:

x project index

p_i^x project x's delivery on criterion i

New project suitability grade $\sum_{i=1}^{I} \frac{p_i^x w_i}{d_i}$ represents a project's overall suitability as a response to portfolio deviations. The above table can also be presented in a bar chart, see Figure 3-5

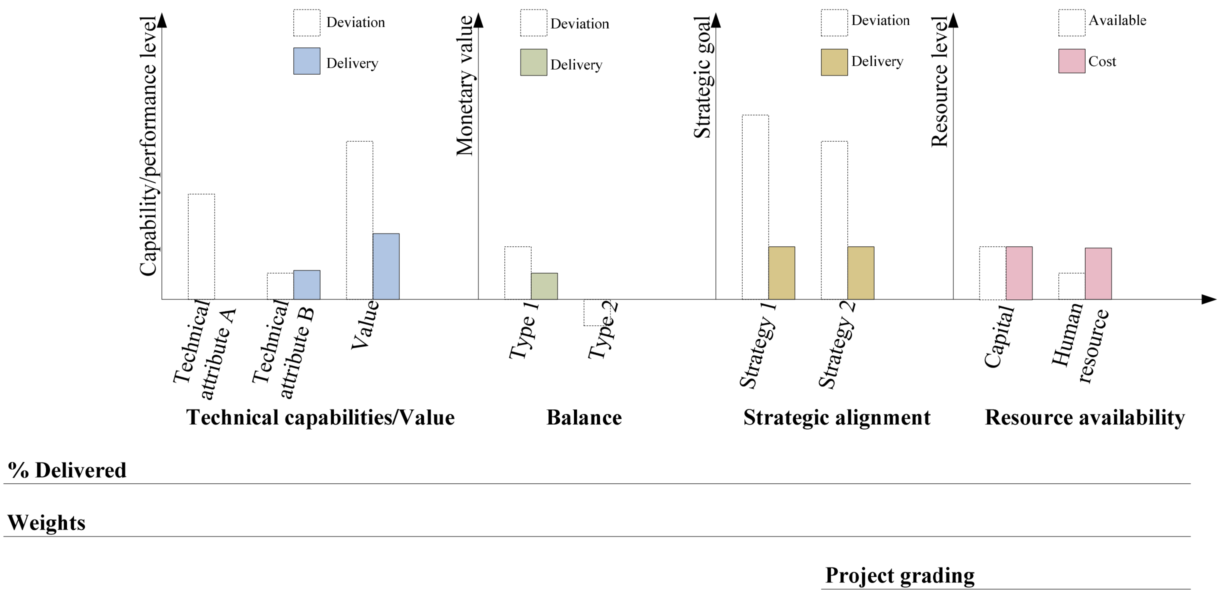

Figure 3-5 Project suitability evaluation bar charts

3.5.2. Hold existing projects

If a project in the portfolio gets out of control, provides poor performance, or no longer fits into the changed portfolio goal, it should be either revised or deleted.

Poor performance projects should be killed at the project control level. This is not a result of the portfolio dynamics; on the contrary, it may be a trigger of dynamics in the portfolio to generate new projects to make up for the gap.

Projects with acceptable performance however no longer aligned with the adjusted goal may be revised or killed. This adjustment is caused by portfolio dynamics when an environmental change enters and leads to dramatic change is portfolio goal. The determination is also through a project evaluation process which is similar to the previous new project section, to see how suitable is the project regarding the changed portfolio goal. Through comparing the cost of continue development and the expected deliveries, the manager has to decide whether to release its resource for other projects with higher potential.

3.5.3. Modify existing project plans

Changes occur may provide more information regarding only existing projects. Besides being hold, existing projects can also be modified, in terms of time schedule, scale, and resource assigned. For example, it may indicate that the product launch has to be advanced, thus the adjustment could be solely adding recourse and reschedule an existing project activities.

4. Interactive projects: project evaluation and control

4.1. Interactive projects

Value of NPD projects is difficult to estimate due to its strong association with uncertainty and risk. Dealing with unfamiliar technologies and new markets, the technical performance and marketing outcomes are highly uncertain. Moreover, it is complicated by the frequent interaction and interdependence between projects in the portfolio. Figure 4-1 demonstrates a part of the complex interactions between projects. This chapter aims to provide an approach for project evaluation with the considerations of uncertainty and interaction among NPD projects in the portfolio.

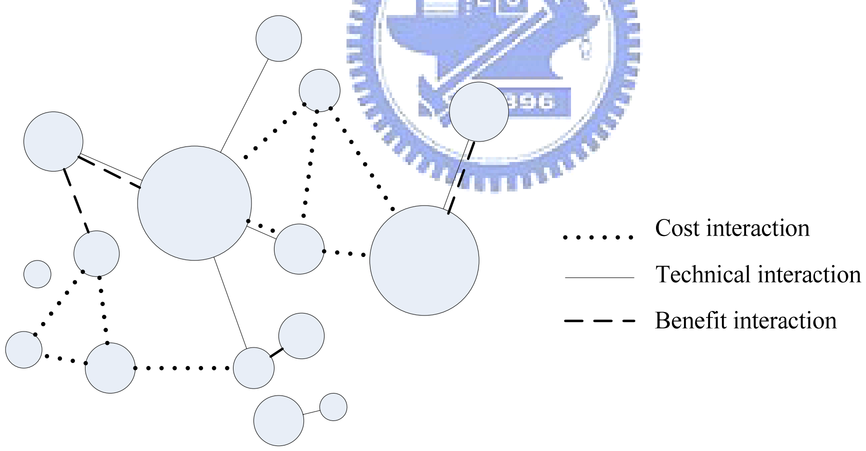

Figure 4-1 Complex interactions between projects

A decision tree approach for decision-making has been developed by Huchzermeier et al. (2001). We continue to use their real option concept for evaluating project value, in which decision can be made at every gate during development process as a response to the uncertain project outcome. The overall procedure of the project evaluation approach is demonstrated in Figure 4-2.

