Instituto Universitário de Lisboa

Project Selection & Portfolio Considering Strategy Orientation and Resource Limitation—Huashi Installation Engineering Company

LUO Wei

Thesis submitted as partial requirement for the conferral of the degree of

Doctor of Management

Supervisor:

Prof. Leandro Pereira, Assistant Invited Professor, ISCTE University Institute of Lisbon

Co-supervisor:

Prof. YAN Pengyu, Associate Professor, University of Electronic Science and Technology of China, School of Management and Economics

January, 2019

ISCTE IUL
Instituto Universitário de Lisboa

Project Selection & Portfolio Considering Strategy Orientation and Resource Limitation—Huashi Installation Engineering Company

LUO Wei

ISCTE IUL
Instituto Universitário de Lisboa

Project Selection & Portfolio Considering Strategy Orientation and Resource Limitation—Huashi Installation Engineering Company

LUO Wei

Thesis submitted as partial requirement for the conferral of the degree of

Doctor of Management

Jury:

President: Professor Ana Simaens, Assistant Professor, ISCTE-IUL

Prorf.XIAO, Wen, Associate Professor, UESTC

Prof. LIU, Lei, Professor, UESTC

Prof. João Manuel Afonso Geraldes, Professor, Instituto Piaget

Prof. Leandro Pereira, Assistant Professor, ISCTE-IUL

January, 2019

[This page is deliberately left blank.]

ISCTE IUL
Instituto Universitário de Lisboa

Statement of honor

Submission of master's dissertation or project work or doctoral thesis

I the undersigned state on my honor that:

- The work submitted herewith is original and of my exclusive authorship and that I have indicated all the sources used.
- I give my permission for my work to be put through Safe Assign plagiarism detection tool.
- I am familiar with the ISCTE-IUL Student Disciplinary Regulations and the ISCTE-IUL Code of Academic Conduct.
- I am aware that plagiarism, self-plagiarism or copying constitutes an academic violation.

Full name LUO Wei

Course Doctor of management

Student number 201314

Email address wellwellluo@163.com

Personal email address

Telephone number +86 13348999666

ISCTE-IUL, 21/1/2019

Signed Luowei 罗伟

[This page is deliberately left blank.]

Abstract

With the rapid development of Chinese construction and installation industry, many companies undertook various types of construction and installation projects in the past decades. However, it is observed that most of these companies just focused on their cash flows when they make decisions on project selection. It is true that the cash flow is a fundamental and important metric but this metric hardly reflects the comprehensive effects of projects on the companies' development and strategy implementation. Thus, besides the cash flow metric, the company's strategic objectives in terms of technology innovation, management innovation, and social responsibility need to be involved in the procedure of project portfolio and selection. On the other hand, scarce resources in a company hardly support executions of all candidate projects simultaneously, and thus the allocation of scarce resources within the portfolio has to be considered additionally. Otherwise, there may be some conflicts of using the resources within the selected projects in practice.

In the existing literature, it has been proved that a reasonable project portfolio management is an effective way to implement company strategy through the success of the selected projects. Some research has proposed general frameworks and methods for project selection and portfolio with respect to the company's strategy. However, these general frameworks and methods are hardly directly applied to a specific industry and company since they fail to capture the characteristics of a specific industry and companies. Moreover, some existing researchers have enforced the resources limitation into their project selection and portfolio procedure. However, in the operational levels, the allocation of scarce resources among the selected projects is seldom considered and integrated to the project selection and portfolio procedure, which results in that the generated project portfolio scheme is impractical or cannot be carried out in specific industry and company.

Motivated by both industry and existing literature, this thesis studies project portfolio problem with considering a company's strategy and resource allocation. The following two questions are addressed in this study: 1) How to comprehensively evaluate projects according to a company's predetermined strategy? 2) How to select projects and allocate scarce resources in order to maximize the whole strategic contribution of the project portfolio? To answer the first question above, we first decompose a company's predetermined strategic goal into four objectives: *financial objective, management innovation, technological innovation, and social responsibility*. We then apply the analytic hierarchy process (AHP) method to establish a project evaluation system composed of hierarchical criteria and the relative weights of the criteria to the strategic goal. To solve the second question, we define an evolution metric to measure a project’s contribution ratio to the strategic goal by consuming per unit scarce resource. We then formulate the second problem as a 0-1 *Knapsac*k problem by mixed integer programming method and further develop a heuristic rule to determine the allocation of the scarce resource among the selected projects. Finally, the proposed project evaluation system and resource allocation approaches are applied to a real case in Huashi Installation Engineering Company (HIEC), a state-owned installation engineering enterprise in Sichuan Province of China. The application results show that our approach helps HIEC to improve the performance of the project portfolio management. The results of this thesis give some inspiration and guidelines to project portfolio management in the construction and installation of industry and other industries in China.

Keywords: Construction and installation projects; Project portfolio management; Evaluation and selection; Resources-constraint

JEL: O22; M11

Resumo

Com o rápido desenvolvimento da indústria chinesa de construção, muitas empresas empreenderam vários tipos de projetos de construção e instalação nas últimas décadas. No entanto, constatou-se que a maioria dessas empresas se concentra apenas em fluxos financeiros quando tomam decisões sobre a seleção de projetos. É um facto que os fluxos financeiros constituem-se como uma métrica fundamental e importante, no entanto essa métrica dificilmente reflete os efeitos abrangentes dos projetos sobre o desenvolvimento das empresas e a sua implementação estratégica. Assim, além da métrica dos fluxos financeiros, os objetivos estratégicos das empresas em termos de inovação tecnológica, gestão da inovação e responsabilidade social precisam de estar envolvidos num processo de seleção e gestão de portfólio de projetos. Por outro lado, os poucos recursos existentes numa empresa dificilmente suportam a execução de diversos projetos a que uma empresa se candidate em simultâneo, portanto, a alocação dos poucos recursos existentes dentro do portfólio de projetos tem que ser considerada adicionalmente. Caso contrário, poderão existir alguns conflitos sobre a gestão dos projetos que se encontram em execução.

Durante a revisão de literatura, foi verificado que uma gestão equilibrada do portfólio de projetos traduz-se numa maneira efetiva de implementar a estratégia de uma companhia através do sucesso dos projetos selecionados. Foi efetuada uma pesquisa que propôs uma metodologia geral bem como métodos para a seleção de portfolios de projetos em linha com a estratégia da empresa. No entanto, essas estruturas e métodos gerais dificilmente são aplicados diretamente a uma indústria ou a uma empresa específica, uma vez que não conseguem capturar as características específicas dessa indústria ou empresa. Além disso, alguns autores reforçaram, o facto das limitações dos recursos nos seus projetos e processos de portfólio. No entanto, em níveis operacionais, a alocação de recursos dispersos entre os diversos projetos selecionados é raramente considerada e integrada no processo de seleção do portfólio de projetos, ou seja, a estrutura do portfólio em projeto não é realista ou então não pode ser colocada em prática numa indústria ou empresa específica.

Motivado pela indústria e pela literatura existente, esta tese estuda o problema do portfólio de projetos considerando a estratégia definida por uma empresa e a sua alocação de recursos. Neste estudo são abordadas duas questões: 1) como avaliar de forma abrangente os projetos de acordo com a estratégia predefinida de uma empresa? 2) como selecionar projetos e alocar os poucos recursos para maximizar toda a contribuição estratégica do portfólio de projetos? Para responder à primeira questão, primeiro é desagrupado o objetivo estratégico pré-definido de uma empresa em quatro grandes objetivos: objetivo financeiro, gestão de inovação, inovação tecnológica e responsabilidade social. Em seguida, aplicamos o método do processo de hierarquia analítica (AHP) para estabelecer um sistema de avaliação de projeto composto por critérios hierárquicos e ponderações relativas para a definição do objetivo estratégico. A resposta à segunda questão foi obtida através da elaboração de uma métrica evolutiva que permitiu medir o rácio de contribuição de um projeto para um objetivo estratégico através da análise da contribuição de cada recurso num dado projeto. Posteriormente, foi definido o segundo problema como um problema 0-1 *Knapsack* através da programação linear mista e, em seguida, através de uma função heurística que permitiu determinar a alocação dos poucos recursos existentes numa determinada empresa aos projetos selecionados. Por fim, o sistema evolutivo proposto e as métricas de alocação dos recursos existentes foram aplicados a um caso real, nomeadamente à empresa de engenharia Huashi (HIEC), uma empresa pública chinesa localizada na província de Sichuan. Os resultados da aplicação destes modelos demonstraram que a abordagem desenvolvida ajudou a HIEC a melhorar substancialmente o seu desempenho na gestão do portfólio de projetos. Os resultados desta tese providenciaram conhecimento e linhas gerais contributivas uma eficaz para a gestão do portfólio de projetos das diversas industrias na China.

Palavras Chave: Construção e instalação de projetos, gestão de portfolio de projetos, avaliação e seleção, constrangimento de recursos

JEL: O22; M11

Acknowledgments

I come from a small town.

Before I graduated from junior high school, I lived in the mountains in southwest China's with minority ethnic groups. I went to school in a small county, the imagination of outside world only stayed in the textbooks. In high school, I went to Xichang, a larger mixed minority city. To a rural child, a county is not only a small city, but also means that I have a deep-rooted cognition of the world: only two streets and the local accented dialect, where I once had my original imagination and vision of the world.

At that time, my dream was to have a job in the county: a reporter who could really see the truth of the world or a poet who could freely imagine the world. The key was to have a cabin on a cliff on the edge of the county. Working in the daytime, writing poems at night, listening to the wind in the morning, watching the stars at night, which is the happiness I wanted.

Then I went to the college, out of the small county, and away from the small village I ever lived. I came to Chengdu, a brand-new world.

I have lived in this city which is not my hometown for 30 years, and it’s been a crucial 30 years in my life. Time passed like the sands that I cannot hold, I changed from the youth to the middle age, but my thirst for knowledge never changed. I am so lucky to be admitted to the University of Electronic Science and Technology and the University of Lisbon to study for my doctor's degree. Dean Li Ping's game theory class, director Xiao Wen's methodology, professor Virginia and professor Nelson's corporate governance, and especially the meticulous guidance and enlightenment form professor Yan Pengyu and professor Leonardo, they showed me the broadness of knowledge, brought me a more brilliant and wonderful life. My body is no longer composed by those light poems and essays, but full of deep thinking. In the ordinary years, the thought they taught will accompany me for my whole lifetime.

During my study, I got my love and family, especially the continuation of my life, my daughter Luo Lingyue. I hope I could be a father who loves learning and thinking in her mind. The life I got is enough for me, thank god.

My graduation thesis is almost finished, and all of a sudden, I felt a deep desire from my heart: to love and think before I get old. I will read, think, and write as before, and live my life in the joy of learning. So, when I get really old, this experience and the words I write about it will not only be the memory of what I have gone through but also the evidence that I have loved lived and thought.

Contents

List of Tables

[This page is deliberately left blank.]

List of Figures

[This page is deliberately left blank.]

Chapter 1: Introduction

1.1 Background

With the rapid development of Chinese construction and installation industry, companies engaging in this industry, undertake many types of projects, such as civil engineering construction, architectural construction, and industrial architectural constructions. Some of these projects relate to company development and marketing, others relate to changes in production flows and management processes, etc (Cooper, Edgett, & Kleinschmidt, 2006). A managerial challenge for these companies is to select projects to constitute a suitable portfolio. However, most construction and installation companies in China just focus on how to successfully manage a single project or a group of projects to achieve a single objective, such as the expected schedule, cost and quality objectives specified in contracts (Zhu, 2015). Little attentions are paid on the relationship between the executed projects and the company’s strategy and considering the resource limitations. In some worst cases, the selected projects consume most resource but contribute little to the company’s strategy implement. Some companies consider the project selection but just focus on their cash flows when they make decisions on project selection. The cash flow is a fundamental and important metric (Wetekamp, 2011) but it hardly reflects the effects of projects in terms of the company’s technology innovation, management innovations, social responsibility and so on. Thus, the company’s strategy and objective need to be considered into the procedure of project selection.

For example, Huashi Installation Engineering Company (HIEC), a largest state-owned installation engineering company in Sichuan province of China, it undertook about 90 projects with a revenue of about 550 million yuan (approximately 70 million euro) in 2014. However, almost half of these projects are low-tech and low-value civil installation projects consuming nearly 50% of the company's resources but contributing less than 20% profit to the overall profit of the company. Furthermore, these executed projects have few positive effects on the improvement of the company's management capacity and technology innovations and social responsibility. Consequently, it is found that a large amount of resources is consumed by such low-tech and low-value projects.

On the other hand, resources in a company, including materials, human resource, capacity, equipment and so on, are limited and hardly support the executions of all projects simultaneously (Promislow, 1996; Pan & Liu, 2004; Huang & Niu, 2010). When making project selection, it does not only need to consider the strategy implement but also the resource-constraints. Therefore, the priorities of projects in using and consuming resource have to be determined and the company's resources need to be allocated within the selected projects.

In the existing literature, project portfolio theory (Archer & Ghasemzadeh, 1999) connects the strategy management to the operational project evaluation and selection. Project portfolio is a group of projects that compete and share for rare resources and are implemented under the auspices and management of a specific organization (Khalili-Damghani, Sadi-Nezhad, Lotfi, & Tavana, 2013), which includes interrelated organizational processes through which to evaluate, select, prioritize and allocate its limited resources to best accomplish organizational strategies that are aligned with its vision, mission and values (Martinsuo, 2013). Early research focuses on how to select and combine different types of projects to increase profits or decrease the total risk of enterprises (Cooper, 2001; Söderlund, 2004). Some research investigates the relationship between project portfolio management and the company's strategies management. It is shown that a reasonable project portfolio is an effective way to implement company strategy (Sanchez & Benoit, 2010; Kraiczy, Hack, & Kellermanns, 2014; Zeng & Wang, 2014; Irja, H, 2014). Then some research proposes general frameworks and methods of project selection and portfolio with considering the strategy of the company (Archer & Ghasemzadeh, 1999; Meskendahl, 2010; Tang, Bai, & Guo, 2012; Teller, Unger, Kock, & Gemünden, 2012).

Based on the above brief literature review, it is found that, firstly, a majority of the proposed frameworks and methods of project portfolio management are generalized methodologies. Although some researchers propose some specific frameworks and methods for a certain industry or s company, these results usually cannot be directly applied to the installation of engineering companies in the Chinese market and economic environment. Therefore, this thesis focuses on the specific frameworks and methods for installation engineering companies in the Chinese market and take HIEC as an instance to illustrate our proposed framework and method. Secondly, some researches enforce the resource limitation constraints to the project portfolio and selection procedure. However, proposed project portfolio schemes may impractical or cannot be carried out, because there are still conflicts of using the resources among the selected projects. Therefore, resources allocation in the operational level should also be considered the project portfolio and selection procedure.

1.2 Research Questions and Strategies

Based on the above reviews on both industry and literature, this thesis focuses on Chinese construction and installation industry and addresses the project selection and portfolio considering the company's strategy and the resource limitation. This study deals with the following two related questions, by using the theories and methods of project portfolio management, strategy management, and project evaluation and selection methodologies.

Question 1：How to comprehensively evaluate projects according to a company's predetermined strategy?

To solve this problem, we first analyze the company's predetermined strategic goal and decompose it into several measurable strategic objectives. Secondly, we construct a project evaluation system composed of hierarchical criteria and the relative weights of the criteria to the strategic goal.

Question 2：How to select the optimal projects and to allocate the limited resources to the projects?

To solve this problem, we first identify the company's scarce resources that restrict the implementation of multiple projects. Then we calculate a metric defined as the strategic contribution ratio of a project consuming per unit scarce resource. We then determine the priorities of projects in using resource according to the metric and select a reasonable project portfolio.

1.3 Research Results and Contributions

1.3.1 Research Results

According to the research questions raised in section 1.2, the following research results are obtained in this thesis.

(1) The framework of project selection and portfolio

According to the actual situation of Chinese construction and installation industry, the overall process of project selection and portfolio is constructed as in Figure 1-1.

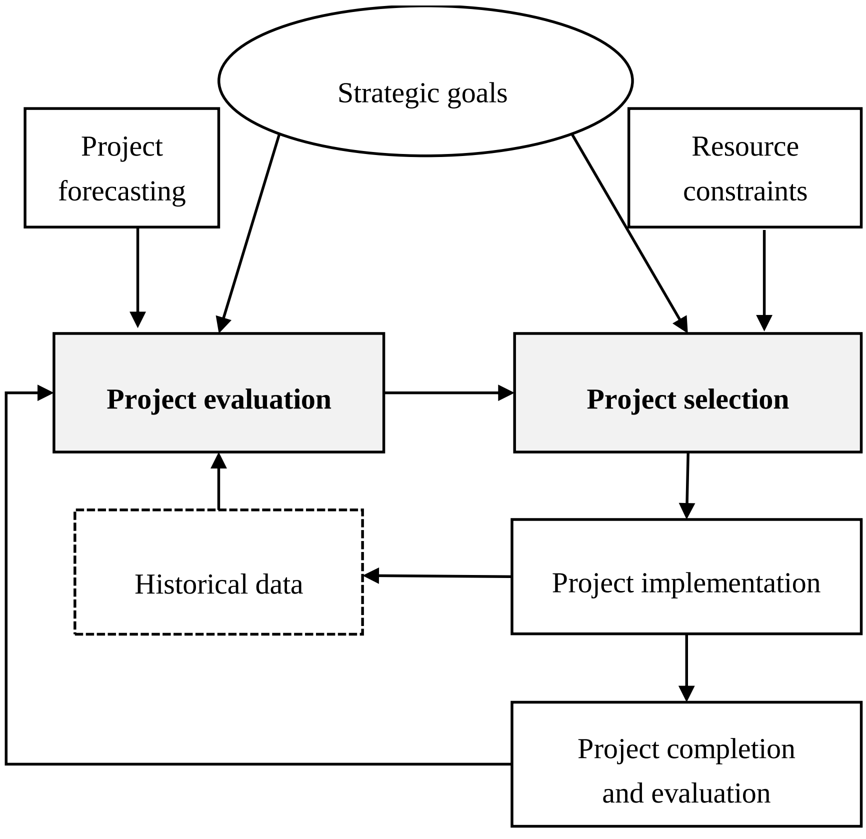


Figure 1-1 Framework of project selection and portfolio

Source: Author finishing

Figure 1-1 shows that project portfolio management process begins with forecasting and collecting candidate projects and establishes a project evaluation system based on the predetermined strategic goal and historical data. Then, the project portfolio is determined according to the contribution rate of the candidate project and the constraints of the scarce resources. The status of the selected projects and resource utilization are recorded during the implementations, and the project portfolio performance is evaluated after projects are completed. These records and assessment materials as the company's historical data will be used for adjusting the project evaluation system and selection methods in the next time.

(2) Project evaluation system based on the strategic goal

We divide a strategic goal into four objectives: financial objective, management innovation objective, technological innovation objective, and social responsibility objective. Then, the corresponding two-level quantifiable evaluation criteria are selected for the four objectives, respectively. Finally, a four-level project evaluation criteria system is constructed. By applying the hierarchical analysis method (AHP), the relative weights of hierarchical criteria are calculated.

(3) Project selection method considering resource constraints

We define and calculate the "strategic contribution rate” as the metric to confirm the priorities of the candidate projects to access the scarce resources. Such metric represents the contribution of the project by consuming per unit scarce resources to the company's strategic goal. Then, the company resources are allocated to the candidate projects according to the order of the projects’ priorities. The allocation procedure does not terminate until the remaining resources are unable to meet the demand of a single project. This method takes into account both the effect of the project on the realization of the strategic goal and the situation of the project consuming resources. Therefore, the selected project portfolio is more in line with the company strategic development and actual resource constraints.

1.3.2 Contributions and Significance

The research involved in this thesis has both important theoretical value and practical significance, which are summarized in the following two aspects.

(1) Theoretical contribution

Based the literature review in Section 2, it is found that majority of the early researches in project portfolio management concern on the how to combine the projects to increase the profits or decrease the total risk of companies. Some research proposes project evolution and selection methods with considering the strategy of the company. However, few studies consider the allocation of resources in the project portfolio management process. The determined project portfolio scheme may be impractical or cannot be conducted if the company's resource hardly supports the executions of these selected projects.

To deal with this issue, this thesis imposes the resources allocation into the project portfolio management by considering the scarce human resource (i.e., designers). Especially, the thesis first defines a selection metric calculated as the project's contribution ratio to the strategic goal when the project consuming per unit scarce resource. A mathematics mixed integer programming (MIP) model is then established to find an optimal project portfolio scheme with the maximized total strategic contribution of the selected projects. The formulated model can be seen as a 0-1 knapsack problem from an operational research filed (Martello & Toth, 1990). An efficient heuristic rule is developed to fast select projects and provide a good solution (project portfolio scheme) to practical managers. It is worthy to note that the proposed MIP model and heuristic rules are ready to be sued for the project selection and portfolio problem with resource constraint in other different industries and companies.

(2) Practical significance

With the rapid development of the Chinese real estate industry in recent years, the enterprises in the installation engineering industry grow fast and get great profits. However, most enterprises just focus on how to manage every single project to successfully satisfy the expected schedule, cost and quality objectives of each project. Little attentions are paid on the relationship between the selected projects and the company's strategic goal. Recently some generalized frameworks and methods of project portfolio management are proposed for specific industries and companies but they cannot be directly applied to the installation engineering industry in the Chinese market and economic environment, due to the characteristics of such companies.

This research captures the characteristics of Chinese construction and installation industry and proposes a specific project evaluation and selection framework and approach that connects the selected projects to the company's strategic goal as well as considering the resource limitation. Especially, an installation engineering company's strategic goal is first decomposed into four objectives: c. Then based on the review on the existing evaluation criteria in the literature (please see Table 4-1 in Chapter 4), a hierarchy criteria system is established for each objective above. The proposed approaches are based on the real situations of HIE company, which is a largest and representative company in the west of China, so results of this thesis are ready to be extended to other companies in Chinese construction and installation industry and other similar industries.

1.4 Main Contents

This thesis consists of six chapters and is organized as follows.

Chapter 1: *Introduction*. This chapter first introduces the research background and raise two questions need to be studied in this thesis. Then the research strategy and the main results and contribution are listed in this chapter.

Chapter 2: *Literature review*. Relevant literature in project portfolio management, project evaluation, and selection methods and other related theory are reviewed in this chapter.

Chapter 3: *Research framework and methodology*. Based on the literature review, we introduce the research framework and methodology used in this study.

Chapter 4: *Strategy-oriented Project Evaluation and Selection*. This chapter is the focus and core of the thesis. In this part, we establish the project evaluation system with respect to the strategic goal of a company and develop a method to select the projects with the resource limitation.

Chapter 5: *Application analysis*. The proposed evaluation and selection approaches are applied to HIEC and the application results are analyzed in this chapter.

Chapter 6: *Conclusion*. The main work and contributions are concluded in this chapter. The shortcomings of this thesis and future research direction are discussed as well.

Chapter 2: Literature Review

This chapter reviews the relevant theory and methodologies in the existing literature on project portfolio management.

2.1 Project and Project Management

2.1.1 The Definition of Project and Project Management

The project is an extremely universal and widely used concept. A narrowly defined project refers to an engineering project, and a broadly defined project includes activities other than the engineering project that meet the project definition. Project management is the use of specialized knowledge, skills, tools, and methods in project activities to enable projects to meet or exceed the needs and expectations of project designers (Kerzner & Kerzner, 2017). That means planning, organizing, coordinating, controlling and evaluating the whole process of the project to achieve the goal of completing the project.

Construction project management refers to the project management body planning, organizing, directing, coordinating and controlling all work within the whole life cycle of a construction project through the application of system engineering perspectives, theories and methods. Its core task is to achieve control over the objectives of construction projects such as quality, cost, and construction period, so as to meet the needs and expectations of the owners while achieving project functions（Martinsuo, 2013）.

Although projects are widely different in various fields and it is difficult to learn from each other's experiences, all of the projects still have some characteristics in common. Specifically, construction projects have the following three characteristics (Ding, 2014):

(1) One-time (Temporary)

Projects in the construction industry have a clear start and end date. The project will be terminated when a project has been completed or for some other reasons. The project will also be terminated when the completion of project objectives has been impossible. However, this does not mean that projects are short-lived. Sometimes a construction project may take only a few months, but sometimes a large-scale construction project may last for several years. The timing of the project is determined, but not uninterrupted.

(2) Specificity

No one has ever done a project of construction before, so the specificity of each project of construction is inevitable. For example, there are a number of classrooms around the world, but because of different construction teams, different materials and different construction sites. The consistency of construction project categories does not change the nature of each construction project.

(3) Progressive Elaboration

Progressive elaboration is the comprehensive characteristics of one-time and specificity. This is because each construction project has specificity, and each project also has progressive elaboration, that is, with the project construction progress, the projects' characteristics are gradually clear and specific with the progress of construction project. In the early stages of a project of construction, the characteristics of a construction project are vague and general. But with the progress of the construction process, they will gradually become clear and the project team's professional knowledge will also work. Although the characteristics of construction projects will be a gradually progressive elaboration, the basic scope of work should be kept in a reasonable range.

Project Management Institute (PMI) defines the "project management" as: "Using the expertise, skills, tools, and methods of project activities to enable or exceed the needs and expectations of the project designer." That is, planning, organizing, coordinating, controlling, and evaluating the entire process of the project, which achieves the goal of completing a project.

Ferrada, Núñez, Neyem, Serpell, and Sepúlveda (2016) refers that the construction project management is the body of project management plans, it organizes, directs, coordinates and controls all the work of the whole life cycle of a construction project by using the theory and method of system engineering. Its core task is to achieve control of quality, cost, duration, and other construction project objectives, so as to meet the project's function, customer needs, and expectations of the project.

2.1.2 Project Life Cycle

The four phases, start, plan, implementation, and completion, of the project from start to finish are called the project life cycle. Like the general project, the construction project also has its life cycle. Combined with the unique characteristics of the construction project, and according to the performance of the whole process life cycle of the construction project, the construction project life cycle can be divided into four phases: concept phase, plan phase, implementation phase, and completion phase.

（1） Construction project concept phase

At this stage, the client needs to provide a Request for Proposal (RFP) to the contractor or project undertaker. After the contractor receives the request for proposals, they first determine the type of project and design the plan according to the content and requirements of the requirements proposal. Then they discuss and develop alternatives. Finally, the project plan was determined and the project feasibility was analyzed. At the start-up phase of the project, fewer resources are required. The main job of this period was to identify the type of project and conceive the project. These jobs are purely mental work and require fewer participants.

This phase lasts for a short time. Because when customers have project requirements, they generally provide the RFP to multiple companies that have the same type of service or product. And then they select the contractor that they think will best meet the requirements of the company, among the contractors who replied to the RFP. This form is tantamount to the way of bidding and bidding, and the competition among contractors is fierce. This not only tests the strength of the contractor, but also efficiency.

Therefore, if the contractor wants to win the project after receiving the RFP, he must shorten the time to identify the project type and design the project plan. Otherwise, he is very likely to miss important business opportunities. Although the project's start-up period consumes less time and resources, the importance of the entire project is very obvious. For the contractor, it directly determines whether the contractor can obtain the contractual right to the project. For the project implementer, it directly determines the project expectations and basic structure.

（2） *Construction project plan phase*

It is generally believed that after the contractor has signed a project cooperation contract with the customer, it means the end of the first phase and officially enters the second phase, the planning phase. After the first phase of preparation, the contractor has a complete and executable scheme, marking that the project cycle has officially opened the second phase. The tasks of the contractor at this stage include: First, the development of the scheme paper, the main contents of which include determining the scope of work, carrying out project work decomposition, resource and cost estimation, time estimation, schedule, personnel arrangement. Second, the formulation of project plan, including schedule planning, cost planning, quality management planning, organizational planning, resource allocation planning, and risk management planning.

