THE PRICING STRATEGY AND FINANCING MODE ANALYSIS FOR THE CONSTRUCTION SUPPLY CHAIN OF PROJECT X

By

Miss Yingxi ZHANG

A Thesis Submitted in Partial Fulfillment of the Requirements

for Master of Engineering ENGINEERING MANAGEMENT

Department of INDUSTRIAL ENGINEERING AND MANAGEMENT

Silpakorn University

Academic Year 2024

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Under the increasingly powerful conditions of the Internet of Things and information platforms, the competitive advantages of building technology and material costs are weakening. Optimizing engineering management and innovating management concepts will become the main competitive advantage of various construction enterprises, and will also play a crucial role in promoting the progress of engineering management.

On the basis of elaborating and analyzing the current situation of the construction industry, construction project management, construction supply chain, supply chain pricing, supply chain financing theory and research status, this article selects the X residential community engineering project for empirical research. Based on the engineering characteristics of the project, a decision-making model for the construction supply chain of X residential community was established through the EPC contracting mode and relevant assumptions. Finally, an analysis was conducted on four optimal pricing strategies: financing without funding constraints, financing without funding constraints, financing within the funding constraint chain, and financing outside the funding constraint chain.

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Yingxi ZHANG

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CHAPTER 1
INTRODUCTION

1.1 Background of the Research

The construction industry has been a pillar industry in China. Although various industries have been affected to varying degrees in the past three years due to the epidemic's impact, the demand for housing is still high in the face of the accelerating urbanization development process, and the development prospects of the domestic construction industry are bright. According to a survey conducted by the National Bureau of Statistics on the national construction industry in recent years, it can be concluded that the total output value of the national construction industry in 2022 was 311,980 billion yuan, a year-on-year increase of 6.5%; The construction area of houses in the national construction industry is 15.6 billion square meters. Figure 1.1 shows the growth rate of the national construction industry.

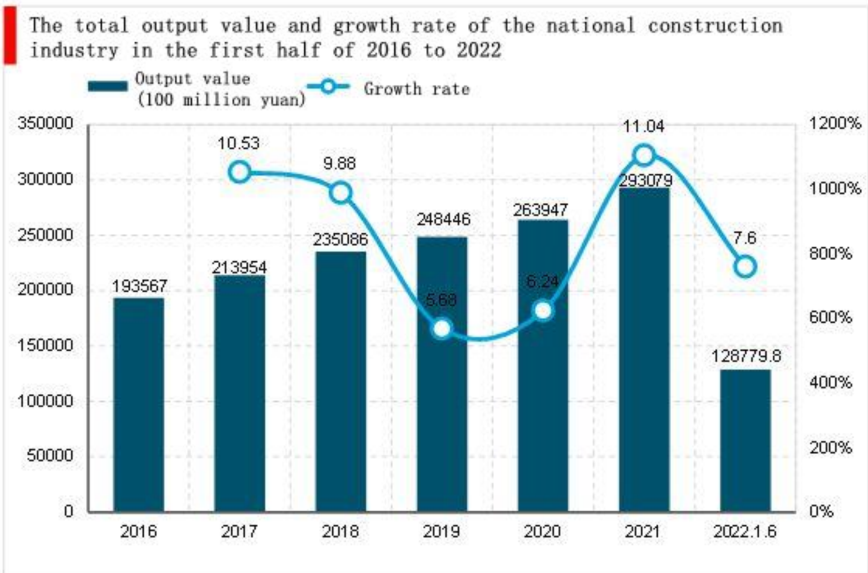


Figure 1.1 The total output value and growth rate of the national construction industry in the first half of 2016 to 2022

Source: National Bureau of Statistics

With the continuous development of information technology, advanced information management methods represented by BIM technology are also constantly penetrating the construction industry, and information asymmetry is gradually weakening. The transparency and openness of information among all participants in construction products have promoted the realization of maximizing common interests. Some large and well-known construction companies have started to develop horizontally, establishing project-centered supply chain relationships with their upstream and downstream suppliers. The suggestion of this relationship will not only ensure stable profits for all participating enterprises but also facilitate the formation of strong brand effects and market competitiveness.

This study takes project X as a research case, mainly because it is a typical supply chain product. Since its construction in 2019, a targeted engineering pricing and financing decision-making model has been formed based on the supply chain capital flow. This is not only solves the problems of huge capital demand, narrow financing channels, and difficult financing processes in the construction industry, but also promotes the project to reduce costs and improve economic benefits.

1.2 Research Objective

1. To explore the characteristics of project X and study the definition, connotation, and model architecture of the construction supply chain.

2. To explore the pricing mechanism and financing model of the construction supply chain for project X, and define relevant parameters.

3. To study the supply chain model and pricing decision-making problem of the above project, and analyze and obtain management suggestions without financing conditions.

4. To discuss the pricing strategies of the above construction supply chain under two financing modes: internal and external financing, compare and analyze the financing schemes of the construction supply chain, and obtain management suggestions related to financing.

1.3 Scope and Limitations

The scope of this study is to conduct a data survey on the pricing strategy and financing mode of the X project construction supply chain, conduct quantitative analysis on the collected information and data, and introduce stackelberg game theory as the basis for model analysis and solution in the construction supply chain based on the different decision-making positions of the construction investor and the construction contractor.

1.4 Contribution

In the current construction industry, optimizing the components and costs of the supply chain has become a key issue, and more methods are needed to determine the pricing methods applicable to enterprises, in order to adjust and transform financing models based on specific funding needs. This study mainly focuses on this, helping enterprises obtain more optimal pricing advantages from the perspective of the supply chain, in order to improve market competitiveness.

CHAPTER 2
LITERATURE REVIEW

The relevant literature will be carefully reviewed. The rest of this chapter is organized as follows. Section 2.1 Analysis of Traditional Construction Engineering Management.Section 2.2 Definition and structure of the construction supply chain. Section 2.3 The difference between the construction supply chain and the manufacturing supply chain.Section 2.4 The Connotation of Construction Supply Chain.Section 2.5 The structure of the construction supply chain.Section 2.6 Supply Chain Pricing.Section 2.7 Conclusion.

2.1 Analysis of Traditional Construction Engineering Management

2.1.1 Content of construction project management

Construction engineering refers to the engineering entity formed by a series of construction activities such as the construction of various types of housing buildings and their ancillary facilities, including the installation of their supporting pipelines, which is the construction product mentioned in this article. The core task of construction project management is to add value to the construction and use of construction projects, throughout the entire lifecycle of the project, including planning and management (DM) in the decision-making stage, project management (PM) in the implementation stage, and equipment management (FM) in the use stage. Each of the three stages has different resource management priorities. In the DM stage, it is necessary to determine financing models, contract management models, project resource procurement models, bidding management models, etc; The main tasks of the PM phase are bidding and evaluation, resource acquisition, optimization of configuration, and effective management of contractors; The FM stage focuses on property management after the construction products are put into use.

On the other hand, from the perspective of all parties involved in the engineering project. The engineering management of the construction investor runs through the entire project cycle of the construction product. After passing the DM stage, the design party, construction party, and supplier undertake their respective construction and management tasks for the PM and FM stages, as shown in Figure 2.1. All parties involved must also carry out cost control to maximize profits while achieving progress and quality goals in accordance with the contract. Both parties involved and their respective goals are opposed and unified.

	Decision stage	Prepare	Implementation phase design	Construction	Practical stage
Construction investor	DM		PM		FM
Designer			PM		

Construction party				PM	
Supplier				PM	
Property management party					FM

Figure 2.1 Schematic diagram of construction project management stage

2.1.2 Construction project management

(1) Project management organization.

According to the project management organizational model of the construction investor and the depth of their participation in project management, they are divided into two categories: the engineering construction agency system and the project management contracting mode (PMC).

PMC refers to the hiring of a professional company by the construction investor to represent the investor in project management throughout the entire or partial process of project implementation. According to the different scope of work, this model can be divided into three categories: as a consultant, only supervising and inspecting the project and reporting the situation in real-time to the construction investor; As an extension of the management of the construction investor, participate in the management of the entire project process; As the full representative of the construction investor, in addition to managing the entire project process, I also undertake some or all of the design, construction, and procurement (EPC) work of the project. For the project management team, this approach has the highest risk and profit. Because optimizing design schemes, unifying project procurement agreements, and optimizing cash flow can effectively reduce the cost of the entire life cycle of construction projects and save construction investment, the PMC management model is highly advantageous.

Under the PMC management mode, an Integrated Project Management Team (IPMT) will be established - a management organization based on the target project consisting of representatives from the construction investor and project management personnel from the project management party. Among them, according to the project stage division method described above, when the project adopts the EPC general contracting mode, project management undertakes different work contents in the decision-making and implementation stages. In the project decision-making stage, the main tasks of IPMT are to optimize the project construction plan, develop risk response strategies, provide financing plans, organize basic design, and overall design; During the project implementation phase, IPMT represents the construction investor in comprehensive coordination and supervision of the engineering project, providing management services related to design, construction, and procurement, including completing detailed design content, coordinating relevant technical documents, and cooperating with the construction investor to organize trial operation and acceptance. Of course, with the accumulation of a large amount of actual engineering data, advanced management concepts, scientific management methods, and high-level management talents are the core factors that determine the effectiveness of PMC management.

The engineering construction agency system is mainly aimed at non operational management projects invested by the government, with specialized project management enterprises as the construction agent, fulfilling the responsibilities of the construction investor according to the contract agreement between both parties.

(2) Project management under different contracting modes.

During the implementation process of the project, the construction investor will choose different contractor management modes based on the needs of the project. According to the contractual relationship between construction investors and contractors, the contracting modes of construction projects can be mainly divided into six categories.

Parallel contracting mode: The parallel contracting mode refers to the project construction investor signing contracts with several design units, construction units, and material and equipment suppliers for corresponding engineering tasks. At this time, the organizational relationships of each contractor are parallel, and the construction investor needs to coordinate and supervise each contractor throughout the construction process, placing high requirements on the management ability of the construction investor.

General subcontracting mode: The general subcontracting mode refers to the construction investor who, after the project is approved, contracts all or part of the design, construction, material and equipment procurement tasks (design and construction) of the engineering project to a qualified enterprise, and then chooses to further subcontract non main engineering tasks with strong professionalism to corresponding specialized subcontracting enterprises, Finally, submit an engineering project that meets the conditions for use to the construction investor. According to the different depths of contracting, representative general contracting models internationally include the "Turn key" model, the Design Build (DB) model, and the Engineering Procurement Construction Engineering Procurement Construction (EPC) model. In addition, in recent years, with the increasing diversification of demand from construction investors, DBO, EPC+O&M models have also emerged. In this mode, the construction investor only needs to manage the general contractor of the project, which is conducive to controlling the project management objectives.

Joint venture contracting mode: The joint venture contracting mode is mainly applicable to engineering projects where a contracting enterprise does not have sufficient strength to contract due to its large scale or extremely complex technology. In this case, several enterprises form a one-time joint venture organization to participate in competition and contracting, and determine the manpower, material resources, and financial resources invested in the joint venture through joint consultation among members, And select a representative of the consortium to negotiate with the construction investor in the name of the consortium. The contract structure is similar to the general subcontracting model, and the consortium members have strong risk resistance ability.

Cooperative contracting mode: When multiple contracting enterprises do not have the ability to independently implement general contracting, and are both willing to cooperate but unwilling to form a consortium, a contracting mode appears where the cooperative enterprise signs a basic contract with the construction investor and each contractor signs a cooperation contract. Compared to the consortium contracting model, when one of the partners goes bankrupt, the risk will be borne by the construction investor.

CM contracting mode: CM mode refers to a contracting mode in which the project management enterprise accepts the commission of the construction investor and adopts the fast path method for engineering management. Its basic idea is to achieve a full connection between design and construction by adopting the fast path method, which involves designing, bidding, and constructing simultaneously, in order to shorten the entire construction period. Especially suitable for large and complex projects with tight deadlines.

Patnering mode: This emerging contracting mode is relatively rare in China. However, with the rapid development of information technology, it has received increasing attention from the domestic engineering management academia in recent years. Patnering can be seen as a comprehensive collaborative management model. This model is based on the voluntary participation of multiple contracting enterprises such as construction investors, design contractors, and engineering contractors. Senior managers from corresponding participating parties form a working group to share risks and resources, and negotiate and sign a Patnering agreement to determine common goals and task division. It is worth mentioning that this model is different from other models. The Patnering model does not exist independently and is often used in combination with the above models. Open and honest communication allows each participant to obtain information in a timely, convenient, and accurate manner, achieving resource sharing. In fact, the increasing popularity of this model also marks an inevitable direction for the development of construction project management: from project management that previously had its own responsibilities to collaborative management based on trust and partnership.

In construction project management, information has always been an extremely important project resource, and it is also a key barrier for various parties involved in construction projects to establish good cooperative relationships.

However, with the vigorous promotion and rapid development of information technology such as BIM, while various engineering participants are controlling and managing their own engineering project goals, they should open up their thinking, start from the overall engineering project, adhere to the original intention of engineering management as project value-added, extend from self-management to joint management, and achieve win-win cooperation. In terms of win-win cooperation, supply chain management is a skilled player.

2.2 Definition and structure of the construction supply chain

2.2.1 Supply chain thinking

The supply chain is a comprehensive functional network structure centered around the core enterprise, consisting of suppliers, manufacturers, distributors, and end users, starting from parts to intermediate and final products, and finally delivering products to consumers through sales networks. Supply chain management refers to various activities and processes that plan, coordinate, control, and optimize the information flow, capital flow, and product flow of the entire supply chain system. Its goal is to deliver the products required by customers to the correct location in the correct quantity, quality, and state at the right time, and minimize the total cost. Due to the mature research on supply chain management, there are numerous research results with great application value.