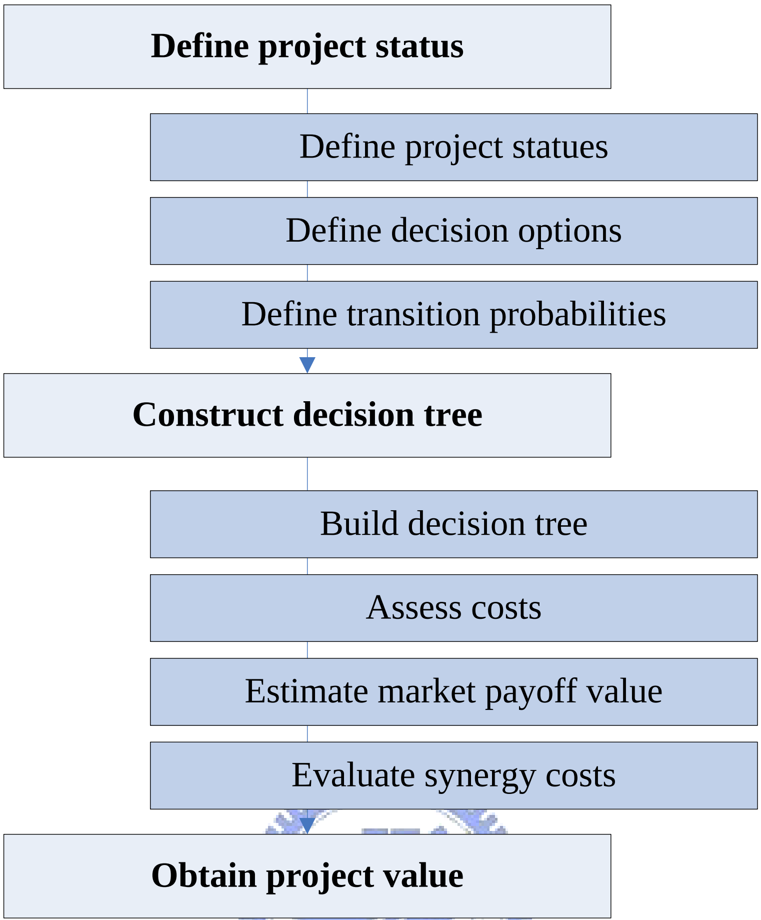

Figure 4-2 Procedure of the proposed evaluation approach

An overview of the decision tree is given in Figure 4-3. Scenarios are built to identify possible tracks of project outcomes throughout the development process. According to the scenarios, we then construct the decision tree for obtaining optimal policy at every progress gate. On the tree’s right-hand and bottom sides, values and costs are evaluated respectively to together generate the project’s possible values at the end nodes of the tree (final stage statuses or hold statuses). The project value at each status is then obtained from a backward calculation.

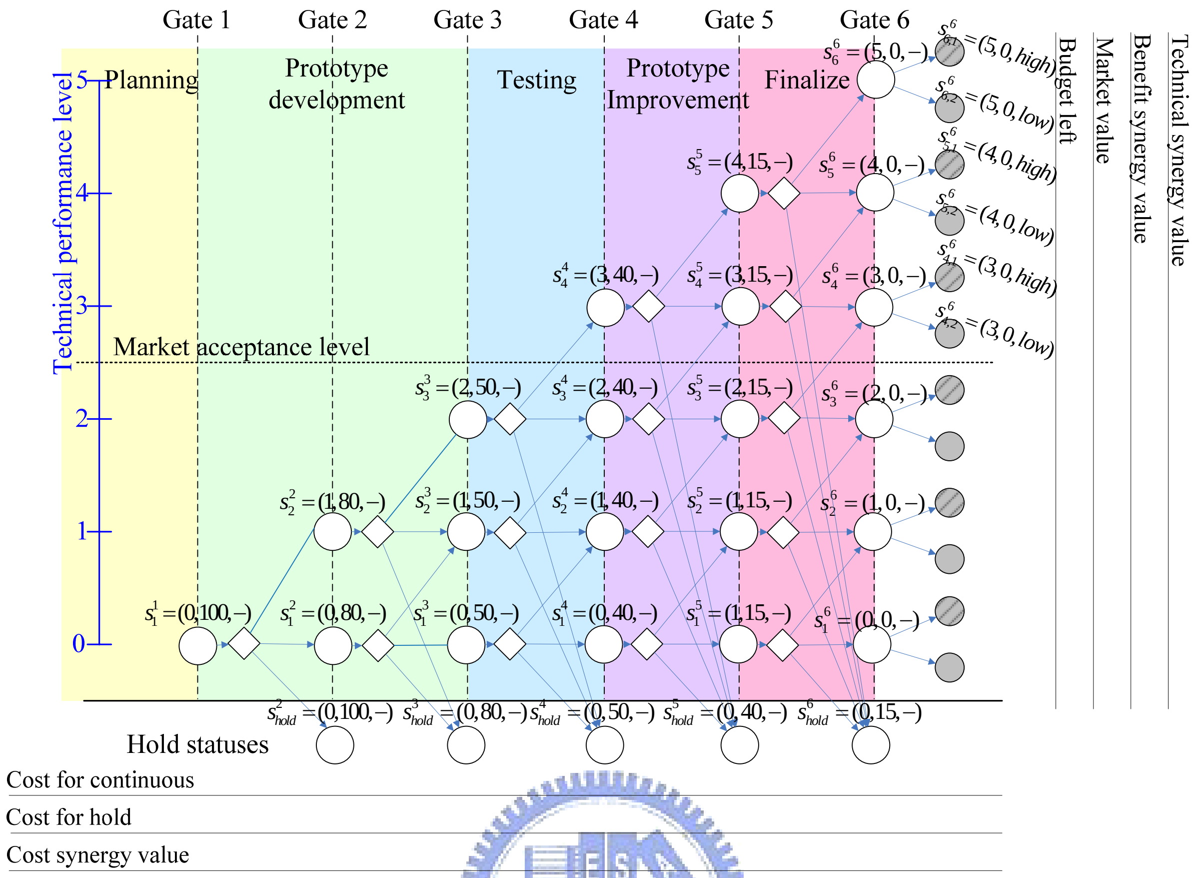

Figure 4-3 Overview of the decision tree for project evaluation

4.2. Definitions

4.2.1. Notations

Index

t gate index, $t = 0, \ldots, T$, where T is the final gate of the development process.

n^t the number of possible status at gate t; $n^t = |S^t|$

i, j status index; $i = 1, 2, \cdots, n^t$; $j = 1, 2, \cdots, n^{t+1}$

x project index

y product index

k technical attribute index; $k = 1, 2, \ldots, K$

l resource type index; $l = 1, 2, \ldots, L$

Input data

s_i^t — the ith possible status of the project at gate t, which is defined as $s_i^t = \left(f_{Ti}^{\,t}(\bullet), f_{Ri}^{\,t}(\bullet), f_{Ei}^{\,t}(\bullet) \right)$, where

- $f_{Ti}^{\,t}(\bullet)$ — function of technical performance level
- $f_{Ri}^{\,t}(\bullet)$ — function of resource availability level
- $f_{Ei}^{\,t}(\bullet)$ — function of environmental situation

S^t — the set of all the n^t possible status at gate *t*.

$p_{i,j}^t\left(d_i^t\right)$ — project's transition probability from the ith status of gate t, s_i^t, to the jth status of gate $t+1$, s_j^{t+1}, if the decision made at gate t is d_i^t

D_i^t — the option set for decision at s_i^t

Parameters

MV_i^T — market payoff value at statuses in the final gate, s_i^T. This is the result of an optimal pricing and production volume based on the market demand curve at s_i^T

Sc_i^t — cost synergy, realized during development

St_i^T — technical synergy, realized when project is completed

Sb_i^T — benefit synergy, realized when project is completed

C_i^t — budget remained for further development; C_i^1 is the total available budget at the starting gate $t=1$

$c\left(d_i^t\right)$ — cost for implementing the decision if the decision d_i^t at status s_i^t

Decision variables

d_i^t — the decision made at the ith status of gate t; $d_i^t \in D_i^t$

4.2.2. Project status

A general project status is defined in this section. Project status could be influenced by controllable factors such as product technical performance and available resources, and uncontrollable factors such as environmental situation. $S^t = \left\{ s_1^t, s_2^t, ..., s_i^t, ..., s_{n^t}^t \right\}$ is the set of all possible statuses at gate *t*, where

$n^t = \left| S^t \right|$ is the number of possible status at gate *t*, and

$s_i^t = \left(f_{Ti}^{\,t}\left(a_{1i}^t, a_{2i}^t, ..., a_{ki}^t\right), f_{Ri}^{\,t}\left(C_i^t, R_{1i}^t, R_{2i}^t, ..., R_{li}^t\right), f_{Ei}^{\,t}\left(M_i^t, CP_i^t, ...\right)\right)$ is the i^{th} possible status at gate *t*, which is a function of technical performance level, resource availability, and environmental situation.