（3） *Construction project implementation phase*

After the second phase finished, the project officially entered the third phase, the implementation phase. The main task at this stage is to implement a pre-planned project plan and to supervise and guide the entire process. During the execution of the project, the input of resources will gradually reach the maximum as the project progresses, which tests the strength and professionalism of the contractor.

In the third phase, the supervision, control and other ancillary work of the management began to reflect its importance. Even if a complete project plan has been developed, the implementation of the project is still affected by many factors. If there are major mistakes or accidents, the project still cannot be completed smoothly. Therefore, during the implementation period of the project, the supervision of the management department and the prevention of risks are important guarantees to ensure the completion of the project on schedule.

（4） *Construction project completion phase*

The final phase of the project cycle is the completion of the project. When it is clear that the project is about to be completed, or will be terminated, it marks the end of the project.

The main work of the project at the end of the project includes completion, acceptance, handover of the project, evaluation, and summary of the project, and commissioning of the project. The finishing touches of the project during this period cannot be ignored. It is necessary to leave a good impression of the customer from beginning to end and lay the foundation for the next cooperation.

2.2 Project Portfolio

2.2.1 Project Portfolio

Archer and Ghasemzadeh (1999) define the "project portfolio" as: "A set of projects executed by a specific organization or executives". Projects could be related or independent but have the same strategic goal and compete for limited resources. The PMI (2014) thinks project portfolio is a combination that through efficient management of projects and programs to satisfy the strategic objectives of the organization. Cooper (2001) divides the project portfolio into static project portfolio and dynamic project portfolio. Static project portfolio refers to the establishment of a project portfolio in which the individual projects are implemented simultaneously. Dynamic portfolio refers to the process of adding a new project into an existing portfolio. This thesis addresses the static project portfolio, which is usually determined at the beginning of each year.

Project Portfolio Management is able to be understood as a set of management ideas and strategies of multiple projects (Martinsuo, 2013). That is a process, in line with company strategic goals under the premise that dynamically determines, evaluates and manages the company project to realize the purpose of accurately selecting the superiority projects, strictly controls the potential risks, project progress, and project relations, as well as creates more profits for the company.

2.2.2 Effects of Project Portfolio

The project portfolio is often faced with what should be chosen and what should be discarded. The best way to solve these problems is to keep pace with the company strategy and accurately adjust the requirements and criteria for the project portfolio. Among them, managers should also consider the scope of the project that company can afford, which is company capabilities, as well as company needs what projects, which is company goals (Bai, Bai, & Guo, 2016). The project portfolio is also considered as an organizational activity that enables project decision making with limited company resources.

For companies, especially project-driven construction companies, the project portfolio has the following functions (Cao, Bai, & Guo, 2014; Walker, 2015):

(1) Improving the Core Competitiveness of Company

The limited human resources, material and financial resources often lead the most company to choose "small" projects with low investment, low risk, and short duration. Generally speaking, these projects have no public help to the development and growth of a company or cannot improve the technological innovation level and overall competitiveness of the company. However, "big" projects that help the company to improve their competitive advantages and bring about improvements in their actual technological level have not received enough attention, which loses some advantageous opportunities to cultivate innovative technical talents and core competitiveness for the company. Through the reasonable project portfolio strategy, the project selection ought to be in line with the companies' development strategy and help to improve the ability to carry out projects, which is of great significance for companies to consolidate and enhance industry status and thus improve core competitiveness.

(2) Executing the Company Development Strategy

With the continuous and reasonable evaluation mechanism and selection criteria of a project, the companies can select a project portfolio among different projects types. This way is very suitable for its strategy, can achieve rational allocation, utilization of resources, and ensures maximum profits while laying the foundation for the company's strategic goals for the next stage. Also, the development and use of ever-changing project selection mechanisms have increased the efficiency and reliability of the managers responsible for different projects (Zhang, 2010).

(3) Balancing the Relationship Between Company Projects

A company has different candidate projects to be chosen every time in a while, so the company must balance the risk and the revenue level between different projects through the flexible project combination mechanisms. And the company must make the accurate judgment to itself resource utilization, so that the limited resources can be allocated to the worthwhile projects, which ensure that the company can always achieve the strategy global, such as the maximum profits.

Obviously, the accurate and efficient project portfolio is a valid methodology, which enables a company to make rational use of existing resources, to fully adapt to external environment changes, to improve the overall capacity of project execution, and to reduce the potential risks of project selection (Klingebiel & Rammer, 2014).

2.3 Processes of Project Portfolio

To promote the long-term development of the company, managers should accurately identify and discard the candidate projects that have lower correlations to the company's strategic goals or even run in the opposite direction with the strategic goals. The most effective way to achieve this goal is to establish a complete evaluation mechanism that can organically combine the project selection concerning the company strategic objectives. Archer and Ghasemzadeh (1999) indicate that the project portfolio selection can be split into three stages: the stage of strategic planning, the stage of single project evaluation and the stage of project portfolio selection. They are shown in Figure 2-1.

(1) The first stage: Strategic Planning

The primary function in the first stage of the project portfolio is to identify the existing situation. The purpose of this is to validate the company strategy before the project portfolio and confirm whether it is compatible with the current environment and the actual situation of the company. If they are not compatible, managers should make the appropriate adjustments. The strategic goal is the embodiment of company mission and function, that is, every department that relates to the survival of company needs to have a goal, and the goal also depends on the different strategies of the individual company. Therefore, the company strategic goals are diversified. They include both economic and non-economic goal and also include both qualitative and quantitative goals. They are two steps:

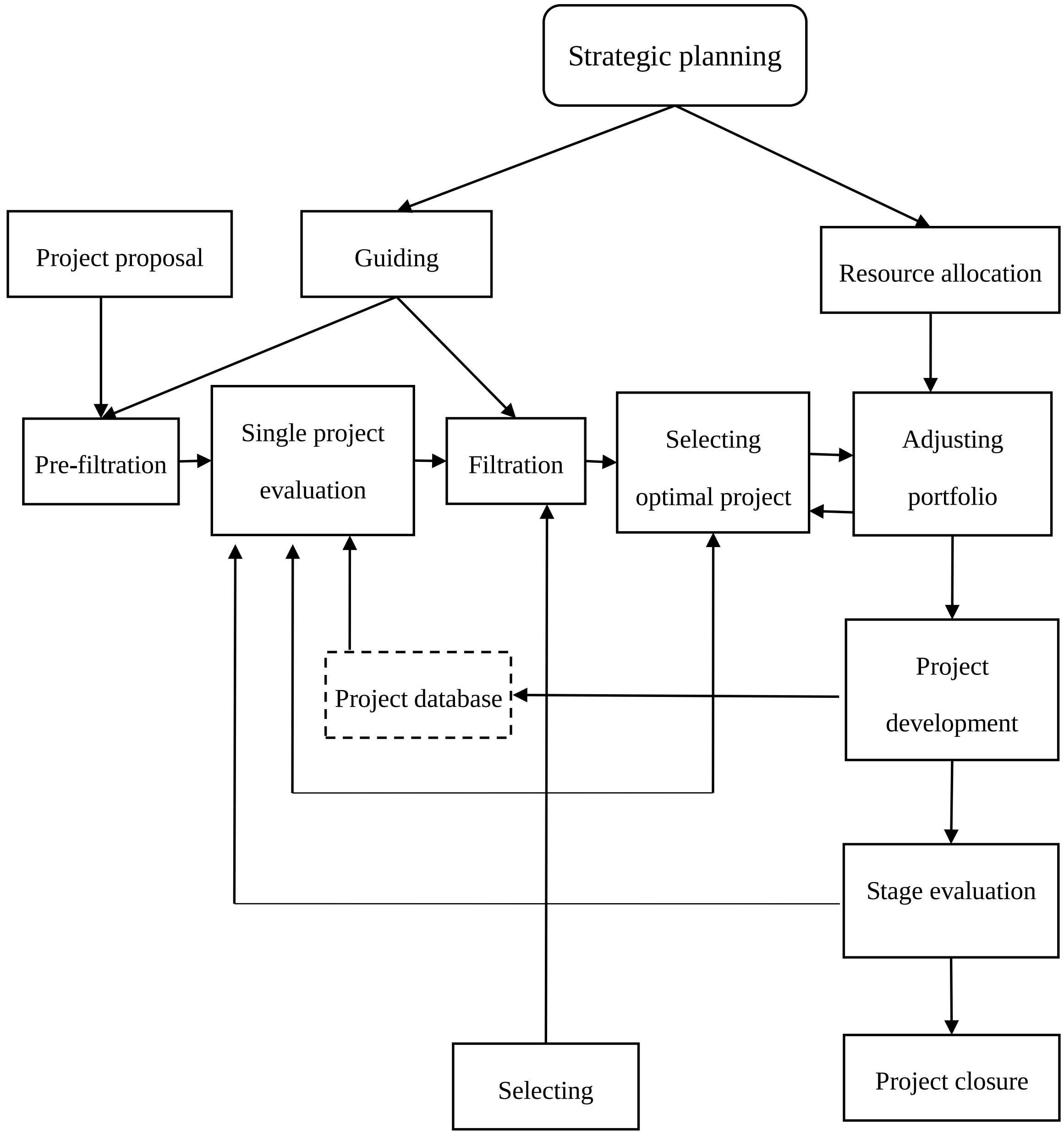


Figure 2-1 Project Portfolio Selection System

Source: Archer and Ghasemzadeh (1999)

1) First, it is necessary to clarify whether the company has established a complete strategic goal and long-term planning. By using the balanced scorecard method, the company's strategic goals are gradually decomposed, transforming from financial, customer, internal business processes, learning and growth into a balanced system of mutual influence. And then through the balance system, the contribution rate of candidate projects to achieve the strategic goals will be analyzed and evaluated.

2) Secondly, building a system for identifying the type of projects. Managers must establish a complete set of the process of describing the characteristics of the projects, such as the project description, project objectives, project sponsors, the correlation with the company strategic goals, project cost estimates, project revenues, and risks. Also, before further follow-up research and investment on the project, minimum contribution rate standards, as part of the project, need to be established, and there are underlying conditions that must be realized for the candidate projects.

The company management also called the strategic project office, which is in charge of the implementation of project portfolio assessment process, evaluates every project and initially determines the synergistic effects between these projects and the company strategic goal. If the evaluation results are satisfactory, the project can enter the next stage of the inspection. If there are contradictions or low correlation, the project should be eliminated in the first stage.

(2) The second stage: Single Project Evaluation

This stage is mainly to evaluate all the candidate projects systematically. Through the decomposition of the strategic goal, an evaluation system is established consisted of a set of criteria like the first-level indicators, the second-level indicators, and third-level indicators. The first-level indicators are the financial indicators, technical feasibility, market competitiveness prospects, and the degree of strategic matching. The second-level indicators and third-level indicators are subs- indicators under the first-level indicators.

Starting from a single project, a specific project evaluation method is used to evaluate and screen each project. Projects that do not realize the company strategic goal or fail to realize the basic requirements are eliminated. The specific steps are as follows:

1) Managers collect data and indicators of various aspects of the project that cover the expected revenues, costs, resource requirements, potential risks, customer expectations, software and hardware requirements, project mutual influence and resource conflicts. The project database formed in this step is the basis of the order of priority of the project and the construction of the specific project portfolio evaluation model in the next stage.

2) Managers must use the evaluation indicators in line with the status of the development of the company to establish a sound evaluation system, and then use the subjective score of experts or objective assignment based on actual data to calculate the weight of each indicator. After that, the candidate project is evaluated and classified separately from several perspectives, such as value contribution, customer orientation, operational efficiency, and development potential, using the comprehensive and integrated approach respectively. The candidate projects are arranged in order of priority. Among them, the projects that are not in line with the company strategic goals are eliminated and the other projects that realize the company strategic goals will become the options for entering the third stage.

(3) The third stage: Project Portfolio Selection

The stage of project portfolio selection is to make an organic combination of the projects and to consider the project portfolio priorities from the company's competitive advantage, economic interests, resources, risks, and other aspects. Ultimately, managers choose the best project portfolio among them. Simultaneously, when choosing the best project portfolio, managers need to consider the various constraints of resources, that is, the best project portfolio not only meets the established goal of the company but also must meet the actual situation of resources.

The project portfolio selection mainly considers that the project with weak resources should be continuously eliminated in the candidate projects selected in the second stage to form the final project portfolio to ensure the full utilization of resources. The specific steps are as follows:

1) Establishing the mathematical model of project portfolio selection. Taking the relationship between the demands of resources and the mutual influence among the projects

as the main consideration and running the mathematical model after assignment, the optimal project portfolio is established. And the optimal project portfolio must be consistent with the company's strategic goal.

2) It is necessary to allocate resources in terms of the project priorities and constantly updated resource allocation to realize the project portfolio demands in the project portfolio implementation process. Considering that the project portfolio is continuously being completed and the new project is started during the operation, the ongoing project needs to be re-evaluated to interrupt the risk project that may endanger the entire project portfolio process in a timely manner.

2.4 Methods of Project Evaluation

Most managers choose the projects through the establishment of the project evaluation system, as well as use a certain method to give priority to the candidate projects. The existing project evaluation methods in literature can be divided into three categories: *qualitative* evaluation, *quantitative* evaluation, and *comprehensive* evaluation. The rest of this subsection will review the three categories as follows.

2.4.1 Qualitative Evaluation

The qualitative evaluation does not use mathematical methods but makes a value judgment of qualitative conclusion based on the evaluators' observation and analysis of the daily performance, existing situation, and status of the object or the literature review. The qualitative evaluation focuses on analyzing the "qualitative" or types of the research object, describing its general characteristics to reveal its relationship with other objects. The qualitative evaluation is often used to study the question of "yes or no", "is or not" or "what is it" for an object, which mainly depends on people's daily experience. Therefore, the qualitative evaluation is a kind of most basic and most commonly used analytical methods, mainly including *Delphi Method* and *Weight Grade Method*.

(1) Delphi method

The Delphi method is a structured communication technology or method, which is primitively empoldered as a systematic, interactive forecasting method. It relies on expert groups, needing experts to answer questionnaires in two or more rounds. And after each round, the facilitator provides an anonymous summary of the last round of expert predictions and the reasons they provided for the judgment. Experts are therefore encouraged to revise their earlier answers based on the responses of other members of this expert group. It can be shown that during this process, the range of answers will be reduced, and the group will be clustered towards the "right" answers. The process cannot be terminated unless reaching a predefined stop criterion (e.g. a number of rounds, achievement of consensus, and the stability of results) and the result is determined based on the average or median score of the last round. Delphi method has been widely used in all fields. It not only can be used in the field of prediction but also can be widely used with the establishment of various evaluation criteria system and the determination of specific indicators. However, the method is limited to calculating the average, standard deviation and other data of experts' feedback, but ignore the authority of experts (Gordon, 1994; Gallego & Bueno, 2014).

(2) Weight Grade Method

Weight grade method is a kind of fuzzy mathematics. Firstly, this method comprehensively considers the various factors and determines the corresponding weights according to the importance of each factor. Secondly, the various factors are graded from excellent to inferior, and each grade will be scored. Finally, Multiplying the score by the corresponding weights of the factors, we get a rank of the total score for each candidate project, and project having the highest score is the best one (Pinter & Pšunder, 2013).

There are two significant advantages of weight grade method. One is that the result depends on all the judging information, and the other is that the calculation is very simple. As a special fuzzy mathematics method, it has a general formula and the calculation is relatively simple. It is very convenient for managers who do not possess professional math skills. This is one of the reasons why weight grade method is widely used.

2.4.2 Quantitative Evaluation

The quantitative evaluation is a method that uses mathematical calculations to get evaluation conclusions. According to analyzing quantity, this method evaluates and selects scientific data resources from the objective quantitative point of view. The quantitative evaluation provides people with a systematic and objective method of quantitative analysis, which makes the results more intuitive and specific.

(1) Principal Component Analysis

Principal Component Analysis, which is also known as Principal Component Regression, purposes to utilize the thinking of reducing dimensionality to change multiple indicators into a couple of composite indicators. Research on practical problems, so as to analyze the problems comprehensively and systematically, a large of influencing factors must be considered, which are generally referred to indicators and are also called variables in the multivariate statistical analysis (Bro & Smilde, 2014).

Each variable reflects some information on the problem in certain degrees, and there are some kind of relationships between the indicators. So, the knowledge obtained and made known by the statistical data could be overlapped in some ways.

Redundant variables will increase the amount of calculation and the complexity of analyzing problems when we research the multi-variable problems with statistical methods. Accordingly, people expect that fewer variables will be involved and more knowledge will be obtained during the quantitative analysis (Abdi & Williams, 2010).

(2) Financial Analysis Method

Financial analysis is a traditional project evaluation method, which is also called as a *cost-benefit* analysis at first. With the extensive use of cost-benefit analysis, many different methods have emerged. Based on the dynamic angle of the economic indicators of project evaluation, financial analysis method can be divided into static evaluation methods and dynamic evaluation methods. The static evaluation methods include *Rate of Return on Investment method* and *Payback Period method* etc. The dynamic evaluation methods include *Net Present Value method* (Wetekamp, 2011) and *Internal Rate of Return method*

(Promislow & Spring, 1996) etc. Most of these methods are aimed to evaluate a single-project, take some economic indicators of the project as evaluation criteria. So, there are many deficiencies of such methods during the multi-project selection.

2.4.3 Comprehensive Evaluation

A comprehensive evaluation method, specifically, is to establish an evaluation system considering all the influencing factors. This method makes an overall and comprehensive consideration of the object, summarizes and assesses the impact of all factors, that is, the system can assign a non-negative number (evaluation value) according to company conditions. Then managers choose the best factors in the light of the ranking of the evaluation values (Carazo, Gómez, Molina, Hernández-Díaz, Guerrero, & Caballero, 2010). According to the comprehensive evaluation system, this work is to select suitable comprehensive evaluation methods. The most used methods in the literature are *AHP*, *Fuzzy Comprehensive Evaluation*, and *Artificial Neural Network*. This study will use AHP to establish a comprehensive evaluation system, so we only review this method as follows.

(1) AHP

As a multi-goal comprehensive evaluation method, AHP is put forward by Vargas and Saaty (2013). *AHP* constructs a hierarchical weighted evaluation system that in term of the decomposition of the related elements into objectives, criteria, and programs, makes a qualitative and quantitative analysis. The implementation of *AHP* can be split into four steps: step one is the establishment of hierarchical structure, step two is the construction of judgment matrix, step three is the calculation of weight vector, and step four is consistency test.

1) Establishment of a hierarchical structure

Based on an in-depth analysis of actual problems, the related factors, in term of different attribution, are decomposed into various levels from top to bottom. These factors that stay at the same level are subordinated or influenced by the upper-level factors, which, simultaneously, dominate the factors that belong to the next level. The top-level named goal level, which frequently has one and only factor. The bottom level is generally called object level. The middle level could have one or more levels, which ordinarily called criteria or indicator level.

2) The construction of judgment matrix

The construction of judgment matrix starts with the second level of the hierarchical structure. With regard to these factors that are subordinated to the upper level, there are the comparison matrixes that are constructed by the paired comparisons grade from 1 to 9. An important characteristic of *AHP* is to express the corresponding importance grades of the two schemes in terms of the importance degree ratio between the two schemes. For example, when comparing the importance of the factor i with the factor$j$ relative to a certain factor of upper level, we often use a quantified relative weight a_{ij}, to describe it. Suppose that there are n factors in the comparison, then $A = (a_{ij})_{m\times n}$ is called a judgment matrix. The proportion scale shows in Table 2-1.

Table 2-1 Proportion scale table

The ratio of factors and factors	The value of quantification
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
The intermediate value between the two adjacent judgments	2、4、6、8

Source: Brunelli (2014)

Table 2-1 shows the nine importance grades and their assignments. 1 means that both are equal importance. 3 means that the former is moderate importance than the latter. 3 means that the former is strong importance than the latter. 7 means that the former is very strong importance than the latter. 9 means that the former is extreme importance than the latter. 2, 4, 6, 8 mean that the intermediate value between the two adjacent judgments.

3) The calculation of weight vector

The *eigenvector* corresponding to the largest eigenvalue can be calculated after the judgment matrix is constructed. Then the eigenvector is normalized as the weight value. There are two methods to calculate the weight of each candidate factors. One is the geometric average, and the other is the normalized column average. The former is to normalize vectors by calculating the n times square root of the product of n factors, and the result is the weight vector. The latter is to normalize vectors by calculating the sum of $n$factors.

4) Consistency test

After the relative weights of the elements of a criterion level according to the judgment matrix are calculated, it must be necessary to make a consistency test.

Although the judgment matrix A is not required to be consistent when it is constructed, it is not allowed to judge that the deviation from the consistency is too large. Therefore, the consistency test of A needs to be performed. The following procedure is to test the consistency of pathergies comparison matrix$A$:

The first step is to calculate the indicator CI which indicates the inconsistency degree of a contrast matrix A ($n > 1$ order square matrix).

$$\boldsymbol{CI} = \frac{\lambda_{max} - n}{n - 1}, \tag{2-1}$$

Where $\lambda_{max}$is the maximum eigenvalue of matrix$A$.

The second step is to calculate the random consistency ratio (CR) by combining RI. The formula is as follow.

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}}, \tag{2-2}$$

where RI is the average random consistency index of the judgment matrix A.

The final step is to check whether $CR < 0.1$ or not. If so, the judgment matrix A has satisfactory consistency. Otherwise, the judgment matrix can be adjusted the pairwise comparison matrix A until a satisfactory consistency is reached. Where the same-order mean random consistency indicator RI relies on the matrix order *n*. According to Xu S.B. (1998), when the matrix order *n* is from 1 to 12, and the RI is 0, 0, 0.58, 0.90, 1.12, 1.24, 1.32, 1.41, 1.45, 1.49, 1.52, 1.54, respectively.

(2) Fuzzy Comprehensive Evaluation

The Fuzzy Comprehensive Evaluation (*FCE*), generally, refers to a comprehensive evaluation method in term of multiple fuzzy factors and object systems (Tian & Liu, 2004).

In the basic of theory and method of *Decision Support System*, the comprehensive evaluation method, in line with the membership degree theory of fuzzy mathematics, converts the qualitative evaluation into the quantitative evaluation, that is, using fuzzy mathematics to give an overall evaluation to objects, but which is constrained by various factors. The *FCE* is to apply the principle of fuzzy transformation and membership degree, considering the factors associated with the rated object and making a comprehensive evaluation. This method has the characteristics of the clear result and strong systematisms, which can resolve the problem of ambiguous and difficult to quantify, and is also suitable for solving various non-deterministic problems.

The FCE is widely used, especially in the comprehensive evaluation of "soft" indicators, it can play its unique advantages and obtain better results than other evaluation methods.

Most of the required indicators that evaluate a company project are "soft" indicators, so the FCE is more frequently used in the evaluation of the project. However, it has its own shortcomings, as follows

1) The process of the *FCE* cannot resolve this problem such as the repetition of evaluation information caused by the unclear boundaries of evaluation indicators. Therefore, before using the *FCE*, it is necessary to process the indicators in advance, identify and delete the indicators with high repetition, and improve the accuracy of the evaluation results.

2) In the FCE, the weight indicator is not calculated by the evaluation process but artificially set. Although artificially setting the weight of indicators is more flexible and focuses on the importance of project indicators, there are some problems need to be solved that how to weigh people's subjective feelings and whether the set result reflects the objective's fact.

3) The first-level FCE is the basic form of the FCE, which can be used for the evaluation of simple projects and works. However, for the projects with complicated indicators, there are many influencing factors and the different factors have different levels, so the multi-level FCE need to be adopted.

(3) Artificial Neural Network

Scientific research about the Artificial Neural Network (ANN) began in the 1940s, and the technology has made significant progress since the 1980s. The basic principle of the ANN is an empirical model that imitates the function of the biological neural network. The transformation relationship between input and output is nonlinear. First of all, the neurons are established based on the obtained information. The corresponding nonlinear mathematical models are established by grasping the rules or self-organizing, and the gap between the output result and the actual value is narrowed down through constant adjustment (Gupta, 2013).

Because the *ANN* has the non-linear characteristics, and it only needs to focus on targeted training in the actual operation of the neural network model, the characteristics of the problem can be reflected by the interconnected weights between the neurons. Therefore, as we input the parameters of the actual problem into the *ANN*, the corresponding solution can be obtained. The evaluation and selection of project are complex processes, which have the characteristics of multi-goal and multi-factor. Therefore, the hierarchical structure of project evaluation is formed, and it has a very good correspondence with the structure of the neural network.

There are corresponding relationships between hierarchical structure and neural network structure of project comprehensive evaluation. Ann (2007) point out that the indicator level of evaluation and selection of the project is equivalent to the input level of the neural network, and each indicator corresponds to the input information of the neural network node. The criterion level is equivalent to the hidden level in the neural network system. And the goal level is equivalent to the output level of the neural network system, the result of the output node is the result of the scheme evaluation of the goal level.

In summary, the *ANN* model is through the study of the existing cases, as well as obtains to the experience, knowledge, comprehensive judgment of evaluation experts and the importance of weighing data on the goal. The network can reproduce the experience, technical and intuitional thinking of evaluation experts, thereby reducing the workload, lowering the human factors in the evaluation process, better guaranteeing the objectivity of the evaluation process and enduing the evaluation tools with learning ability. Domestic and foreign scholars have tried to use this method to evaluate and select projects. However, there are still some areas that need to be improved in the practice of the *ANN* to evaluate the multi-goal project, and further research is needed, especially in the multi-project evaluation.

2.4.4 Comparison of the Three Types of Evaluation Methods

As mentioned above, the existing methods of project evaluation include qualitative evaluation, quantitative evaluation, and comprehensive evaluation. For the qualitative evaluation, it’s simple and easy to operate. But it has a strong subjectivity, which results that the conclusions obtained are more abstract and not easy to understand. So, it is hard to distinguish the differences between factors, and its application performance is not good, either. However, the quantitative evaluation is more intuitional, laconic, precise and has a good application performance than the qualitative evaluation, but which exists some difficulties in the process of operation. For instance, several relational factors are hard to quantify, which affects the accuracy of quantification. At the same time, it is not appropriate if the data is inadequate or the analyst's mathematical basis is frail. Besides, the comprehensive evaluation combines the characteristics of qualitative and quantitative evaluations and makes an overall and comprehensive consideration of the evaluation object.

Among comprehensive evaluation methods, the *AHP* regards the study object as a system and makes decisions based on the ways of decomposition, comparison, evaluation, and united thinking. The impact of each factor that belongs to each level on the effect is quantitative, unambiguous and explicit. Actually, this method is a concise and practical decision-making method. The *Fuzzy Comprehensive Evaluation* deals with the fuzzy evaluation object through accurate digital means and can make a more scientific, reasonable and realistic quantitative evaluation of the information with ambiguous information. The calculation of the *FCE* is complex and the determining subjectivity of the indicator weight vector is strong. From this, we can see that the *AHP* is the most suitable evaluation method for our problem.

Specifically, the *AHP* can take the selection process of a construction company project portfolio as a whole and set the goal level as a scheme of the project portfolio. Then according to the type of project involved factors, the project is decomposed into several levels, and each level is continuously subdivided. If the level is more complicated, the factors are continuously downwards subdivided. In this way, a system hierarchy of project portfolio choices is constructed.

Next, according to importance degree of each project and factor evaluated by the experts in the construction field and company's top leaders, the pairwise comparison matrices are constructed, as well as the consistency is tested. If the consistency test isn't passed, each project and factor will be constantly adjusted or re-scored, until all pairwise comparison matrices pass the test.

