Contract Management for International EPC Projects

A Major Qualifying Project Report:

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By

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Abstract

The Second Construction Company of Sinopec (SCCS) is one of the largest construction companies in China and handles many construction projects in Saudi Arabia. The company was actively seeking various ways to analyze, characterize, and avoid contract risks in their global business. Through on-site visits, interviews, surveys, and extensive data collection, we in this project helped establish a contract management system that consists of an improved contract management process, tools for risk management, and a step-by-step performance evaluation procedure.

Acknowledgements

There were many people who aided us in the completion of this project. First we'd like to thank Southeast University for accommodating us during our stay in China. We would also like to thank all of the SCCS for their help with our project. It was truly great to have a CEO and top project managers come to meet with us and take time out of their day to help us with our project. Last but certainly not least we would like to thank our advisors Amy Zeng and Yaming Zhuang because without them this project would not have been possible.

Authorship Page

Kyle Costa and Cristian Pimentel of Worcester Polytechnic Institute, and Huadong Gan, Yanjing Gu, and Pinwu Dai of Southeast University - China participated in WPI's China Project Center and worked together as one team on this project during the summer of 2009. The literature review was equally written between the five group members. Kyle Costa wrote the Abstract and Executive Summary. Cristian Pimentel wrote the methodology section. Kyle Costa and Cristian Pimentel wrote the introduction and the company profile. Kyle Costa and Pinwu Dai wrote the findings section for the international EPC project process. Yanjing Gu and Pinwu Dai wrote the section in findings for contract risk analysis. Huadong Gan and Cristian Pimentel wrote the findings section for contract management. The recommendations section was written by all of the group members. Huadong Gan and Kyle Costa wrote the conclusion. Yanjing Gu put the appendix section of our paper together. Huadong Gan was the main translator from Chinese to English. Kyle Costa and Cristian Pimentel edited the paper for proper English and formatting.

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Executive Summary

The Second Construction Company of Sinopec (SCCS) is seeking methods to analyze, characterize, and avoid contract risk in global construction projects. After communicating with the SCCS about their specific needs, this project was formulated with a goal of establishing a contract management system that optimizes the contract management process, develops strategies for risk management, and establishes a performance evaluation system for the company.

To accomplish this goal we interviewed company personnel and we analyzed our gathered data. In order to fully optimize contract risk management, we researched the four international delivery systems, contract management processes and systems, risks involving contracts, and performance evaluation methods.

This project is based off of a case study on the Polyolefin project the company has been working on in Saudi Arabia. The responsibilities of the SCCS were construction and construction management, building materials procurement, anti-corrosion/insulation materials procurement, holstering transport, provide temporary offices, storage materials, and other necessary equipment.

After finding and analyzing the risks in construction projects we created a contract management system. This system consists of six parts; law system, organization, contract management process, contract controlling process, contract risk management, and performance evaluation.

A problem the SCCS faces is that when an accident happens it is difficult to find who should answer for it. By setting up a contract management system the company will be able to hold people responsible when an accident happens because each department will be working closely with the contract management department. In order for the contract management system to be fully effective the company will need a very thorough information flow system. All of the departments in the organization need to be in close communication with the contract department. During the establishment phase of the contract these departments should work with the contract engineer on what their specific needs are, to ensure that there is not anything left out. This will also make the implementation phase of the contract more efficient.

Finally, a performance evaluation was set up based on Fuzzy-AHP (Analytical Hierarchy Process). It is an effective method to deal with multi-objective, multi-criteria, multi-factor, and multi-level comprehensive evaluations. This method combines qualitative and quantitative methods.

After establishing a contract management system, an information flow, and a performance evaluation we created a contract management process. Our process consists of three phases. The first phase is the establishment phase of the contract. The second phase is the implementation of the contract. The third phase is the termination of the contract.

1 Introduction

The Second Construction Company (SCC) of Sinopec has done several Global Construction Projects one of which is most representative is the Sinopec-Saudi polyolefin project, which is located in Yenbo, Saudi Arabia. The project is an EPC (Engineering – procurement – construction) project The Sinopec-Saudi polyolefin project has a variety of risks, and they have been divided into project tender risk and implementation risk. Project tender risk includes the risks of pre-tender risk, and the risks at the tender offer phase, while project implementation risk includes engineering, procurement, and construction risk. Quality risk, cost risk, security risk, etc all belong to the construction risk.

We have been allotted seven weeks to work on this project, and during this period we are going to review their project, while trying to develop qualitative and quantitative methods to assess and control the project risk. We will be making regular visits to the company to conduct research. With the information gathered, we will begin to formulate means of measuring risk. By the end of our project, we aim to have completed a review of their project, along with methods that help measure and control the projects risks.