2.2.2 Comparative advantages of supply chain thinking

On the one hand, traditional construction project management provides practitioners with theoretical foundations such as technical management and operational processes, but these management knowledge and theories often do not involve the complexity of the entire construction system, such as the impact of the minds and behaviors of various entities on their decisions in the process of resource acquisition and allocation, and the correlation mechanisms between entities. These issues have been extensively studied in supply chain management and are worth learning from. On the other hand, the process of construction project management from feasibility study to design, construction, and later use is accompanied by resource acquisition, evaluation and selection, organizational management, and resource allocation. This is very similar to supply chain management, and the resources involved in construction project management are more abundant. Complex management relationships urgently require excellent management methods to solve. Figure 2.2 has fully clarified the key tasks of construction project management in different stages, and it is not difficult to find that each key task can obtain decision-making methods supported by supply chain management theory. For example, determining the appropriate financing mode and funding channels for the Hong Kong Zhuhai Macao Bridge during the DM stage is a key task related to the success or failure of the project. By comparing various financing modes such as BOT, ABS, BT, etc., the main body was ultimately chosen to use the government's full capital contribution method.

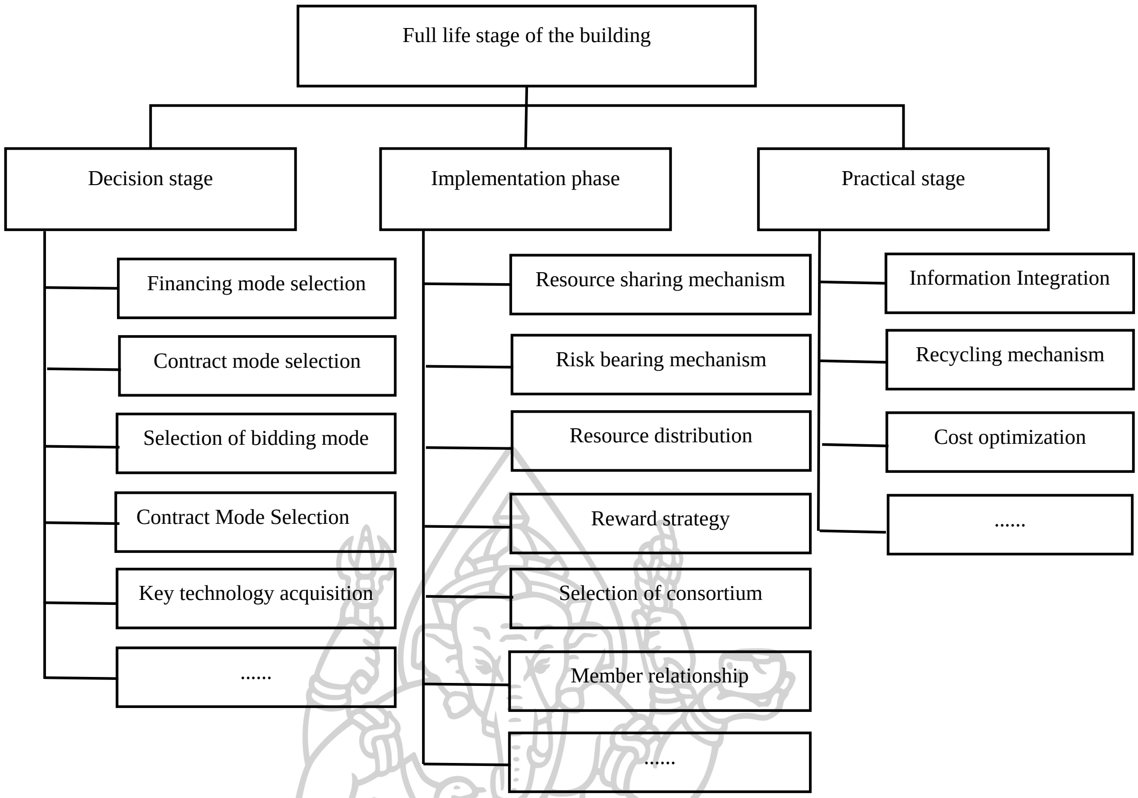


Figure 2.2 Key tasks in the project

In summary, supply chain management has a mature theoretical foundation and a large number of decision analysis models. In order to improve the efficiency of construction project management, it is necessary to cross integrate traditional engineering management, supply chain management, and other related theoretical methods to build a construction supply chain.

2.3 The difference between the construction supply chain and the manufacturing supply chain

The construction supply chain is a demand oriented pull type supply chain, which has many differences from the manufacturing supply chain. Firstly, construction products have a long production cycle, diverse characteristics and required processes, are fixed in space and large in volume, and cannot be produced repeatedly. Therefore, valuable construction products are not allowed to have defective products. Secondly, the characteristics of construction products determine that their production process is significantly different from that of the manufacturing industry. The spatial fixity and diversity of processes make participants mobile, and the network structure of the construction supply chain is not as stable as that of the manufacturing supply chain. At the same time, as the entire life cycle of construction projects progresses, the core enterprises at each stage of this process are also not fixed. Thirdly, the manufacturing supply chain mainly produces goods, with the main goal of pursuing systematic benefits and maximizing personal benefits. In addition to commodities, some of the products provided by the construction supply chain also have public goods attributes, involving entities not limited to the market, and their goals are more diversified. On the basis of comprehensive quality, environmental protection, and other factors, they also need to fully integrate social service functions. To effectively apply supply chain management methods, it is necessary to establish a targeted construction supply chain based on the above characteristics and focus.

2.4 The Connotation of Construction Supply Chain

From the analysis of the construction project management mode and supply chain thinking in the previous text, it can be seen that the construction supply chain should adopt a management approach of organizing thinking, comparing the concept of supply chain management, treating the construction investor as a distributor, the engineering contractor as a manufacturer, and the raw material supplier as a supplier. Starting from various participants in the supply chain, the resources in the entire supply chain should be planned, controlled, and coordinated in an integrated manner. Based on this, this article believes that the construction supply chain is a complex network formed by various participants in the construction project through cooperative games, interest coordination, and other interactive relationships in the dynamic network environment of the entire life cycle of the construction project. In this network, personnel intelligence, information, funds, materials, and other resources flow among the participating parties, while continuously allocating and applying them in the production process of construction products, driving the operation of the supply chain. In summary, the construction supply chain refers to the planning, coordination, operation, control, and optimization of various resources in the entire system, aiming to achieve the overall quality and progress goals of the construction project according to the expectations of the construction investor, and minimize the total cost of this process within controllable risks.

2.5 The structure of the construction supply chain

Although multiple participants are generally required to collaborate and collaborate throughout the entire construction project management process, there are differences in the roles of each participant at different stages, resulting in varying types of resources, organizational allocation, and management tasks required. Secondly, there are multiple modes of construction project management, such as parallel contracting, EPC, and CM. Each mode involves different stages of the project, and each participant has its own characteristics in terms of cooperation methods, contractual relationships, and interest relationships. The supply chain network structure built naturally varies.

For example, in the implementation phase, the parallel contracting model, due to its main characteristic of breaking down into parts, and its contract model, the core enterprise of the supply chain is the construction investor, and various resources flow more frequently. The network structure of the construction supply chain under this condition is shown in Figure 2.3.

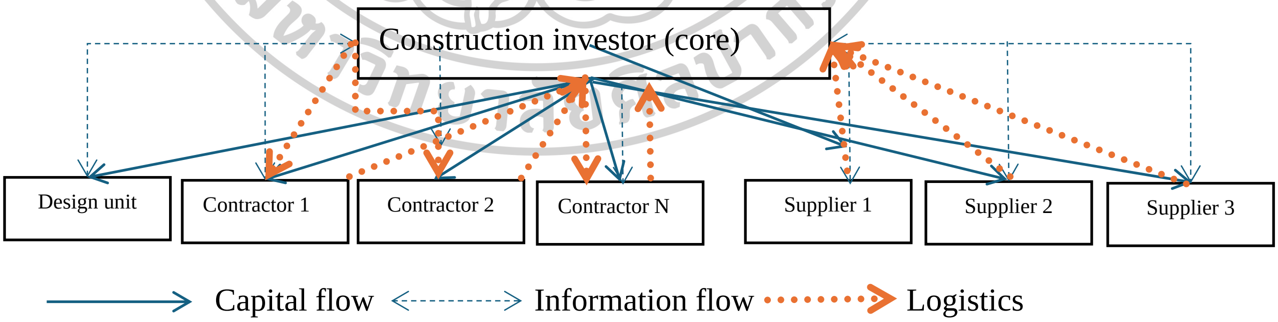


Figure 2.3 Construction supply chain architecture under the parallel contract issuance model during the implementation phase

Although the construction general contracting mode in the implementation stage only undertakes the construction tasks of the project, it has a direct contractual relationship with professional subcontractors, and therefore is at the core of the construction supply chain. Resource flow is mostly concentrated between the general contractor and subcontractors, and the management content of the construction investor is relatively simple. The construction supply chain network is shown in Figure 2.4.

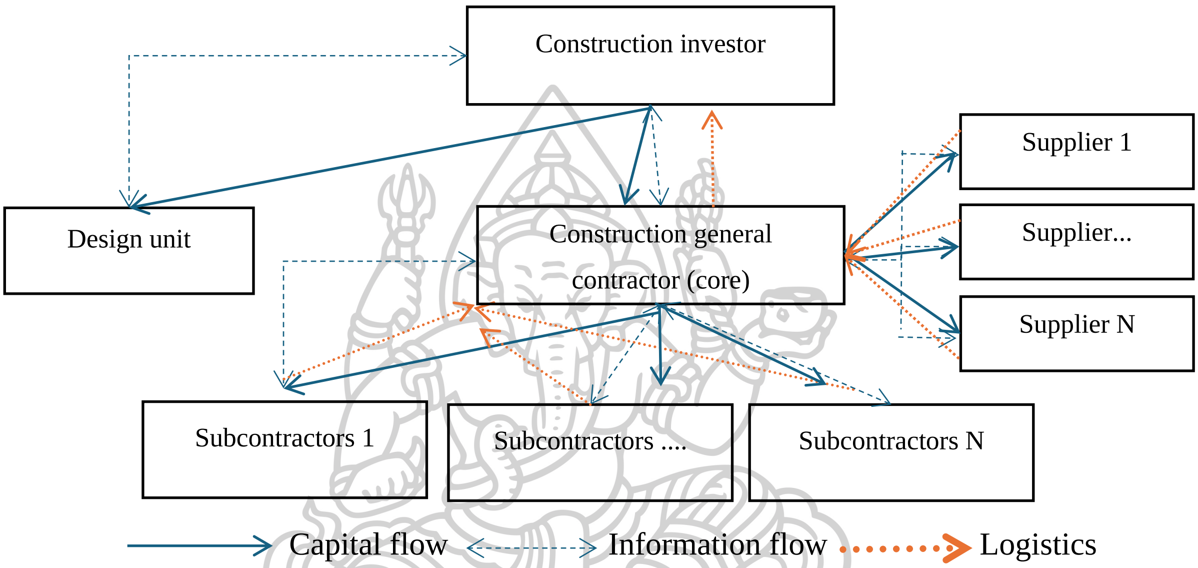
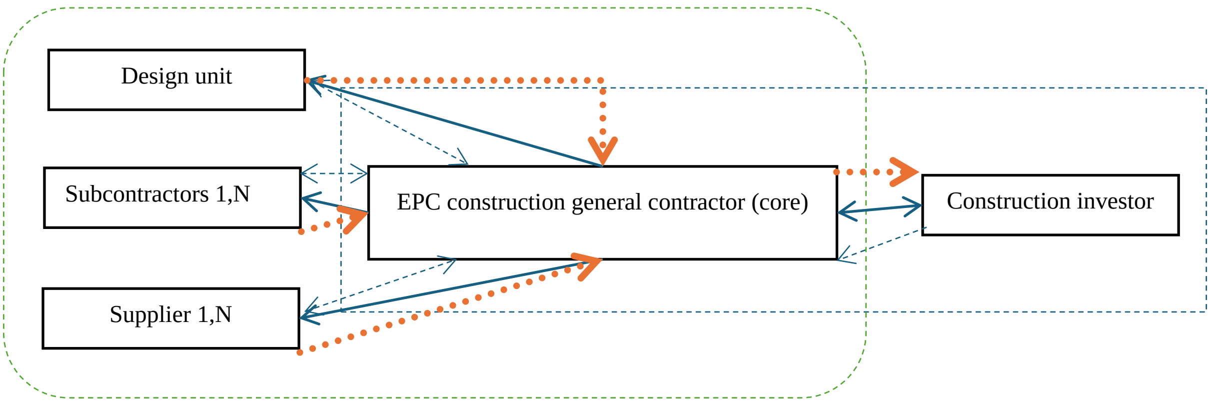


Figure 2.4 Construction supply chain architecture under the construction general contracting mode during the implementation phase

Since 2003, the Engineering General Contracting Management Model (EPC) vigorously promoted by the Ministry of Construction throughout the country has borrowed the idea of organizational integration management in industrial production. The EPC management mode closely combines design and construction, turning the design, construction, and supply sides into a community of interests, deeply participating in engineering projects, overcoming the drawbacks of increased investment and coordination difficulties caused by the separation of design and construction, reducing risks, and achieving the goal of adding value to project construction.