Finally, the weight of each construction project factor (combination of weights vector) at the candidate's level is calculated and sequenced, which can acquire the ranking of the proportion of each factor in the construction project. And the ranking can be used as the basis for the subsequent project portfolio selection.

2.5 Other Related Theories and Researches

Besides the much-closed theories and methods reviewed above to the research topic of this thesis, some other related theories and researches on strategy management are briefly reviewed in this subsection. We first introduce some basic concepts on strategy management and then review three well-known strategy management theories: a resource-based view, dynamic capacity, and absorptive capacity. After that, we talked over the connection between the strategic management and project management and given a comparison analysis of these theories. Finally, we conclude that some researches have investigated the relationships between the strategic management and project management but it still needs more deep researches to connect the strategic management and project management. We found out that the project portfolio is a good theory and tool to implement the strategic goal through the success of a set of projects.

2.5.1 Brief Review of Strategy Management

The term "strategy" was initially used to generalize the tactics and strategies in the military field in the war. While the idea of strategic management at that time had an important guiding role for modern managers in managing companies, which was also applied to various social level, for instance, politics, economy, culture etc. Moreover, with the research and extension of theories both at home and abroad, scholars began to think from the angle of company practice and operation, and gradually introduced their strategic thinking and methods into the actual management activities of companies (Zeng & Wang, 2014).

As to the definition of company strategy, there is no unified conclusion in the study of strategic management at home and abroad, and different definitions have different emphases. In general, most studies divide company strategy into two categories (Robson, 2015). One type of view holds that company strategy is the tactic of a company from the time when it is set to the time when it achieves its goals. This type of view focuses on the practicality, integrity, and continuity of the strategy. The other view is that company strategy is a set of decisions, execution and evaluation methods.

Comprehensive consideration of different views and bases, Zhu (2015) thinks that company strategy can be defined as follows: in order to obtain sustainable profitability and long-term sustainable development, companies must adapt themselves to the changes in their own environment, industry environment and external development environment. Therefore, based on a full analysis of these environments, companies make the general, long-term planning and strategies that are suitable for their actual situations. Company strategy helps the company with making a short-term, medium-term and long-term development objectives, priorities, requirements and outlines, as well as the corresponding safeguard measures. Company strategic management reflects the overall coordination ability, strategic management ability and long-term global view of company managers. As the economy and technology rapidly develop, the thought of strategic management is the focus, difficulty and key point for construction companies in the process of development. Some researchers such as Hill, Jones, and Schilling (2014), Kerzner and Kerzner (2017) point out that company strategy has the following six characteristics:

(1) Global view

The global view is one of the most crucial characteristics of company strategy, which stand for the highest level of management activity and goals in the organization. A company's strategy is not only confined to the internal and external resource allocation, personnel division and departmental setting, but also determines the choice, deployment, and execution of company projects, which means that the company strategy is the company's "guidelines and policies". All the resources of companynies are allocated to each department in the guideline of the company strategy, only in this way can company complete all various businesses, and promote the overall goal of the company.

Only by establishing a good global view, managers can break through the limitations of traditional thinking and cultivate their own strategic vision and intuition. In the face of instability in the market environment, managers can quickly make the right judgments and decisions. It is precisely for this reason that in the face of the thorny problems of companies, managers must break the shackles of inherent thinking, identify and eliminate the interference factors, and achieve company's strategic goal unswervingly from the global and long-term view of the company. Based on the clear control over the overall situation and the judgment of company's future development, managers can formulate the development goals and requirements for the next stage, which brings the most favorable internal and external development conditions.

(2) Long-term

Generally speaking, the company strategy is the setting of the company's goals in the future for a long period of time, which has a relatively long time span. Based on the practical experience of most companies, company strategy is mainly to solve the company development direction for the next five years or even longer, and also consider the uncertainties of the market environment. Many companies are eliminated in the fierce market competition due to the lack of planning for the company's long-term goals. Therefore, managers cannot put forward effective solutions to respond according to the current development situation of the company when the company is in a difficult situation.

(3) Competitiveness

Company strategy is emerged based on the analysis of competitors in the market, it focuses on the crisis and threats that the company will face in the next stage. Based on these situations, the company strategy puts forward the correct response and countermeasures so that it can dominate advantages more quickly than competitors, which lays a more favorable basis for the development of the company. This is different from the strategy that the company strives for a certain profit in order to survive in the traditional static market and improves the way of organization of the company. So, the company strategy pays more attention to adapting itself to the changing situation in a dynamic environment to enhance its management level and coping ability.

(4) Guidelines

The company strategy, as the goal of development, direction and action guide of the company in the long-term development process, has formulated and planned the steps and methods to realize these company's vision and requirements. The actual needs of the company's daily management and production activities have a strong guiding role, as well as have remarkable significance. In the process of decision-making, formulation and arrangement of the plans in each stage of the future, so that company can gradually realize the long-term goals based on the strategic objectives and with their guidance and assistance.

(5) Systematisms

Because the company strategy needs a very long period of time to finish and cannot be made within a very short time, it is an evident systematism and requires the support of manpower, material, and financial resources. Not only that, the company's strategic goal does not exist alone, but by many strategic objectives formed by the close contact with the target network, and then layers of distribution, are assigned to the functional departments to complete.

Only when the company managers realize and understand the integrity and complexity of the company strategy clearly so that they can prolong towards the back to make the relevant strategies from a systematic perspective successively. In the large-scale system the company strategy is not only a systematic project but also should be located in the overall management of the company, which means that company managers must look upon the position and development potential of the company in the market from a systematic perspective.

(6) Riskiness

Small, short-term decision-making always exists a certain risk. For the big company strategy, it needs to consider all sectors of the company, all stages of the factors close to all aspects of the company in the future, it is self-evident that the risks it faces. Therefore, when there is a deviation or mistake in the company strategy, which will lead to problems with the company's basic principles and create a tremendous crisis in the company's development. Only fully understanding and evaluating the development status of the company objectively so managers can formulate a strategic guideline that truly suits the development of the company. If company strategy relies on managers' subjective judgments and preferences to determine the future development in the past, which may cause serious mistakes in the development of a company and may even lead to the closure of a company.

Strategic management can be understood as developing and executing and evaluating the arts and sciences that enable organizations to achieve their goals and make cross-functional decisions. Lu (2005) indicates that strategic management concern on the marketing, financial accounting, production operations, R&D and integrated management computer information systems, which aims at carrying out business success and benefits. For a construction company, the main purpose of effective management of company strategy is to create more opportunities and conditions for the future development of the company.

Company's strategic management process generally includes four stages, strategy formulation, strategy decomposition, strategy execution and strategy evaluation (Robson, 2015).

The first stage is the formulation of company strategy. In this stage, the company needs to identify competitors and potential threats to the company in the external market, determines company's internal goals and formulates long-term strategic goals, formulates alternative strategies and corresponding execution strategies.

The second stage is the company strategy decomposition. In this stage, the company can use *MBO* (Management by Objectives), *KPI* (Key Performance Indicator), *BSC* (Balanced Score Card), *SM* (Strategy Map) or the cross-use of the above-mentioned methods to decompose the company's strategy, which can provide the basis for the next step of the company strategy execution.

The third stage is the company strategy execution. This stage includes the establishment and promotion of company culture, the formation of cohesion, the creation of an efficient company structure, the adjustment of the main business, and the reinforcement of the core competitiveness. In addition, it is necessary to establish an internal information system for staff daily assessment and document preservation.

The fourth stage is the company strategy evaluation, which is feedback and assessment of the previous three stages. The company needs to re-examine the internal and external information to measure business performance, identify and correct problems in time. For construction companies, they need to control the execution of individual projects in real time to prevent from deviations.

The general model of company strategic management is shown in Figure 2-2.

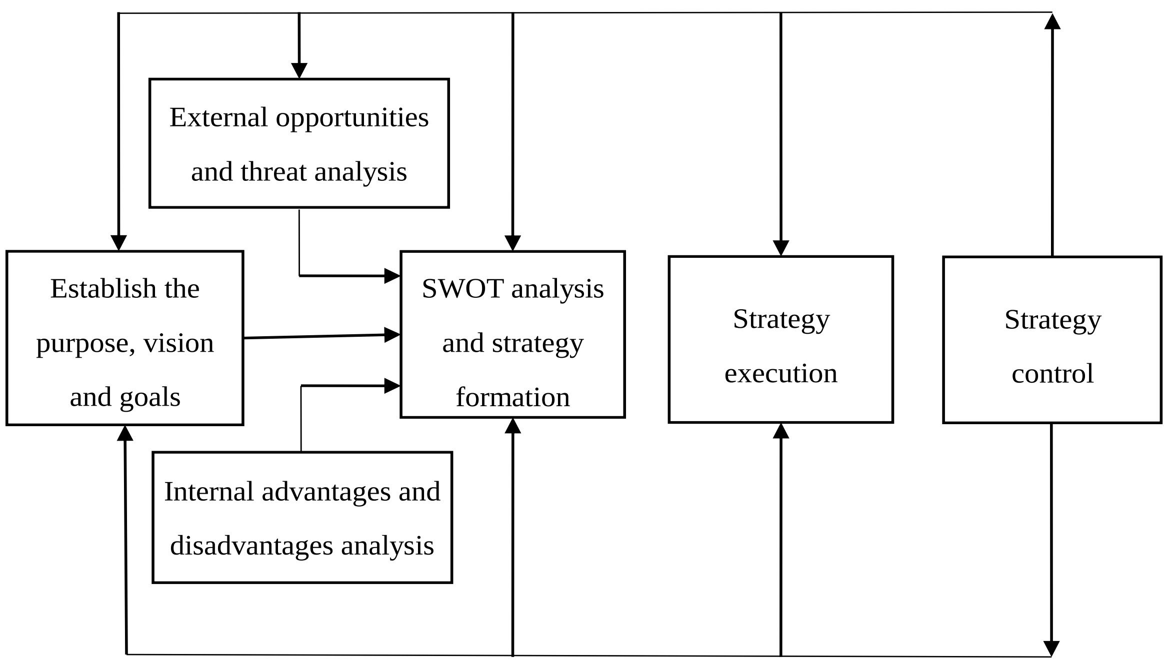


Figure 2-2 Strategic Management Model

Source: Lu (2005)

Figure 2-3 shows that the process of company strategy management is dynamic and successive. Any transform of one factor in the model will lead to the changes of other factors and even the entire model, which will bring a certain impact and fluctuation to the company.

2.5.2 Three Strategic Management Theories

Strategic management theory refers to the basic ideas and viewpoints that guide the development and implementation of strategies and is the soul of strategic management of companies (Barney, Wright, & Ketchen Jr, 2001). This section will introduce three well-known strategy management theories: *Resource-Based View*, *Dynamic Capabilities*, and *Absorptive Capacity*.

2.5.2.1 Resource-based View

As a managerial framework, the resource-based view (RBV) is applied to identify strategic resources that have the potential to provide a comparative superiority to the business, which can carry out a sustainable competitive advantage. It is an interdisciplinary knowledge which is developed in the process of the specialized field of marketing, economics, management, supply chain management, and project management etc. As a means of organizing process, RBV focuses on an organization's internal strengths to obtain a competitive advantage. Barney Wright and Ketchen Jr (2001) stated that, as the sources of sustainable competitive advantage, the resources should be valuable, rare, inimitable, and non-substitutable (now generally known as VRIN criteria). The RBV demonstrates that organizations must impolder core competencies that are particular and firm-specific, which can render it is possible for them to be more benefits than competitors during operation. Despite a host of literature introduce various dissimilar notion around the resource-advantage perspective, the consensus, essentially, shows that the company's resources are financial, legal, human, organizational, informational and relational. These resources are incompletely removable and heterogeneous. Therefore, the key task of company's executors is to identify and organize resources to acquire sustainable competitive strengths (Teece, 2009). Other researchers such as Lin and Wu (2014) demonstrate that comprehending the causal link between the strength resources and company strategies that make business successful can be fully hard in reality. Therefore, a lot of crucial management tasks must be invested to identify, comprehend and classify key strengths. Furthermore, the executive level must concern on organizational learning to empolder and keep core resources. The crucial managerial tasks are:

1) Recognize the company's hidden core resources.

2) Assess whether these resources satisfy the VRIN criteria.

3) Empolder, cultivate and preserve these resources that have passed through assessment.

All in all, the research on strategy and competitive advantage from the perspective of the RBV has evolved to advance the understanding of how organizations develop and sustain competitive advantage, and how a combination of resources and knowledge processes are arranged and adjusted. Research on the correlation between company strategy and key competitive strengths in term of RBV has facilitated comprehending how organizations empolder and keep these strengths, and how to arrange and adjust the combination of resources.

Nevertheless, several researchers animadvert on RBV and oppugn its practicality to operate. They remind of the definitional difficulty and demonstrate that according to the characters of RBV, it is suitable for relatively steady business environments to be operated in actuality. A primary expansion step must be taken to resolve these existing shortcomings of the RBV, which renders 'dynamic capabilities' to have to be proposed as a category of organizational competencies that render company to impactfully react to varies in the dynamic and competitive environments. (Daniel, Ward, & Franken, 2014).

2.5.2.2 Dynamic Capability

As an organizational notion, dynamic capability (DC) is the competency of a company to purposefully fit their basic resources. Teece (2009) defined the concept of DC as: "A company's capability to conform, formulate, and allocate internal and external resources to effective fully react to varies environments". The thought of DC is a little equivalent to the notion of operational competencies that has existed before. The latter belongs to the present operations of a company. However, the former, by contrast, is their competency to alter these operations and empolder its key resources efficiently and responsibly. The DC notion focuses more on that senior executives formulate strategies to adapt to aggressive, discontinuous changes, which can maintain minimum competency standards to guarantee competitive survival (Ludwig & Pemberton, 2011).

If managers intend to master the unique capabilities at the company level, it must be necessary to understand many aspects of the business. Three dynamic capabilities thinking is presented by Teece (2014) as a requirement for a company to carry out novel problems, for instance, the ability of employees to learn quickly and the competence of managers to formulate new strategic resources. Three dynamic capabilities dimensions are as follows.

(1) Learning

As the first stage, learning is a repetitive and experimental process that renders work to be implemented better and more rapid, and furthermore to recognize new profits chances. In the background of the company stagey, several core features of learning can be summarized.

To start with, it includes organizational and personal technical abilities. While personal technical abilities have other relevant elements, work value strongly relies on their organizational formulation of culture. Learning processes are essential activities of society and group, which germinates through the simulation and imitation of individuals (e.g. teacher-student or master-apprentice), also because of union dedications to the comprehending of intricate problems. In addition, the organizational information occurred by such activities exist in new models of activities, in "routines", or a novel strategy of the company. As formerly mentioned, those are responding models that demonstrate perfect solutions to specific problems, which are existed in group activities, as certain subroutines might be existed in individual activities.

(2) New assets and transformation of existing assets

Garvin (1988) pointed out the effect of quality relies on company actual competency for selecting and dealing with information, association guest experience with engineering programming selection and collaborating plant and assembly suppliers. Increasing competitive environment also requires the integration of external activities and technology through alliances to enhance strengths. Khalid (2009) demonstrated that restructuring the company's asset structure to quickly meet internal and external transformations can enhance the company's commercial success in a rapidly changing market. Firms must develop processes to make changes inexpensively while accomplishing reconfiguration and transformation ahead of the competition. This can be supported by decentralization, local autonomy, and strategic alliances. Companies must complete restructuring and transformation before the competition while developing a cost-effective, significant transformation process, which can be supported by decentralization and alliances.

(3) Co-specialization

In addition, there is a concept of "dynamic competence" that is common specialization. For instance, the company's physical assets, human resources, and intellectual property develop together over time, are more valuable in combination than being offered separately, and provide companies with a sustainable competitive strength.

2.5.2.3 Absorptive Capacity

After a lot of work by researchers, absorptive capacity (AC) has been formed different theoretical viewpoints, but they complement each other in nineteen cases, all of which refer to generating economic value for the company.

(1) Cohen and Levinthal's model of AC

Absorptive capacity (AC), in business administration, is defined by Cohen and Levinthal (1990) as: "The competency of companies to identify new information values, collect new information, and apply that information to the company for profitable purposes". For them, AC relies heavily on the diversity of previous relevant knowledge and background. Therefore, they put their investment in a company's R&D, which is the core of their development of the AC model. In addition, AC is one reason for the company's investment in research and development. The reason is not simply to reduce the cost of purchasing production patents and increase the competitive advantage, but also to make the internal R&D team increase the ability to communicate. Therefore, the investment in R&D of the company directly impacts on AC. This is enough to prove that the more a company invests in research and development activities, the more fully it can collect and apply the value of new external information.

(2) Zahra and George's model of AC

As mentioned above, Cohen and Levinthal concern more on investments in R&D to impact on AC. but, finally, other several literatures showed that there are some other fields can be developed to impact on company's AC. This a reason that the concept of novel AC is generated and a definition is reformulated by Zahra and George (2002). They redefine absorptive capacity as: "A set of organizational practices and processes in which companies acquire, absorb, transform, and use company information to generate dynamic organizational capabilities". This definition greatly extends the AC model of Cohen and Levinthal and further defines it as consisting of two different absorptive capacities: potential absorptive capacity and realized absorptive capacity.

The AC was further studied in detail by Zou, Ertug, and George (2018). The following new knowledge is found:

1) As strong predictors, AC can perfectly regulate the impact of innovation and knowledge transfer on financial performance.

2) The relationship between company size and AC is enthusiasm for small companies, but negative for large companies. The relationship between the age of the enterprise and the AC is negative for mature enterprises, and the impact on new enterprises is not significant.

3) Corporate culture, employee relations, management support, and communication skills all have a positive and important impact on the relationship between absorptive capacity and innovation. Environmental dynamism has a negligible impact on the relationship between absorptive capacity and innovation.

4) In addition, the survey of AC has been conducted through questionnaires rather than through literature surveys, and it can be seen that the relationship between absorptive capacity and innovation are stronger.

2.5.3 Relationship Between Strategic Management and Project Management

An increasing number of literature indicates that the company regards the ability to control project management or portfolio management as a resource based on RBV, DC and AC. According to RBV's knowledge theory, intangible project management resources, such as the application and sharing of tacit knowledge, are often scarce and cannot be imitated. Therefore, these resources have a greater probability of becoming a source of competitive strengths than tangible resources. Jugdev (2007) applied RBV to project management for the first time. By combining Nonaka's relevant knowledge, they put forward the empirical results of the company's information sharing practical research in project management. Ethiraj, Kale, Krishnan, and Singh (2005) through the joint application of qualitative and quantitative methods, combined with VRIO standards to analyze their use in project management, the results show that the advantages of intangible resources, which are in line with the strategic management literature of VRIO standards. The literature on the application of DC in project management field is relatively small, and a few articles such as Verona and Ravasi (2003), in their studies, emphasized the importance of information-based resources in the project's innovative environment. It is worth mentioning that although AC theory has a long history, the research on AC theory in the field of project management is minimal except Bakker, Cambré, Korlaar, and Raab (2011). Killen, Jugdev, Drouin, and Petit (2012) provided four cases of applying resource management knowledge to PM and PPM research. A high level of AC of the project owner was found to be a necessary condition for successful project knowledge transfer, and successful project knowledge transfer was shown to be a complex process involving con-figurations of multiple factors in which successful project managers needed to cope with complexity by paying attention to both relational and organizational processes. The other study investigated how organizations manage the early phases of R&D projects in the pharmaceutical industry and found that optimizing combinative capabilities (i.e., adaptive, absorptive, innovative, project, and multi-project capabilities) can provide powerful leverage and boost frequent innovation.

All in all, the above literature focus more on the competitive advantages of strategic management in reviewing the RBV, DC, and AC theories. It can be seen that this knowledge is continuously developed with the accumulation of experience and active research. Practice and literature have fully demonstrated that RBV and DC and AC theory can provide indispensable value guidance for strengthening project management and portfolio management.

2.5.4 Summary

Based on the literature review on project management, project portfolio management, project evaluation, and selections and other related theories and researches, it found that project portfolio management is an effective theory and method to connect the strategic management and the project management within a company. Project portfolio management is used to implement the predetermined strategic goal through the success of projects.

There have been a large number of papers investigating the relationships between strategic management and project portfolio management. Many proposed frameworks and methods of project portfolio management are generalized methodologies in existing literature. Although some researchers propose some specific frameworks and methods for a certain industry or a company, these results usually cannot be directly applied to the companies (especially installation engineering companies) in the Chinese market and economic environment. On the other hand, some researches enforce the resource limitation constraints to the project portfolio and selection procedure. However, proposed existing project portfolio schemes may impractical or cannot be carried out, because there are still conflicts of using the resources among the selected projects at the operational level. Thus, the resources allocation should also be considered and integrated into the project portfolio and selection procedure.

[This page is deliberately left blank.]

Chapter 3: Research Framework and Methodology

3.1 Research Framework

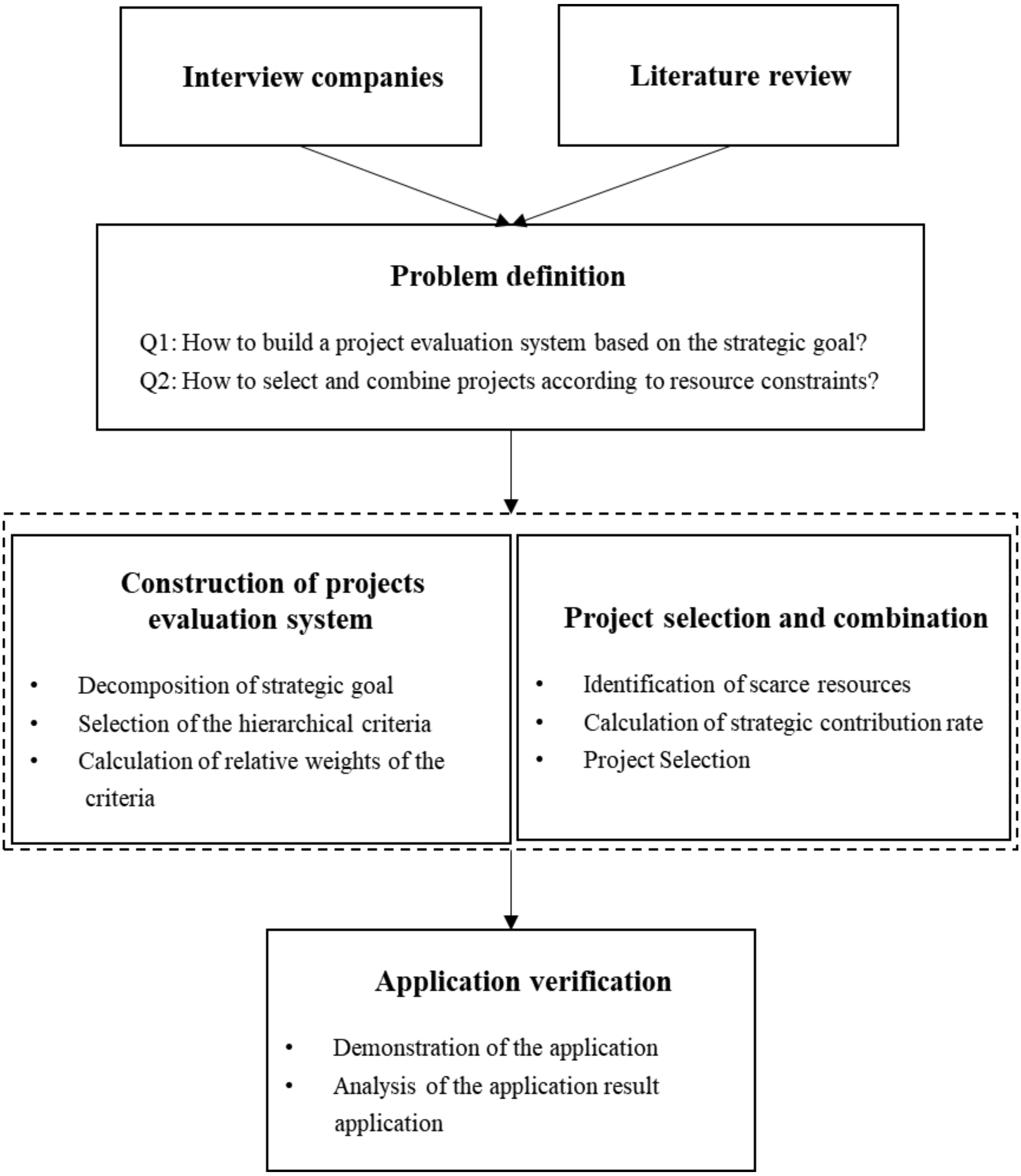


Figure 3-1 Research framework of this thesis

Source: Author finishing

This thesis focuses on Chinese construction and installation industry and addresses the project selection and portfolio considering company strategy and the resource limitation. To answer the first question raised related in subsection 2.1 we assume the company's strategy is determined in advance and we then decompose the strategic goal into several measurable objectives based on Peter Drucker's strategic management decomposition method. Secondly, we apply the analytic hierarchy process (AHP) to further establish a complete project evaluation system composed of hierarchical criteria and the relative weights of the criteria to the strategic goal. The established evaluation system enables us to grade and rank the contribution of the candidate projects to the company's strategic goal. As the fact that the limited resources cannot support the executions of all the candidate projects, to answer the second question in subsection 1.2, we propose a rule that the projects with higher strategic contribution rate have the priorities of using the resources. In this thesis, the strategic contribution rate is defined as the contribution of the project of consuming per unit of scarce resources. Through this method, the efficient projects in term of strategic contribution rate are selected and accordingly the project portfolio is constructed.

The research framework of this thesis is shown in the following Figure 3-1.

3.2 Methodology

The main research theories and methods of this thesis are listed as follows:

(1) Literature research

The method of literature research primarily is to gather, recognize, and arrange literature, and furthermore take shape a scientific comprehending of tangible according to studying literature. This method is an ancient, yet vigorous scientific study method. Generally, the process of literature research method includes five parts: proposing a subject or hypothesis, studying design, collecting literature, arranging literature, and writing a literature review. Proposing a subject or hypothesis refers to the thought of analyzing and classifying related literature according to now available doctrine, real situation, and requirement. The first step of studying design is to establish a study goal, which is to devise the content of proposing a subject into a particular, operable, reproducible literature study activity, which can solve specific problems and has a certain significance (Smith, J. A., 2015). The main advantages are as follows:

- The literature research method surpasses the limitation of space and time. This method is able to study complex and extensive social problems by examining all of the literatures that are from ancient and modern China and abroad. This strength is not possible with other study methods.
- The literature research method is primarily to be written an investigation. Supposing that the collected literature is effective, researchers can acquire more precise and trustworthy information than verbal investigations, which avoids the various record mistakes that might arise in verbal investigations.
- The literature research method is a secondhand, non-invasive investigation. This method merely surveys and researches various literature without being touched by respondents, which refrains multifarious reactive mistakes that might happen during the interaction between the investigator and the respondent that often take place in a direct investigation.
- The literature research method is an absolutely convenient, free and secure survey method. This method is less subject to outer restraints. Just find the documents you need and you can check them anytime, anywhere. Even if you make a mistake sometimes, you can delete it and come back again. Therefore, the security condition is relatively high.
- The literature research method saves time and money but also improves efficiency. In other words, this method is based on the published results of the survey, is an effective way to obtain knowledge of the predecessors. In addition, this method does not require a large number of staff and special equipment, so that more manpower, money and time can be invested in other areas to obtain more information.

Through using literature research method, this study reviews and analyzes existing articles relevant to the topic of this thesis, which offers a theoretical basis for our study.