1. *Technical performance level*

$f_{Ti}^{\,t}\left(a_{1i}^t, a_{2i}^t, ..., a_{ki}^t\right)$ is an evaluation of product's overall technical performance based on the performance level of each technical attribute a_{ki}^t. a_{ki}^t is the technical performance level of the k^{th} attributes at s_i^t. Normally, the quality of a product is determined by the performance of certain technical attributes, depending on the nature of technologies used. Note that not all attributes has to be tracked, only the ones that will have direct influence on product performance and will thus affect the market outcome.

2. *Resource availability level*

$f_{Ri}^{\,t}\left(C_i^t, R_{1i}^t, R_{2i}^t, ..., R_{li}^t\right)$ is the resource availability level at s_i^t; C_i^t represents its budget level; R_{li}^t is the level of the l^{th} resource available. The level of available resources and capability, $f_{Ri}^{\,t}\left(C_i^t, R_{1i}^t, R_{2i}^t, ..., R_{li}^t\right)$, includes capital (monetary), human resource, facilities, and technical capabilities.

3. Environmental situation

$f_{Ei}^{t}\left(M_i^t, CP_i^t, \ldots\right)$ is the environmental situation at s_i^t, which concerns a market attractiveness level M_i^t, and the competition level CP_i^t. The environment situation is an uncontrollable anticipation on customer needs, market demand, technical requirement level, competition level, and so on.

4.2.3. Decision alternatives

At every gate where project status can be observed, a decision d_i^t can be made as a control to the development process. There is a set of decision options D_i^t for each status s_i^t since it is dependent to the different gates and scenarios. The decision options may be improving the performance by adding resources, continuing the planed schedule, seizing development and release occupied resource, and so on (see Figure 4-4). The decision made will influence the transition probabilities to statuses at the following gate. Each decision option has an associated cost $c\left(d_i^t\right)$ if selected. This cost for carrying out the activity will occupy the budget resources.

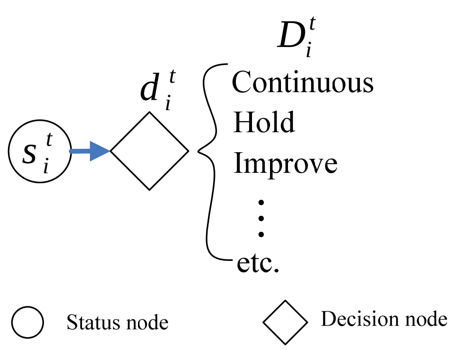

Figure 4-4 A set of decision alternatives at a certain status

4.2.4. Transition probabilities

Transition probability describes the likelihood of the project outcome to be at a certain status from the current status. The outcome is mainly a result of development effort, decision, and uncertainty. Figure 4-5 demonstrates a general transition between statuses at different gates with decision options.

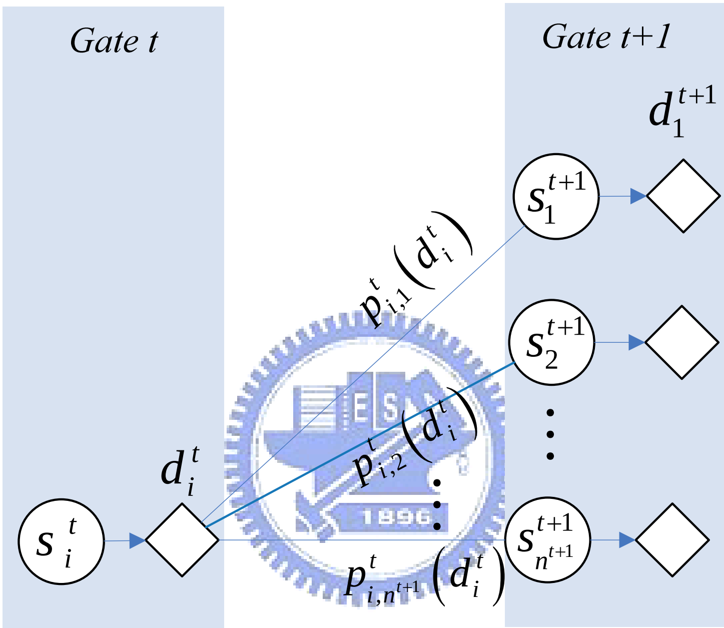

Figure 4-5 Transition probabilities depend on the decision at gate t

The probability for transiting from status s_i^t to s_j^{t+1} is dependent to the scenario built and the decision made at gate *t*. The transition probability is defined as $p_{i,j}^t\left(d_i^t\right)$, representing the likelihood of status s_i^t transits to s_j^{t+1} if the decision at gate *t* is d_i^t.

$$\sum_{j\in S^{t+1}} p_{i,j}^t\left(d_i^t\right)=1,$$

4.2.5. Example

In this study, a simplified case is used for illustrating the approach. For project status, the example case considers one technical attribute performance level (leveled 0 to 5), capital budget, and two levels of market demand curve for each final performance level.

$s_i^t = \left(a_{1i}^t, C_i^t, M_i^t \right)$

a_{1i}^t expected performance level of the final deliverable according to the project's performance at gate *t;* $a_{1i}^t \in [0,5]$

$C_i^t = C_i^1 - \sum_{n=1}^{t-1} c\left(d_i^n\right)$

C_i^t budget remained for further development

C_i^1 available budget at the starting gate

$c\left(d_i^t\right)$ the cost for development if the decision at status s_i^t is d_i^t

M_i^t market attractiveness at status s_i^t, simplified into *high* and *low* market demand.

$$M_i^t = \begin{cases} low, & \text{if market attractiveness is low} \\ high, & \text{if market attractiveness is high} \end{cases}$$

Expected market demand curve $Q = \alpha_i^t - \beta_i^t P$

Q demand of the final deliverable

α_i^t, β_i^t constant values describing the market situation according to market attractiveness and product's technical performance

P price level of the final project deliverable

Decision alternatives

In our example, the decision option set D_i^t is set to be identical under every status. Decision d_i^t can be made to either continuous or hold the project development at each gate *t*.

$d_i^t \in D_i^t$, $D_i^t = \{C : continuous, H : hold\}$, for $i = 1, \ldots, n^t$; $t = 1, \ldots, T$

The "continuous" decision leads the project to the next gate. New level of performance, budget, and market situation will then be observed, and new decision will be made depending on the new status. The "hold" decision leads the project to a hold status in which no further progress and decisions will be made on the project.