1.1 Project Background

We have been allotted seven weeks to work on this project, and during this period we are going to review their project, while trying to develop qualitative and quantitative methods to assess and control the project risk. We will be making regular visits to the company to conduct research. With the information gathered, we will begin to formulate means of

measuring risk. By the end of our project, we aim to have completed a review of their project, along with methods that help measure and control the projects risks.

In order to accomplish our goal, we interviewed company personnel and analyzed the data that was gathered. The company personnel that we interviewed were top managers who were directly involved with the Saudi Arabia project, we were not able to interview the labor force because they were unable to be contacted. In order to fully optimize contract risk management, we also researched the four international delivery systems, which consist of contract management processes and systems, risks involving contracts, and performance evaluation methods.

With the completion of this project we were able to analyze the contracts life cycle along with determining the main elements of risk that should be taken into account during each specific phase. The individual risks were analyzed in greater detail to provide a more comprehensive evaluation. After the life cycle was analyzed we proceeded to analyze the SCCS's legal department. Seeing as how the Saudi polyolefin project was their first international project, they had no experience and little knowledge of international contracts and laws. This led them to hire other consulting firms to handle this work for them. Through our analysis of their legal department, we decided on two recommendations that we determined to be plausible. The first recommendation consists of recruiting or training law personnel who specialize in international regulations and laws. Once the law personnel are acquired the next recommendation we opted to have was to create a legal department focused on international projects.

Lastly, a performance evaluation was established based on the Fuzzy-AHP (Analytical Hierarchy Process), which helped combine various criteria to help evaluate individual workers performance. This method allows the combination of qualitative and quantitative methods to help analyze the worker's performance.

1.2 Company Profile

The company has 2,082 management personnel with 505 administration staffers, 685 engineers, and 892 project management staffers. They also have 2,808 skilled workers including 589 welders with each kind of welding certificate. Below is an organizational chart of the SCC from top to bottom.