(2) *Field research*

Field research refers to the process of collecting first-hand information personally by researchers. When market researchers do not have enough second-hand information, they must collect raw data (Bailey & Bailey, 2017). The degree of difficulty in the collection of foreign source materials is different from that in China. The key factor affecting the success of the survey is whether the respondent is willing and able to provide the required information. In some cases, the desk investigation cannot meet the purpose of the survey. It is necessary to conduct timely field research and obtain first-hand information and intelligence to solve problems so that the investigation can be carried out effectively and smoothly. With the development of social economy and the deepening of marketing activities, there are more and more methods for gathering information on the spot. The ways of field research are as follows:

- **Interview method**. It refers to the method of investigation in which the matter to be investigated is asked in person or by smartphone or in writing a letter to acquire the required information. This method is often used in the wild field, and which is that the whole interview process is a process of mutual influence and interaction between surveyors and respondents, as well as a process of interpersonal communication. It includes interviews, telephone interviews, letter surveys, conference surveys, and online surveys.
- **Observational survey**. It refers to the method by which an investigator observes and records the situation of the respondent from the side to collect market information. The difference with interview method is that the latter asked the inquirer to feel "I'm under investigation;" and the former can only obtain the results of speculative judgments by investigators' observation of the behavior, attitude, and performance of the respondents. The frequently-used observation methods include direct observation survey and actual trace measurements.
- **Experimental method**. This method is the most formal one. It refers to the control of one or more factors from the subject under control to decide the connection between these factors. Its purpose is to seize causality by ruling out contending

interpretations from the observations. In causality research, experimentation is a very important tool. It mainly has product testing and marketing experiments and other methods.

Through the interview of HIEC's senior executives and project managers, we can learn about their perspective and recognition of company strategy, and the real situation of the project management. We also collect and analyze the historical data of the projects in HS.

(3) Strategic decomposition method

Strategic decomposition refers to the transformation from the company's strategy to a behavioral process which is understandable and executable by all employees through a visual approach.

1) Strategy decomposition principle

- **Horizontal consistency**. Support for business processes: Based on the company's end-to-end processes link responsibility and collaboration between departments are established to ensure horizontal consistency.
- **Balanced and oriented**. The selection of indicators should be considered in a balanced manner and reflect the responsibilities and characteristics of the department: The selection of indicators should be combined with the four dimensions of the balanced scorecard and the company-oriented and departmental responsibility balance.
- **Implement responsibility**. KPI Index Responsibility Decomposition Matrix: Implement the department's commitment and responsibilities to higher-level goals and provide a basis for individual PBC determination.

2) Strategy decomposition ways

- **Strategy map**. The strategy map based on the balanced scorecard. But there are two layers more than the balanced scorecard: granular layer and dynamic layer, which means that each layer can be decomposed into many elements and the strategic map is dynamic and can be drawn together with the process of strategic planning. The strategic map is in terms of the four-level targets of the Balanced

Scorecard which are called financial level, customer level, internal level, learning and growth level, and the company's strategy causality diagram drawn by analyzing the relationship between these four levels of targets. The strategy map example is in Figure 3-2.

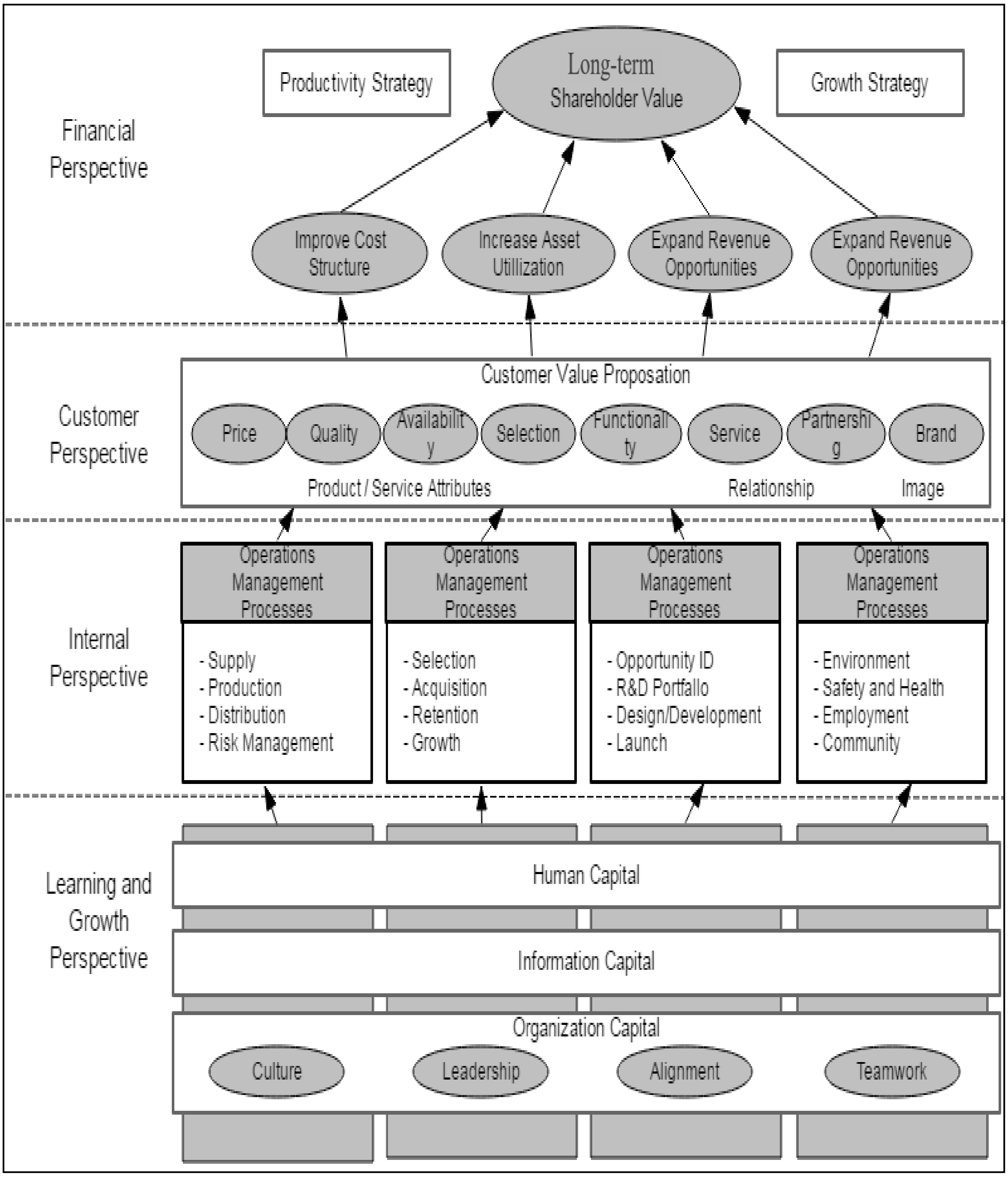


Figure 3-2 Strategy map example

Source: Author finishing

- **Fishbone diagram**. It, also known as the Ishikawa diagram, refers to a method of analysis that finds the "root cause" of the problem. Modern business management education divides it into problematic, cause-type, and countermeasure-type fishbone diagrams. The Fishbone diagram example is in Figure 3-3.

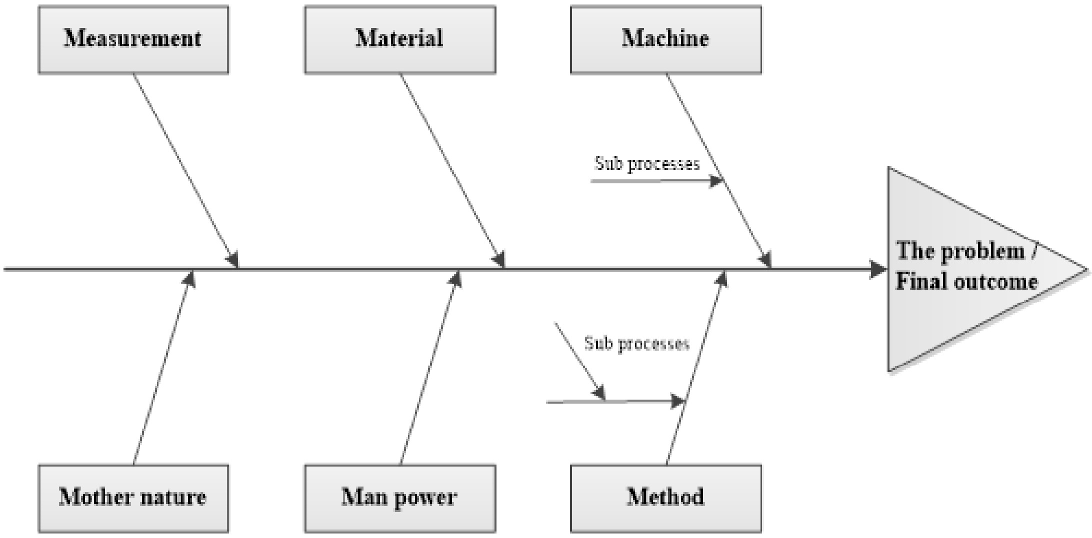


Figure 3-3 Fishbone diagram example

Source: Author finishing

In this study, the company’s strategic goal will be analyzed and decomposed into quantifiable strategic objectives through strategic management theory and method.

(4) AHP

With the method of AHP and expert interview, we select reasonable project evaluation criteria and calculate relative weights of criteria, and then construct a project evaluation system. After building a hierarchy, decision makers systematically assess their all kinds of factors by comparing them in pairs and their influence on the factors above them in the hierarchy. In the comparison process, decision makers can use the particular character of the elements, but they usually make their own determinations based on the relative meaning and importance of the factors. Human judgments are the nature of the AHP, which is not only based on the underlying information, but also the performance of evaluations.

The AHP particularly focus a lot on the departure degrees from consistency, which is be depended on measurement and on dependence within and between the groups of elements of its structure. It has become widespread applications in multicriteria decision making, planning, resource allocation and conflict resolution.

(5) Delphi method

Developed primarily by Dalkey and Helmer (1963) at the RAND Corporation, Delphi method is a widely used and publicly recognized technology used to implement real-world knowledge sought by experts in certain subject areas. The technology is devised as a group communication process, purposing to carry out the integration of thought of practical problems. The Delphi method is a structural approach to the consensus of experts on the development of a certain aspect of a business organization. It is a complex and time-consuming method, except that it does not require group members to attend, and other is similar to the nominal group method.

It illegally uses an anonymous or back-to-back approach in accordance with certain procedures, so that each expert can make his or her own judgment independently and independently; experts must not discuss each other, do not have horizontal links, and can only have relationships with organizational personnel. After receiving the expert's questionnaire receipt, the organizer will classify and summarize their opinions, and then feedback the results to the experts without any inclination for them to make further analysis and judgment. Usually, the Delphi method has following steps.

Usually, the Delphi method has following steps.

Step 1: Choose a Facilitator

The first step is to choose your facilitator. You may wish to take on this role yourself or find a neutral person within your organization. It is useful to have someone that is familiar with research and data collection.

Step 2: Identify Your Experts

The Delphi technique relies on a panel of experts. This panel may be your project team, including the customer, or other experts from within your organization or industry. An expert is any individual with relevant knowledge and experience of a particular topic.

Step 3: Define the Problem

What is the problem or issue you are seeking to understand? The experts need to know what problem they are commenting on, so ensure you provide a precise and comprehensive definition.

Step 4: Round One Questions

Ask general questions to gain a broad understanding of the experts views on future events. The questions may go out in the form of a questionnaire or survey. Collate and summarize the responses, removing any irrelevant material and looking for common viewpoints.

Step 5: Round Two Questions

Based on the answers to the first questions, the next questions should delve deeper into the topic to clarify specific issues. These questions may also go out in the form of a questionnaire or survey. Again, collate and summarize the results, removing any irrelevant material and look for the common ground. Remember, we are seeking to build consensus.

Step 6: Round Three Questions

The final questionnaire aims to focus on supporting decision making. Hone in on the areas of agreement. What is it the experts are all agreed upon?

Step 7: Act on Your Findings

After this round of questions, your experts will have, we hope, reached a consensus and you will have a view of future events. Analyze the findings and put plans in place to deal with future risks and opportunities to your project.

Theoretically, the Delphi process can be continuously iterated until a consensus is determined to have been achieved. Usually, there are up to three iterations to assist those who decide to use the Delphi process as a data collection technique when it is determined that additional iterations beyond three are needed or valuable.

***Round* 1**: In the first round, the Delphi process traditionally begins with an open-ended questionnaire. The open-ended questionnaire serves as the cornerstone of soliciting specific information about a content area from the Delphi subjects. After receiving subjects' responses, investigators need to convert the collected information into a well-structured questionnaire. This questionnaire is used as the survey instrument for the second round of data collection. It should be noted that it is both an acceptable and a common modification of the Delphi process format to use a structured questionnaire in Round 1 that is based upon an extensive review of the literature.

Round 2: In the second round, each Delphi participant receives a second questionnaire and is asked to review the items summarized by the investigators based on the information provided in the first round. Accordingly, Delphi panelists may be required to rate or "rank-order" items to establish preliminary priorities among items. As a result of round two, areas of disagreement and agreement are identified". In this round, consensus begins forming and the actual outcomes can be presented among the participants' responses.

Round 3: In the third round, each Delphi panelist receives a questionnaire that includes the items and ratings summarized by the investigators in the previous round and are asked to revise his/her judgments or "to specify the reasons for remaining outside the consensus". This round gives Delphi panelists an opportunity to make further clarifications of both the information and their judgments of the relative importance of the items. However, compared to the previous round, only a slight increase in the degree of consensus can be expected.

Round 4: In the fourth and often final round, the list of remaining items, their ratings, minority opinions, and items achieving consensus are distributed to the panelists. This round provides a final opportunity for participants to revise their judgments. It should be remembered that the number of Delphi iterations depends largely on the degree of consensus sought by the investigators and can vary from three to five.

To sum up, The Delphi method has a relationship with common convening experts, and through group discussions and expert meeting laws, there are differences and differences. Compared with other methods, the Delphi method coexists:

The advantage is that, first of all, the experts participating in the argument will not meet each other and will not have authoritative pressure, so they can freely and fully express their opinions, and thus obtain a more objective evaluation. Secondly, this method can give full play to the strengths of experts, brainstorming and high accuracy. It can avoid the defects caused by face-to-face discussions and avoid the limitations of personal one-off attitude. In addition, this method can express the divergence points of expert opinions and help to discover new problems.

The disadvantages are that, first of all, although the Delphi method can gather the length of the people, it is mainly based on the subjective judgment of experts, lack of objective standards, especially those who do not have the corresponding professional knowledge is difficult to remove from the overall opinion. Secondly, due to the high number of times and the long feedback time, some experts may quit halfway due to busy work or other reasons, which affects the accuracy of decision-making.

(6) Numerical instance study

Numerical instance study is using the real or randomly generated instances to test and evaluate the validity and performance of proposed approaches, including mathematical model and algorithms to the studied problems. Numerical instance study can be seen as a variety of the quantitative research method in Case studies.

The Numerical instance study is originally used as an educational technique in the relevant educational practice of senior managers and business policies. It was later borrowed from many companies to become an important method for cultivating the employees of the company. By using this method to train employees, it can significantly increase employees' understanding of the company's various businesses, foster good interpersonal relationships among employees, improve employees' ability to solve problems and increase the company's cohesiveness. It refers to the method of analyzing the single object in combination with the literature to obtain the general and universal laws of things.

[This page is deliberately left blank.]

Chapter 4: Project Evaluation and Selection

In this chapter, project evaluation and selection methods are constructed with respect to the company's strategic goal. On the project evaluation, we assume that the company's strategic goal will not change over a certain period of time (e.g. five years). Then taking HIEC as an example, we decompose the Companys strategic goal into four relatively independent objectives (Tao & Wu, 2001). The selection of these independent objectives depends on not only the strategic management theory but also the current situation of the company. After that, the evaluation criteria for each objective are determined through the interview of the company's senior executives and literature review. Then we apply AHP to decide the weights of the criteria and then construct the project evaluation system.

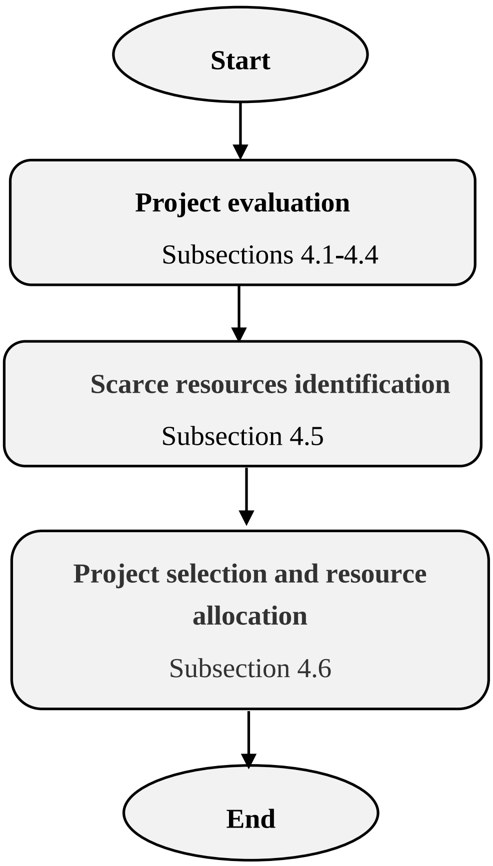


Figure 4-1 Main procedure of project evaluation and selection

Source: Author finishing

On the project selection, we first identify the scarce resource in HIEC and calculate the demands on the scarce resource of each candidate project. After that, we propose a metric to calculate a project's strategic contribution rate by consuming per unite of the scarce resource. We then reduce the project selection and resource allocation problem as 0-1 knapsack problem and formulated as a MIP model to maximize the total contributions of the selected projects. To obtain an optimal project selection solution, CPLEX software tool is used to solve the MIP model. As the MIP model is *NP*-hard to solve, for the middle- and large-size instances, we develop heuristic rules to determine the priorities of the project and then select project into the project portfolio scheme and allocate the scarce resource to the selected projects according to the calculated metric of projects.

The main procedure of project evaluation and selection is illustrated in Figure 4-1 above.

4.1 Decomposition of the Company's Strategic Goal

Generally, as mentioned by strategy decomposition method in the article (Tao & Wu, 2001), a company's strategic goal can be decomposed into several objectives by considering the following aspects.

- *Profit*: the expected profitability with one or several economic indicators.
- *Marketing*: the market share or position that the company hopes to achieve in a competitive environment.
- *Human resources*: the acquisition, training and development of human resources, the training of management personnel, and the improvement of individual talents.
- *Enthusiasm*: the employee incentives.
- *Technical improvement and risk*: the improvement and development of new products, and the provision of new services.
- *Social responsibility*: pay attention to the influence in society.
- *Material and financial resources*: the obtainment for material and financial

resources, and their effective usage.

- *Productivity*: the calculation of the consumption of raw materials, the maximum product quality and quantity.

Taking HIEC as an example, the strategic goal of this company (2015-2020) is defined as:

"*Improve personal skills, improve management performance, enhance innovation ability and social responsibility, improve the efficiency of resources, build a quality brand image and provide the first-class service*."

Based on the interview with the company's senior executives, we decompose the strategic goal of the HIEC into four objectives:

- *financial*
- *management innovation*
- *technological innovation*
- *social responsibility*

The reasons why we choose these four objectives are listed as follows.

1) All companies are commercial. The profitability of the project is a core criterion of assessment, which is also the financial objective to evaluate the economic return of a project.

2) Management innovation is the foundation of a company long-term development. Effective management innovation can improve the efficiency of the company's operation and optimize resource allocation and utilization. Then enhance the company's competitiveness in the fierce market.

3) Technological innovation is another basis for the long-term development of a company. Technological innovation can optimize the duration of the project and decrease the wasted cost and enhance the quality of the production. Therefore, technological innovation is very important to the company's development and strategy.

4) For any company, especially a state-owned company (HIEC for example), should

undertake its social responsibility and obligation, especially in environmental protection during the execution of the construction projects. On the other hand, a good reputation will bring more potential projects to the company, which provide better development opportunities.

These four objectives are universal for most companies in Chinese construction and installation industry. For different companies, the relative importance (i.e., weights) of the four objectives are different. The relative importance of the objectives will be studied and identified in the following subsection 4.3.

4.2 Construction of Project Evaluation System

In subsection 4.1, the company goal is decomposed into four objectives， known as financial，management innovation，technological innovation，social responsibility. However, to evaluate a project by directly quantifying or grading the four objectives is still difficult. Thus, we further decompose each objective into some specific criteria, and we then establish a complete evaluation system. This system can perfectly evaluate the project that are selected from Candidate project.

In this part, we establish a hierarchical criterion system, which includes the four objectives and a series of criteria linked to each objective, where each criterion can be further decomposed into sub-criteria. Before the formally present the criterion system, we review the existing project evaluation criteria in existing research focusing on the construction industry. We group and classify the existing project evaluation criteria into the four objectives determined in subsection 4.1, which are listed in Table 4-1 (Scott & Chan, 2002; Dawood & Sikka, 2006).

In Table 4-1, the criteria proposed in the existing articles can be split into two classes: the first one is constant, objective, tangible and measurable, for instance, criteria of time, cost, and quality, the other one is variable, subjective, intangible, and hard to measure, such as criteria of technical performance, health and safety, management ability, team cooperation, personnel quality and environmental sustainability.

Table 4-1 Project evaluation criteria of existing research

Literature	Criteria			
	Financial	Management innovation	Technological innovation	Social responsibility
Chan and Scott (2012)	cost, profitability	conflict, skill, effect	time, security, efficiency	satisfaction, education
Pan and Liu (2004)	economic benefits, capital usage, capital resources	management ability, team cooperation, personnel quality	the advanced degree of technology, the final level of achievement	social benefits, environmental requirements
Dawood and Sikka (2006)	cost, productivity	work quality, team efficiency	time, safety	customer satisfaction
Yang, Xie, and Zhang（2006）	capital in place rate, asset profit ratio, debt asset ratio	team harmony, internal cohesion, management breadth	null	employment benefit, ecological environment, natural resources conservation
Fu, Zeng, and Wang (2007)	payment ratio, investment "three super" rate, financing cost	project management, team composition, company management, multi-project portfolio	the number, ability, and initiative of solving technical problems	harmonious management
Iniestra and Gutiérrez (2009)	profit cost ratio, economic return	technical improvement, environmental sustainability	health and safety, available labor, applicability	contribution, social impact
Nilashi, et al. (2014)	economic environment	project type, project nature, project scale	complexity, experience, resources, policies	social environment, contribution

Source: Author finishing

In this study, we select the criteria from both types for the four objectives identified in subsection 4.1. It can be seen from the Table 4-2 that we select nine criteria and 21 sub-criteria in terms of the existing situation of the company. Thus, the strategy-oriented hierarchical evaluation criteria system is established in Figure 4-2.

Table 4-2 Criteria for the Strategic-oriented evaluation system

	Objective	Criteria	Sub-criteria
Strategic goal（A）	Financial objective（B_1）	Investment benefit（C_1）	Return on investment（D_1）
			Net present value rate（D_2）
			Payback period（D_3）
			Profitability index（D_4）
		Payment schedule（C_2）	Payout ratio（D_5）
			Punctuality of payments（D_6）
		Financial risk（C_3）	Project type（D_7）
			Proprietor type（D_8）
			Project duration（D_9）
	Management innovation objective（B_2）	Development of project team（C_4）	Professional competence（D_{10}）
			Staff qualities（D_{11}）
		Improvement of management system（C_5）	Project management（D_{12}）
			Business management（D_{13}）
	Technological innovation objective（B_3）	Incremental innovation（C_6）	Producing mode innovation（D_{14}）
			Process innovation（D_{15}）
		Revolutionary innovation（C_7）	Application of new material（D_{16}）
			Application of new technology（D_{17}）
	Social responsibility objective（B_4）	Social benefit（C_8）	Employment contribution（D_{18}）
			Social stability（D_{19}）
		Environmental benefit（C_9）	Environmental protection（D_{20}）
			Natural resource conservation（D_{21}）

Source: Author finishing

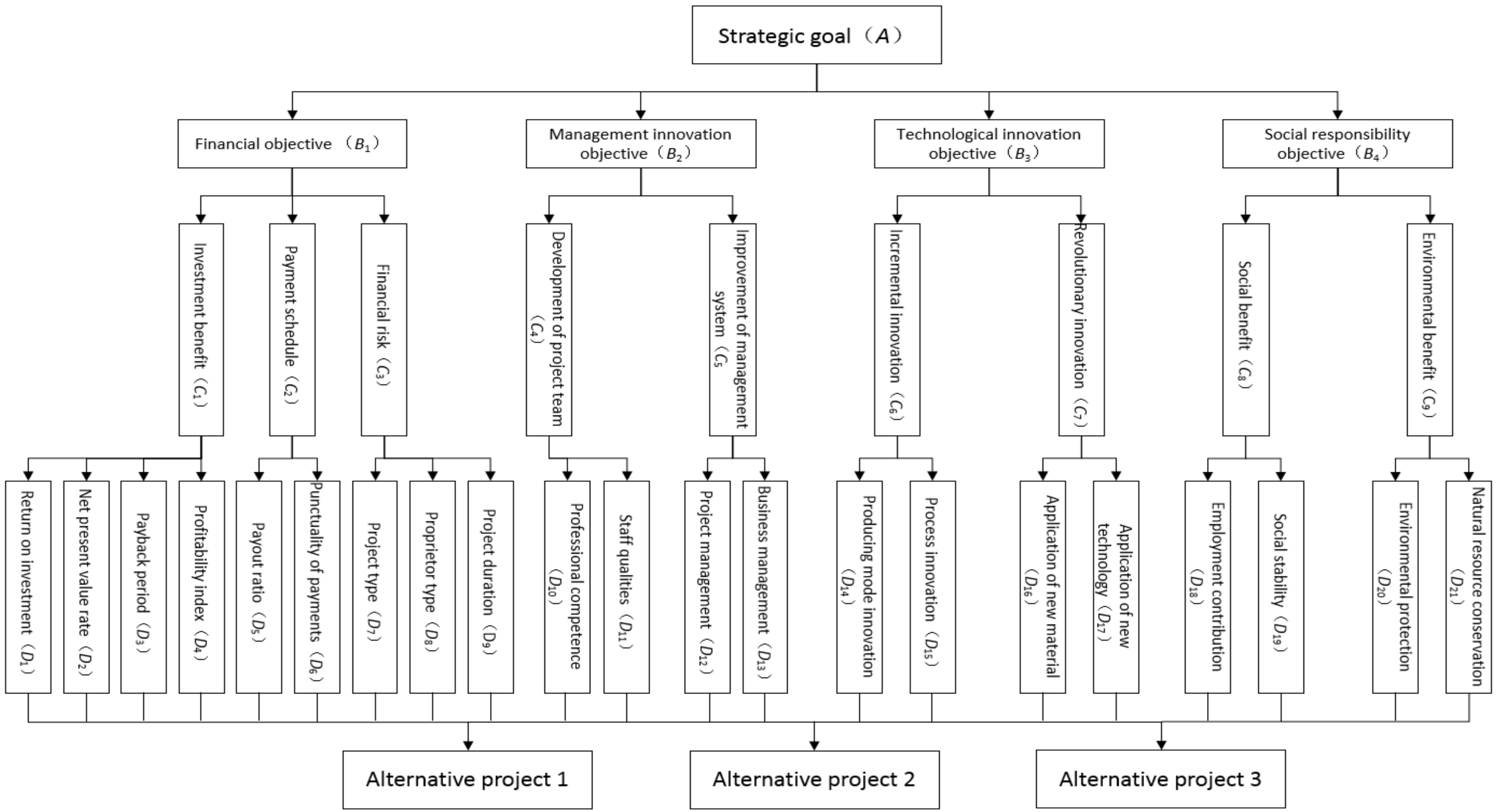


Figure 4-2 Strategy-oriented hierarchical evaluation criteria system

Source: Author finishing

In the rest of this subsection, we describe and introduce the selected criteria in the evaluation system from the top layer to a low layer.