Transition probabilities

In our example case, a "continuous" decision will result in two possible statuses at the successive gate, representing the improvement of technical performance. One possible transition outcome is that the performance had not been improved during the stage. Another possibility is a one-level improvement on technical performance. The probabilities of the two outcomes are both $\frac{1}{2}$.

$$\begin{cases} p_{i,j}^{t}(C)=\frac{1}{2}, & \text{if } j=i \\ p_{i,j}^{t}(C)=\frac{1}{2}, & \text{if } j=i+1 \\ p_{i,j}^{t}(C)=0, & \text{otherwise} \end{cases}$$

A "hold" decision made on any status s_i^t will lead the project directly to the "hold status" at the next gate.

$$p_{i,hold}^{t}(H)=1$$

4.3. Construct decision tree

4.3.1. Build decision tree

Scenario can be built by taking into concern the available environmental information, such as trends and key uncertainties, and the possible changes in the future. (The identification of possible environmental change is discussed previously in section 3.2.) The identified possible effects may have influences on the several factors consisting project statuses, thus forming a number of postulated sequence of events in the future time frame. The sequence of events are then expressed in the form of project statuses at each decision gate, s_i^t.

Decision points are also built in the scenarios as the controllable part by management. The structure of a decision tree can then be pictured.

Figure 4-6 illustrates our example with a "continuous" decision at every decision point: a six-gate decision tree structure considering one technical attribute (evaluated by levels 0 to 5) and market attractiveness (high or low demand).

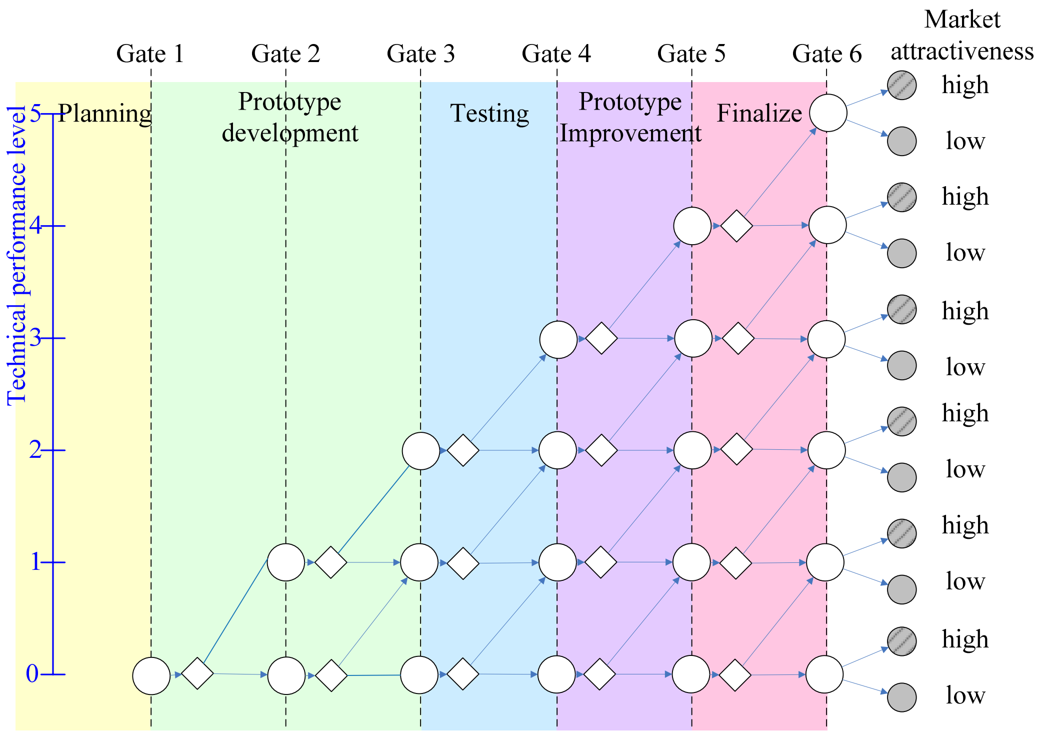

Figure 4-6 A tree structure expressing possible future outcomes of the project

Figure 4-7 shows the "hold" statuses and a market acceptance level. With a "hold" decision, deleted projects come to the nodes at the bottom of each gate. When being held, except for external information, other attributes of the project status will remain the same as in the former gate. A market acceptance level is then settled. Performance under this level will not be accepted by the market, either in high or low demand situation, thus will not generate market payoff values when development completes.

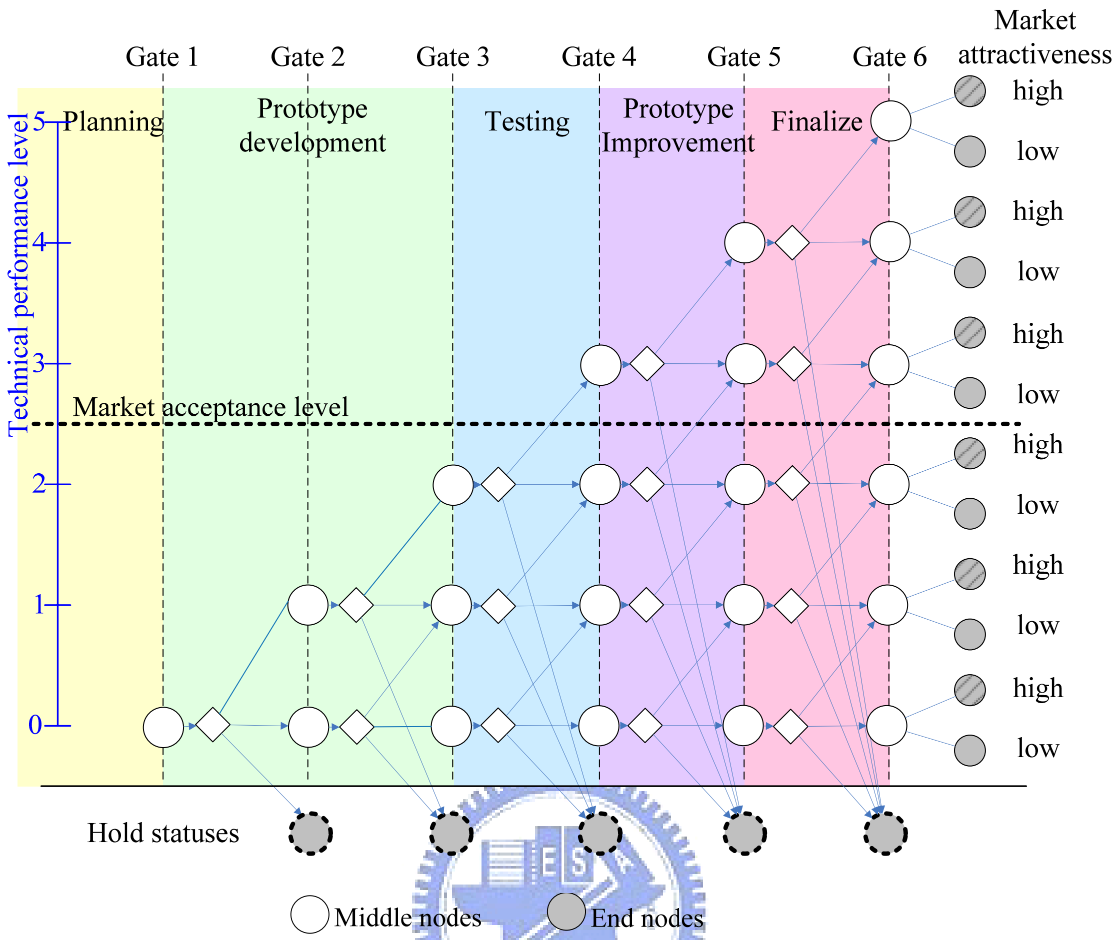

Figure 4-7 Acceptance level and "hold" statuses

After building the tree structure, values will be attached at each node. The values for middle nodes (statuses where decisions can be made) include development cost and synergy value resulting from the interactions of projects. At the end nodes (statuses at the final gate and hold statuses), an additional market payoff value is realized, representing the launch of product in the market. The following sections are created for estimating these values: market payoff value, cost synergy value, benefit synergy value, technical synergy value, and costs.