Nowadays, EPC is a very common contracting mode. From the perspective of overall project management, the construction investor only establishes a contractual relationship with the general contractor, and its supply and demand network is relatively clear, forming a manufacturer distributor secondary construction supply chain model based on construction projects. But the internal network of the contractor is relatively complex, involving many participants. The analysis of the project management organization and management mode of EPC in the previous text shows that for the project decision-making stage, the construction investor should be the core enterprise in this stage, and master the core resources of this stage, namely funds, while the EPC contractor assists its decision-making with professional and advanced management methods. However, during the project implementation phase, the EPC contractor, as the only bridge for the flow of various resources between the construction investor and other participants, fully controls the information flow, logistics, and capital flow of the entire construction supply chain. Therefore, it should be at the core of the construction supply chain.

In summary, firstly, the core enterprises of the construction supply chain in the EPC mode are different at different stages; Secondly, the construction supply chain should be divided into the supply chain of the entire engineering project and the supply chain within the EPC. But the flow of various resources is fixed. As the demand side, the construction investor inputs demand information and capital flow to the general contractor. The general contractor purchases engineering materials and equipment from material suppliers to produce construction products for the construction investor. The construction supply chain structure under EPC mode is shown in Figure 2.5.



Capital flow Information flow Logistics

Figure 2.5 Construction supply chain architecture under EPC mode in the implementation phase

2.6 Supply Chain Pricing

Pricing and economies of scale Most supply chain activities demonstrate the role of economies of scale. Facing different supply relationships, supplier pricing methods are usually divided into the following five types:

1. Cost+Profit=Price

In the process of supply chain management, it has been found that suppliers in the buyer's market have greater say, and the pricing method of "cost+profit" is more common. This pricing method basically does not consider the external market situation and only looks at the difference between profit and cost.

2. Price Cost=Profit

When suppliers aim to achieve profits, whether it is to maximize profits or reasonable profits, their pricing system will be centered around profits. In this case, the supplier should adopt a profit oriented "price cost profit" approach. Considering the correlation between cost and error rate, in order to ensure that the expected target profit can be obtained through product pricing, the supplier will calculate the final pricing based on the estimated total sales volume and total cost. At this point, the supplier needs to use the Break even chart.

The breakeven chart represents the changes in total revenue and total cost when the sales volume of a product changes. Suppliers can find the breakeven point based on the breakeven chart, which is the minimum quantity that must be sold without loss. They can also estimate the total cost corresponding to the expected sales volume based on this.

3. Price profit=cost method

Just as companies enhance their cost competitive advantage by reducing procurement costs, suppliers' market competitive advantage also relies on effective cost control. Therefore, many suppliers will determine the costs that need to be controlled to achieve target profits based on their own conditions during production, after examining the market environment and analyzing and calculating cost related factors.

The target cost plus the target profit and taxes is the product price. The target cost is generally a cost that suppliers need to work hard to achieve. Therefore, cost oriented pricing methods help suppliers actively control and reduce costs, thereby enhancing their cost competitive advantage. However, in specific implementation, if the supply deviation is not accurate in predicting cost related factors, it may lead to the failure of this method.

4. Jump pricing method

The situation of internal price reduction of products during the packaging time is not common. In the view of the purchaser, this is an incomprehensible jump pricing method. From the perspective of suppliers, this is actually a sense of security driven by market demand, which is a reflection of market demand and non buyers, even if the average cost of the product is the same.

5. Social Responsibility Pricing Method

In the supply market, some suppliers aim to fulfill their social responsibility, that is, to maximize the public interest as the basic criterion for enterprise pricing. Generally speaking, there are two types of enterprises that adopt the social responsibility pricing method.

① Public utility enterprises, such as bus companies, water companies, power companies, gas companies, etc. They usually provide products and services to customers at lower prices.

② Enterprises that adhere to the concept of social market. Their main goal is to meet customer needs and provide social welfare, setting product prices low and only obtaining limited or meager profits, in order to balance corporate profits, customer needs, and social interests.

2.7 Conclusion

Through the study and sorting of literature, it can be found that the current funding problems of construction enterprises in the construction industry are prominent, mainly manifested as: weak growth in operating performance, generally tight operating cash flow, and the urgent need to update traditional management ideas and financing methods in the industry. In this context, many industry insiders and scholars have paid attention to the mature management method of manufacturing industry - supply chain management, and have achieved certain research results. At the same time, supply chain financing, as a relatively new research field in the supply chain, has gradually attracted scholars' attention. As the relevant research is still in its infancy, its content tends to be more theoretical. Research at home and abroad is mainly divided into two modes: one is financing between members within the supply chain, and the other is financing from financial institutions obtained by core supply chain enterprises or pledging supply chain products as a whole. In recent years, there has been a gradual emergence of decision-making research on two financing models.Due to the practical significance of supply chain financing in solving the most critical and core funding issues of enterprises Our research will definitely be more detailed and in-depth. However, this article believes that existing research still has the following issues: firstly, there is still no clear and unified definition and structural model for the construction supply chain. Secondly, research on the construction supply chain in different situations may deviate from the actual construction project from the perspective of financial management, resulting in poor universality; Or from the perspective of engineering management without departing from traditional engineering management methods, it is difficult to innovate. Finally, there is a lack of efficient application of supply chain management methods in the construction supply chain, and most research lacks a quantitative decision-making mechanism. There is almost no research on the funding problem of construction enterprises in the construction supply chain, which is the most core challenge in the industry.

CHAPTER 3
RESEARCH METHODOLOGY

The common financing models currently used in the construction industry are mostly financing measures adopted by enterprises themselves to meet their funding needs. Due to the characteristics of the construction industry, construction companies and various participants in their supply chain have intricate relationships. Therefore, when analyzing the pricing and financing models of the construction supply chain, corresponding parameters can be introduced through model establishment for quantitative research and analysis.The steps for establishing the model are as follows:

3.1 Establishing a financing framework for the construction supply chain

The X project plans to adopt the EPC engineering general contracting model. As a seller of construction products, Company F is the only demander of construction products for Company C at this time; Company's C construction products are the manufacturer and the only supplier of F company's demand for construction products. Referring to the architecture of the construction supply chain model under EPC mode in Figure 2.5, assuming that Company C unconditionally and smoothly purchases various building materials and mechanical equipment, and forms a stable and trusted partnership with upstream material suppliers, labor subcontractors, and various professional subcontractors, Company C can be designated as the engineering contractor and can establish a second-order construction supply chain with the construction investor, Company F. In addition, the research content of this article takes place in the decision-making stage of engineering projects. Through the analysis above, it can be seen that Company C provides decision-making opinions for Company F, which is the core enterprise of the supply chain. This study will be based on the construction supply chain network under this condition.

In the construction supply chain composed only of Company F and Company C, logistics is relatively clear: from Company C to Company F; The capital flow is from Company F to Company C, but due to the characteristics of the construction industry, Company C needs to use its own funds for product production to meet the standards required by Company F in order to obtain the corresponding project settlement payment. Previously, when Company C cannot produce according to Company F's requirements with its own funds, it must seek other financial support and repay after the payment is received; The information flow in the construction supply chain should maintain two-way flow and ensure the authenticity, timeliness, and accuracy of information. This is also a prerequisite for F Company and C Company to achieve construction supply chain cooperation, obtain supply chain financing, and share supply chain advantages. The structure of Company F and Company C is shown in Figure 3.1.

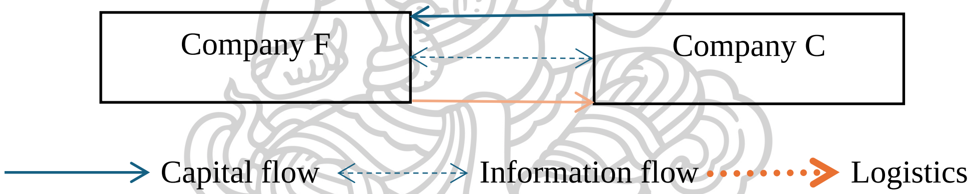


Figure 3.1 F-C Construction Supply Chain

In this study, when financial constraints arise in the construction supply chain, the financing sources are divided into F company's own surplus funds and loans from financial institutions such as banks. The self owned funds of Company F can be regarded as internal funds of the construction supply chain, while the loans from Bank K are external funds of the construction supply chain. If there is sufficient internal funding in the supply chain, there is no financial constraint on the overall construction supply chain; On the contrary, there is a financial constraint, and only by introducing external funds from the supply chain can the most efficient operation of the construction supply chain be achieved.

When the funds come from Company F, based on the contractual relationship of the construction supply chain, Company F can lend the surplus funds f_s to

Company C at the interest rate rs. For Company F, not only can it obtain profits greater than the market risk-free return rate R (i.e. srR<), but it also solves the financial problem of Company C, which is beneficial for engineering construction and accelerates the efficiency of the construction supply chain; For Company C, compared to external funds in the supply chain, internal financing in the construction supply chain does not require the provision of enterprise credit and other information. The procedures are simple and the funds are obtained quickly. The disadvantage is that the amount is low and sometimes cannot meet the demand. This financing model supported by internal funds in the construction supply chain is shown in Figure 3.2.

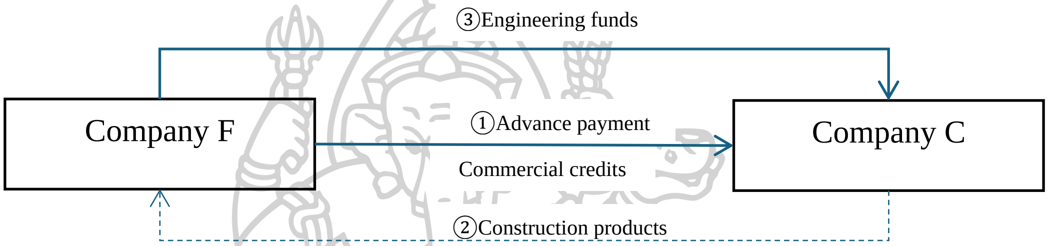


Figure 3.2 Internal financing structure of the construction supply chain

When using loans from financial institutions, as the funds come from external funds in the construction supply chain, this part of the funds is called off chain funds. This article believes that there are three main ways for Company C to obtain external funding support from the supply chain. The first type is to rely on one's own credit for financing, the second type is to borrow core enterprise F Company and engineering projects through the construction supply chain for financing, and the third type is to use property pledge based on the construction supply chain to achieve financing. From the above analysis, it can be seen that due to its high asset liability ratio, Company C has no advantages in terms of credit limit and interest rate compared to the second financing method in obtaining loans based on its own creditworthiness. Therefore, it will not be repeated. The corresponding financing products of the second financing method mainly include factoring and accounts payable financing. Conceptually, it is financing from K Bank using accounts receivable formed by enterprise credit sales. From the above analysis, it can be seen that, under the premise of excluding the right to use construction land, construction products or projects under construction (semi-finished products) that have passed the acceptance of Company F can be considered as "credit sales" products from Company C to Company F. That is, the construction projects that have passed the acceptance of Company F have corresponding value, forming accounts payable of Company F and accounts receivable of Company C. In construction projects, it is possible to use the engineering progress confirmation form as the basis for accounts receivable. The progress payment confirmation form is a document issued by Company F to confirm the total amount of various expenses calculated based on the monthly or multi month total or visual progress or control interface acceptance of qualified engineering quantities during the construction process. Using accounts receivable notes as collateral and based on the reputation of core enterprise Company F, break down its credit limit for financing. The main difference between factoring and accounts receivable guarantee lies in whether to transfer the accounts receivable into possession. To make this study clearer, under this approach, the bank provides Company C with a loan with an interest rate of r_b, and the financing model is shown in Figure 3.3.

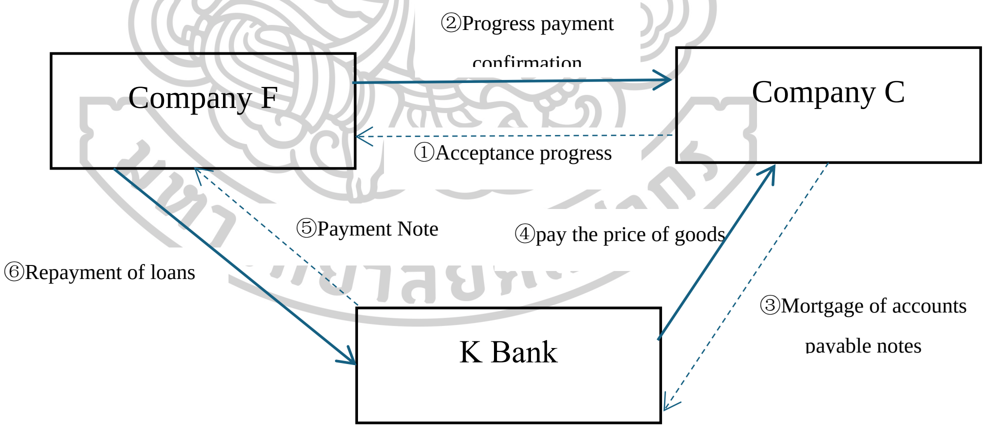


Figure 3.3 External financing structure of construction supply chain

3.2 Assumptions related to the construction supply chain of engineering projects

Assumption 1: Both Company F and Company C, members of the construction supply chain, are rational economic individuals who pursue profit maximization as rational decision-makers.

Assumption 2: Both parties have complete information on the costs and profits of each member of the construction supply chain.

Assumption 3: Neglecting the impact of inflation on monetary value during the research period, while there is no debt issue between the upstream raw material suppliers in the construction supply chain and Company C, Company C can successfully obtain construction materials by paying off the payable amount.