1. Financial criteria(B_1)

In the many industries, typical financial criteria, such as Net Present Value (*NPV*), Internal Rate of Return (*IRR*), Payback Period (*PP*), Return on Investment (*ROI*), Profit Index (*PI*), and Net Present Value Rate (*NPVR*), are used to measure the financial feasibility of candidate projects when making investment decisions. However, in the construction engineering industry, construction companies as contractors are responsible for completing a project in the construction stage and transfer the project to an owner. So, they focus on whether they can satisfy the requirements in the contracts in terms of the project's duration, cost, and quality. In other words, they do not concern the performance of the project in the using stage. So, the financial criteria above are not applicable to evaluate a single construction project in the term of finance.

In this thesis, we interview some experts and senior executives in HIEC and other companies. We finally choose the following three criteria: *profitability*, *payment schedule* and *financial risk*, to measure the contributions of candidate projects to the financial objective.

(1) Investment benefit (C_1)

Investment benefit is the ratio relationship between the performance output and the investment. The senior executives usually measure whether the investment is feasible, whether it has high earnings expectations, and whether the benefit of input and output is obvious, from the perspective of the enterprise. After the literature review, we select sub-criteria: *ROI* (D1), *NPVR* (D2), *PP*(D3), and *PI*(D4) to further enumerate the investment benefit.

(2) Payment schedule (C2)

This criterion refers to the total cost calculated according to the agreed price and project quantity completed by the contractor during the construction process. According to time limitation, the settlement methods of a project include monthly settlement, subsection settlement, one-time settlement after completion and other settlement methods. Generally, the developer will pay 60% to 90% of the payment within 14 days after confirming and measuring the workload of the contractor. In consideration of payment schedule, senior executives need to focus on the payout ratio and punctuality of payments, which is the foundation of the implementation and completion of projects.

Statistical analysis of construction development in 2015 shows that the growth rate of the construction company's receivables is still pretty high in 2015, the problem of project receivables for housing construction contractors is still serious. The project receivables from the company for the past two years are shown in Table 4-3.

It can be seen in Table 4-3 that, the growth rate of electromechanical installation company's receivables was over 20%, and the growth rate of the elevator installation projects' receivables is 203.94%. Therefore, the appropriation of a project should be an important factor to be considered when undertaking a project.

(3) Financial risk (C_3)

Financial risk is the risk of expected revenue decline due to the company's unreasonable investment, causes the company to lose the ability of debt repayment and management. To further measure the financial risk of the candidate projects, this study selects three criteria: *project type*, *proprietor identity*, and *project duration*.

- *Project type*(D_7) is an important criterion to evaluate the financial risk of projects. According to the previous experience of HIEC, there are four main project types: 1) government and public installation (GPI) projects, 2) municipal installation (MP) projects, 3) industrial installation (II) projects, and 4) civil installation (CI) projects. Generally, in the term of the return risk on investment, civil installation projects are higher than II projects, higher than MP projects and higher than GPI projects.

- *Proprietor identity* (D_8) is another important criterion to evaluate the financial risk of projects, especially in Chinese construction installation industry. It reveals the characteristics of proprietors, including the progress payment ability, credit level, corporate image, and public praise of the proprietor.

• *Project duration* (D_9) has a significant impact on the occupying the company's resources (human rescore and equipment), the company's management fee and the opportunity cost of working capital.

Table 4-3 Accounts receivable comparison between different project categories

categories	criteria	accounts receivable (Million Yuan)		
		2015	2014	relative growth（%）
total 48 categories		2392.98	2163.64	10.60
fast-growing categories	elevator installation project	13.24	4.35	203.94
	earth and rock project	74.52	34.86	113.76
	specialty project	0.82	0.43	90.82
	basic treatment project of hydraulic structures	2.29	1.29	76.96
	installation project of thermal power equipment	12.50	7.20	73.67
negative growing categories	port and coastal project	2.87	4.80	-40.26
	river renovation project	1.46	2.58	-43.48
	environmental project	10.13	19.67	-48.50
	hydroelectric equipment installation project	1.46	3.51	-58.26
	highway subgrade project	4.47	13.30	-66.41

Source: Ministry of Housing and Urban-Rural Development Program Finance and Foreign Affairs Division (2015).

Therefore, we select sub-criteria: *payout ratio* (D_5) and *punctuality of payments* (D_6) to further evaluate the Payment schedule.

2. Management innovation (B_2)

Management innovation refers to the introduction of new management theory, methods, and resources into the company's management system, so as to achieve the company's strategic goal efficiently. It guarantees that the effective implementation of company strategy, meanwhile, it can reduce the complexity and cost of the management process and create more value for the company. This study uses two criteria: *project team development* and *management system improvement*, to measure the management innovation objective.

(1) Development of project team (C_4)

Development of the project team is one of the main strategic objectives of HIEC because the competition among companies is ultimately the competition of talents. A good project team with experienced and skilled members guarantees the success of projects under the constraints of budget, time and quality. In this study, the criterion of the project team development is further divided into two sub-criteria: *professional competence* and *staff comprehensive abilities*.

- *Professional competence* (D_{10}): team members need to develop their own professional skills by taking part in some high-technique-requirement projects. In other words, some projects are low-return and high-risk but are very helpful to develop and enhance the professional and comprehensive skills of the staffs. So we use this criterion to measure the contribution of the candidate project to project team development.

- *Staff comprehensive abilities* (D_{11}): team members also need to improve their comprehensive abilities of communication, team cooperation, responsibility, and other good qualities through projects.

(2) Improvement of management system (C_5)

Management is a key factor that determines the success of a business, which is important to the growth of a company. It enables companies to properly handle internal and external risks in the face of major crises. According to the actual situation of the company and the definition of the management system, *project management*, and *business management* are selected as two sub-criteria to evaluate the improvement of the management system.

Project management(D_{12}) focuses on project progress, organization and resource control. *Business management* not only manages all projects of the company but also includes the company's planning, organization, coordination, control, leadership, innovation and other functions. At the same time, the advanced management concepts and effective implementation system will be adopted, to establish a unified command and responsive senior executive team.

Business management (D_{13}) can solve the difficulties and challenges of the company during the reformation. Promoting management innovation is very important for a company to solve problems such as project selection and project management difficulties, especially in the period when the real estate industry is not as prosperous as before.

3. Technological innovation (B_3)

With the development of construction technology, construction companies can gain more profit from technological innovation, and build up the industry barriers. In reality, companies are qualified to undertake projects and get higher customer satisfaction only if they own the core technology and satisfy clients' requirements timely and effectively. Otherwise, companies will be faced with problems such as fewer projects, less business scope and unable to achieve a strategic goal. Therefore, technological innovation is crucial to the implementation of the company strategy.

Technological innovation mainly includes *incremental innovation* and *revolutionary innovation*. *Incremental innovation* is the continuous improvement of technology or production mode, and *revolutionary innovation* is the major breakthrough in materials or technology.

(1) Incremental innovation (C_6)

Incremental innovation is the innovation of persistence technology, which improves the existing products and services according to the needs of users. For architectural installation companies, incremental innovation is usually the innovation of production mode and technology that cause changes in the industrial structure over a period of time. The production model of the company determines the production cost and pattern. For example, whether multiple projects are independent will greatly affect the project schedule and cost control of the company. When the project cannot be carried out through traditional construction techniques, the company needs to innovate the existing process to meet the requirements of the project. Therefore, the technological innovation is also scarce in the project implementation process. For the architectural installation industry, technological innovation is usually about the construction technology and installation method, and it is more important to projects with difficult construction.

Based on the analysis above, we select two sub-criteria: *production mode innovation*(D_{14}) and process innovation (D_{15}) to support *Incremental innovation*.

(1) Revolutionary innovation (C_7)

For the HIEC, the revolutionary innovation is the application of new material and new technology.

- *Application of new materials* (D_{16}) often solves the problems that appear in each project. For example, the service life of the pipeline is less than five years under harsh conditions, leading to the rework of the project. Therefore, the success of the project is guaranteed by finding a pipeline material that guarantees the service life under harsh conditions.

- *Application of new technology*(D_{17}) can provide strong support for the construction of the high-quality project. The application of new technology and subsequent promotion can maximize project profit, and it is also indispensable in the implementation of projects. For example, steel structure technology, electromechanical installation engineering technology, waterproof technology.

4. Social responsibility (B_4)

Different from the traditional concept of business that takes profit as the only goal, social responsibility means that companies should not only create profits for shareholders and employees but also take responsibility and make a contribution to the environment, society, and proprietors. In this study, *social benefit* and *environmental benefit* are selected to describe the social responsibility.

(1) Social benefit (C_8)

Social benefit is used to measure the comprehensive benefits of the company for society and environment, which includes *employment contribution*, *social stability,* and *improvement of residents' living standards*. As HIEC is a state-owned company, we choose *employment contribution* and *social stability* to describe its social benefit.

Employment contribution(D_{18}): it can effectively reflect the employment opportunities created by the investment of a project. *Direct employment contribution* refers to the increase in the number of employees, and *indirect employment contribution* refers to the indirect employment opportunities created by supporting projects or related projects.

Social stability (D_{19}): by performing corresponding social responsibility, companies can effectively maintain social stability. For example, the labor and resource idle problems in the location of the project will be resolved with centralized management and human resource advantage. It can also help improve the transportation, power supply, water supply through philanthropy, so as to achieve social benefit.

(2) Environmental *benefit* (C_9)

As all we know, installation projects would have a huge impact on the local environment. Therefore, *environmental protection* and *natural resource conservation* should be the two criteria to measure the environmental benefit of a project.

- *Environmental protection* (D_{20}) must be done during the construction of an installation project. The wastewater, dust, noise and solid waste must be harmless disposed, to meet the requirements of the green installation project, and protect local environment from construction sewage, construction dust, equipment noise, construction waste, and other pollution.

- *Natural resource conservation* (D_{21}) is an important aspect of green construction. Which on the basis of project quality and safety, reduce the natural resources consumption, realize the objectives of energy saving, land saving, water saving and material saving through scientific management methods and advanced construction technology.

4.3 Calculation of Criteria Weights

After the hierarchical evaluation criteria system is constructed in subsection 4.2, the next job is to calculate the weights of the criteria through a series of pairwise comparisons between two criteria in the same layer and belonging to the same upper criteria. The criteria are pairwise compared to the strategic goal for importance. To obtain the relative weights of criteria, we use Delphi method that organizes an expert team in which the expert members conduct pairwise comparisons between two criteria and give their own scores. The detailed steps of the Delphi method used in this thesis are introduced as follows.

1. Delphi method

(1) Determine the members of the evaluation team

The evaluation team composed of experts and senior staffs in the industry, a total of 10 members. They include two senior executives from HIEC (assistant manager and chief financial officer), two senior executives in the fellow trader (manager or senior executives), two suppliers' supervisor, two downstream customers' representative assistant manager or purchasing department supervisor, two finance or supply chain management professor. The criteria for selecting these members include deputy senior or above title, 5 or more years' experience in this industry.

(2) Scoring tables

To determine the relative weights, experts are asked to pairwise compare two criteria in the same layer and belonging to the same upper criteria. They give their scores on each pairwise-compared criterion from 1 to 9 denote degree of the importance to the strategic goal. Value "1" means the least important and value "9" denotes the most important. In our evaluation criteria system, there are four criteria in layer *B*, including financial objective(B_1), management innovation objective (B_2), technological innovation objective (B_3) and social responsibility objective (B_4). We then design a scoring table for the four criteria in layer *B*, which is presented as Table 4-4. The other scoring tables for the criteria in layer C and layer D are also attached as Table 4-5 and Table 4-6.

Table 4-4 Importance rating scale of strategy-oriented portfolio evaluation criteria of Layer B

Number	Criteria	Weighted value	Score	Comment
1	Financial objective（B1）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The effective grasp of the company's Financial objective can realize the continuous strengthening of company management and the significant improvement of economic benefit.
2	Management innovation objective（B2）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Management innovation is the guarantee of the effective implementation of the company strategy, which can reduce the complexity and cost of the management process and create more value for the company.
3	Technological innovation objective（B3）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Technological innovation plays an important role in obtaining orders, expanding market share, improving customer satisfaction and establishing barriers to entry.
4	Social responsibility objective（B4）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Different from the traditional concept of business that takes profit as the only goal, the company also take responsibility and make a contribution to the environment, society, and proprietors.

Source: Author finishing

Table 4-5 Importance rating scale of strategy-oriented portfolio evaluation criteria of Layer C

Number	Criteria	Weighted value	Score	Comment
1	Investment benefit（C1）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	It is an important reference for investment decision to reflect the ratio relation between investment performance and resource consumption.
2	Payment schedule（C2）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	It is an important embodiment of the rights and obligations of the two parties, which affects the quality and duration of the project.
3	Financial risk（C3）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Financial risk runs through the whole business cycle of the company, which can be divided into four aspects: investment risk, capital recovery risk, financing risk, and income distribution risk.
4	Development of project team（C4）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The project team is a solid foundation for the implementation of the project, which is of great significance in promoting the project and ensuring the quality of the project.
5	Improvement of management system（C5）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Good management is a key factor in the success of the company, enabling the company to properly handle the internal and external risks in the face of major crises or large turnover.
6	Incremental innovation（C6）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Continuous improvement of existing products and services from the aspects of customer need on product performance and services.
7	Revolutionary innovation（C7）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Create new materials, technologies, products, services to develop new markets.

8	Social benefit（C8）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The contribution to employment, social stability, and the improvement of the living standards of residents.
9	Environmental benefit（C9）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Construction activities would bring external influence to the natural environment at the location of the project

Source: Author finishing

Table 4-6 Importance rating scale of strategy-oriented portfolio evaluation criteria of Layer D

Number	Criteria	Weighted value	Score	Comment
1	Return on investment（D1）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Return on investment=Annual profit/Total investment Choose whether to undertake the project according to the return on investment.
2	Net present value rate（D2）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Net present value rate = NPV /Original investment Dynamically reflect the relationship between project investment and project net output.
3	Payback period（D3）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Payback period = Original investment/Annual net cash flow Reflect the investment recovery speed and investment risk, the smaller the better.
4	Profitability index（D4）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Profitability index = The present value of future benefits / The present value of the investment Combined with the NPV rate, Payback period and other criteria to comprehensively select the project.
5	Payout ratio（D5）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The project progress payment is usually paid to the contractor by 60% to 90% of the project price.

6	Punctuality of payments（D6）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The Punctuality of payments affects the project construction schedule and the contract relationship between the project developer and the contractor.。
7	Project type（D7）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The rank of Return on investment of different Project type is： government and public installation projects > municipal installation projects > industrial installation projects > civil installation projects。
8	Proprietor type（D8）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The Proprietor type is used to assess the owner's progress payment ability, credit rating and other information. The proprietor type includes government, a public institution, enterprise, individual, etc.
9	Project duration（D9）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Project duration will have a strong impact on the use of the company's resources, the company's management costs and the opportunity cost of working capital.
10	Professional competence（D10）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The project management team needs to adapt to the professional skill requirements of various installation projects, to develop their unique professional skills advantages.
11	Staff qualities（D11）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Team members' communication ability, physical and mental quality have important influence on the project.
12	Project management（D12）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Project management includes planning, organizing, directing, controlling and coordinating the progress and resources of the project.
13	Business management（D13）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Through advanced management concept and effective implementation system, enterprise can establish a unified command and responsive senior executive team.

14	Producing mode innovation（D14）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The production mode and the allocation of resources among multiple projects will affect the project schedule and cost control of enterprises.
15	Process innovation（D15）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	In the construction and installation industry, the innovation of construction technology and installation method has a positive effect on the projects which are difficult to construct.
16	Application of new material （D16）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Application of new materials often solves the problems that appear in each project, like the problem that pipeline loss in the bad environment is fast
17	Application of new technology（D17）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Application of new technology can provide strong support for the construction of high-quality project, it has obvious effect on the smooth implementation of each project.
18	Employment contribution （D18）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Through the implementation of the project, the employment at the location of project will be directly or indirectly promoted.
19	Social stability（D19）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	The social stability could be promoted by providing employment opportunities and improving the living environment at the location of project.
20	Environmental protection （D20）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Reduce the emission of wastes during the construction of the project, so as to avoid pollution to the location.
21	Natural resource conservation（D21）	9	□1 □2 □3 □4 □5 □6 □7 □8 □9	Adopt the scientific management method, advanced construction technology to realize energy saving, land saving, water saving and material saving.

Source: Author finishing

(3) Statistics

After collecting the scores given by experts in the scoring table, the criteria scores are concluded as shown in Table 4-7.

Table 4-7 Scores of the criteria in layer B

Experts serial number	Financial objective （B_1）	Management innovation objective（B_2）	Technological innovation objective（B_3）	Social responsibility objective（B_4）	Source of members
1	9	8	5	5	company
2	9	6	2	4	company
3	9	9	4	5	customer
4	8	7	8	3	customer
5	7	8	3	4	supplier
6	7	5	2	5	supplier
7	8	6	2	4	fellow trader
8	7	5	3	3	fellow trader
9	7	7	6	6	professor
10	8	8	5	7	professor

Source: Author finishing

In Table 4-7, we can obtain the scores of layer *B*, financial objective, management innovation objective, technological innovation objective, social responsibility objective, from 10 experts. For a financial objective, the criteria scores given by experts are 9, 9, 9, 8, 7, 7, 8, 7, 7, 8, respectively. For management innovation objective, the criteria scores given by experts are 8, 6, 9, 7, 8, 5, 6, 5, 7, 8, respectively. For management innovation objective, the criteria scores given by experts are 8, 6, 9, 7, 8, 5, 6, 5, 7, 8, respectively. For technological innovation objective, the criteria scores given by experts are 5, 2, 4, 8, 3, 2, 2, 3, 6, 5, respectively. For social responsibility objective, the criteria scores given by experts are 5, 4, 5, 3, 4, 5, 4, 3, 6, 7, respectively. In the same way, we can get the grade of layer C and layer *D*. The details are in Table4-8 and 4-9.

Table 4-8 Scores of layer C from experts

Experts serial number	Investment benefit （C1）	Payment schedule （C2）	Financial risk（C3）	Development of project team（C4）	Improvement of management system（C5）	Incremental innovation （C6）	Revolutionary innovation （C7）	Social benefit （C8）	Environmental benefit （C9）	Source of members
1	9	9	8	6	9	1	2	6	3	company
2	7	8	9	5	8	8	3	6	3	company
3	8	6	7	7	9	6	5	7	4	fellow trader
4	8	3	5	6	9	9	6	8	5	fellow trader
5	7	5	3	3	8	4	3	5	9	supplier
6	8	8	4	5	6	4	4	6	6	supplier
7	6	3	3	3	7	6	8	8	8	customer
8	9	6	4	4	5	7	9	9	8	customer
9	5	7	8	8	9	8	6	6	9	professor
10	9	9	9	9	9	5	6	5	7	professor

Source: Author finishing

Table 4-9 Sores of layer D from experts.

Number	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	Member
1	8	8	7	6	8	8	8	8	8	5	8	7	8	3	7	3	5	5	3	3	3	company
2	8	5	8	7	7	6	8	8	4	7	7	8	8	3	8	3	5	6	4	7	3	company
3	5	3	4	7	4	7	5	6	5	6	2	9	5	2	5	5	6	8	5	4	2	customer
4	9	4	4	8	7	6	6	7	5	6	5	9	7	6	7	6	4	6	3	5	2	customer
5	5	6	6	5	8	3	5	3	3	5	5	7	3	3	8	5	3	7	3	6	2	supplier
6	9	6	9	5	8	3	4	4	2	6	3	8	5	3	6	5	3	6	7	6	2	supplier
7	6	7	7	4	5	6	7	4	7	7	6	5	7	1	5	3	6	7	4	8	6	Fellow trader
8	7	8	8	3	6	7	7	4	8	7	7	9	8	1	5	5	6	7	7	8	6	Fellow trader
9	8	6	6	5	7	8	7	4	5	2	4	7	4	5	4	2	5	6	5	6	6	professor
10	9	7	5	8	8	8	8	8	5	4	7	8	8	4	6	2	6	7	5	7	7	professor

Source: Author finishing

2. Calculation of weights

In this section, we apply the scores data based on the relative importance of the criteria obtained by the evaluation team through the Delphi method to the AHP in section 2.4.3. Firstly, the experts score each criterion according to the importance of the first-level criteria relative to the target layer. Then we rank every criterion according to their score. Finally, we formulate pairwise comparison matrices and verify its consistency.

(1) Hierarchical structure establishment

According to table 4-2, the hierarchical structure of strategy-oriented project evaluation system was constructed.

(2) According to the ratings of the panel, establish the judgment matrixes as follows.

$$\begin{pmatrix} A & B_1 & B_2 & B_3 & B_4 \\ B_1 & 1 & 2 & 2 & 3 \\ B_2 & \frac{1}{2} & 1 & \frac{3}{2} & \frac{6}{7} \\ B_3 & \frac{1}{2} & \frac{2}{3} & 1 & \frac{3}{7} \\ B_4 & \frac{1}{3} & \frac{7}{6} & \frac{7}{3} & 1 \end{pmatrix}$$

(3) The calculation of the hierarchical order of judgment matrix and consistency check.

1) The calculation of eigenvectors.

Calculate the product M_i of each row of judgment matrix A-B, and calculate n times square root of M_i, where:

$$M_1 = 1 \times 2 \times 2 \times 3 = 12\text{，}\quad \bar{W}_1 = \sqrt[4]{M_1} = 1.861;$$

$$M_2 = \frac{9}{14}\text{，}\quad \bar{W}_2 = \sqrt[4]{M_2} = 0.895;$$

$$M_3 = \frac{2}{14}\text{，}\quad \bar{W}_3 = \sqrt[4]{M_3} = 0.165;$$

$$M_4 = \frac{49}{54}\text{，}\quad \bar{W}_4 = \sqrt[4]{M_4} = 0.976;$$

Normalizing vector $\overline{W}_i = [\overline{W}_1,\ \overline{W}_2,\ \overline{W}_3,\ \overline{W}_4]^T$, where:

$$W_1 = \frac{\overline{W}_1}{\sum_{i=1}^{n} \overline{W}_i} = \frac{1.861}{1.861+0.895+0.615+0.976} = 0.428\,;$$

$$W_2 = \frac{\overline{W}_1}{\sum_{i=1}^{n} \overline{W}_i} = \frac{0.895}{1.861+0.895+0.615+0.976} = 0.206\,;$$

$$W_3 = \frac{\overline{W}_1}{\sum_{i=1}^{n} \overline{W}_i} = \frac{0.615}{1.861+0.895+0.615+0.976} = 0.141\,;$$

$$W_4 = \frac{\overline{W}_1}{\sum_{i=1}^{n} \overline{W}_i} = \frac{0.976}{1.861+0.895+0.615+0.976} = 0.225\,.$$

Therefore, we can calculate the eigenvector as follows:

$$W = \left[0.428, 0.206, 0.141, 0.225\right]^T\,;$$

$$AW = \begin{pmatrix} 1 & 2 & 2 & 3 \\ \frac{1}{2} & 1 & \frac{3}{2} & \frac{6}{7} \\ \frac{1}{2} & \frac{2}{3} & 1 & \frac{3}{7} \\ \frac{1}{3} & \frac{7}{6} & \frac{7}{3} & 1 \end{pmatrix} \left[0.428, 0.206, 0.141, 0.225\right]^T\,;$$

$$AW_1 = 1\times 0.428 + 2\times 0.206 + 2\times 0.141 + 3\times 0.225 = 1.796\,;$$

$$AW_2 = 1/2\times 0.428 + 1\times 0.206 + 3/2\times 0.141 + 6/7\times 0.225 = 0.825\,;$$

$$AW_3 = 1/2\times 0.428 + 2/3\times 0.206 + 1\times 0.141 + 3/7\times 0.225 = 0.589\,;$$

$$AW_4 = 1/3\times 0.428 + 7/6\times 0.206 + 7/3\times 0.141 + 1\times 0.225 = 0.938\,.$$

2) *The calculation of the largest characteristic root of a matrix.*

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} = \frac{1.796}{4\times0.428} + \frac{0.825}{4\times0.206} + \frac{0.589}{4\times0.141} + \frac{0.938}{4\times0.225} = 4.135 .$$

3) Consistency check.

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{4.135-4}{4-1} = 0.045 .$$

As $RI_4 = 0.89$，then the consistency ratio is：$CR = \frac{CI}{RI} = 0.051 < 0.1$, which have consistency.

According to the results, the contribution of each criterion to the strategy can be obtained, as shown in table 4-10.

Table 4-10 Strategy contribution of each criterion in layer *B*

	Objective	Weight value	Ranking of the weight value
Strategic goal（A）	Financial objective B_1	0.428	1
	Management innovation objective B_2	0.206	3
	Technological innovation objective B_3	0.141	4
	Social responsibility objective B_4	0.225	2

Source: Author finishing

It can be seen in Table 4-10 that the weight values of objectives B_1, B_2, B_3, and B_4 are 0.428, 0.206, 0.141, and 0.225, respectively. Thus, the ranking of the weight value is B_1, B_4, B_2, and B_3. In the same way, we can construct judgment matrix B-C and C-D, the judgment matrix are shown as follows, and the strategic contribution of each criterion can be obtained according to the judgment matrix, as shown in Table 4-11.