4.3.2. Evaluate costs

Except the end nodes, all nodes are given an opportunity to make decisions regarding the project's development. In our case, two decisions can be made at each middle node: continue and hold. The cost for decision $c(d_i^t)$ at each gate is tabled below:

Table 4-1 cost for decisions

Decision \ Gate	1	2	3	4	5
Continuous	20	30	10	25	15
Hold	0	0	0	0	0

With the estimated costs at each gate, and the expected performance levels obtained in the previous section, the decision tree can be further developed, as illustrated in Figure 4-8.

Project status = (technical performance, budget left, market demand)

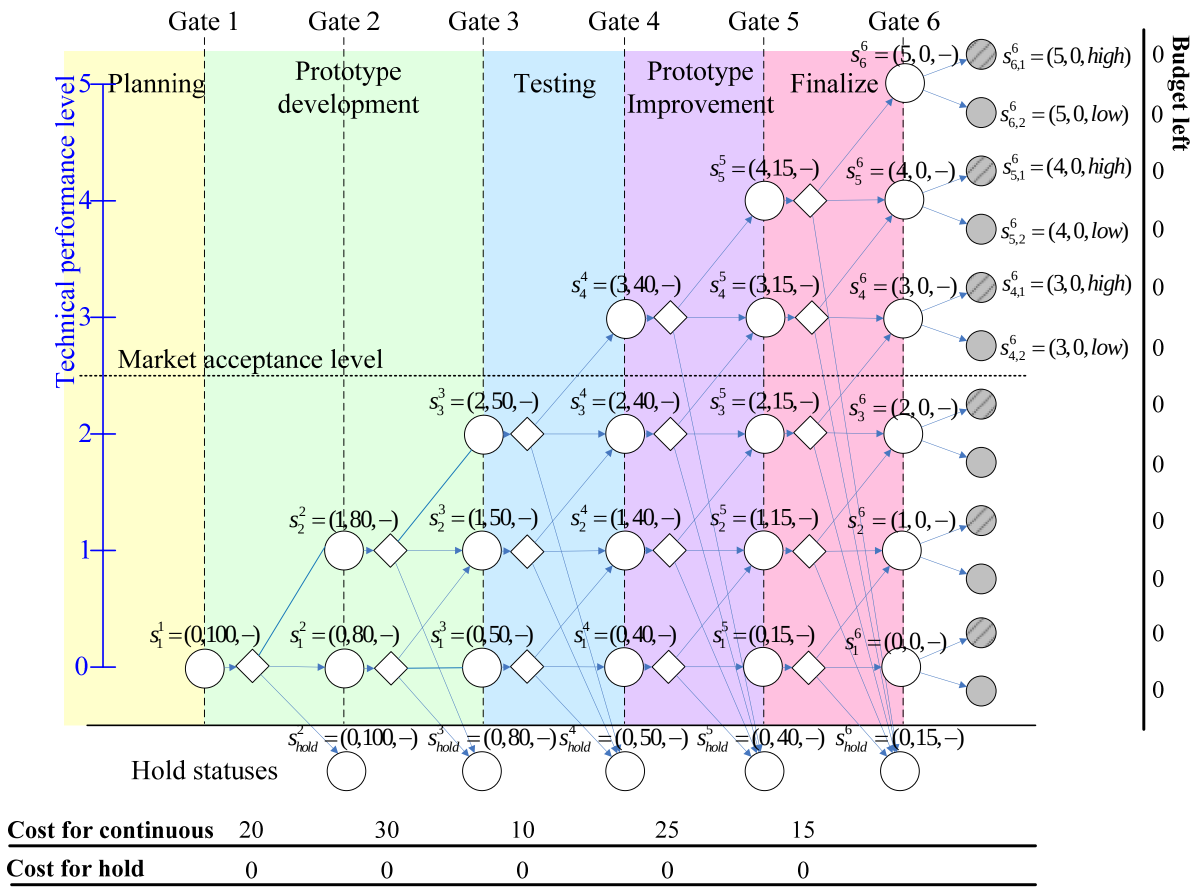

Figure 4-8 Decision tree with statuses and costs

4.3.3. Anticipate market payoff

At the final statuses, when a project is successfully implemented and its deliverable product is launched, market payoff can be expected. The market demand curve $Q = \alpha_i^t - \beta_i^t P$ is depending on the environment and the performance of product delivered. In our case,

α_i^t, β_i^t describes the market based on market attractiveness (high or low) and product's technical performance (3 to 10, above market acceptance level) at the final status. Figure 4-9 shows the demand curves udder the combination of different levels of market attractiveness and technical performance. Once the demand curve is found for a final status, its respective market payoff can be obtained through a profit-maximizing pricing strategy, as illustrated in Figure 4-10.