Assumption 4: Looking at the real estate situation yearbook, there are both completed housing area and sales area of commercial housing. It is not difficult to compare the relevant data statistical results. It is not difficult to find that the completed housing area in each region is greater than the sales area of commercial housing every year, and the "inventory" scale of commercial housing continues to rise. It is undeniable that the real estate market shows a state of supply exceeding demand, and the inventory depletion cycle is at a low level. When national policy intervention or market emergencies occur, especially in the current state of global economic downturn, inventory will be reduced, and on-demand production is called "supply equals demand", in order to reduce the capital consumption of the entire construction supply chain and complete the entire supply chain operation process from production to revenue as soon as possible.

Assumption 5: In the process of engineering valuation, according to national regulations, the calculation of value-added tax is relatively complex: building materials belong to general goods specified in the Provisional Regulations on Value Added Tax, and their value-added tax rate is 17% for general taxpayers; The design project belongs to the service category, and the corresponding value-added tax rate is 6%; The corresponding value-added tax rate for the construction contractor is 9%; At the same time, if the taxpayer is a small-scale taxpayer, its value-added tax rate is 3%. Under different scenarios, tax plans may vary depending on the proportion or company situation. Whether it is the developer or the general contractor, how to choose a suitable tax plan is a topic worth in-depth research. The main purpose of this article is to study the financing plan for the construction supply chain to ensure the optimal profit while ensuring the smooth progress of the engineering project. To make the decision-making research in this article clear, it is assumed that the data related to prices in this article are all tax-free amounts.

Assumption 6: The data source is true and reliable, with no missing or false data. During the period from the data generation to the sales period of the research object in this article, the government's policies on real estate fashion will not undergo significant changes or have a significant impact on the real estate market.

3.3 Parameter Setting of Engineering Construction Supply Chain

3.3.1 The construction cost per unit area c, the construction quotation ω, and the pricing of commercial housing p

The engineering cost c per unit building area in this article is the total cost of the general contractor completing the unit building area, including: design expenses, all consumption of raw materials, auxiliary materials, and purchase of accessories; The amortization and leasing expenses of turnover materials, all expenses incurred in the use of construction machinery, labor costs, and expenses incurred in organizing and managing engineering related organizations.

When the developer and the general contractor complete the settlement, they audit the construction cost in accordance with relevant national regulations and contract agreements, and can calculate the quotation w for the unit building area. The construction cost mainly consists of the expenses included in the above-mentioned construction project cost c, the profit of the general contractor, and taxes. In relevant laws and regulations and bidding documents, it is stipulated that the tax ratio is clear, and the contractor determines the enterprise profit ratio in the bidding quotation. At the same time, the EPC general contractor has internal agreed fee standards for design rates and procurement costs. It can be concluded that the main difference between the cost c of unit building area and the quoted price w of unit building area comes from the different quotas used for accounting during the construction phase.

The construction cost c, also known as the construction cost, is calculated using the construction quota, which is prepared by the contracting enterprise based on its internal production capacity and management level. It details the engineering quality requirements, construction technology, and various materials, working days, specifications, and other information. The construction quota is only applied within the contractor's enterprise and is an important means for the contractor to promote internal responsibility system, reduce production costs, and improve business management. The construction quota represents the average advanced level of the market. Due to the advanced construction technology or excellent management ability of the construction party, the material and daily consumption can be lower than the general calculation level of society, and the efficiency of machinery and turnover materials is higher than the average efficiency of society. This effectively reduces costs, provides contractors with greater profits and broad market space.

The construction part of the unit area building cost w is mainly based on budget quotas. The budget quotas are not as specific as the construction quotas, but only the labor days, material consumption, and mechanical shifts required to complete a certain work content according to the general level of society. If complete cost materials need to be formed, the enterprise management fees will be recorded based on the quota calculation according to the regulations of the project location and the contract agreement Fees and taxes. This calculation method is applicable to both the developer and the contractor, and is also the basis for bidding quotation. In years of practice in the construction industry, through dynamic comparative analysis of construction cost c and construction quotation w, not only can cost be effectively controlled, but also losses can be prevented in a timely manner.

The listing price for developers entering the sales process of commercial housing is usually composed of three parts: unit building area pricing, land price, and marketing premium. Among them, land prices and marketing expenses are the main sources of real estate premiums. Premium refers to the sale income of a certain thing or product that is higher than a reasonable price through various reasonable means. The land price and bidding transaction price include the land cost price (usually calculated based on the starting bidding price of the land) and the land premium caused by factors such as the surrounding facilities, cultural environment, and ecological environment of the plot. Based on the statistical results of the real estate professional data of CREIS, the land premium in China has a significant impact on land prices and cannot be ignored.

Marketing premium is composed of two aspects: market environment and corporate brand. From the perspective of market environment, high-end consumers tend to prefer high-quality and high priced projects, positioning accurate product grades for customers, and grasping consumers' sensitive points to create profits; Corporate branding is an advanced stage of achieving premium, focusing on the medium to long term, identifying the characteristics of participating companies and their products, which is crucial for improving project profits and corporate competitiveness.

As a construction supply chain product, commercial housing differs from manufacturing products in that the premium rate can range from 1% to 50%, which is more common in 30%. The numerical influencing factors are very complex and difficult to determine. In the study of the construction supply chain, this article found that it is necessary to exclude the extremely unstable premium and define it based on the setting of commodity prices in the manufacturing supply chain, and conduct further research based on this. Therefore, this article defines the unit building area pricing p as the sum of the quoted price w per unit building area and the developer's unit profit. Based on the above discussion, there must be: unit building area cost c<unit building area quotation w<unit building area pricing p.

3.3.2 Market demand for building area D（p） and completed area q

The market demand area D (p) set in this article is the market demand building area inferred by the developer based on the company's own engineering experience, the project situation and research results to be determined by the target project, and based on the selling price. The completed area q refers to the building area that the contractor constructs according to the agreement with the contracting party and is confirmed by the contracting party upon completion. In this article, the completed building area q is considered as the "supply" building area. In the compilation and analysis of previous research literature, it is found that the pricing of commercial housing is linearly negatively correlated with the completed area, and the setting satisfies the requirement of q=a - bp (a and b are constants greater than 0). Based on the discussion of hypothesis 4, establish a supply and demand balance model, and set the market demand for construction products to meet q = D（p）= a - bp (a and b are constants greater than 0).

3.3.3 Interest rate setting

Risk-free return rate R: Based on the assumption of rational economic agents for Company F and Company C, for the surplus funds of the company's own funds f_s and f_m after the company pays amateur funds, at least a risk-free return rate of R will be obtained.

Enterprise loan interest rate r: When Company C makes a loan based on its own corporate credit, its loan interest rate is r; When Company C uses commercial credit financing provided by Company F based on a supply chain partnership, its loan interest rate is r_s. When company C applies for financing as a supply chain member to K bank, due to F company providing credit support and K bank providing Company C with accounts receivable financing business based on the accounts receivable generated in the actual transaction between Company C and Company F, the loan interest rate is r_b.

Due to Company's F high credit rating, excellent financial condition, and deep cooperation with K Bank, when Company C adopts supply chain accounts receivable financing, its interest rate must be lower than the interest rate that Company C directly borrows from K Bank, i.e. $r_b <$ r ; The financing interest rate provided by Company F is lower than the direct loan interest rate provided by Bank K to Company C, i.e. $r_s <$ r ; When implementing supply chain financing, Company C can choose multiple financing models, but it is necessary to plan the entire process's funding amount, payment nodes, etc. Compared to this, the structure of the accounts receivable financing model is simple and the plan is clear. Company C has saved the planning cost of the financing plan, so there should be $r_b < r_s$. The interest rates of various financing methods are higher than the risk-free return rate. In summary, there are $R < r_b < r_s < r$.

3.3.4 Other

Engineering Advance Payment B: The engineering advance payment, also known as material reserve payment or material advance payment, is used by the contractor to purchase the necessary materials, engineering equipment, and machinery for the project. The implementation of advance payment for engineering mainly depends on the relevant provisions of the general terms of the contract and price settlement methods or the relevant provisions in the special terms of the contract between both parties. This article will conduct a quantitative analysis on whether to agree on a project prepayment with the contractor and make decision recommendations. In order to standardize risks and facilitate financial auditing, in accordance with the relevant provisions of the "Valuation Specification for Construction Engineering Bill of Quantities", the proportion of advance payment B shall not exceed 30% of the contract price, and in principle, shall not be less than 10% of the contract amount. In addition, set the subscripts s and m to represent the construction investor company F and the contractor company C respectively; The superscripts N, RN, R, M, and B represent four situations: unfunded status, unfunded status without prepayment status, internal financing status within the supply chain under financial constraints, and external financing status within the supply chain under financial constraints. All parameters in this article are organized and explained in Table 3.1.

Table 3.1 Parameter setting

Parameter	Representative value
Company F	Sales side of construction products
Company C	Manufacturer
c	EPC contractor's construction cost per square meter
ω	Cost per square meter of construction area approved by construction enterprise accounting

Table 3.1 Parameter setting (continued)

Parameter	Representative value
p	Pricing per square meter of building area
q	Completed building area
R	Market risk-free return rate
r	Loan interest rate from banks for construction enterprises
r_s	Interest rate for inter member loans issued by construction enterprises
r_b	Supply chain members borrow interest rates from banks
B	The advance payment amount agreed upon between the construction unit and the construction enterprise before the commencement of construction
f_b	Enterprise owned funds
π	On the Profit Function of Output q
D	On the Demand Function of Price p
a, b	Constant term in the price demand function
d	Land cost per unit area

3.4 Numerical Analysis of Supply Chain Related to X Project Construction

(1) Analysis and Calculation of Cost Structure in Construction Projects

Based on the X project completed and settled by Company C in May 2019, the market environment differences were investigated, the comprehensive difference coefficient was calculated, and the construction cost per unit area was calculated using a similar engineering budget method. The composition of unit area engineering cost for X project is shown in Table 3.2

Table 3.2 X Project Cost Composition

	Cost Name	Amount (¥)	Proportion (%)
Direct costs	Labor cost	6502870.11	21.38
	Material cost	12630654.34	60.95
	Machinery costs	1581163.13	7.63
	Temporary facility fees	397881.15	1.92
	On site funding	553303.48	2.67
	Design fee	530508.21	2.56
Indirect costs	Enterprise management fees	996775.18	4.81
Total Cost		20722976.78	100
Building area (m^2)	15707.79	Cost per unit area (¥)	1319.280228

According to Article 9.7.1 of the "Valuation Specification for Construction Engineering Bill of Quantities", when the unit price of materials and engineering equipment changes by more than 5%, and the unit price of construction machinery shifts changes by more than 10%, the excess part shall be adjusted. This indirectly indicates that Company C needs to bear the risk of material and mechanical equipment unit price increases within 5%. According to Company C's prediction, the material cost will be increased by 5%, and the mechanical usage fee will be increased by 2.5%. In addition, due to management upgrades, the coefficient of difference in management costs is 0.95, with other differences being relatively small. The comprehensive difference index can be calculated based on the above information:$z = \sum a_i \times k_i$, Among them, a_i is the proportion of the unit engineering cost of the corresponding cost station in the X project engineering budget, and k_i is the coefficient of difference for this cost. Based on the data in Table 3.1, it can be calculated that the comprehensive coefficient of difference z is 104.92. Therefore, the construction cost $c = c' \times z$, per unit area is calculated and brought into the data. It is proposed to determine that the value of construction cost c in this article is 1384.16 Yuan/㎡.

Land cost per unit building area d.As can be seen from the previous text, the land area is 55598.2 ㎡, with an estimated price of 70.6313 million yuan and a transaction price of 166 million yuan. If the plot ratio is determined to be 1.3, it can be inferred that the evaluation price per unit building area, i.e. the land cost per unit building area, is 1270.4 yuan/㎡, and the land premium per unit building area is 2985.7 yuan/㎡

A functional model of the demand for building area and pricing in the commercial housing market. There is a significant correlation between real estate prices and various factors, among which the components with higher contribution rates include: residential supply area, number of real estate industry employees, per capita GDP, per capita disposable income, loan interest rates, industry investment, urban population, and political factors, as well as the influence of characteristic prices.

Company F has internal calculation principles for the prices of commercial housing developed by the company. Firstly, using the internal real estate market prediction model of Company F, the relationship between the predicted average price and the supply area is obtained by incorporating the corresponding values for 2019 based on Hypothesis 3. Because the predicted average price of the city is P, which consists of building costs, land costs, and premium costs, it is necessary to conduct premium analysis on the sold properties based on the prediction model. Premium refers to the portion of the sales income of a certain thing or product that exceeds reasonable pricing through various reasonable means, which can be divided into land premium and marketing premium. The land premium is mainly influenced by the surrounding environment, plot ratio, and development prospects of the plot; The marketing premium is influenced by the company's brand awareness, product positioning, and marketing quota investment. By summarizing and analyzing the sales situation of Company's F development properties, the hedonic price method (one of the mature methods for studying the impact of external environment on property prices in foreign countries) is adopted. This method believes that the factors that affect residential prices start from three categories: neighborhood environment, location factors, and building structure.Company F adopts a premium model is $\mathrm{prise_i} = \beta_0 + \sum_{i \in D} \beta_i q_i + \varepsilon_i$,(Where $\mathrm{prise_i}$ is the premium; β_0 is a constant term, β_i is the corresponding estimation coefficient; D is the variable set of regional characteristics, public service facilities, etc.Based on the historical real estate statistics of Company F, this model calculates the relevant data of Project X to obtain the marketing premium calculation value. Then, considering the land premium based on the land situation, the quantitative value of the set variable is brought in, and the relationship between the real estate price and the sales area is finally obtained. Given the complexity of the research process and the fact that it is not the subject of this study, it will not be further elaborated here.