Now we can figure out the contribution of each project to the company's strategy by using the evaluation system proposed in subsections 4.2 and 4.3. In the rest of this chapter, we identify the scarce resources that candidate projects need and propose a method to calculate determine the resource strategic contribution rate of each project. For the projects with a high resource strategic contribution rate, we will prioritize the allocation of limited company resources, to maximize the strategic contribution of projects.

$$\begin{array}{cc} B_1 & \begin{matrix} C_1 & C_2 & C_3 \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \end{matrix} & \begin{pmatrix} 1 & 2 & 3 \\ \frac{1}{2} & 1 & \frac{3}{2} \\ \frac{1}{3} & \frac{2}{3} & 1 \end{pmatrix} \end{array}$$

Judgment matrix B1-C3

$$\begin{array}{cc} B_2 & \begin{matrix} C_4 & C_5 \end{matrix} \\ \begin{matrix} C_4 \\ C_5 \end{matrix} & \begin{pmatrix} 1 & \frac{2}{3} \\ \frac{3}{2} & 1 \end{pmatrix} \end{array}$$

Judgment matrix B2-C5.

$$\begin{array}{cc} B_3 & \begin{matrix} C_6 & C_7 \end{matrix} \\ \begin{matrix} C_6 \\ C_7 \end{matrix} & \begin{pmatrix} 1 & \frac{6}{5} \\ \frac{5}{6} & 1 \end{pmatrix} \end{array}$$

Judgment matrix B3-C7

$$\begin{array}{cc} B_4 & \begin{matrix} C_8 & C_9 \end{matrix} \\ \begin{matrix} C_8 \\ C_9 \end{matrix} & \begin{pmatrix} 1 & \frac{11}{10} \\ \frac{10}{11} & 1 \end{pmatrix} \end{array}$$

Judgment matrix B4-C9.

$$\begin{array}{cc} C_1 & \begin{matrix} D_1 & D_2 & D_3 & D_4 \end{matrix} \\ \begin{matrix} D_1 \\ D_2 \\ D_3 \\ D_4 \end{matrix} & \begin{pmatrix} 1 & \frac{3}{2} & 2 & 2 \\ \frac{2}{3} & 1 & \frac{3}{2} & \frac{6}{5} \\ \frac{1}{2} & \frac{2}{3} & 1 & \frac{4}{3} \\ \frac{1}{2} & \frac{5}{6} & \frac{3}{4} & 1 \end{pmatrix} \end{array}$$

Judgment matrix C1-D4

$$\begin{array}{cc} C_2 & \begin{matrix} D_5 & D_6 \end{matrix} \\ \begin{matrix} D_5 \\ D_6 \end{matrix} & \begin{pmatrix} 1 & \frac{4}{3} \\ \frac{3}{4} & 1 \end{pmatrix} \end{array}$$

Judgment matrix C2-D6.

$$\begin{array}{cc} C_3 & \begin{matrix} D_7 & D_8 & D_9 \end{matrix} \\ \begin{matrix} D_7 \\ D_8 \\ D_9 \end{matrix} & \begin{pmatrix} 1 & 2 & 2 \\ \frac{1}{2} & 1 & 2 \\ \frac{1}{2} & \frac{1}{2} & 1 \end{pmatrix} \end{array}$$

Judgment matrix C3-D9

$$\begin{array}{cc} C_4 & \begin{matrix} D_{10} & D_{11} \end{matrix} \\ \begin{matrix} D_{10} \\ D_{11} \end{matrix} & \begin{pmatrix} 1 & \frac{9}{7} \\ \frac{7}{9} & 1 \end{pmatrix} \end{array}$$

Judgment matrix C4-D11

$$\begin{pmatrix} C_5 & D_{12} & D_{13} \\ D_{12} & 1 & 2 \\ D_{13} & \frac{1}{2} & 1 \end{pmatrix}$$

Judgment matrix C5-D13

$$\begin{pmatrix} C_6 & D_{14} & D_{15} \\ D_{14} & 1 & \frac{3}{5} \\ D_{15} & \frac{5}{3} & 1 \end{pmatrix}$$

Judgment matrix C6-D15

$$\begin{pmatrix} C_7 & D_{16} & D_{17} \\ D_{16} & 1 & \frac{7}{5} \\ D_{17} & \frac{5}{7} & 1 \end{pmatrix}$$

Judgment matrix C7-D17

$$\begin{pmatrix} C_8 & D_{18} & D_{19} \\ D_{18} & 1 & \frac{7}{6} \\ D_{19} & \frac{6}{7} & 1 \end{pmatrix}$$

Judgment matrix C8-D19

$$\begin{pmatrix} C_9 & D_{20} & D_{21} \\ D_{20} & 1 & \frac{7}{5} \\ D_{21} & \frac{5}{7} & 1 \end{pmatrix}$$

Judgment matrix C9-D21.

Table 4-11 Calculation of each judgment matrix.

Judgment matrix	M_i	$\overline{W}_i$	W_i	AW_i	λ_{max}	CI	RI	CR
B1—C3	M_1=6.000 M_2=0.750 M_3=0.222	$\overline{W}_1$=1.817 $\overline{W}_2$=0.909 $\overline{W}_3$=0.606	W_1=0.545 W_2=0.273 W_3=0.182	AW_1=1.636 AW_2=0.818 AW_3=0.546	3.000	0.000	0.58	0.000
B2—C5	M_1=0.667 M_2=1.500	$\overline{W}_1$=0.817 $\overline{W}_2$=1.225	W_1=0.400 W_2=0.600	AW_1=0.800 AW_2=1.200	2.000	0.000	0	0.000
B3—C7	M_1=1.200 M_2=0.833	$\overline{W}_1$=1.095 $\overline{W}_2$=0.913	W_1=0.545 W_2=0.455	AW_1=1.091 AW_2=0.909	2.000	0.000	0	0.000
B4—C9	M_1=1.100 M_2=0.909	$\overline{W}_1$=1.049 $\overline{W}_2$=0.953	W_1=0.524 W_2=0.476	AW_1=1.048 AW_2=0.952	2.000	0.000	0	0.000

C1—D4	M_1=6.000 M_2=1.200 M_3=0.444 M_4=0.313	$\overline{W}_1$=1.565 $\overline{W}_2$=1.047 $\overline{W}_3$=0.816 $\overline{W}_4$=0.748	W_1=0.375 W_2=0.251 W_3=0.196 W_4=0.179	AW_1=1.500 AW_2=1.009 AW_3=0.789 AW_4=0.722	4.023	0.008	0.89	0.009
C2—D6	M_1=1.333 M_2=0.750	$\overline{W}_1$=1.155 $\overline{W}_2$=0.866	W_1=0.571 W_2=0.429	AW_1=1.143 AW_2=0.857	2.000	0.000	0	0.000
C3—D9	M_1=4.000 M_2=1.000 M_3=0.250	$\overline{W}_1$=1.587 $\overline{W}_2$=1.000 $\overline{W}_3$=0.630	W_1=0.493 W_2=0.311 W_3=0.196	AW_1=1.507 AW_2=0.949 AW_3=0.598	3.054	0.027	0.58	0.046
C4—D11	M_1=1.286 M_2=0.778	$\overline{W}_1$=1.134 $\overline{W}_2$=0.882	W_1=0.563 W_2=0.438	AW_1=1.125 AW_2=0.875	2.000	0.000	0	0.000

C5—D13	M_1=2.000 M_2=0.500	$\overline{W}_1$=1.414 $\overline{W}_2$=0.707	W_1=0.667 W_2=0.333	AW_1=1.333 AW_2=0.667	2.000	0.000	0	0.000
C6—D15	M_1=0.600 M_2=1.667	$\overline{W}_1$=0.775 $\overline{W}_2$=1.291	W_1=0.375 W_2=0.625	AW_1=0.750 AW_2=1.250	2.000	0.000	0	0.000
C7—D17	M_1=1.400 M_2=0.714	$\overline{W}_1$=1.183 $\overline{W}_2$=0.845	W_1=0.583 W_2=0.417	AW_1=1.167 AW_2=0.833	2.000	0.000	0	0.000
C8—D19	M_1=1.167 M_2=0.857	$\overline{W}_1$=1.080 $\overline{W}_2$=0.926	W_1=0.538 W_2=0.462	AW_1=1.077 AW_2=0.923	2.000	0.000	0	0.000
C9—D21	M_1=1.400 M_2=0.714	$\overline{W}_1$=1.183 $\overline{W}_2$=0.845	W_1=0.583 W_2=0.417	AW_1=1.167 AW_2=0.833	2.000	0.000	0	0.000

Source: Author finishing

4.4 Project Evaluation

By applying the established evaluation criteria system in subsection 4.3, the following steps are used to evaluate the strategic contributions of candidate projects.

Step 1: *Determine team members*

In order to effectively determine the grades of the candidate projects will be undertaken by HIEC, we organize an expert team consisting of experts from different functional departments of HIEC.

Step 2: *Design grade table of projects and comment set*

Design the grade table and set that the comment set V= {V_1 is very good, V_2 is better, V_3 is generally, V_4 is worse, V_5 is very poor}, and the corresponding range is {8~10, 6~7.9, 4~5.9, 2 ~3.9, 0~1.9}. The team members give their scores on projects in terms of the criteria in layer *D* of the evaluation system in Figure 4-2. We calculate the average value of the scores given by experts and determine the strategic contribution of candidate project *i* by the following equation.

$$Z_i = \sum_{n=1}^{21} w_n y_n , \tag{4-1}$$

Where w_n is the strategic contribution weight of criterion D_n of the hierarchical evaluation system in Figure 4-2 and y_n is the score on criterion D_n.

4.5 Calculation of Resource Demands

4.5.1 Identification of Scarce Resources

When multiple projects under construction in parallel, company resources will be assigned to each project. In the current situation, the use of resources has not been systematically controlled, and its allocation mode is to distribute the existing resources according to the needs of the project. This kind of mode of allocation has biggish drawbacks, which will cause the demands for resources of the high-return projects in the parallel cannot be effectively satisfied, resulting in the delay or failure of some projects so that the company strategy cannot be realized. This indicates that, in the process of running multiple projects, the company needs to systematically control its resources and reasonably allocate them.

The main resources used in the project can be divided into two categories (Huang, & Niu, 2010): Nonrenewable Resources and Renewable Resources. The entire project determines the acquisition and consumption of nonrenewable resources. That is, at the beginning of the project, the maximum amount of nonrenewable resources is available, and gradually reduces as the project implementation progresses, such as energy and raw materials. Many companies often buy a large number of nonrenewable resources as inventory or sign JIT agreements with suppliers, to ensure that the usage amount of nonrenewable resources will not exceed the maximum amount of resources that they hold. Therefore, in this paper, the strategic contribution rate of nonrenewable resources is not taken into account.

Renewable resources refer that the usage amount of resources during the execution of a project activity is limited for each period (day, week, month, etc.). However, at the end of this period, its usage amount of resources will be supplemented and restored to its original level in the next period, such as machines, equipment and venues and so on. Compared with nonrenewable resources, the number of renewable resources is always limited. Therefore, conflicts always happen to the allocation of renewable resources when multiple projects are under construction in parallel.

4.5.2 Demands of Scarce Resources

This section focuses on the scarce resources, namely technical designers in HIEC according to the project files, including project WBS files, project schedule (Gantt Charts) and resource demand files. The main idea of calculation the demands of scarce resources is described as follows.

Under the premise of ensuring the logical relationship between project activities and that the total duration of the project does not exceed the contract duration, we determine the demands of the scarce resources of each project's work package through WBS file. Then allocate the demands resources through the project schedule in Gantt Charts. Thus, the demands for the scarce resources are determined as the maximum numbers demanded at an arbitrary period (e.g. one week) within the total project duration.

4.6 Project Selection and Resource Allocation

4.6.1 Optimal Programming Approach

(1) Introduction on CPLEX Optimizer

IBM CPLEX Optimizer uses the simplex method of primitive or dual variants or barrier internal point method, convex and non-convex two-time programming problems, and convex two-time constraint problems (through the second solution) to solve integer programming problems, very large linear planning problems to order conical programming or SOCP). CPLEX Optimizer has a modeling layer called a concert, which provides interfaces for the C++, C# and Java languages. There is a Python language interface based on the C interface. In addition, connectors for Microsoft Excel and MATLAB are available.

Finally, a separate interactive optimizer executable file is provided for debugging and other purposes. CPLEX Optimizer can be accessed through stand-by modeling systems such as AIMMS, AMPL, GAMS, OPTIMJ, and TOMLAB. In addition, AMPLE also provides an interface for CPLEX CP Optimizer. The complete IBM ILOG CPLEX optimization Studio includes CPLEX optimizer for mathematical programming, IBM ILOG CPLEX CP Optimizer for constrained programming, optimized programming languages (OPL), and tightly integrated Ides.

(2) Apply CPLEX for optimal project selection

According to the calculated strategic contributions of candidate projects in subsection 4.4 and the resource demands of projects in subsection 4.5, the project selection and portfolio problem with resource constraint can be seen as a classical *0-1 knapsack* problem (Martello and Toth, 1990), which is described as follows.

0-1 *Knapsack problem*: *Given a set of items (i.e., projects), each with a weight (i.e., resource demand) and a value (i.e., strategic contribution), determine which items (i.e., projects) should be included in a collection (i.e., project portfolio) so that the total weight (i.e., total resource demand) is less than or equal to a given limit (i.e., total resource supply) and the total value (i.e., total strategic contribution of the portfolio) is as large as possible.*

In our problem, we define the following notations to formulate our project selection and portfolio problem as a 0-1 *Knapsack* problem.

Table 4-12 Strategy contribution of each criterion in layer *B*.

Notations	**Description**
N	Number of candidate projects, each project is indexed as project i, $1 \le i \le N$;
Z_i	Strategic contribution of project i, which is calculated in Section 4.4;
K	Number of the types of scarce resource, each resource is indexed as resource k, $1 \le k \le K$;
Q_k	Total supply of resource k;
$q_{i,k}$	Demand of resource k by project i;
Decision variable	
$x_i \in \{1, 0\}$	Binary variable, $x_i = 1$ indicate project i is selected to portfolio; otherwise, $x_i = 0$

Source: Author finishing

Using the notation listed in Table 4-12, we formulate the problem as following mixed integer programming model.

$$\textbf{Problem } \boldsymbol{P} \qquad \textbf{\textit{Maximize}} \ \sum_{i=1}^{N} x_i Z_i \ , \tag{4-2}$$

$$\textbf{\textit{Subject to}} \sum_{i=1}^{N} x_i q_{i,k} \le Q_k \, , \ 1 \le k \le K \, , \tag{4-3}$$

$$x_i \in \{0,1\}, 1 \le i \le N \, . \tag{4-4}$$

In above model, the optimization function (4.2) is to maximize the total strategic contributions of the selected projects, where term $x_i Z_i$ is the strategic contributions of project i depending on whether the project is selected. More specially, decision variable $x_i = 1$ means that the project is selected and accordingly it has a Z_i values of the strategic contribution to the portfolio. The constraint (4.3) makes sure that the total demand on resource k of the selected project, namely $\sum_{i=1}^{N} x_i q_{i,k}$ cannot exceed the total supply of resource k, where $1 \leq k \leq K$. The last constraint indicates that decision variable x_i either equals to 1 or 0, which means that project i is selected or not.

To solve the model, we apply the optimization software tool: IBM ILGO-CPLEX Optimizer, to obtain an optimal solution $X^* = \{x_i | 1 \leq i \leq N\}$, where $x_i = 1$ implies that project i is selected into the project portfolio.

4.6.2 Heuristic Selection Rule Based on Strategic Contribution Rate

Note that the optimal programming approach introduced in subection 4.6.1 always guarantees to generate an optimal project portfolio solution with the maximum total strategic contribution, but it is difficultly applied into practice due to its high computational time and cost. In this subsection, we develop an easy and efficient heuristic rule to select projects. The strategic contribution rate of the project consume scarce resources is determined, which provides a basis for the rational allocation of resources for selecting a project. The strategic contribution rate of the project renewable resources is the ratio of the project resources contribution rate to the demands of a project renewable resource. Which means the contribution of per unit renewable resources consumption to the company strategy. The equation to calculate the contribution rate α_i of project P_i can be calculated by the project resources contribution Z_i and the amount of resource demands $\sum_{k \in K} q_{i,k}$, shown in formula (4.5).

$$a_i = \frac{Z_i}{\sum_{k \in K} q_{i,k}} \times 100\% \tag{4-5}$$

According to the strategic contribution rate of project resources calculated by formula

(4.5), the projects are sorted in terms of the contribution rate from high to low. Then, we allocate the scarce resources to candidate projects with the higher strategic contribution rates, which means that the candidate projects with higher strategic contribution rates have higher priorities to obtain resource and enter into current project portfolio. It should be noted that when the resources are not enough to allocate to a project, we can skip this project to go on judging whether the resources can meet the demands of subsequent projects. When a subsequent project can be met, the resources are allocated to this project. Therefore, through the above resource allocation, either the company resources are fully allocated to the projects, or the resources cannot meet the demand of any unselected projects.

[This page is deliberately left blank.]

Chapter 5: Application Analysis

To examine the effectiveness of the proposed project evaluation system and project selection and resource allocation approaches in Chapters 3 and 4. This chapter gives a real case: the project portfolio management in HIEC, which belongs to a large state-owned construction group in Sichuan Province of China. We compare the performances of project portfolio before and after implementing the proposed approaches in 2014 and 2017 years, respectively. Before the formal comparison analysis, we first give a brief introduction on the background, history and current project management of HIEC and give the explanation on why we select HIEC as a numerical instance in this thesis.

5.1 Introduction on HIEC

Sichuan Huashi Group Company Limited (SHGCL) is a large state-owned construction group which was built in May 1950. SHGCL is under the direct supervision of the state-owned assets supervision and administration commission of Sichuan provincial people's government. The company holds the building construction general contract extra grade qualification approved by the ministry of construction, has the rights of foreign economic and trade management and has AAA corporate credit rating. SHGCL has total assets of 10 billion Yuan, an annual income of its main business exceeds 12.7 billion Yuan, and annual income tax exceeds 500 million Yuan. In August 2016, SHGCL ranked no. 256 in the "top 500 Chinese enterprises 2016".

Sichuan Huashi Group is an affiliated enterprise consortium, the generic terms of all investment and management business units of SHGCL. Including 12 construction engineering subsidiaries, 8 special professional and supporting professional subsidiaries, 6 overseas institutions, 4 public institutions, and more than 200 branches invested or established by the affiliated enterprises.

SHGCL has 1 building construction general contract extra grade qualification, 10 building construction general contract first-grade qualification, 4 municipal public engineering construction general contract first-grade qualification, 1 highway engineering construction general contract first-grade qualification, 2 electromechanical installation engineering construction general contract first grade qualification, all kinds of professional engineering construction general contract secondary qualification, 2 special construction qualifications and 5 real estate development qualifications.

SHGCL has 12,310 professional technical and economic managers, including 16 experts on special government allowances, 390 first-level project managers and 844 second-level project managers. SHGCL currently has total assets 5.5 billion Yuan, net assets 1.2 billion Yuan. In 2002, the output value was 6.4 billion Yuan.

Huashi Installation Engineering Company (HIEC) affiliates to SHGCL. HIEC has following four additional items of special qualification of the parent company: the first class qualification of top general contracting for electromechanical installation engineering construction, the first class qualification of specialized contracting for fire-fighting facilities engineering, the first class qualification of specialized contracting for electromechanical equipment installation engineering, and the first class qualification of specialized contracting for elevator installation engineering. And functional structure of HIEC can be shown in figure 5-1.

HIEC inherits the history and resources for more than 60 years of SHGCL. As a subordinate professional branch of a famous super-large state-owned construction company, HIEC has more than 400 employees, more than 60% of which have a junior college degree or above. Economic and technical managers make up about 75% of the total employees (35% of them are managers with intermediate and senior professional titles, and 25% of them are constructors and associate constructors). The company aims at market development, set up branches of equipment, fire-fighting, electromechanical and elevator. It had set up offices in Mianyang, Xi'an, and Guangzhou, and formed the leap-forward development mode with Chengdu as the center. HIEC is a state-owned medium-sized comprehensive construction company, which integrates installation and construction, engineering inspection, technical consultation, and personnel training. In 2017, the company realized 2.7 billion yuan of operating revenue, more than 200 million yuan of pretax profit and 3.08 billion yuan of new contracts.

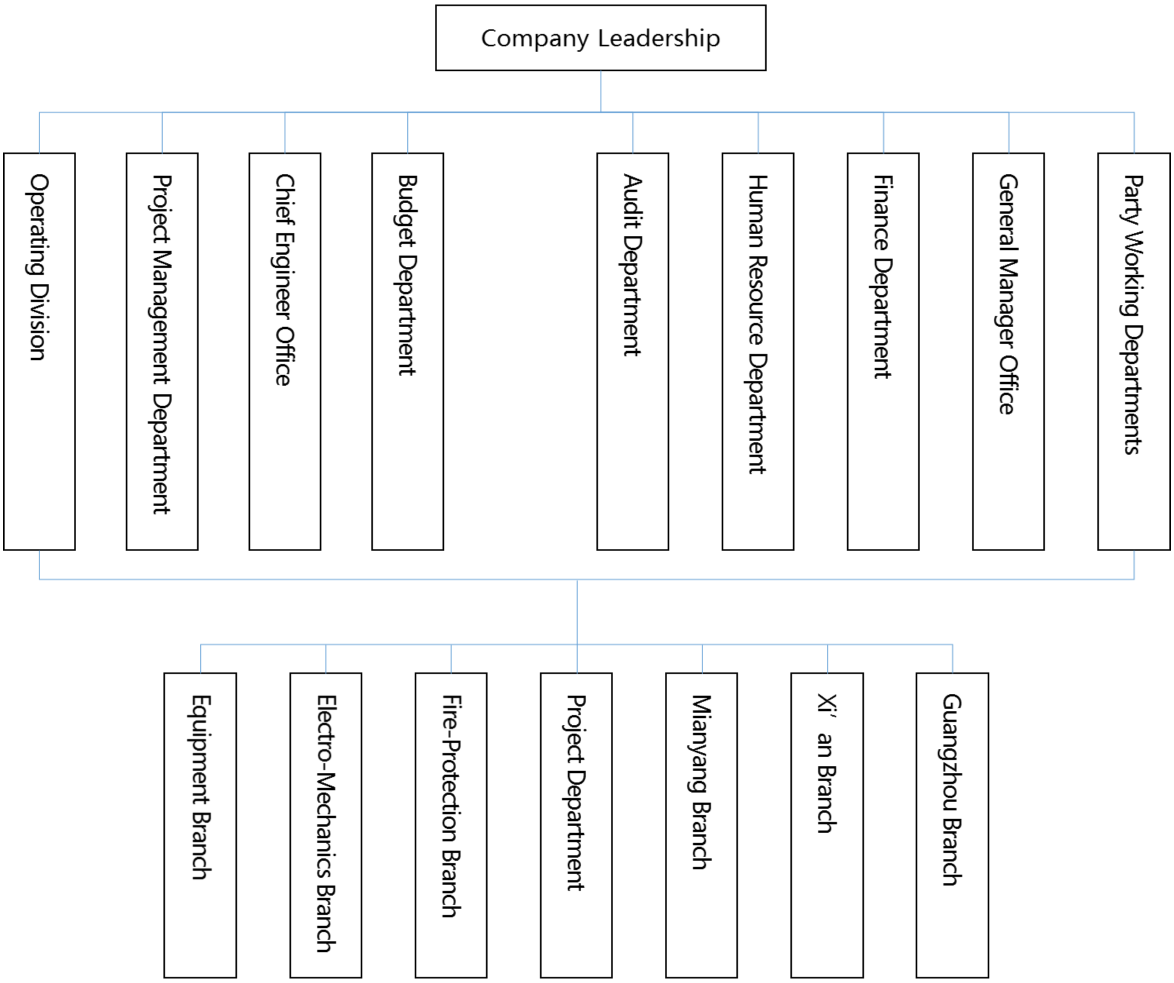


Figure 5-1 Functional structure

Source: Author finishing

HIEC has a complete engineering construction system, and it has the capability of general contract for electromechanical installation and professional contract for fire control engineering and petrochemical industry, the professional contracting qualification of urban and road lighting project and environmental protection project, and also the licenses of pressure pipeline, pressure vessel, boiler and elevator special equipment, which passed the quality, environment and occupational health and safety management system certification. HIEC is capable of serving various fields, including industrial, civil and public project construction, which involved in petrochemical industry, aerospace industry, national defense military industry, energy and environmental protection, housing construction, transportation, machinery manufacturing, culture and education, sports, medicine and health, electronics, light industry, textile and other industries. HIEC is capable of undertaking installation and commissioning of all civil buildings, commercial squares, industrial equipment, large buildings, intelligent buildings, and subway projects.

HIEC aims to "construct the perfections and build a beautiful life", and build good engineering projects and promote the technology demonstration project. With advanced technology, strict management, strong strength, high-quality service, HIEC has been praised by all circles of society and users and has been recognized in provincial and ministerial level. HIEC has received many honors, include 2 awards of China's construction industry's top awards "Luban Prize", 2 awards of "Chinese National Quality Award", "Zhan Tianyou Prize", "Municipal gold cup demonstration project", "China installation star", 2 awards of Shanghai quality engineering "White Magnolia Cup" and 47 awards of provincial and municipal quality engineering and quality structure award. The company also won national and provincial honors for advanced installation enterprise, integrity unit, and model worker's home. And emerged many outstanding individuals recognized by the state and province.

HIEC repeatedly won the national and provincial honorary title, including the "Good Credit Unit for Compliance with Contract", "National Excellent Construction Enterprise", "National Excellent Enterprise of Construction Project Quality Management", "National Integrity Unit", "Advanced Enterprise of Construction Industry in Sichuan Province", "Best Civilized Unit in Sichuan Province", "Key Construction Advanced Unit in Sichuan Province", "Customer Satisfaction Enterprises of Engineering Construction System in Sichuan Province", "May 1 Labor Certificates in Sichuan Province", etc.

HIECE has also published the first national high-rise building installation manual, "High-Rise Building Equipment Installation Manual", and participate in writing the national standards and local standards for many times, has 18 awards of national and provincial science and technology progress award, 25 engineering method, 19 invention patents and utility model patents. HIEC is highly praised by professionals and industrials, and the company’s construction technology level in construction and installation ranks among the forefront of the industry in China.

In recent years, HIEC has established a development line that "Based in Chengdu, serve the domestic market, expand overseas, and take the road of multi-structure specialization". Focusing on transformation and upgrading, promoting the development of municipal engineering and infrastructure business as the key to the strategic transformation of the company, expanding the installation field of municipal rail transit equipment.

Multiple engineering projects have been undertaken in Sichuan, Shanghai, Guangzhou, Xi 'an, Changsha and Tibet, include Deng Xiaoping's memorial hall, 5•12 Wenchuan earthquake memorial, high-altitude cosmic ray observatory of Chinese Academy of sciences, Ya'an Lushan county disaster reconstruction series projects, Chengdu Wangfujing mall, China national electric power Dadu river basin cascade power station dispatch center, subway electromechanical projects in Guangzhou and Changsha, Raffles City in Chengdu, PetroChina ethylene project in Sichuan, Mianyang Changhong PDP production line, Luzhou liquor concentration development area convention and exhibition center project, Chengdu Renhe Spring international plaza, comprehensive maintenance and reconstruction of gymnasium in Sichuan province, Sichuan modern car final assembly and supporting workshop project, Sichuan airlines plaza, Luzhou parking lot PPP construction project etc. A comprehensive, multi-field and large-span construction and installation market competition based on Chengdu has been formed.

Over the past 12 years, the company had made a series of brilliant achievements. The company's operating capacity has continuously improved, and its production scale has been continually expanded (the annual output value is more than 500 million). With the expansion of the company's business, the number of projects increases year by year. How to choose the right project portfolio is the main problem facing the company? Firstly, the selected projects should be able to help the company to achieve its strategic goal, then maximize the company's strategic contribution by using as few resources as possible and ensure the smooth implementation of the project at the same time.

The company has always been adhering to the enterprise spirit of "fellow morality and build the world", and the corporate value of "responsibility, integrity, cooperation, innovation", to become the industry leader in construction and installation field among twelve provinces in western China.

To make sure that HIEC could choose the suitable project portfolio, we need to evaluate projects efficiently and allocate resources reasonably, by using scientific portfolio management knowledge and corresponding project management tools. In this chapter, we will evaluate the projects undertaken by HIEC, and verify the example by the project portfolio selection method proposed in this paper.

5.2 The Reasons for Selecting HIEC as an Instance

Base on the above introduction on HIEC, it is found that HIEC is one of the leadership installation engineering companies in Sichuan province or even in China. As presented in Figure 5-1, this company conduct four types of the project simultaneously. This is a very good example or case to testify and exam our proposed project evaluation and selection methods. The detailed reasons are presented as follows.

1) HIEC is one of the leadership installation engineering companies in Sichuan province or even in China. In 2014, HIEC undertook 90 projects with a revenue of about 550 million yuan (approximately 70 million euro). Although A single project is well managed in the company in the past decade, the multiple project management, especially the project selection and portfolio management is a challenge for this company's development. Therefore, HIEC needs to develop a reasonable project selection and portfolio approach to improve the company's management capacity and accomplish the strategic goal.

2) HIEC has a long history and a good information system which recorded sufficient information and data on the conducted projects in the past decade. Therefore, this information and data on the conducted projects can be used to analyze the performance of the project management in HIEC and can be further used to test the proposed project evaluation and selection approach in the thesis.