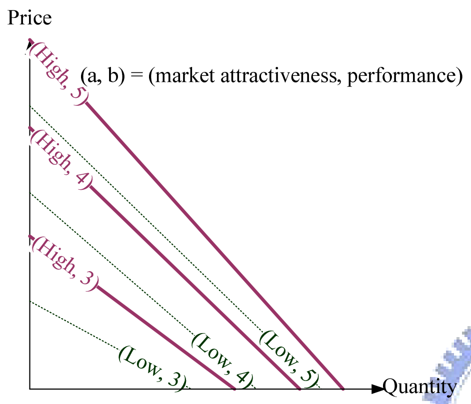

Figure 4-9 Demand curves: market attractiveness and technical performance

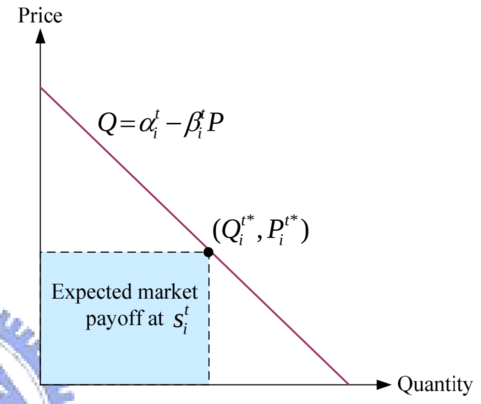

Figure 4-10 Result of a profit-maximization pricing strategy

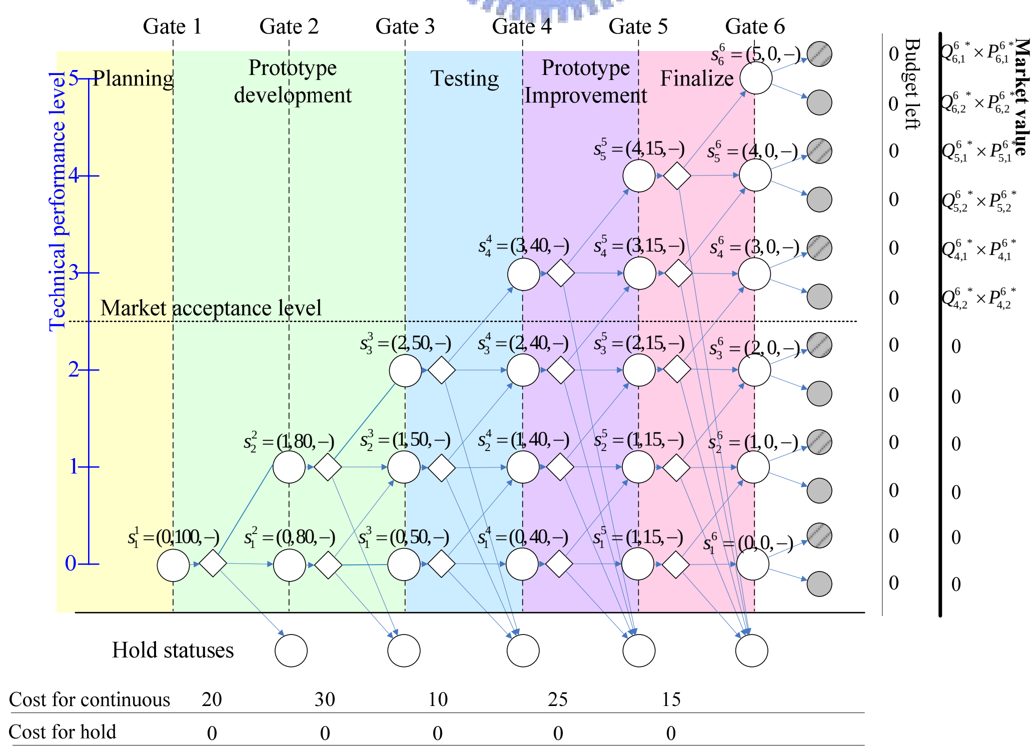

Figure 4-11 Market values for statuses at the final gate

Figure 4-11 shows the decision tree with the market values calculated for statuses at the final gate.

4.3.4. Evaluate synergy value

Besides market payoff which can be realized at the end nodes, synergy value is another form of project value that rises during the process of development. Though more complex to be estimated, synergy value should not be ignored. According to Wikipedia[2], Synergy refers to the phenomenon in which two or more discrete influences or agents acting together create an effect greater than that predicted by knowing only the separate effects of the individual agents.

"Interdependence creates the possibility of synergy, where each person receives more than they put in." (Lewis, 2003) Three types of interdependence (or interaction) have been agreed in the R&D literature (Asker and Tyebjee, 1978; Backer and Freeland, 1975; Gear and Cowie, 1980): (1) cost or resource utilization interaction, (2) outcome, probability, or technical interaction, and (3) benefit, payoff, or effect interaction. From the three types of interdependence, three types of corresponding synergy are derived: cost synergy value, benefit synergy value, and technical synergy value.

As illustrated in Figure 4-12, the three types of synergies are accounted at different statuses: cost synergy is accounted during development gates, while technical and benefit synergy are accounted at the final gate. The ways for evaluate these synergies are explained in the following paragraphs.

[2] Definition of synergy in Wikipedia: http://en.wikipedia.org/wiki/Synergy

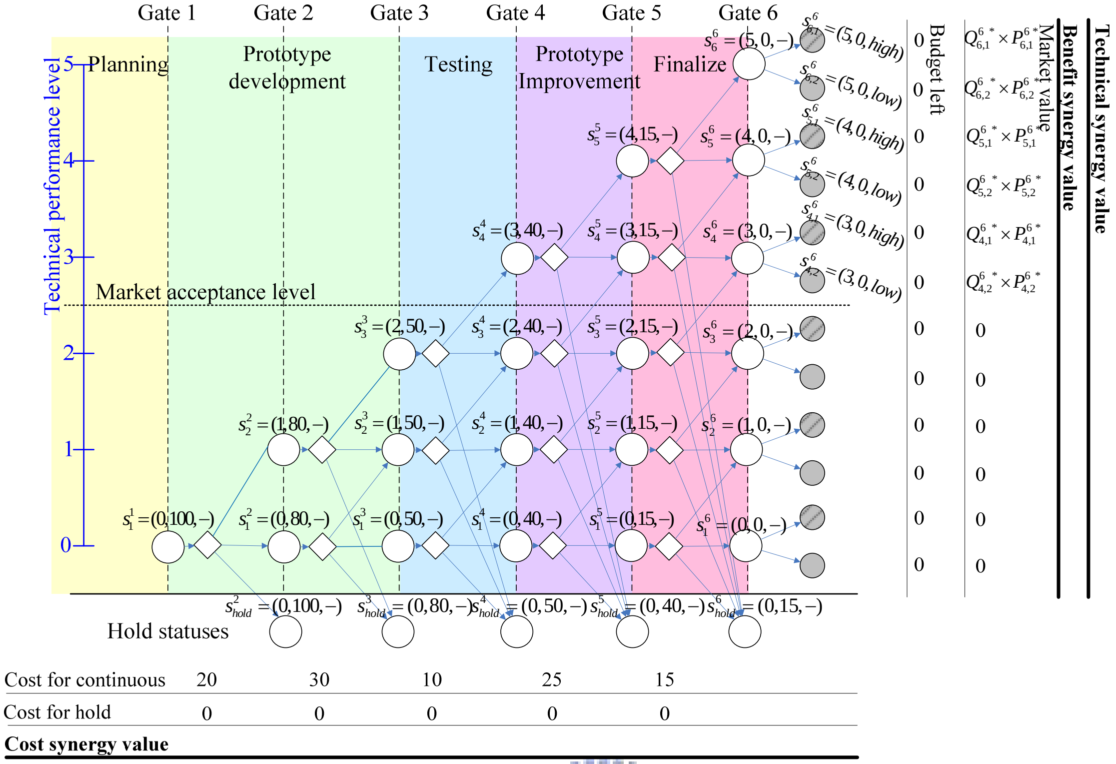

Figure 4-12 Cost, technical, and benefit synergy

(1) Cost synergy value—

Cost synergy stems from the concept of fixed cost sharing. The shared resource that has the fixed cost nature could be laboratory equipments, facilities, machines, and so on. In the portfolio, projects utilizing the same kind of these resources will generate cost synergy when considering individually.