If the price of residential commercial housing is regarded as a natural result of supply and demand balance, based on the above assumption 4, Company F's production decision is based on the pricing of residential commercial housing. Establish a supply and demand balance model. Based on the calculation results of Company F, the functional relationship of D with respect to p, $D = 34129.17 - 94.24p$, is used to obtain the values of a and b.

Company C has its own funds and prepayments. After conducting an inventory of monetary funds, accounts receivable, inventory and other working capital, as well as confirming the budget for other construction in progress expenses and daily operating expenses of the company, Company C plans to determine a fund of 24.57 million yuan that can be used for the X project, which will be used for expenses such as labor compensation, equipment purchase payment, subcontracting payment, etc. Company F plans to determine a prepayment amount of 10 million yuan based on its own situation.

Interest rate. In the case of construction supply chain financing accounts receivable business, the engineering progress payment confirmation form will be used as the basis for accounts receivable. In this financing mode, the interest rate provided by Bank K to Company C is based on a 10% increase in the short-term loan interest rate of the bank, which means the comprehensive annualized interest rate r_b is 4.4%; But if Company F proposes a loan based on the company's own salary, after comprehensive evaluation, K can provide it with a loan interest rate of r is 4.79%. The commercial credit loan interest rate provided by Company F to Company C is r_s,which is 4.5%.

Market risk-free return rate R. The interest rate of savings treasury bond is taken as the market risk-free interest rate. Calculate the interest rate of bookkeeping treasury bond issued by the Ministry of Finance in 2018 and 2019, and convert it into annual compound interest rate, as shown in Table 3.3. Determine a risk-free return rate of 1.062.

Table 3.3 Calculation of risk-free rate of return

Term (year)	Annual interest rate (%)	Compound annual interest rate	Risk-free return rate
5	4.27	0.844	1.062
3	4	1.28	

Source:Data of China Bond Information Network in 2018 and 2019

3.5 Conclusion

This chapter analyzes the pricing mechanism and supply chain financing mode of the construction supply chain. Based on this, the required parameters are analyzed and explained, and relevant data is analyzed based on the actual engineering project. By organizing, simplifying, and calculating, numerical values are obtained for parameter assignment, which enhances the practical significance of the model and parameters. This lays the foundation for the analysis of X project's construction supply chain pricing and financing decisions in the following text, At the same time, it provides guarantee for accurate management suggestions.

CHAPTER 4
PRICING STRATEGIES OF X RESIDENTIAL COMMUNITY ENGINEERING CONSTRUCTION SUPPLY CHAIN UNDER DIFFERENT FINANCING MODELS

From the analysis in the previous chapter, it was found that there are indeed financial constraints in the construction supply chain of the X residential community project, and D company has a higher financing cost based on its own credit level, so it will inevitably choose supply chain financing methods to overcome its financial difficulties. This chapter will analyze the pricing decisions and benefits under different financing models, and then compare and analyze to provide decision-making suggestions for D company on how to choose internal and external financing in the supply chain.

When the building supply chain based on X residential community project is in a state of financial constraints, even if F company provides advance payment to D company, it still cannot solve the financial problem, that is$B + f_m \leq cq^N$.

4.1 Pricing Models for the Construction Supply Chain of X Residential Community under Different Financing Models

4.1.1 Internal financing pricing model for the construction supply chain

If financing is carried out among members in the building supply chain based on the X residential community project, assuming that both F and D companies are rational economic agents, it is necessary for F company to provide financial support to D company through commercial credit loans at an interest rate of r_s on the basis of paying advance payment B to D company. At the same time, F company loses the opportunity cost of a risk-free return rate of R. Based on the partnership, Company F has a more complete understanding of Company D's financial capabilities and project status information. At the same time, Company D has relatively simple procedures for obtaining funds, making financing faster and more convenient. When F company's own funds fs can meet D company's funding gap for the X residential community project, there is no financial constraint on the building supply chain based on the X residential community project, that is:If financing is carried out among members in the building supply chain based on the X residential community project, assuming that both F and D companies are rational economic agents, it is necessary for F company to provide financial support to D company through commercial credit loans at an interest rate of rs on the basis of paying advance payment B to D company. At the same time, F company loses the opportunity cost of a risk-free return rate of R. Based on the partnership, Company F has a more complete understanding of Company D's financial capabilities and project status information. At the same time, Company D has relatively simple procedures for obtaining funds, making financing faster and more convenient. When F company's own funds f_s can meet D company's funding gap for the X residential community project, there is no financial constraint on the building supply chain based on the X residential community project, that is:$f_s + f_m \geq cq$,Due to the prepayment B being paid before the construction of the project, this amount is not considered as a commercial credit loan. Therefore, for the convenience of calculation, when $f_m + B = \theta$.

When independent decision-making is adopted, the decision model of Company F is Equation (4-1), and the decision model of Company D is Equation (4-2).

$$\pi_s^M = (p - w - d)q + (cq - \theta)(r_s - R) - BR \qquad (4-1)$$

$$\pi_m^M = wq - (cq - \theta)r_s - cq \qquad (4-2)$$

Pricing decisions can be obtained:$w^M = \frac{a+bc(2r_s-R+1)-bd}{2b}$, $q^M = \frac{a-bc(R+1)-bd}{4}$,The optimal completed area at this time is:$P^M = \frac{3a+bc(R+1)+bd}{4b}$.

The maximum profit of Company F can be obtained as Equation (4-3), and the maximum profit of Company D can be obtained as Equation (4-4). At this point, the maximum profit of the supply chain is obtained as Equation (4-5).

$$\pi_s^M = \frac{[a - bc(R+1) - bd]^2}{16b} - \theta r_s + f_m R \qquad (4-3)$$

$$\pi_m^M = \frac{[a - bc(R+1) - bd]^2}{8b} + \theta r_s \qquad (4-4)$$

$$\pi_c^M = \frac{3[a - bc(R+1) - bd]^2}{16b} + f_m R \qquad (4-5)$$

When using joint decision-making, the supply chain profit function $\pi_{C0}^M = (p - c - d)q - (cq - f_m)R$,At this point, the optimal completion area for the supply chain is $q_0^M = \frac{a-bc(1+R)-db}{2}$, Pricing is $p_0^M = \frac{3a+bc(R+1)+bd}{2b}$,Maximizing profits in the supply chain is $\pi_{c0}^M = \frac{[a-bc(R+1-bd]^2}{4b} + f_m R$.

Comparing the data of joint decision-making and independent decision-making, it is not difficult to find that although there are financial constraints and financing, the same conclusion can still be drawn in Chapter 5 without financial constraints, so it will not be repeated here; By analyzing equations (4-3) and (4-4), it can be concluded that:$\frac{d\pi_s^M}{dr_s} = -\theta < 0, \frac{d\pi_m^M}{dr_s} = \theta > 0$.From this, it can be seen that the maximum profit of the construction investor F company is a decreasing function of r_s, and the profit of the construction contractor D company is an increasing function of r_s. However, according to equations (4-5), rs does not have an impact on the overall profit π_c^M and π_{c0}^M of the supply chain, nor does it have an impact on output. Therefore, it only plays a role in regulating the internal profit distribution of the supply chain.

Therefore, it can be concluded that as the commercial credit loan interest rate r_s provided by Company F increases, Company F's profits decrease, resulting in an increase in Company D's profits. This indicates that under the financing model among supply chain members, when F company increases the commercial credit loan interest rate r_s, it will cause D company to increase the unit area quotation w, thereby transferring the loan cost to F company. Therefore, increasing the commercial credit loan interest rate r_s by F company will erode F company's profits and instead cannot obtain more profits.

4.1.2 Pricing model for external financing in the construction supply chain

Under financial constraints, when $f_m \leq cq^N$, and D companies can also choose external financing in the supply chain to make up for insufficient funds. When using the building supply chain based on X residential community engineering to rely on external supply chain funds to solve financial constraints, K Bank needs to provide external supply chain financing services. For the sake of discussion, assuming that K Bank can provide sufficient funds with an interest rate of r_b based on supply chain credit, in this case, F Company provides advance payment B to maximize its own interests. For the convenience of calculation, so $f_m + B = \theta$.

When using independent decision-making, the decision-making model of Company F is:$\pi_s^B = (p - w - d)q - BR$, so $q^B = \frac{a-bw-bd}{2}$.The decision-making model of Company D is:$\pi_m^B = wq - (cq - \theta)r_b - cq$.

By optimizing the solution, the pricing decision can be obtained as follows: The optimal unit area quotation is$w^B = \frac{a+bc(r_b+1)-bd}{2b}$,The optimal unit area pricing is $P^B = \frac{3a+bc(r_b+1)bd}{4b}$,The optimal completed area is$q^B = \frac{a-bc(r_b+1)-bd}{4}$.

At this point, the maximum profit of Company F is shown in Equation (4-6), Company D is shown in Equation (4-7), and the overall maximum profit of the supply chain is shown in Equation (4-8).

$$\pi_s^B = \frac{[a - bc(r_b + 1) - bd]^2}{16b} - BR \qquad (4-6)$$

$$\pi_m^B = \frac{[a - bc(r_b + 1) - bd]^2}{8b} + \theta r_b \qquad (4-7)$$

$$\pi_c^B = \frac{3[a - bc(r_b + 1) - bd]^2}{16b} + \theta r_b - BR \qquad (4-8)$$

When using joint decision-making, the supply chain decision function is $\pi_{c0}^{B} = pq - dp - \theta - (cq - \theta)(1 + r_b) - BR$,At this point, the optimal completed area is $q_0^B = \frac{a-bc(1+r_b)-bd}{2}$,The pricing per unit area is:$P_0^B = \frac{a+bc(r_b+1)+bd}{4b}$,At this point, the maximum profit of the supply chain is expressed as equation (4-9).

$$\pi_{c0}^{B} = \frac{[a - bc(r_b + 1) - bd]^2}{4b} + \theta r_b = BR \quad (4-9)$$

Whether independent or joint decision-making is adopted, the external financing interest rate of the supply chain has a direct impact on the profits of Company F and Company D. For Company D,When r_b increases Δr_b ($\Delta r_b > 0$), the profit change is:$\Delta\pi_m^B = \frac{[a-bc(r_b+\Delta r_b+1-bd]^2}{8b} + \theta(r_b + \Delta r_b) - (\frac{[a-bc(r_b+1)-bd]^2}{8b} + \theta r_b)$,After simplification, it can be obtained that$\Delta\pi_m^B = \Delta r_b[\theta - c\frac{a-bc(r_b+\Delta r_b++1)-bd}{8b}]$,There must be $cq^N > G$,Because our own funds f_m meet $\theta < cq^N$,Therefore, there may be $\theta \geq G$. Among them:$G = c\frac{a-bc(r_b+0.5\Delta r_b+1)-bd}{8}$.

By inputting specific numerical values for calculation, it can be concluded that $\theta \geq G$, based on the above analysis, an increase in external financing interest rates in the supply chain will enable Company D to obtain more profits. For Company F, when the external financing interest rate of the supply chain increases Δr_b, the maximum profit of Company F will decrease, which indirectly indicates that Company D will transfer the increased capital cost to Company F by increasing its unit area quotation w.

4.2 Comparative analysis of different financing models in the construction supply chain of X residential community engineering

4.2.1 Pricing Strategy and Financing Plan Comparison

Assuming that internal financing in the supply chain can maximize the profits of Company F, when using joint decision-making, it is necessary to satisfy equations (4-5) greater than equations (4-8), which can be obtained $r_b > R$.

When using independent decision-making, it is necessary to satisfy that equation (4-3) is greater than or equal to equation (4-6), and the calculation can be obtained as follows: $r_s \leq \varphi_s$,among $\varphi_s = \frac{-bc^2r_b^2+2c(a-bc-bd)r_b-Rc[[2a-bc(2+R-2bd]}{16\theta} + R$.

Meanwhile, in order for Company D to maximize profits, it is necessary to satisfy equations (4-4) that are greater than or equal to equations (4-7), and the calculation can be obtained as follows: $r_s \geq \varphi_m$,among $\varphi_m = \frac{-bc^2r_b^2+2c(a-bc-bd)r_b-Rc[2a-bc(2+R)-2bd]}{8\theta} + r_b$, It is known that there must exist: $\varphi_s \geq \varphi_m$.

Thus, the decision threshold is obtained, as shown in equations (4-10).

$$\begin{cases} r_b \geq R \\ r_b \leq \frac{6c(a-bd)-16\theta}{3bc^2} - R - 2 \end{cases} \tag{4-10}$$

Therefore, when the bank's supply chain financing interest rate r_b for Company D meets $\mathrm{R} \leq \mathrm{r_b} \leq \frac{6c(a-bd)-16\theta}{3bc^2} - \mathrm{R} - 2$,The use of inter supply chain financing can maximize profits for supply chain members. When it is less than the market risk-free return rate R or greater than the decision value $\frac{6c(a-bd)-16\theta}{3bc^2} - \mathrm{R} - 2$, inter supply chain financing should be abandoned.

4.2.2 Comparison of Supply Chain Performance of X Residential Community Engineering Construction

Organize and calculate the independent decision profit and centralized decision profit under the no financing mode and the two financing modes studied in this article, and the results are shown in Table 4-1.