3) HIEC is a representative case. It is because there are different types of project are

carried out in this company simultaneously. For example, in 2014, HIEC undertook 90 projects, including 12 public buildings or government investment (PB) projects, 43 civil building (CB) projects, 10 industrial equipment installation (IE) projects, and 25 civil architecture (CA) projects. Since the implementation of these projects is far beyond the company's resource supply, there are resource contention and conflicts among multiple projects. In our studied problem, we focus on the project portfolio based on the resource constrained. Therefore, the situation and constraints in HIEC’s project management are very close to the problem addressed in Chapter 4.

To sum up, first of all, HIEC is a representative installation engineering company in Sichuan province and even in China. Second, there are sufficient information and data on the conducted projects, which can be used to analyze the performance of the existing project management in HIEC and can be further used to test the proposed project evaluation and selection approach in the thesis. Last, the situation and constraints in HIEC’s project management are very close to the problem addressed in this study. Therefore, HIEC is a good case to be used for applying the proposed project evaluation and selection approaches in this thesis.

5.3 Application Process and Analysis

At present, the projects undertaken by HIEC can be divided into the following four types, including public or government investment projects, municipal projects, industrial equipment installation (factory), and general civil construction. In this subsection, four projects respectively selected from four project types in 2017 are used to illustrate the application processing of the project evaluation and selection approaches proposed in Section 4.

5.3.1 Introduction of Four Projects

In this section, the knowledge of Work Breakdown Structure (WBS) and Gantt chart will be applied. The WBS is mainly used to draw network plan maps, Gantt charts, cost control, draft quality plans, and build responsibility systems. Through the preparation of the project WBS, we can know the division and distribution of responsibilities, ensure that the project objectives can be implemented from top to bottom to specific work, and lay a common foundation for the smooth development of resources planning, work coordination, budgeting, and progress control. The foundation ensures that the measurement and control of the project schedule is quantifiable and has a baseline.

The Gantt chart is a bar chart that shows how the project's progress, progress, and other time-related systemic progress are progressing over time. The Gantt chart graphically shows the order and duration of specific items through the activity list and time scale. A line graph with the horizontal axis representing time, the vertical axis representing the item, and the line indicating the period plan and actual completion. Visually indicate when the plan is going, and the progress is compared to the requirements. It is convenient for managers to clarify the remaining characters of the project and assess the progress of the work.

We then give following brief introductions on the four projects.

(1) WBS of projects

The project of Xihua University Experimental Training Center, denote as P1, is the government investment project and its owner are Xihua University in Chengdu, Sichuan. According to the function of the project decomposition, the project can be divided into the heavy-current installation and light-current installation. The main work of heavy-current installation can be further divided into lightning protection grounding installation and lighting installation. The main work of weak light-current installation can be further divided into telephone / TV cable installation and monitoring system installation. So, the project WBS decomposition diagram of Xihua University Experimental Training Center (referred to as the P1 project) is shown in Figure 5-2.

The project of Feixianguan Nanchang town resettlement housing, denoted as P2, could be divided into the electrical installation, weak electricity installation and water supply and drainage system installation. The electrical installation includes lighting installation only, and the weak electricity installation also includes telephone/TV cable installation only. The water supply and drainage system installation can be further divided into rainwater system installation, domestic wastewater system installation and water supply installation. So, the project WBS decomposition diagram of Feixianguan Nanchang town resettlement housing (P2) is shown in Figure 5-3.

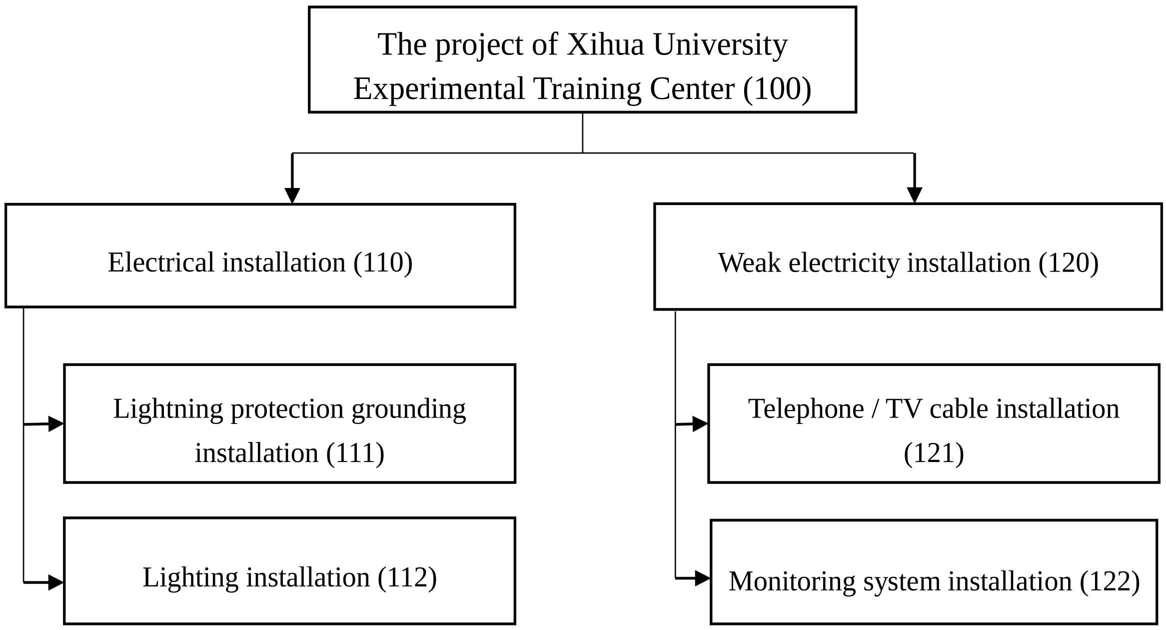


Figure 5-2 WBS diagram of P1 project

Source: Author finishing

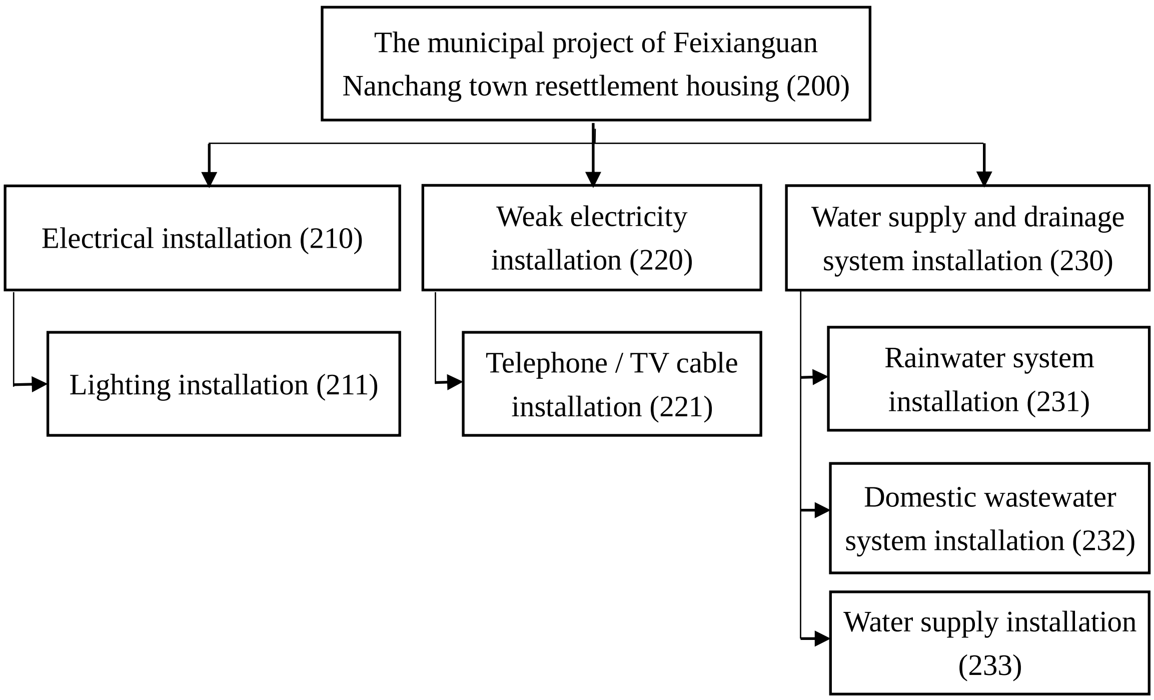


Figure 5-3 WBS diagram of P2 project

Source: Author finishing

The project of Sichuan Hyundai commercial vehicle production base engineering industrial equipment installation, denoted as P3, could be divided into the electrical installation, weak electricity installation and firefighting system installation. The electrical installation includes lightning protection grounding installation and lighting installation, the weak electricity installation includes telephone/TV cable installation only, and the firefighting system installation can be further divided into firefighting linkage installation and firefighting water supply installation. So, the project WBS decomposition diagram of Sichuan Hyundai commercial vehicle production base engineering industrial equipment installation (P3) is shown in Figure 5-4.

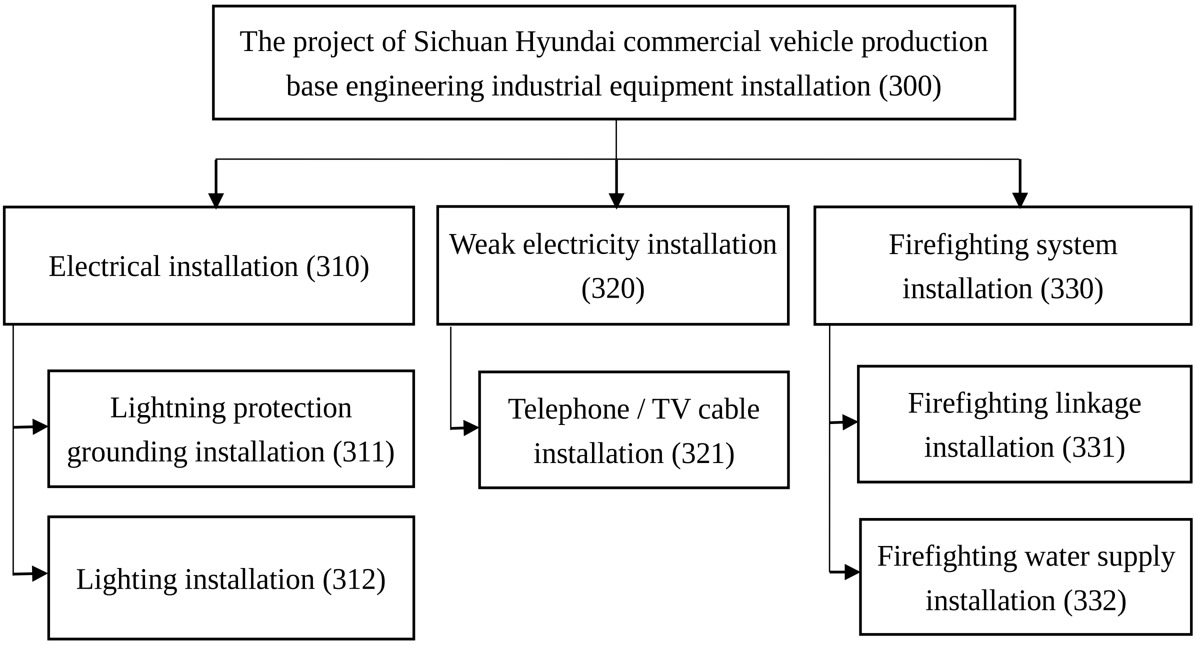


Figure 5-4 WBS diagram of P3 project

Source: Author finishing

The project of general civil construction installation project of Dongjiang capital, denoted as P4, could be divided into the electrical installation, weak electricity installation and water supply and drainage system installation. The electrical installation includes lightning protection grounding installation and lighting installation, the weak electricity installation includes telephone/TV cable installation only, and the water supply and drainage system installation can be further divided into domestic wastewater system installation and water supply installation. So, the project WBS decomposition diagram of general civil construction installation project of Dongjiang capital (P4) is shown in Figure 5-5.

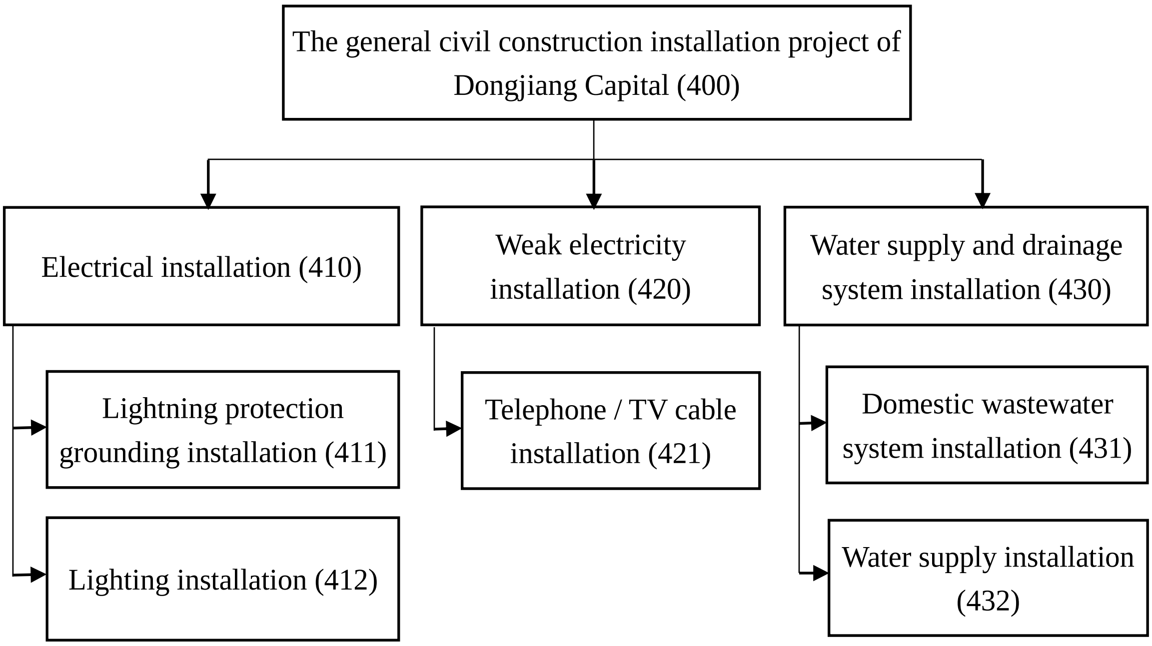


Figure 5-5 WBS diagram of P4 project

Source: Author finishing

In Figure 5-3, the P1 can be breakdown into two structures and four work packages. In Figure 5-4, the P2 can be breakdown into three structures and five work packages. In Figure 5-5, the P3 can also be breakdown into three structures and five work packages. In Figure 5-6, the P4 can also be breakdown into three structures and five work packages.

(2) Gantt Charts of projects

In this section, we first calculate the mean completion time of the activity based on the Three-time Estimation Method. The Three-time Estimation Method divides the completion time into optimistic time a, most likely time m, and pessimistic time b. Optimistic time is the completion time in the case of a smooth job. The most likely time is the most likely completion time for completing a process. Pessimistic time is the time it takes for the work to proceed unfavorably. And the mean duration T of the activity can be calculated by equation 5.1 (Mohamed, Abdel-Basset, Hussien, & Smarandache, 2017).

$$T = \frac{a + 4m + b}{6} \tag{5-1}$$

As mentioned above, P1 can be divided into four sub-packages: lightning protection grounding installation, lighting installation, telephone / TV cable installation, and monitoring system installation. According to the company's historical experience and data, we can know that the optimistic time *a*, most likely time *m*, and pessimistic time *b* of lightning protection grounding installation are 25, 27, and 33, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of lighting installation are 51, 55, and 63, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of telephone / TV cable installation are 16, 22, and 23, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of monitoring system installation are 12, 13, and 17, respectively. According to equation 5.1, we can calculate the mean completion duration of four sub-packages below:

$$T_{1-1} = \frac{25 + 4 \times 27 + 33}{6} = 27.66 \approx 28\ ;$$

$$T_{1-2} = \frac{51 + 4 \times 55 + 63}{6} = 55.66 \approx 56\ ;$$

$$T_{1-3} = \frac{16 + 4 \times 22 + 23}{6} = 21.16 \approx 21\ ;$$

$$T_{1-4} = \frac{12 + 4 \times 13 + 17}{6} = 13.5 \approx 14\ .$$

Thus, the mean duration of four sub-packages, lightning protection grounding installation, lighting installation, telephone / TV cable installation, and monitoring system installation, of P1 are 28, 56, 21, and 14, respectively.

Correspondingly, P2 can be divided into five sub-packages: lighting installation, telephone/TV cable installation, rainwater system installation, domestic wastewater system installation, and water supply installation. According to the company's historical experience and data, we can know that the optimistic time *a*, most likely time *m*, and pessimistic time *b* of lighting installation are 51, 55, 63, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of telephone/TV cable installation are 16, 22, and 23, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of rainwater system installation are 12, 13, and 17, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of domestic wastewater system installation are 25, 27, and 33, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of water supply installation are 16, 22, and 23, respectively. According to equation 5.1, we can calculate the mean completion duration of five sub-packages below:

$$T_{2-1} = \frac{51+4\times55+63}{6} = 55.66 \approx 56\ ;$$

$$T_{2-2} = \frac{16+4\times22+23}{6} = 21.16 \approx 21\ ;$$

$$T_{2-3} = \frac{12+4\times13+17}{6} = 13.5 \approx 14\ ;$$

$$T_{2-4} = \frac{25+4\times27+33}{6} = 27.66 \approx 28\ ;$$

$$T_{2-5} = \frac{16+4\times22+23}{6} = 21.16 \approx 21\ .$$

Thus, the mean duration of five sub-packages, lighting installation, telephone/TV cable installation, rainwater system installation, domestic wastewater system installation, and water supply installation, of P2 are 56, 21, 14, 28, and 21, respectively.

Similarly, P3 can be divided into five sub-packages: telephone / TV cable installation, firefighting linkage installation, firefighting water supply installation, lightning protection grounding installation, and lighting installation. According to the company's historical experience and data, we can know that the optimistic time *a*, most likely time *m*, and pessimistic time *b* of telephone / TV cable installation are 16, 22, and 23, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of firefighting linkage installation are 12, 13, and 17, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of firefighting water supply installation are 12, 13, and 17, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of lightning protection grounding installation are 25, 27, and 33, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of lighting installation are 51, 55, and 63, respectively. According to equation 5.1, we can calculate the mean completion duration of five sub-packages below:

$$T_{3-1} = \frac{16 + 4 \times 22 + 23}{6} = 21.16 \approx 21\ ;$$

$$T_{3-2} = \frac{12 + 4 \times 13 + 17}{6} = 13.5 \approx 14\ ;$$

$$T_{3-3} = \frac{12 + 4 \times 13 + 17}{6} = 13.5 \approx 14\ ;$$

$$T_{3-4} = \frac{25 + 4 \times 27 + 33}{6} = 27.66 \approx 28\ ;$$

$$T_{3-5} = \frac{51 + 4 \times 55 + 63}{6} = 55.66 \approx 56\ .$$

Thus, the mean duration of five sub-packages, telephone / TV cable installation, firefighting linkage installation, firefighting water supply installation, lightning protection grounding installation, and lighting installation, of P3 are 21, 14, 14, 28, and 56, respectively.

Uniformly, Similarly, P4 can be divided into five sub-packages: telephone / TV cable installation, domestic wastewater system installation, water supply installation, lightning protection grounding installation, and lighting installation. According to the company's historical experience and data, we can know that the optimistic time *a*, most likely time *m*, and pessimistic time *b* of telephone / TV cable installation are 16, 22, 23, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of domestic wastewater system installation are 25, 27, 33, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of water supply installation are 16, 22, 23, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of lightning protection grounding installation are 25, 27, 33, respectively. The optimistic time *a*, most likely time *m*, and pessimistic time *b* of lighting installation are 51, 55, 63, respectively. According to equation

5.1, we can calculate the mean completion duration of five sub-packages below:

$$T_{4-1} = \frac{16+4\times 22+23}{6} = 21.16 \approx 21\ ;$$

$$T_{4-2} = \frac{25+4\times 27+33}{6} = 27.66 \approx 28\ ;$$

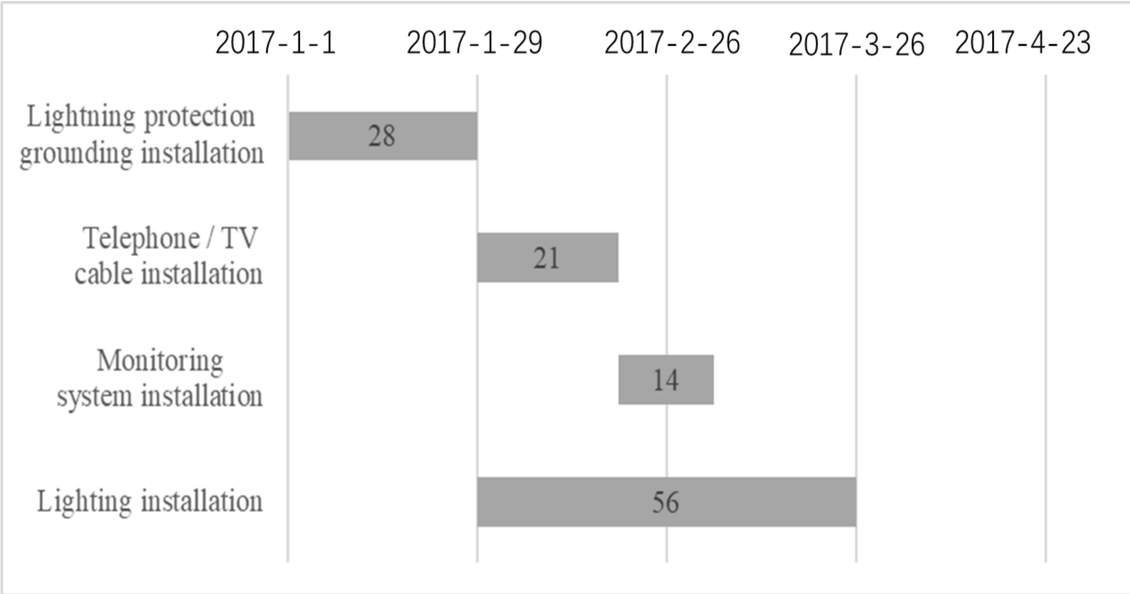
$$T_{4-3} = \frac{16+4\times 22+23}{6} = 21.16 \approx 21\ ;$$

$$T_{4-4} = \frac{25+4\times 27+33}{6} = 27.66 \approx 28\ ;$$

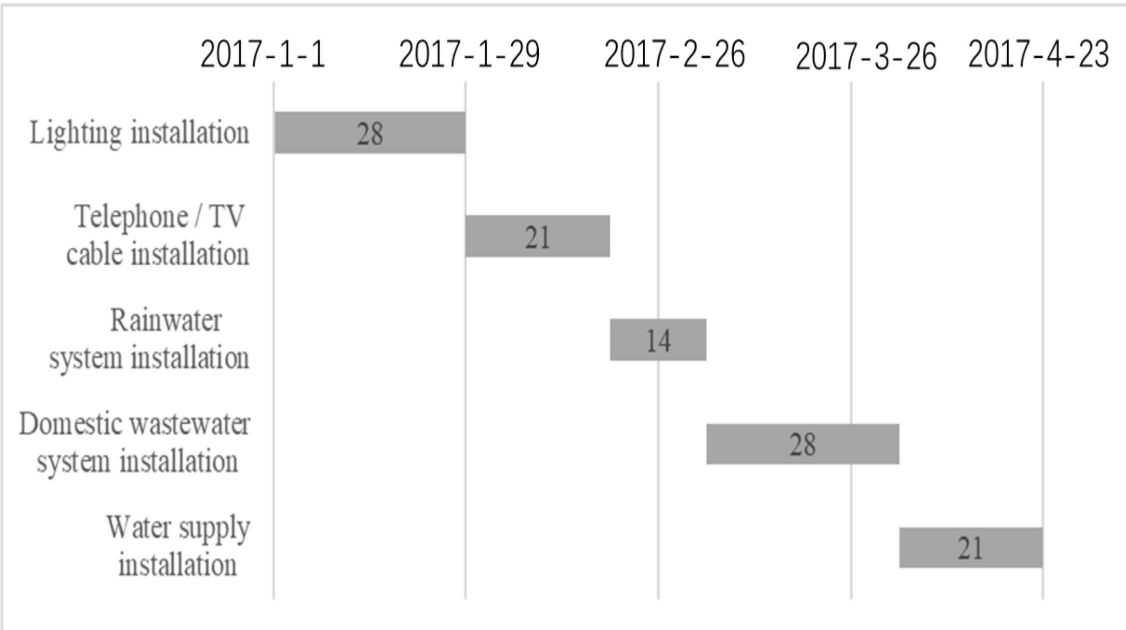
$$T_{4-5} = \frac{51+4\times 55+63}{6} = 55.66 \approx 56\ .$$

Thus, the mean duration of five sub-packages, telephone / TV cable installation, domestic wastewater system installation, water supply installation, lightning protection grounding installation, and lighting installation, of P3 are 21, 28, 21, 28, and 56, respectively.

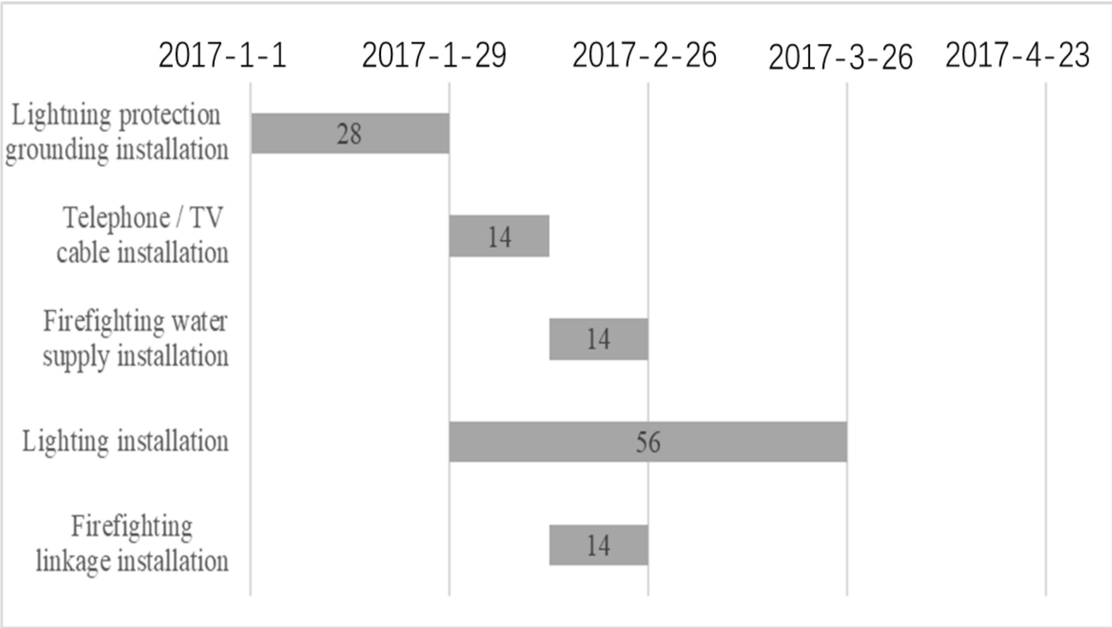
According to the WBS for four projects and the calculation of the mean completion time of the activity, we can draw the Gantt Charts of P1, P2, P3, and P4, respectively as shown in Figure 5-6. According to these Gantt Charts, we can calculate the critical path of P1, P2, P3, and P4. Further, we clearly see the earliest start time and finish time.