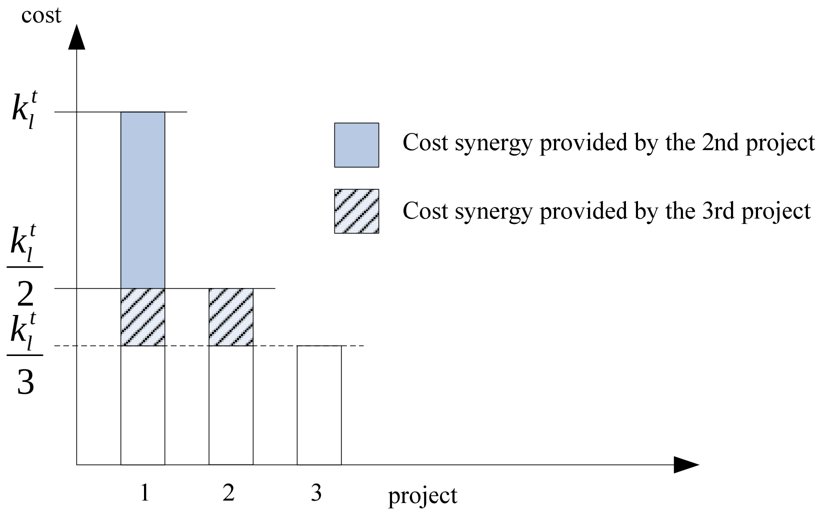

Figure 4-13 Concept of cost synergy

Figure 4-13 demonstrates the concept of cost synergy, when an additional project utilizing the shared resource *l*. The additional project *a*'s synergy value on cost through sharing resource *l* with other projects is then $Sc_l^t = \left(\frac{k_l^t}{n_l^t} - \frac{k_l^t}{n_l^t+1}\right) \times n_l^t = \frac{k_l^t}{n_l^t+1}$, where

n_l^t	number of projects already sharing resource *l* over period *t*
k_l^t	fix cost of resource *l* over period *t*
$\frac{k_l^t}{n_l^t}$	amortized fix cost for projects sharing resource *l* before initiating project proposal *a*
$\frac{k_l^t}{n_l^t+1}$	amortized fix cost for projects sharing resource *l* if project proposal *a* is initiated

Total cost synergy provided by project a at gate *t* is

$Sc^t = \sum_{l \in L} Sc_l^t$, where *L* is the set of all sharable resources

(2) Technical synergy value—

Technical synergy occurs when the success of a given project has influence on the outcome other projects. For example, if the project proposal *a* is successfully developed, its resulting technology would contribute to the success rate of other existing projects. This technical synergy of project *a* should be accounted as the increased expected value of the affected projects.

Figure 4-14 shows the decision tree of another existing project *x* whose transition probability is affected by the outcome of project *a*, which is under estimation. If project *a* succeeded at gate *T*, it will, as the same time, start to affect project *x* on its transition probability between subsequent nodes. This change in transition probability will result in a change in the value of project *x*. The difference between project *x*'s affected and not affected values is then accounted as the technical synergy provided by project proposal *a*.

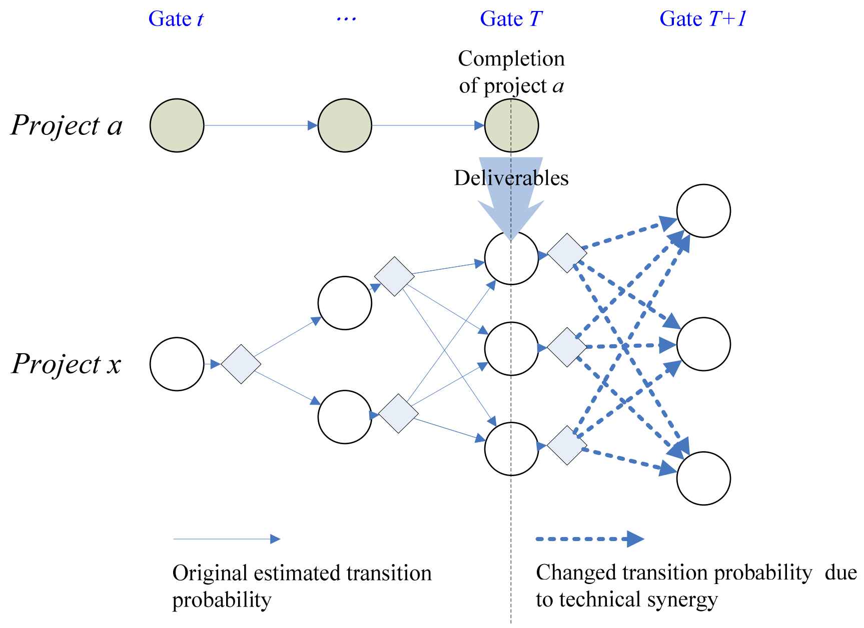

Figure 4-14 Accounting technical synergy

$V(s_x)$ original value of project x

$V(s_x, a)$ value of project x affected by the outcome of project a

Technical synergy between proposed project a and an existing project x

$$St_x = V(s_x, a) - V(s_x)$$

Overall technical synergy provided by proposed project a

$$St = \sum_{x \in \mathbf{p}, x \neq a} St_x$$

$\mathbf{p}$ is the portfolio of project

(3)Benefit synergy value--

The third kind of synergy occurs when the outcome of the project affects other existing products on their sales, unit price, or production cost. The benefit synergy appears in the form of increscent of other products market payoff, as shown in Figure 4-15.

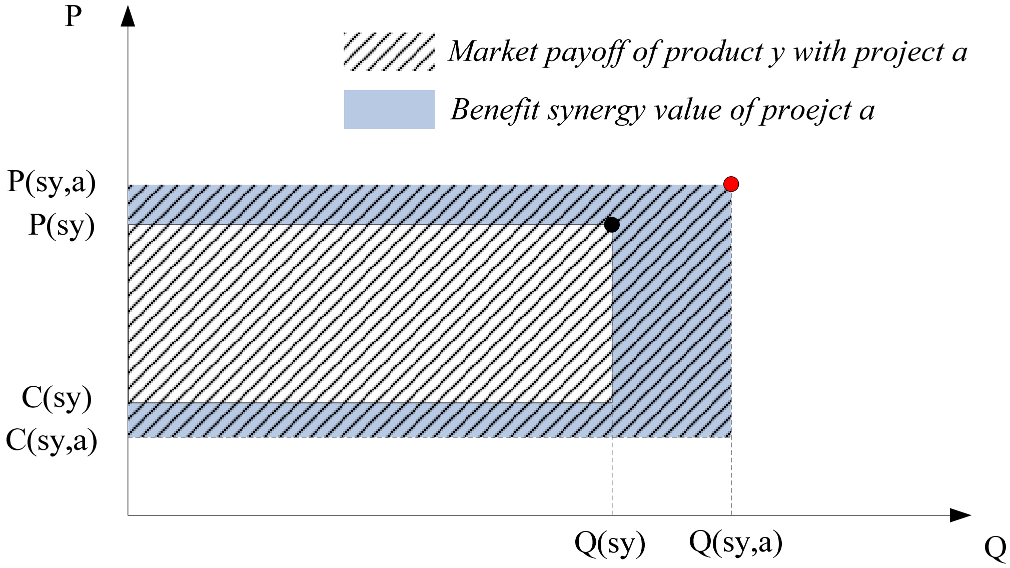

Figure 4-15 Concept of benefit synergy

Benefit synergy may appear in three kinds of possible effects to existing product:

- Possible change in *sales* of an existing product y

$Q(s_y)$ original sales quantity of product *y*

$Q(s_y,a)$ new sales of product *y* affected by project *a* at the time project a is completed

- Possible change in *unit price* of an existing product y estimated at time t

$P(s_y)$ original price of product *y*

$P(s_y,a)$ price of product y affected by project *a* at the time project a is completed

- Possible change in *unit production cost* of an existing product y

$C(s_y)$ product *y*'s original unit production cost

$C(s_y,a)$ new unit cost of product y affected by project *a* at the time project a is completed

Product y's original market payoff, that is, without the consideration of project *a* is

$$MV(s_y)=Q(s_y)\times\left(P(s_y)-C(s_y)\right)$$

Product y's market payoff with the effect of project a's delivery will become

$$MV\left(s_y,a\right)=Q\left(s_y,a\right)\times\left(P\left(s_y,a\right)-C\left(s_y,a\right)\right)$$

Benefit synergy between project a and an existing product y is defined as

$$Sb_y = MV\left(s_y,a\right)-MV\left(s_y\right)$$

Thus, the overall benefit synergy provided by project a at the time a is completed will be:

$$Sb=\sum_{y\in\mathbf{Y}} Sb_y$$

$y\in\mathbf{Y}$ all existing product at the time project a is finished

4.4. Obtain project value

The project value, which we are aiming to evaluate in this chapter, is the value obtained at the project's current status. The way to obtain status value is a backward process, as illustrated in Figure 4-16. The value of final nodes is first obtained, and these values then become the basis of calculating values of former nodes.