Table 4.1 Supply chain values under various modes

No financial constraints	Unit area quotation w^N(yuan/m^2)	Proposed completion area $q^N(m^2)$	Pricing per unit area P^N(yuan/m^2)	Profit of Company F π_s^N(10000 yuan)	Profit of Company D π_m^N(10000 yuan)	Profit from centralized decision-makingπ_{c0}^N(10000 yuan)	Supply chain utility
	2147.97	35990.86	3800.28	1374.49	2749.05	5498.04	75%
Internal financing within the supply chain	Unit area quotation w^M(yuan/m^2)	Proposed completion area $q^M(m^2)$	Pricing per unit area P^M(yuan/m^2)	Profit of Company F π_s^M(10000 yuan)	Profit of Company D π_m^M(10000 yuan)	Profit from centralized decision-makingπ_{c0}^M(10000 yuan)	Supply chain utility
	2202.65	35664.5	3803.95	1222.17	2848.58	5418.99	75.12%
External financing of the supply chain	Unit area quotation w^B(yuan/m^2)	Proposed completion area $q^B(m^2)$	Pricing per unit area P^B(yuan/m^2)	Profit of Company F π_s^B(10000 yuan)	Profit of Company D π_m^B(10000 yuan)	Profit from centralized decision-makingπ_{c0}^B(10000 yuan)	Supply chain utility
	2179.46	34507.07	3816.02	1254.11	2684.99	5203.81	75.70%

From Table 4-1, it can be found that: 1. The utility of the supply chain is relatively stable, and whether or not capital flow is introduced, it will not cause significant changes in the utility of the supply chain; 2. The profit of joint decision-making is superior to that of independent decision-making in all three modes in Table 3-1. As analyzed in Chapter 4, reasonable profit distribution through joint decision-making can make the profits of Company F and Company D both exceed those of independent decision-making, achieving win-win cooperation; 3. By paying attention to various profit data, it can be found that in the engineering background studied in this article, although the introduction of off chain capital flow reduces the profits of Company D and the supply chain, it can improve the profits of Company F.

Meanwhile, as shown in Table 4-1, from the perspective of maximizing profits, based on Hypothesis 2 of this article, the financing decision for the construction of the 10000 yuan supply chain in X residential community is an internal financing model of the supply chain and adopts a joint decision-making approach. At this time, the total profit of the supply chain is 54.1899 million yuan, with a planned construction area of 71290.37 square meters and a unit area quotation of 7607.9 yuan. Regarding the simulation calculation results, F Company has decided to refer to but not fully apply the model calculation method for project planning. When using the above conclusion data, firstly, when the plot ratio is set to 1.3, the required land area is 54838.7 square meters. Although this to a greater extent fully applies the land use rights of F Company's planned construction site (55597.8 square meters), the planning difficulty and profit space of the remaining small area of land is high; If Company F changes the plot ratio, the corresponding supply and demand relationship will need to be recalculated after market research due to the impact of the premium; Secondly, higher prices and larger building areas will inevitably slow down the speed of fund recovery. In the real environment, the speed of fund recovery beyond revenue is also one of the key considerations for projects.

4.3 Management suggestions

1. The impact of off chain financing interest rates on strategies. When independent decision-making is adopted, if $\pi_s^M = \pi_s^B$ obtains the relationship between the internal financing interest rate r_s and the external financing interest rate r_b of Company F under two supply chain financing models, and obtains the functional relationship by inputting specific values:$r_{s1} = -0.3264r_b^2 + 0.7149r_b + 0.03$; if $\pi_m^M = \pi_m^B$, Obtain the relationship between the internal financing interest rate r_s and the external financing interest rate r_b of Company D under two supply chain financing models with the same profits:$r_{s2} = 0.6259r_b^2 - 0.441r_b + 0.0415$. if $r_{s1} = r_{s2}$, The value of r_b obtained from the solution is $r_{b1} = 0.0106$,$r_{b2} = 1.1755$,The conclusion is that when $r_b \epsilon [0.0106,1.1755]$ is reached, internal financing in the supply chain can enable Company F and Company D to simultaneously achieve maximum profits; At the same time, in terms of interest rates, r_{b2} is much greater than r_{b1}, indicating that there is greater cooperation space for financing models within the supply chain. In order to pursue profit maximization, D company and the entire supply chain are more likely to choose this financing model.

2. The impact of capital cost on profit distribution in financing models. In the financing discussed in this article, the cost of funds mainly includes the financing interest rate rb provided by Bank K for Company D and the risk-free return rate R for Company F's losses.

In the case of the same profit for Company D, we borrow the relationship function between the internal financing interest rate r_s and the external financing interest rate r_b in the supply chain from the previous conclusion: $r_{s2} = 0.6259r_b^2 - 0.441r_b + 0.0415$, and use r_b to represent r_s. The results of the function are shown in Figure 5-1.

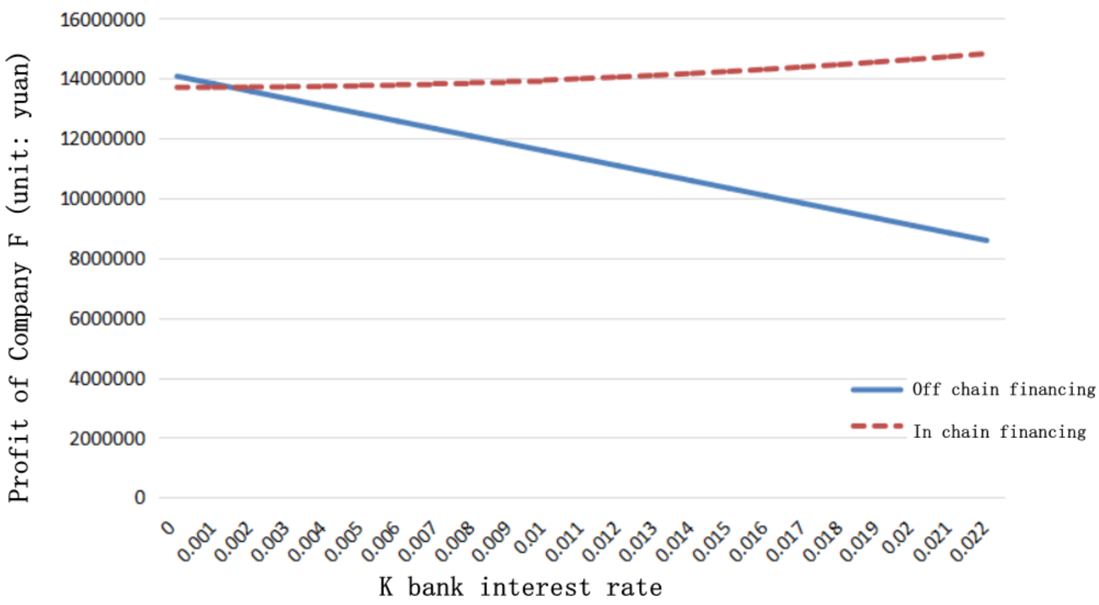


Figure 4.1 Impact of Bank K's rate on Company F's profits

From Figure 4.1, it can be seen that if the internal financing method of the supply chain is adopted, the income of Company F will increase with the increase of the bank interest rate r_b; On the contrary, when choosing an external financing model for the supply chain, F Company's profits will decrease with the increase of K Bank's financing interest rate r_b.

When changing the risk-free return rate R value, the results are shown in Figure 4.2.

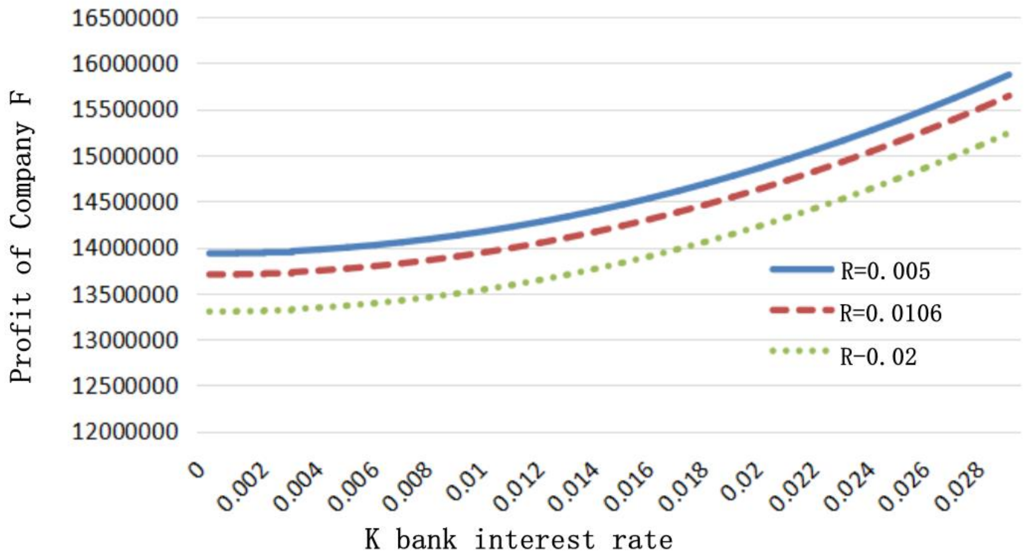


Figure 4.2 Profit chart of F in the internal financing of the supply chain under different risk-free returns

As shown in Figure 4.2, the smaller the risk-free return rate R, the more likely F company will choose internal financing in the supply chain. Meanwhile, combined with Figure 4. 1 and 4.2, as the interest rate r_b provided by banks for financing increases, the profit advantage of F company choosing internal supply chain financing becomes more significant. Based on the analysis above, and only when the financing interest rate r_b provided by the bank is lower than the risk-free return rate R, can F company obtain more profits in the external financing mode of the supply chain. However, based on the assumptions and reality of this article, there is almost no possibility that the financing interest rate r_b is lower than the risk-free return rate R. Therefore, F company will be more inclined to choose the internal financing mode of the supply chain from its own interests perspective.

The impact of D company's own funds on profit distribution. In both internal and external financing states of the supply chain, when the amount of D company's own funds is constrained by funds and there is supply chain financing, the impact on F company's profits changes, as shown in Figure 4.3.

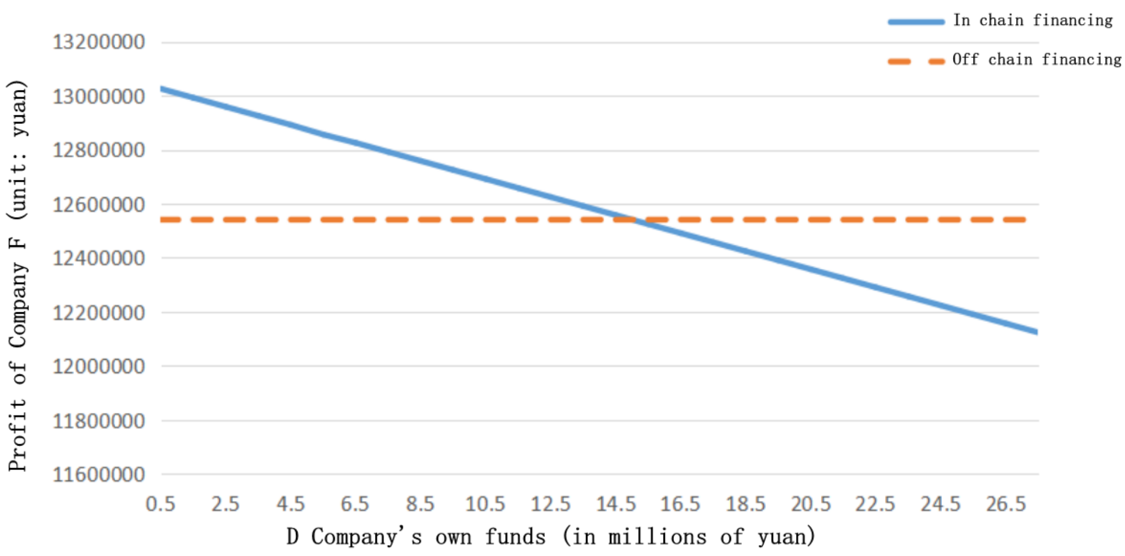


Figure 4.3 The change of company F's profit with the amount of company D's own funds

As shown in Figure 4.3, under the internal financing mode of the supply chain, the profit of Company F will decrease with the increase of Company D's own funds, while under the external financing mode of the supply chain, the profit of Company F will not change accordingly, which is consistent with the analysis results of the decision model.

At the same time, under both internal financing and external financing models in the construction supply chain, Company D's profit changes with the change of its own funds, as shown in Figure 4.4.

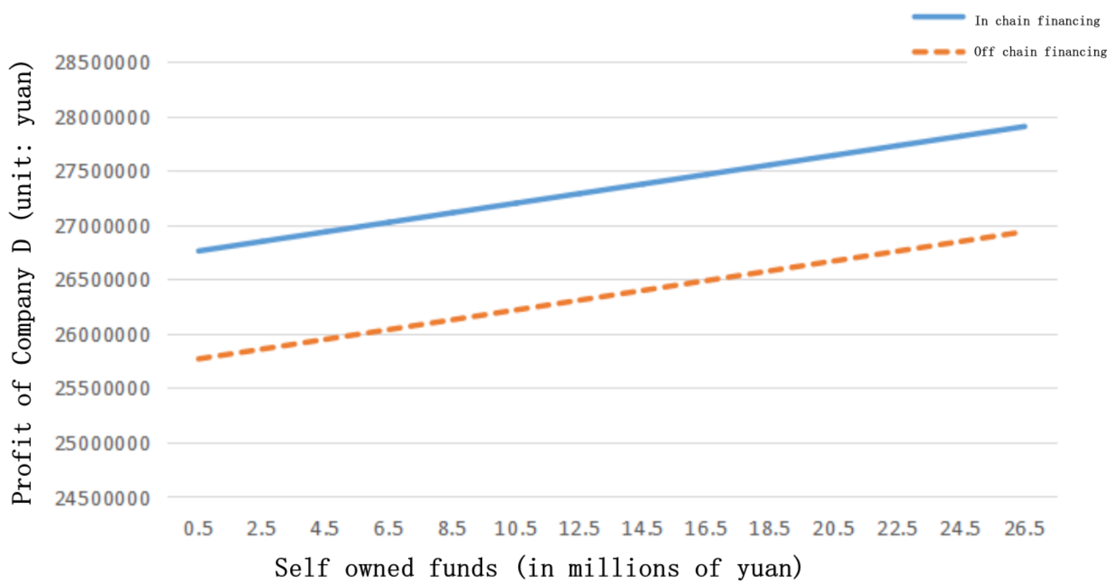


Figure 4.4 Schematic diagram of the change of company D's profit with its own funds

As shown in Figure 4.4, with the increase of D company's own project funds, D's profit shows an upward trend, and the profit of the internal financing mode of the supply chain is higher than that of the external financing mode of the supply chain.