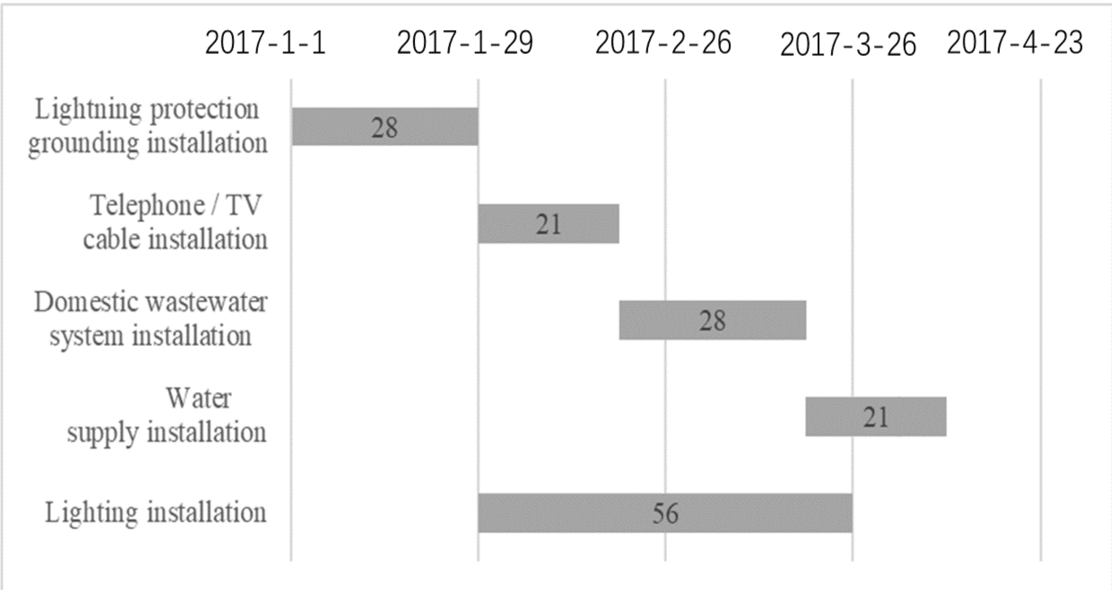
(a) Gantt Chart of P1 project



(b) Gantt Chart of P2 project



(c) Gantt Chart of P3 project



(d) Gantt Chart of P4 project

Figure 5-6 Gantt Charts of the four projects

Source: Author finishing

5.3.2 Calculation Strategic Contributions

Using the established project evaluation system, we organize experts to evaluate the four projects. According to formula (4-1) in section 4.2.3, the strategic contributions of the four projects are calculated as.

$$Z_1 = \sum_{i=1}^{21} w_i y_i = 7.4;$$

$$Z_2 = \sum_{i=1}^{21} w_i y_i = 5.3;$$

$$Z_3 = \sum_{i=1}^{21} w_i y_i = 4.6;$$

$$Z_4 = \sum_{i=1}^{21} w_i y_i = 3.4.$$

In the above formulation, w_i is the strategic contribution weight of criterion $D_i$of the hierarchical evaluation system in Figure 4-2 and y_i is the average scores on given criterion D_i by 10 experts.

5.3.3 Demands of Technical Designer

After the work of project decomposition is completed, the project operation schedule needs to be determined according to the structure of decomposition, to determine the logical relationship between the activities. Taking the project P1 as an example, since the lightning protection grounding installation activity takes precedence over the lighting installation, the lightning protection grounding installation activity is the immediate predecessor activity of the lighting installation in the project operation schedule, and its project activities schedule is shown Table 5-1. In the same way, the project activity schedules of other projects are shown in Tables5-1.

Based on using WBS and Gantt charts in Section 4.2.2, we can calculate the demands of technical designer for candidate projects, and the result shows that the demands of technical designer for P1, P2, P3, and P4, are 30, 15, 19, and 31, respectively.

Table 5-1 Activities schedule of candidate projects

Activities	WBS code	Immediate predecessor activity	Technical designers	Duration (days)
Lightning protection grounding installation	111		8	28
Lighting installation	112	111	15	56
Telephone / TV cable installation	121	111	15	21
Monitoring system installation	122	121	10	14
Lighting installation	211		15	28
Telephone / TV cable installation	221	211	14	21
Rainwater system installation	231	221	2	14
Domestic wastewater system installation	232	231	2	28
Water supply installation	233	232	2	21
Lightning protection grounding installation	311		8	28
Lighting installation	312	311	15	56
Telephone / TV cable installation	321	311	8	14
Firefighting linkage installation	331	321	2	14
Firefighting water supply installation	332	321	2	14

Lightning protection grounding installation	411		10	28
Lighting installation	412	411	16	56
Telephone / TV cable installation	421	411	15	21
Domestic wastewater system installation	431	421	2	28
Water supply installation	432	431	2	21

Source: Author finishing

5.3.4 Calculation Strategic Contribution Rates

According to the demands of technical designers for project P1 to P4 calculated in Table 5-1, we can calculate four projects resource strategic contribution rates using and their selection ranking as shown in Table 5-2.

Table 5-2 Project resource strategic contribution rate

project	project strategic contribution rate	technical designer numbers	project resource strategic contribution rate	ranking
P_1	7.4	30	0.247	2
P_2	5.3	15	0.353	1
P_3	4.6	19	0.242	3
P_4	3.4	31	0.110	4

Source: Author finishing

It can be seen in Table 5-6 that the project resource strategic contribution rates for P1, P2, P3, and P4, are 0.247, 0.353, 0.242, and 0.110, respectively. Further the ranking is P2>P1>P3 >P4.Especially projects P2 (i.e., Feixianguan Nanchang town resettlement housing) has the highest priority, project P1 (i.e., Xihua University Experimental Training Center) is ranked in the second position. Projects P3 and P4 (i.e., Sichuan Hyundai commercial vehicle production base engineering industrial equipment installation and P4 (i.e., civil construction installation project of Dongjiang capital) are ranked in third and fourth ones, respectively. The ranking above is recognized by the company's management, indicating that the strategic project evaluation system established in this study can evaluate the projects effectively. The contribution of the project to the company's strategic development can be quantified through the grade from the established evaluation system, to provide selection basis and evaluation methods for the company's management.

5.3.5 Project Selections and Resource Allocation

Now, we determine the project selection based on the strategic contribution rate of the four projects. The project with higher strategic contribution rate has a higher priority to obtaining the scarce resources and finally enter the project portfolio. We apply the formulated MIP model in subsection 4.6.1 with the total of70 technical designers in HIEC as the resource limitation. Then the heuristic rules in subsection 4.6.2 are applied to determine the allocation of the designers. Consequently, in the generated allocation solution, 15 designers are allocated to project P1, 30 designers are allocated to project P2 and 19 designers are allocated to project P3. The remained 6 designers cannot satisfy the demands of project P4. Finally, three projects (i.e., P1, P2, and P3) allocated enough designers are selected and enter into the final project portfolio scheme, while project P4 is not assigned enough designers and cannot be selected into the final project portfolio scheme.

5.4 Comparative Analysis

5.4.1 The Analysis on the Result of the Four-project Instance

The four projects in the real instant given in Section 5.3 correspond to the four types of projects undertaken by HIEC in2017. The results in subsection 5.3.5show that the project portfolio scheme consists of projects P1, P2, and P3, promotes the company's strategic development and meet the company's resource constraints. According to the resource consumption, project P4 (i.e., a general civil construction installation project of the Dongjiang capital) consumes a large number of resources but return fewer profits. Thus, the computational result on the contribution ratio in subsection 5.3.5 also gives a clear explanation on the decision of the company's project selection that project P4 should not be selected into the project portfolio scheme.

5.4.2 The Comparison of the Project Portfolio Between 2014 and 2017

This subsection compares the two project portfolio schemes before and after the implementation of the proposed approaches in this study for HIEC in 2014 and 2017, respectively. Based on the historical data in HIEC, it is found that in 2014, there are 37 projects are selected and carried out within HIEC, including 5public buildings and government investment (PB) projects, 18 civil building (CB) projects, 10 civil architecture (CA) projects, and 4 industrial equipment installation (IE) projects, and. The proportion of four types of projects is presented in Figure 5-7. The total contract income is 0.79 brilliants yuan (about 0.1 brilliants euros), and the profits are 1.10 million yuan (0.13million euros). The projects totally consume technical designer for 216 person-times.

In 2017, the proposed project portfolio approach was preliminarily applied to the project evaluation and selection procedure in HIEC. In general, the generated project portfolio scheme improves the project portfolio management of HIEC. There are 28 projects are selected and carried out within HIEC, including 15 CB projects, 3 CA projects, 6 PB projects, and 4 IE projects. The total contract income is 0.29 brilliants yuan (about 0.03 brilliants euros), but the expected profits are 1.35 million yuan (0.17 million euros). The proportion of four types of projects is presented in Figure 5-8. The projects totally consume technical designer for 135 person-times. It clear that the proportions of PB and IE projects increased while the proportions of CB and CA projects decreased, compared with the proportions of the four types of project in 2014. More important, the amount of consumed technical designer is much decreased from 216 to 135 person-time while the expected profits increase from 0.13 to 0.17 million euros. The comparing data is listed in Table 5-3.

Table 5-3 Comparing data in 2014 and 2017

years	Contract income (billions euros)	Expected profits (millions euros)	The number of consumed designers (person-time)
2014	0.1	0.13	216
2017	0.03	0.17	135

Source: Author finishing

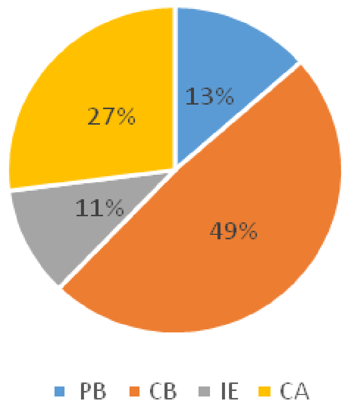


Figure 5-7 Proportion of four types of projects in 2014

Source: Author finishing

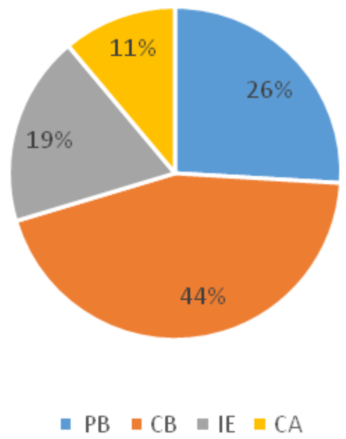


Figure 5-8 Proportion of four types of projects in 2017

Source: Author finishing

[This page is deliberately left blank.]

Chapter 6: Conclusions and Prospects

6.1 Conclusion

The project portfolio management is an important and significant issue in academic and industrial fields. In China, the construction and installation industry is developing very fast in pasted decades. Many constructions and installation companies undertook various types of projects to obtain revenue as much as possible. However, it is observed that most of these companies just focused on their cash flows when they make decisions on project selection, which hardly reflects the comprehensive effects of projects on the companies' development and strategic objectives. The company's strategic objectives in terms of technology innovation, management innovation, and social responsibility need to be involved in the procedure of project portfolio and selection. On the other hand, the allocation of scarce resources among these candidate projects have to be considered, since the available scarce resources in a company hardly support executions of all candidate projects simultaneously.

In the existing literature, the connection between project selection portfolio management and strategy management have been addressed by many researchers. Some research has proposed general frameworks and methods for project selection and portfolio with respect to a company's strategy. Some existing researchers have proposed a variety of resource assignment and scheduling approaches for already selected projects. However, in the operational levels, the allocation of scarce resources is seldom considered and integrated to the project selection and portfolio procedure, which results in that the generated project portfolio scheme is impractical or cannot be carried out in specific industry and company.

Motivated by both industry and existing literature, this thesis addresses this issue by answering the following two questions. Q1: how to establish a project evaluation system according to the company's predetermined strategy? And Q2: how to select the projects and to allocate the limited resources to the projects in order to maximize the strategic contribution of the project portfolio?

To answer Q1, we first analyze the company's predetermined strategic goal and decompose it into several measurable strategic objectives. We then apply AHP method to construct a hierarchical evaluation system with respect to the company’s strategic goal. To answerQ2, we define and calculate a metric, which is defined as the contribution ratio to the strategic goal of the project consuming per unit scarce resource. We then select the best project portfolio according to the calculated metric of candidate projects.

The following results are obtained in this thesis.

(1) Project evaluation system based on strategic goal decomposition.

An overall process of project selection and the combination is constructed as in Figure 1-1. This process begins with the forecasting and collecting the candidate projects and establishes a project evaluation system based on the predetermined strategic goal and historical data. Then, the project portfolio is selected according to the contribution rate of the candidate project and the constraints of the scarce resources. The status of the selected projects and resource utilization are recorded during the implementations, and the performance of the project portfolio is evaluated after the projects are completed. These records and assessment materials as the company's historical data will be used for adjusting the project evaluation system and selection methods in the next time.

(2) Project evaluation system based on strategic goal decomposition

We divide a company’s strategic goal into four objectives: financial objective, management innovation objective, technological innovation objective, and social responsibility objective. Then, the corresponding two-level quantifiable evaluation criteria are selected for the four objectives. Finally, a four-level project evaluation system is constructed. We take HIEC as an example and use the experter scoring method, the relative weights of hierarchical criteria are calculated. Note that the calculated relative weights based on the real situations of HIEC but the proposed calculation method can be directly applied to other similar companies.

(3) Project selection and portfolio method based on resource constraints

We define and calculate the "strategic contribution rate” as the metric to determine the priorities of the candidate projects to access the scarce resources. Such metric represents the contribution of the project by consuming per unit resources to the company's strategic goal. Then, the company resources are allocated to the candidate projects according to the identified priority, until the remaining resources are unable to meet the needs of a single project. This method takes into account both the effect of the project on the realization of the strategic goal and the situation of the project consuming resources. Therefore, the selected project portfolio is more in line with the company strategic development and actual resource constraints.

The research involved in this thesis has both important theoretical value and practical significance. Based on the literature review in Section 2, it is found that most of the early research in project portfolio management focus on how to select and combine the projects by considering the profits and risk objectives. Few research considers the strategic goal or the limitation of resource in their proposed project evolution and selection methods. To deal with this issue, this thesis establishes a project evaluation system with respect to the strategic goal of the company and further imposes the limitation of the resources into the project selection processing. The proposed approaches are based on the real situations of HIEC but they are ready to be extended to another similar company in Chinese construction and installation industry. Therefore, it has a broad application space and important practical significance.

6.2 Prospects

(1) Methods to calculate the relative weights in AHP

This thesis applies AHP method to establish a project evaluation system. The selected criteria in the evaluation system are mostly from literature but several criteria and their relative weights are based on the subjective judgments of the experts. The obtained value of the weights may be infected by the psychological factors of the experts and are therefore not accurate. Thus, the future study may develop methods to calculate more accurate relative weights of the criteria.

(2) Selection methods with the limitation of resource

This thesis selects projects using a metric "strategic contribution rate", which is easy for implication but may not find a good solution for the project portfolio. Therefore, a more elaborated programming model and approach should be developed based on the operational research theory. To solve the mathematical model, some optimized software and tools, such as IBM_ILOG CPLEX, will be used.

Bibliography

Abdi, H., & Williams, L. J. (2010). Principal component analysis. *Wiley interdisciplinary reviews: computational statistics*, 2(4), 433-459.

An, H. G. (2007). *Research on theory trame and method of project portfolio selection*. Master Thesis, Northwestern Polytechnical University.

Archer, N. P., & Ghasemzadeh, F. (1999). An integrated framework for project portfolio selection. *International Journal of Project Management*, 17(4), 207-216.

Bai, L. b., Bai, S. J., & Guo Y. T. (2016). Project portfolio allocation research under strategic orientation. *World Sci-Tech R & D*, 38(4), 887-894.

Bailey, C. R., & Bailey, C. A. (2017). *A guide to qualitative field research*. Sage Publications.

Bakker, R. M., Cambré, B., Korlaar, L., & Raab, J. (2011). Managing the project learning paradox: a set-theoretic approach toward project knowledge transfer. *International Journal of Project Management*, 29, 494-503.

Barney, J., Wright, M., & Ketchen Jr, D. J. (2001). The resource-based view of the firm: Ten years after 1991. *Journal of Management*, 27, 625-641.

Biedenbach, T. (2011). The power of combinative capabilities: facilitating the outcome of frequent innovation in pharmaceutical R&D projects. *Project Management Journal*, 42, 63-80.

Bro, R., & Smilde, A. K. (2014). Principal component analysis. *Analytical Methods*, 6(9), 2812-2831.

Brunelli, M. (2014). *Introduction to the analytic hierarchy process.* Berlin: Springer.

Cao, T., Bai, S. J., & Guo, Y. T. (2014). Research on enterprise project portfolio management process based on the strategy-oriented. *Science and Technology Management Research*, 34(10), 208-218.

Carazo, A. F., Gómez, T., Molina, J., Hernández-Díaz, A. G., Guerrero, F. M., & Caballero, R. (2010). Solving a comprehensive model for multi-objective project portfolio selection. *Computers and Operations Research*, 37, 630-639.

Chan, A. P., & Scott, D. (2004). Factors affecting the success of a construction project. *Journal of construction engineering and management*, 130(1), 153-155.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, 35(1), 128-152.

Cooper, R., Edgett, S., & Kleinschmidt, E. (2001). Portfolio management for new product development: results of an industry practices study. *r&D Management*, 31(4), 361-380.

Cordes-Berszinn, P. (2013). *Dynamic capabilities: How organizational structures affect knowledge processes*. Berlin: Springer.

Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management science*, 9(3), 458-467.

Daniel, E. M., Ward, J. M., & Franken, A. (2014). A dynamic capabilities perspective of IS project portfolio management. *The Journal of Strategic Information Systems*, 23(2), 95-111.

Dawood, N., & Sikka, S. (2006). The value of visual 4D planning in the UK construction industry. *Intelligent Computing in Engineering and Architecture*, 127-135.

Ding, S. Z. (2014). *Project management*. Beijing: China Building Industry Press.

Drucker, P. (2014). *Innovation and entrepreneurship*. London: Routledge.

Ethiraj, S. K., Kale, P., Krishnan, M. S., & Singh, J. V. (2005). Where do capabilities come from and how do they matter? A study in the software services industry. *Strategic Management Journal*, 26, 25–45.

Ferrada, X., Núñez, D., Neyem, A., Serpell, A., & Sepúlveda, M. (2016). A lessons-learned system for construction project management: a preliminary application. *Procedia-Social and Behavioral Sciences*, 226, 302-309.

Fu, Q., Zeng, G. P., & Wang, K. L. (2007). Construction of multi-project harmonious management performance evaluation system for extra-large projects—a case study of large-scale state-owned enterprises. *Construction Economics*, (10), 13-15.

Gallego, D., & Bueno, S. (2014). Exploring the application of the Delphi method as a forecasting tool in Information Systems and Technologies research. *Technology Analysis & Strategic Management*, 26(9), 987-999.

Garvin, D. A. (1988). *Managing quality: The strategic and competitive edge*. New York: Simon and Schuster.

Gordon, T. J. (1994). The delphi method. Futures research methodology, 2(3), 1-30.

Gupta, N. (2013). Artificial neural network. *Network and Complex Systems*, 3(1), 24-28.

Hill, C. W., Jones, G. R., & Schilling, M. A. (2014). Strategic management: theory: an integrated approach. *Cengage Learning*.

Hill, C. W., Jones, G. R., & Schilling, M. A. (2014). *Strategic management: Theory & cases: An integrated approach*. Cengage Learning.

Huang, H. X., & Niu, H. Y. (2010). *Resource Management*. Beijing: China Economic Publishing House.

Huemann, M. (2010). Considering Human Resource Management when developing a project-oriented company: Case study of a telecommunication company. *International Journal of Project Management*, 28(4), 361-369.

Iniestra, J. G., & Gutiérrez, J. G. (2009). Multicriteria decisions on interdependent infrastructure transportation projects using an evolutionary-based framework. *Applied Soft Computing*, 9(2), 512-526.

Jugdev, K., Mathur, G., & Fung, T. S., (2007). Project management assets and their relationship with the project management capability of the firm. *International Journal of Project Management*, 25, 560–568.

Kerzner, H., & Kerzner, H. R. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.

Khalili-Damghani, K., Sadi-Nezhad, S., Lotfi, F. H., & Tavana, M. C (2013). A hybrid fuzzy rule-based multi-criteria framework for sustainable project portfolio selection. *Information Sciences*, 220, 442-462.

Khalid, S. (2009). *Exploring Firm Level Market Knowledge Competence and Its Implications for the Speed and Success of Export Expansion: A Mixed Methodology Study from the Software Industry*. Finland: University of Vaasa

Killen, C. P., Jugdev, K., Drouin, N., & Petit, Y. (2012). Advancing project and portfolio management research: Applying strategic management theories. *International Journal of Project Management*, 30(5), 525-538.

Klingebiel, R., & Rammer, C. (2014). Resource allocation strategy for innovation portfolio management. *Strategic Management Journal*, 35(2), 246-268.

Kraiczy, N. D., Hack, A., & Kellermanns, F. W. (2014). New product portfolio performance in family firms. *Journal of Business Research*, 67(6), 1065-1073.

Li, X. Y., Zhang, X. W., Yao, Y. J., & Zhang, Y. (2002). Indicators of performance tracing and evaluating system for science and technology development fund under condition of asymmetric information. *China Soft Science*, (05), 74-78.

Lin, Y., & Wu, L. Y. (2014). Exploring the role of dynamic capabilities in firm performance under the resource-based view framework. *Journal of business research*, 67(3), 407-413.

Irja, H. (2014). Project Portfolio Management in a Company Strategy Implementation, a Case Study. *Procedia - Social and Behavioral Sciences*,119(19),229-236.

Lu, A. P. (2005). *Project management on an enterprise-strategic basis*. Doctorial Dissertation, Southeast university.

Ludwig, G., & Pemberton, J. (2011). A managerial perspective of dynamic capabilities in emerging markets: The case of the Russian steel industry. *Journal for East European Management Studies*, 16(3), 215-236.

Martello S., & Toth P. (1990). *Knapsack Problems: Algorithms and Computer Implementations*, John Wiley & Sons.

Martinsuo, M. (2013). Project portfolio management in practice and in context. *International Journal of Project Management*, 31(6), 794-803.

Meng, L. (2014). *Research on development strategy of JD Decoration Company*. Master

Thesis, Hunan Normal University.

Meskendahl, S. (2010). The influence of business strategy on project portfolio management and its success—a conceptual framework. *International Journal of Project Management*, (28)8, 805–817.

Ministry of Housing and Urban-Rural Development Program Finance and Foreign Affairs Division. (2015). Statistical analysis on the development of China's construction industry in 2015.

Nilashi, M., Zakaria, R., Ibrahim, O., Majid, M. Z. A., Zin, R. M., & Farahmand, M. (2015). MCPCM: a DEMATEL-ANP-based multi-criteria decision-making approach to evaluate the critical success factors in construction projects. *Arabian Journal for Science and Engineering*, 40(2), 343-361.

Mohamed, M., Abdel-Basset, M., Hussien, A. N., & Smarandache, F. (2017). *Using Neutrosophic Sets to Obtain PERT Three-Times Estimates in Project Management*. Infinite Study.

Pan, Y. J., & Liu, X. L. (2004). Study on evaluation index system and fuzzy optimal decision model of scientific research projects. *Science of Science and Management of S&T*, 25(01), 9-11.

Pinter, U., & Pšunder, I. (2013). Evaluating construction project success with use of the M-TOPSIS method. *Journal of Civil Engineering and Management*, 19(1), 16-23.

Promislow, S. D., & Spring, D. (1996). Postulates for the internal rate of return of an investment project. *Journal of Mathematical Economics*, 26(3), 325-361.

Robson, W. (2015). *Strategic management and information systems*. Pearson Higher Ed.

Saaty, T. L. (2013). Analytic hierarchy process. In Encyclopedia of operations research and management science. 52-64). Boston, MA: Springer.

Sanchez, H., & Robert, B. (2010). Measuring portfolio strategic performance using key performance indicators, *Project Management Journal*, 41(5), 64-73.

Shen, W. L. (2010). *The Sichuan province first building company strategic management research*. Master Thesis, Southwestern University of Finance and Economics.

Shuen, A., & Sieber, S. (2009). Orchestrating the new dynamic capabilities. *IESE Insight*, 58(3), 58–65.

Smith, J. A. (Ed.). (2015). Qualitative psychology: A practical guide to research methods. *Sage*.

Söderlund, J. (2004). Building theories of project management: past research, questions for the future. *International Journal of Project Management*, 22,183–191.

Tang, Y. f., Bai, L. B., & Guo, Y. T. (2012). Research on Project Portfolio Selection Based on Strategy-oriented. *Project Management Technology*, 10(02), 21-25.

Tao, J. C., & Wu, J. M. (2001). New study on determining the weight of index in synthetic weighted mark method. *Systems Engineering-theory & Practice*, 21(8).

Teece, D. J. (2009). Dynamic capabilities and strategic management: Organizing for innovation and growth. *Oxford University Press on Demand*.

Teece, D. J. (2014). A dynamic capabilities-based entrepreneurial theory of the multinational enterprise. *Journal of International Business Studies*, 45(1), 8-37.

Teller, J., Unger, B. N., Kock, A., & Gemünden, H. G. (2012). Formalization of project portfolio management: The moderating role of project portfolio complexity. *International Journal of Project Management*, 30, 596–607.

Tian, Y, M., & Liu, M. (2004). Comprehensive Probability Fuzzy Evaluation of Fire Risk for High-rise Building. *China safety science journal*, 09, 103-107.

Project Management Institute. (2014). The standard for portfolio management. *Project Management Institute*.

Verona, G., & Ravasi, D., 2003. Unbundling dynamic capabilities: an exploratory study of continuous product innovation. *Industrial and Corporate Change*, 12, 577–606.

Walker, A. (2015). *Project management in construction*. John Wiley & Sons.

Wang, G. (2011). Probe into construction enterprises going abroad and equipment management. *Construction Machinery Technology & Management*, 24(07), 31-33.

Wetekamp, W. (2011, September). Net Present Value (NPV) as a tool supporting effective project management. *In Intelligent Data Acquisition and Advanced Computing Systems (IDAACS), 2011 IEEE 6th International Conference*, Czech Republic, 2, 898-900.

Yang, Y., Xie, L. L., & Zhang, Y. L. (2006). Evaliation Of Management Patterns Of Public Projects. *Journal of Chongqing Jianzhu University*, 03, 102-106.

Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. A*cademy of management review*, 27(2), 185-203.

Zeng, Y. C., & Wang, J. C. (2014). Coupling research on enterprise strategic management and project management. *Journal of Sichuan University (Social Science Edition)*, 3, 86-96.

Zhang, C. M. (2010). *Study on Multi-Project Management of Construction Corporations Based on Strategic Development*. Doctorial Dissertation, Tianjin University.

Zhang, X. (2016). On the problems and countermeasures of construction engineering quality Management. *Jiangxi Building Materials*, 21(02), 295-298.

Zhu, K. (2015). *The strategy analysis and selection of studies of the small and medium-sized construction enterprises*. Doctorial Dissertation, Qingdao University of Technology.

Zou, T., Ertug, G., & George, G. (2018). The capacity to innovate: a meta-analysis of absorptive capacity. *Innovation*, 20(2), 87-121.