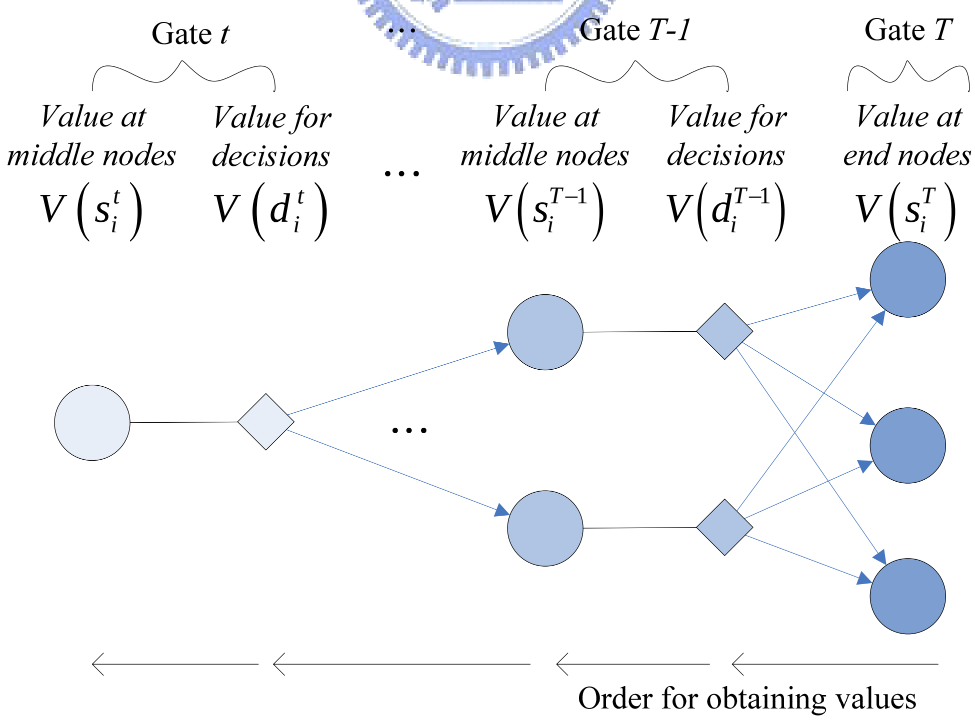

Figure 4-16 Values at statuses (nodes) and decisions

Different types of value are accounted at different stages of the development process. Market payoff, technical synergy, benefit synergy, and budget left are accounted at the end nodes where they are realized. On the other hand, costs for decision and cost synergy are accounted at middle nodes where decisions are made and money is invested.

Steps for obtaining node values:

1. First we calculate the value at each end node (statuses at hold or at the final gate $t = T$). The value is obtained by the summation of market payoff, technical and benefit synergy, and budget left at the ending statuses.

   Statuses at final gate: $V(s_i^T) = MV_i^T + St + Sb + budget$

   Statuses at hold: $V(s_{hold}^t) = Sc^t$

2. Then the value for decisions in the former gate $T-1$ is obtained through an expected value concept. Also, the cost for the each decision is accounted respectively.

   $$V(d_i^{T-1}) = \sum_{j=1}^{n^T} P_{i,j}^{T-1}(d_i^{T-1}) \cdot V(s_j^T) - c\left(d_i^{T-1}\right)$$
   $$i = 1,\ldots,n^{T-1};\ j = 1,\ldots,n^T;\ s_j^T \in S^T;\ d_i^{T-1} \in D_i^{T-1}$$

3. The value at the former gate is then obtained through choosing the most valuable decision. Synergy value occurring at this status is also accounted.

   $$V(s_i^{T-1}) = \max_{d_i^{T-1} \in D_i^{T-1}} \left[V(d_i^{T-1})\right] + Sc^{T-1}$$

4. Repeat step 2 and 3 using the values obtained at its successive gates for evaluating decision and status nodes at $t = T-2,\ T-3,\ldots,$ and so on, until reaching the current gate. The value acquired for the current status node is then the value of project which we are aiming to obtain in this chapter.

Decision nodes: $V(d_i^t) = \sum_{j=1}^{n^T} P_{i,j}^t(d_i^t) \cdot V(s_j^{t+1}) - c\left(d_i^t\right)$

$$i = 1,\ldots,n^t;\ j = 1,\ldots,n^{t+1};\ t = 1,\ldots,T;\ s_i^t \in S^t;\ d_i^t \in D_i^t$$

Status nodes: $V(s_i^t) = \max_{d_i^t \in D_i^t}\left[V(d_i^t)\right] + Sc_i^t$

5. Discussion and future studies

This study aims to provide a conceptual framework for portfolio management in adapting the rapid change in external and internal environments. This dynamic portfolio is a complement to the typical periodical portfolio review. The idea is that portfolio reviews may become more effective when it can be triggered by critical information than solely based on time intervals. Thus, we believe that a previously identified set of possible change factors will contribute in quick detection of change thus initiates the adjusting activities. Also, s systematic portfolio evaluation approach allows manager to quickly evaluate the gap between portfolio goals and performances. This approach does not require all information in the portfolio, and outcomes are clear for decision. Thus, the whole review board does not have to gather for adjustment decisions. The review board can still meet quarterly for overall portfolio decisions, while adjustments triggered by change could be easily made by related managements. With a much lower cost, the proposed dynamic portfolio can be performed constantly, thus keeps the portfolio on the right track.

A subsidiary part of this study is a project evaluation approach that supports the evaluation of portfolio performance, which is a critical and basic piece of information for decision-making. When evaluating a portfolio, one should not ignore the consideration of the high uncertainty within and complex interaction between projects. The decision tree approach is a way that reflects the possibility of control actions during development as a response to uncertain outcomes. Synergy values are then the way we account the effects of project interactions.

Requiring a limited amount of project information and top management devotion, the dynamic portfolio complements the periodical portfolio review and provides the advantage of quick response to critical change information, thus keeps the portfolio on track no matter how the environments change.

Regarding the directions for future studies, case studies are needed for validation of the concept. Also, due to the complex calculations required in the evaluation of project and synergy values when associated with probabilities, there is a need for a simplified calculation in order to be friendlier to take into practice.

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