In the process of D company's own fund changes, the profit situation of the supply chain using independent and joint decisions under the internal financing mode of the supply chain and the supply chain using independent and joint decisions under the external financing mode of the supply chain is shown in Figure 4.5.

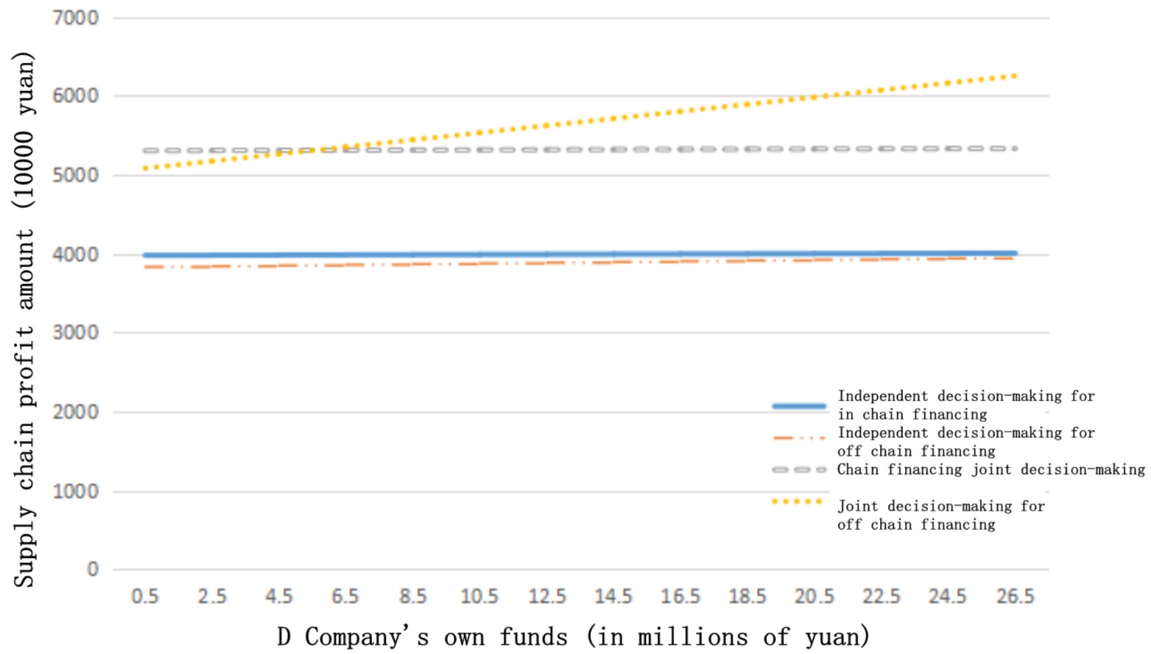


Figure 4.5 Schematic diagram of supply chain profit changes with company D's funds

From Figure 4.5, it can be seen that firstly, whether using internal or external financing in the supply chain, the profits obtained from joint decision-making are higher than those obtained from independent decision-making in the supply chain. This indirectly proves that the conclusion in Chapter 4, without financial constraints, still applies: as long as the unit area quotation w is handled well, F and D companies can obtain profits greater than those obtained from independent decision-making; Secondly, regardless of the mode, as the amount of D company's own funds increases, the overall profit of the supply chain will definitely continue to increase; Thirdly, when D company's own freedom is small enough (below the intersection point in the figure, which is 5.57 million yuan), internal financing in the supply chain has an absolute advantage.

Based on the stage of the project and the participating enterprise environment, it can be seen from the quantitative calculation above that from the overall perspective of the supply chain, choosing internal financing within the supply chain, F Company and D Company abandon the common mode of independent decision-making and focus on centralized decision-making with the goal of supply chain benefits, which can maximize the profits of the supply chain. But as a real estate development project, due to the fact that the land cost is paid in the early stage and is calculated for a fixed area as a whole, the unit area land cost is calculated. If F Company starts from the perspective of fully utilizing land, it should also adopt a joint decision-making model to maximize the completed area and achieve the goal of accelerating capital return for the company.

4.4 Summary of this chapter

Firstly, analyze the pricing decision and profit situation of D company when facing financial constraints and applying the construction supply chain for financing. Based on the two sources of financing, namely internal supply chain financing and external supply chain financing, discussions and quantitative calculations were conducted separately. Simultaneously, from both independent and joint decision-making perspectives, determine the completion area and pricing for F and D companies to achieve maximum profit simultaneously, and thus obtain the maximum profit for F and D companies. A comparative analysis is conducted on the two financing methods mentioned above. By comparing the decision models, the financing decision conclusion is obtained, which is the decision threshold for r_b. The calculation shows that the internal financing mode of the supply chain should be selected and joint decision-making should be adopted for price and completion area decision-making to maximize profits. Subsequently, through more quantitative calculations of the decision model, not limited to the data of the engineering project studied in this article, the impact of two variables, namely the cost of fund utilization and D company's own funds, on supply chain members and overall profits was studied.

CHAPTER 5
PRICING STRATEGY FOR THE CONSTRUCTION SUPPLY CHAIN OF X RESIDENTIAL COMMUNITY PROJECT WITHOUT FINANCING

As analyzed above, the X residential community project is currently in the pre project preparation stage. Accurate and detailed planning is needed regarding residential prices and community size. In previous feasibility study reports, qualitative methods were used to predict residential pricing and building scale. However, with the continuous deepening of the country's supply side structural reform and the transformation and development of commercial real estate, the drawbacks of this rough decision-making method have become increasingly prominent, which can easily lead to excess inventory and overcapacity, resulting in slow capital flow of engineering projects and significant financial pressure on participating enterprises. It is obvious that using quantitative analysis is more accurate. This chapter will construct a decision model for the construction supply chain of X residential community, and based on this, obtain pricing decisions, project scale recommendations, and revenue situations for the construction supply chain under different funding conditions.

5.1 Pricing strategy for X residential community supply chain without financing and financial constraints

When there is no financial constraint on the construction supply chain of the X residential community project, all enterprises on the supply chain, namely the construction investor F company and the construction contractor D company, have no financial constraints,Company D can independently pay for all project costs with a completed area of q and a unit area cost of c, which means it has its own funds is $f_m > cq$.

The decision-making order is D, which decides on output and price based on the profit model and quantity price relationship, while F sets prices based on D company's decisions.

According to Hypothesis 4, Company F decides the completion area based on the sales area required by the market. Referring to the research in the literature, it is assumed that its supply and demand relationship model is as shown in Equation (5-1).

$$q = D(p) = a - bp \qquad (5-1)$$

5.1.1 Price and benefit analysis for independent decision-making

When F Company and D Company make independent decisions, according to Hypothesis 1, both companies use profit maximization as the decision-making basis, that is, both F Company and D Company on the X building supply chain aim to maximize profits. Therefore, a production decision-making model for the developer F Company can be established, as shown in Equation (5-2); The production decision model of the general contractor D company is shown in equation (5-3).

$$\pi_s^N = pq - wq - dq \qquad (5-2)$$

$$\pi_m^N = wq - cq \qquad (5-3)$$

Based on equation (5-1), it can be concluded that$\pi_s^N = pq - wq - dq = -\frac{1}{b}q^2 + \left(\frac{a}{b} - w - d\right) q$, By simplifying the solution, the optimal completed area is calculated as:$q^N = \frac{a-bw-bd}{2}$, After substituting it into equation (5-3), the profit function of Company D can be obtained:$\pi_m^N = -\frac{b}{2}w^2 + \frac{a+bc-bd}{2}w - \frac{ac}{2} + \frac{bcd}{2}$, Solve the optimal unit area price and completed area for it.

From this, it can be seen that under no financial constraints, when F Company and D Company make independent decisions on price and completion area, the optimal unit area quotation is obtained $w^N = \frac{a+bc-bd}{2b}$, Therefore, the optimal completed area can be obtained as:$q^N = \frac{a-bc-bd}{4}$, Optimal pricing per unit building area is $p^N = \frac{3a+bc+bd}{4b}$.

At this point, the maximum profit for Company F is:$\pi_s^N = \frac{(a-bc-bd)^2}{16b}$; The maximum profit of Company D is:$\pi_m^N = \frac{(a-bc-bd)^2}{8b}$, The supply chain is $\pi_c^N = \pi_s^N + \pi_m^N = \frac{3(a-bc-bd)^2}{16b}$.

5.1.2 Price and Benefit Analysis of Joint Decision Making

When Company F and Company D jointly pursue the goal of maximizing the profit of the building supply chain based on the X residential community project, the decision model of the supply chain, namely the profit function, is shown in Equation (5-4).

$$\pi_{c0}^{N} = (p - c - d)\, q \qquad (5-4)$$

By combining equation (5-1) and optimizing the solution, the pricing decision at this point can be obtained as follows: $q_0^N = \frac{a-bc-bd}{2}$, The optimal completion area decision is: $p_0^N = \frac{a+bc+bd}{2b}$, At this point, the maximum profit of the supply chain is $\pi_{c0}^{N} = \frac{(a-bc-bd)^2}{4b}$.

5.1.3 Management suggestions

Based on the above analysis, it can be concluded that: $\pi_{co}^{N} > \pi_{c}^{N}$, Obviously, there exists a situation where the maximum profit of joint decision-making is greater than that of independent decision-making. If the unit building area quotation w is reasonably determined, it will enable F company and D company to simultaneously obtain more profits than independent decision-making, which should satisfy equation (5-5).

$$\begin{cases} (p_0^N - W_0^N - d)\, q_0^N \geq \pi_s^N \\ (w_0^N - c)\, q_0^N \geq \pi_m^N \end{cases} \qquad (5-5)$$

The value of unit building area quotation w can be obtained: $\frac{a+bc-bd}{4b} \leq w_0^N \leq \frac{3a+5bc-3bd}{8b}$, This indicates that as long as the price is within this range, Company F and Company D can occasionally obtain higher profits than independent decision-making. At the same time, it also indicates that if the unit building area quotation w is higher than $\frac{3a+5bc-3bd}{8b}$ or lower than $\frac{a+3bc-bd}{4b}$,Both Company F and Company D will actively choose to make independent decisions due to profit trends, seeking to increase prices in order to obtain greater profits by reducing the completed area, leading to the breakdown of the alliance.

When there is no financial constraint in the building supply chain based on the X residential community project, D company's own funds must meet $f_m \geq cq$. Therefore, when using independent decision-making, the following conditions should be met: $f_m \geq cq^N = \frac{ac-bc^2-bdc}{4}$; When adopting joint decision-making, it should meet the following requirements: $f_m \geq cq_0^N = \frac{av-bc^2-bdc}{2}$. This indicates that independent decision-making only requires half of the funding for Company D compared to joint decision-making. As analyzed in the previous text, it can be concluded that limiting the unit building area quotation w can enable D company to obtain greater profits under joint decision-making. Therefore, it can be inferred that even under supply chain conditions, D company needs to meet a certain amount of self owned funds $f_m \geq \frac{ac-bc^2-bdc}{4}$, Only then can there be the possibility of maximizing profits. When $f_m < \frac{ac-bc^2-bdc}{4}$, Then Company D must be in a state of financial constraints.

When D company's own funds $\frac{ac-bc^2-bdc}{4} < f_m < \frac{ac-bc^2-bdc}{2}$, i.e, $\frac{a-bc-bd}{4} < q^{N*} < \frac{a-bc-bd}{2}$. At this point, joint decision-making still has the potential to generate profits greater than independent decision-making. For the convenience of proof calculation, another $q^{N*} = \frac{3(a-bc-bd)}{8}$ is added within the value range. At this point, the maximum profit obtained from the joint decision-making of the supply chain is: $\pi_c^{N*} = \frac{15(a-bc-bd)^3}{64b} > \pi_c^N$. At this point, equation (5-6) must hold.

$$\begin{cases} (p^{N*} - w^{N*} - d)q^{N*} \geq \pi_s^N \\ (w^{N*} - c)q^{N*} \geq \pi_m^N \end{cases} \qquad (5-6)$$

It can be obtained that $\frac{a+2bc-bd}{3b} \leq w^{N*} \leq \frac{11a+13bc-11bd}{24b}$. Mean while, according to the price pattern, when $q^{N*} < q_0^N$, There should be $w^{N*} > w_0^N > \frac{a+3bc-bd}{4b}$, Therefore, it can be inferred that when the unit building area quotation w range is within ($\frac{a+3bc-bd}{4b}$, $\frac{11a+13bc-11bd}{24b}$),It can be achieved that the profits of both Company F and Company D exceed those of independent decision-making.

From this analysis, it can be seen that when D company's own funds can achieve maximum profits through independent decision-making but cannot achieve maximum profits through joint decision-making, joint decision-making can still enable D company and F company to obtain profits beyond independent decision-making. At the same time, the range of values for selecting unit building area quotation w is actually larger than the range of values for joint decision-making under sufficient funding.

By collecting and organizing relevant data in Chapter 3, the above model can be incorporated into numerical values and analyzed based on real-life situations. Based on the above analysis, it can be concluded that:

When making joint decisions, larger profits can be obtained, $f_m \geq \frac{ac-bc^2-bdc}{2}$ knows that Company D should have at least 99.6342 million yuan (cq_0^N) in its own funds.The profit of the supply chain is 54.9803 million yuan. When the value of w is between the range (1766.07 , 1957.02), both F company and D company can obtain profits higher than independent decision-making. Therefore, the profit range for F company is (1374.49 , 2748.98), and the profit range for D company is (2749.05 , 4123.54), both of which obtain the minimum value when the other party obtains the maximum profit.

In independent decision-making, the standard for D company's sufficient self owned funds is $f_m \geq \frac{ac-bc^2-bdc}{4}$, and it is calculated that D company's self owned funds should be at least 49.8171 million yuan(cq^N),At this time, Company F obtained a profit of 13.7449 million yuan, Company D obtained a profit of 27.4898 million yuan, and the overall profit of the supply chain was 41.2347 million yuan.

However, according to the analysis of D Company's financial situation in Chapter 3, it can be seen that D Company has only 24.57 million yuan of its own funds available for this project, so D Company has financial constraints.

5.2 Pricing Strategy under Financial Constraints in the Construction Supply Chain of X Residential Community Project without Financing

When D company's financial capacity is insufficient, i.e. $f_m < \frac{ac-bc^2-bdc}{4}$, F company can choose to pay advance payment B to D company through contract agreement to ensure the smooth progress of the project. However, at the same time, F company will consider its own interests and choose to pay the advance payment, which will at least result in losing the market risk-free return with an amount of B and an interest rate of R. In the absence of financing, the production and pricing decisions of Company F and Company D are as follows.

5.2.1 Price and profit analysis when F company does not provide advance payment

On the premise that Company F does not provide advance payment, D will, based on its own financial situation, use all its own funds for production in order to reduce capital costs and maximize benefits. Therefore, the completion area can be determined:$q^{RN} = \frac{f_m}{c}$, At this point is $P^{RN} = \frac{ac-f_m}{bc}$.

When making independent decisions, F Company's decision-making model is:$\pi_s^{RN} = (p - w - d)\frac{f_m}{c}$,The decision model of Company D is $\pi_m^{RN} = (w - c)\frac{f_m}{c}$,Both decision models are monotonic functions. In mathematical theory, if D company's profit π_m^{RN} is maximized, then within the range of w values, the extreme point makes the unit building area pricing p equal to the unit building area pricing w, and F company, as an investor, is not profitable. This model does not have practical significance, and in this case, the supply chain profit of independent decision-making is the same as that of joint decision-making. Therefore, this article measures the joint decision-making mode, and the joint decision-making supply chain decision-making model is:$\pi_c^{RN} = (p - c - d)q$.

Therefore, in the absence of advance payment and with financial constraints on Company D, the pricing per unit area is $p^{RN} = \frac{ac-f_m}{bc}$,The completed area is$q^{RN} = \frac{f_m}{c}$,At this point, the profit of the supply chain is shown in equations (5-7).

$$\pi_c^{RN} = -\frac{1}{bc^2} f_m^2 + \frac{a - bd - bc}{bc} f_m \qquad (5-7)$$

5.2.2 Price and profit analysis of F company's payment of advance payment

When F company chooses to pay D company's advance payment, F company will at least lose the market risk-free return with an amount of B and an interest rate of R.

When the advance payment amount can meet the funding gap of Company D's project, that is:$\mathrm{B + f_m \geq cq^N}$,Simultaneously make $\mathrm{B + f_m \geq cq_0^N}$,According to the calculation and analysis in section 4.1.3 above, it can be concluded that in this case, the supply chain can achieve maximum profit under joint decision-making. The decision-making model is:$\pi_{c0}^R = (p - c - d)q - BR$.

The calculation shows that:$q_0^R = q_0^N = \frac{a-bc-bd}{2}$,$p_0^R = p_0^N = \frac{a+bc+bd}{2b}$,At this point, the profit of the supply chain is as follows (5-8).

$$\pi_{c0}^R = \frac{(a - bc - bd)^2}{4b} - BR \qquad (5-8)$$

When the sum of advance payment and self owned funds cannot meet the funding needs of joint decision-making but can meet the funding gap of D company's project, that is: $\mathrm{cq^N \leq B + f_m < cq_0^N}$,Company D is unable to achieve the optimal completion area. Based on assumption 1, in order to maximize profits, Company D must have set a completion area:$q^R = \frac{B+F_m}{c}$,The decision-making model is based on the overall profit of the supply chain is $\pi_c^R = (p - c - d)\frac{B+f_m}{c} - BR$.

There is a pricing per unit building area:$q^R = \frac{B+f_m}{c}$,Completion quantity:$p^R = \frac{ac-B-f_m}{bc}$,At this point, the profit of the supply chain is as shown in equation (5-9).

$$\pi_c^R = -\frac{1}{bc^2}(B + f_m)^2 + \frac{a - bc - bd}{bc}(B + f_m) - BR \qquad (5-9)$$

When the sum of advance payment and self owned funds cannot meet the independent decision-making funding needs, that is $\mathrm{B + f_m < cq^N}$,To reduce capital costs and maximize benefits, the completion area can be determined as follows:$q_1^R=\frac{f_m+B}{c}$,At this point $p_1^R=\frac{ac-(f_m+B)}{bc}$.Referring to the decision-making model without advance payment, the joint decision-making supply chain decision-making model can be obtained as follows: $\pi_{c1}^R=(p-c-d)\,q$.At this point, the profit of the supply chain is expressed as equation (5-10).

$$\pi_{c1}^R=-\frac{1}{bc^2}(f_m+B)^2+\frac{a-bd-bc}{bc}(f_m+B)-BR \qquad (5-10)$$

5.2.3 Management suggestions

Assuming that the profit when no advance payment is made is less than the profit when the advance payment is made, then starting from the overall construction supply chain based on the X residential community project, $\pi_c^{RN}\le\pi_c^R\ or\ \pi_c^{RN}\le\pi_{c\,0}^R$ established, i.e. equations (5-7) are greater than equations (5-8), (5-9), and (5-10), resulting in a relationship as shown in equations (5-11).

$$\begin{cases}\frac{a-bd-bc}{bc}f_m-\frac{f_m^2}{bc^2}\le\frac{(a-bc-bd)^2}{4b}-BR, B+f_m\ge cq_0^N \qquad (5-11)\\ \frac{a-bd-bc}{bc}f_m-\frac{f_m^2}{bc^2}\le\frac{a-bc-bd}{bc}(B+f_m)-\frac{(B+f_m)^2}{bc^2}-BR, B+f_m\ge cq_0^N\end{cases}$$

When equation (5-11) holds, payment of advance payment should be chosen to enable the supply chain to obtain greater profits. Conversely, if not, payment of advance payment should be chosen to achieve greater profits.

Although this section conducted price and profit analysis under the centralized decision-making mode of the supply chain, the previous analysis shows that under the premise of $B+f_m\ge cq^N$, centralized decision-making will enable both F and D companies to obtain profits greater than under independent decision-making. It can be inferred that making prepayment decisions based on the market risk-free return rate R will also maximize the profits of F and D companies.

When $\mathrm{B}+\mathrm{f_m}\ge\mathrm{cq_0^N}$ and $f_m<cq^N$, there must be:$\mathrm{B}\ge(\mathrm{cq_0^N}-\mathrm{cq^N})$,By inputting the numerical value, it can be inferred that a prepayment of B greater than

49.8171 million yuan can establish $B + f_m \geq cq_0^N$.According to the analysis in the previous section, it can be seen that when joint decision-making is adopted and the unit area quotation meets $\frac{a+bc-bd}{4b} \leq w_0^N \leq \frac{3a+5bc-3bd}{8b}$, F company and D company can obtain the maximum profit. According to the regulation that the proportion of national advance payment B shall not exceed 30% of the contract price, and shall not be less than 10% of the contract amount in principle, with $B \leq 0.3wq_0^N$, after entering the value, even if F company chooses to quote w for the largest single-sided area and its own profit is the smallest, even if the maximum value of advance payment B is 42.2909 million yuan, it still cannot meet the funding needs under $B + f_m \geq cq_0^N$. It can be concluded that even with prepayment B, D company's own funds still put the supply chain in a state of financial constraints.

If F company considers its own interests, equations (5-11) can be simplified as $\frac{a-bd-bc}{bc} f_m - \frac{f_m^2}{bc^2} \geq \frac{a-bc-bd}{bc}(B + f_m) - \frac{(B+f_m)^2}{bc^2} - BR$,At the same time, $\varphi = \frac{a-bc-bd}{bc} - \frac{2f_m+B}{bc^2}$, as B decreases, φ becomes larger, and due to $R \geq \varphi$, it can be concluded that the smaller the advance payment amount, the less likely it is to choose not to pay the advance payment.

At the same time, equation (5-11) is simplified and the data shows that when the risk-free return rate R does not exceed 0.775, equation (5-11) is established. However, based on the analysis above, the risk-free return rate R that F company can obtain is far less than 0.775. Therefore, it can be inferred that F company will definitely choose to pay advance payment to obtain greater profits.

5.3 Summary of this chapter

This chapter provides detailed model design and quantitative analysis for pricing and revenue decisions under two modes: no funding constraints and with funding constraints but no financing. Through the model calculation in this chapter, the decision-making problem in the building supply chain based on X residential community can be solved as follows.

Under the condition of sufficient funds in Company D, the completion area and pricing for maximizing profits for both Company F and Company D are determined, and the maximum profits for both Company F and Company D are obtained. The threshold for sufficient funds in Company D is defined; On this basis, a comparative analysis is conducted between joint decision-making and independent decision-making, proposing feasible regions for maximizing profits in joint decision-making and corresponding management insights; When D company has a funding gap lower than the prepayment amount that F can provide, explore the completion area and pricing for F company and D company to achieve maximum profit simultaneously. Through comparative analysis, provide F company with a quantitative decision-making basis for whether to provide prepayment.

CONCLUSION

With the development of market economy, the scale of the construction industry is gradually tending towards a stable development trend, and the issue of engineering funds is still the focus of attention for construction enterprises. Innovative management thinking is one of the effective and important ways. More and more researchers are introducing advanced manufacturing supply chain management into engineering management, striving to take engineering management to a new level. This article innovatively proposes the definition of building supply chain based on supply chain thinking and engineering management theory through the example of X residential community engineering. After clarifying the characteristics of engineering project management, different models of building supply chain are constructed, and targeted building supply chain is established. Based on its application of game theory, comparative analysis, and other methods, the model is constructed and calculated. Pricing and financing strategies are studied, and management insights and suggestions are proposed according to the actual situation. The main conclusions are as follows:

(1) Defined the connotation of the construction supply chain and established a model framework for the construction supply chain. This article compares and analyzes the ideas of supply chain and engineering management, and believes that the construction supply chain is a complex network formed by the various parties

involved in the construction project through cooperative games, interest coordination, and other interactive relationships in the dynamic network environment of the entire life cycle of the construction project. Subsequently, based on different stages of project management, establish a construction supply chain framework under three modes: parallel contracting mode, construction general contracting, and EPC general contracting, distinguishing different organizational forms of project management.

(2) The parameters of the building supply chain model were characterized based on the actual engineering situation. Due to the basic lack of quantitative analysis research on the construction supply chain, based on the theoretical research foundation mentioned above, this article constructs a corresponding construction supply chain model for the characteristics and background of the X residential community project in this article, innovatively characterizes parameters such as product pricing, cost, and product volume of the construction supply chain, and organizes actual engineering data as parameters for assignment. This lays the foundation for the following research and also provides reference for the quantitative analysis of construction supply chain management.

(3) Construct a decision model for the construction supply chain of X residential community engineering and obtain decision recommendations: F company should provide advance payment and choose supply chain financing. The supply chain of X residential community engineering project should adopt a joint decision-making supply chain internal financing model to achieve maximum benefits.

(4) In the research process of this article, it was found that the interest rate of funds provided by one party to the other for financing services during internal supply chain financing does not have an impact on the total revenue of the supply chain, but only serves as a tool for distributing benefits between both parties in the supply chain. Further research has found that the relative advantages of financing within and outside the supply chain will vary with changes in capital usage costs, self owned funds, etc. Firstly, the risk-free return rate in the market will have an impact on the decision-making tendency of Company F in supply chain financing, but as long as the cost of using funds for Company F is lower than the cost of funds required for banks to provide financing, internal financing in the supply chain will enable it to obtain more

profits. Secondly, D company's more self owned funds will enable it to obtain more profits in any mode, while making the advantages of external financing models very obvious. At the same time, if F company adopts internal supply chain financing, its profits will decrease, and it can only obtain more profits through joint decision-making. Finally, in any situation, the performance of independent decision-making is only 75% of that of joint decision-making, and there must be a distribution form in the joint decision-making model that allows both the construction investor and the construction contractor to obtain excess profits from independent decision-making. This indicates that adopting joint decision-making can maxiize supply chain efficiency and achieve true cooperation and win-win.

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