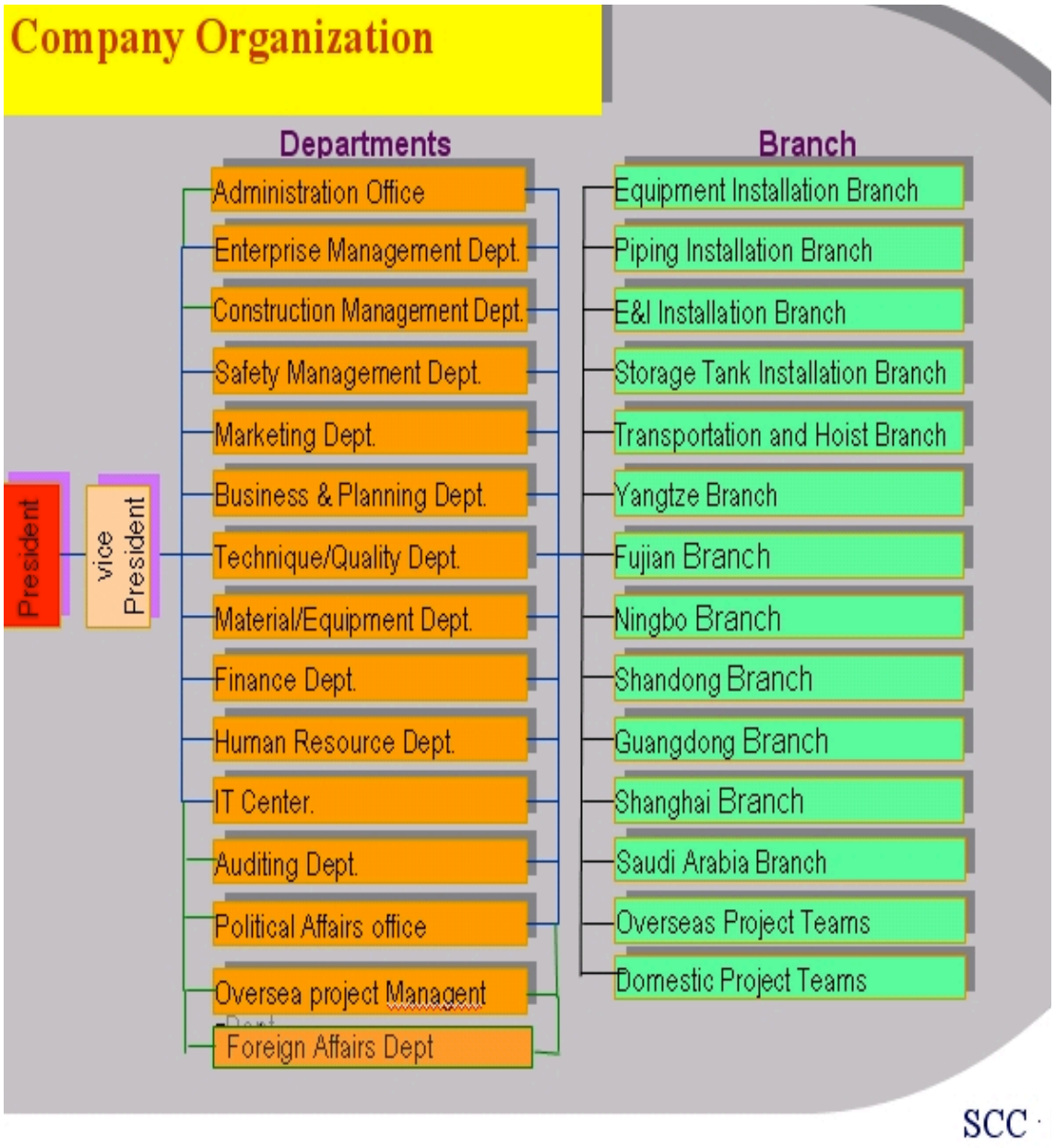


Fig. 1-1 Company Organization

The figure below displays all the fields the SCCS covers and the many different disciplines they maintain.

Fields	**Disciplines**
Chemical	Civil
Refinery	Architecture
Chemical Fiber	Steel Structure
Pharmacy	Erection
Industry Building	Heavy Lifting & Transportation
Municipal Facility	Equipment Manufacturing
	Piping
	Electrical & Instrument
	Painting
	Insulation
	Refractory

Fig. 1-2 Fields & Disciplines

Equipment Engineering

This branch is the main professional branch of SCC. The main work is the installation of steel structure, equipment and all kinds of furnaces. They have an expertise in the

installation and alignment of large assembling equipment, site assembly, and installation of non-standard equipments. They offer very well trained construction workers to projects who manage working efficiency, quality, safety, housekeeping, and services very well.

Piping Engineering

This branch deals with pipe the construction, and has equipment for automatic welding product-line of prefabrication and long distance pipe construction. They have skilled welding technology for special materials, especially that of titanium, allow of aluminum and magnesium, and duplex stainless steel. There main business is long distance pipe and plant process pipe. They have very skilled workers and great equipment. They also offer very well trained construction workers to projects who manage working efficiency, quality, safety, housekeeping, and services very well.

Storage Tank Engineering

This branch has the capability of constructing sphere tanks over 5000m3 wide and 150,000 m3 high. They also have the capability of constructing cryogenic ethylene storage units over 20,000 m3. This branch won the Luban Award in 1998 and the National High Quality Award in 2001.

Electrical and Instrumental Engineering

This branch has the capability of installing and calibrating a 110 kV, kilovolts, substation project. This branch can also install and calibrate DCS, ESD, and PLC instrument systems. They have an auto test center, which includes an electrical and instrument testing room.

The businesses are electrical and instrumental testing for petroleum, petrochemical, architecture and large generations of electricity.

Transportation & Hoisting Engineering

This branch provides well trained workers along with top of the line equipment. They can lift single pieces up to 1,000 tons. They also have single piece delivery up to 700 tons.

Yangzi, Fujian, and Ningbo

The SCC has standing branches in the three petrochemical bases and the main works are project undertaking, construction management, routine repair, and heavy repair.

Subsidiary Companies

The four subsidiary companies are Nanjing Yuchuang Petrochemical Engineering corp., Nanjing Jinling Non-Destructive testing corp., Shandong Shengyue petrochemical engineering Co. ltd, and Nanjing Bohua Engineering corp. These subsidiary companies have the undertake installation, equipment, NDE, and architecture.

2 Literature Review

2.1 Project Delivery Systems

According to ASCE (American Society of Civil Engineers), Project Delivery Systems describe how the project participants are organized to interact, transforming the owner's goals and objectives into finished facilities.

An international construction project has its own character with the global background.

(a) The multinational main body of an international construction project contract.

An n international construction project needs different teams from different countries to take part in. these determine the whole project will be restricted by various laws and provisions from different countries, which will lead to great dispute.

(b) Various impact factors and increasing risks.

Be impacted by politics and economic reasons more and more seriously. So as an international project, the holder not only has to focus on the project itself, but also pay attention to the host country and countries nearby, together with the global situation.

(c) Follow stricter international contract items.

An international construction project follows the international practice and criterion, which is much stricter. In order to carry it smoothly, the project holder should pay much more attention to quality and behavior of the staff as well.

In the field of international construction projects, the project delivery system is divided into the following four basic types:

(1) Design-Bid-Build (DBB)

(2) Management-Contracting-Approach (MCA)

(3) Engineering-Procurement-Construction (EPC)

(4) Build-Operate-Transfer (BOT)

(1) Design- Bid- Build is a Traditional Approach.

This system has long been used in the West, and it has been developed well. So it was called Traditional Approach. Meanwhile the project is divided into small individual parts for construction, so it was called Fragmented Approach as well.

Fig.2-1 is the general schematic diagram of the relationship between the parties.

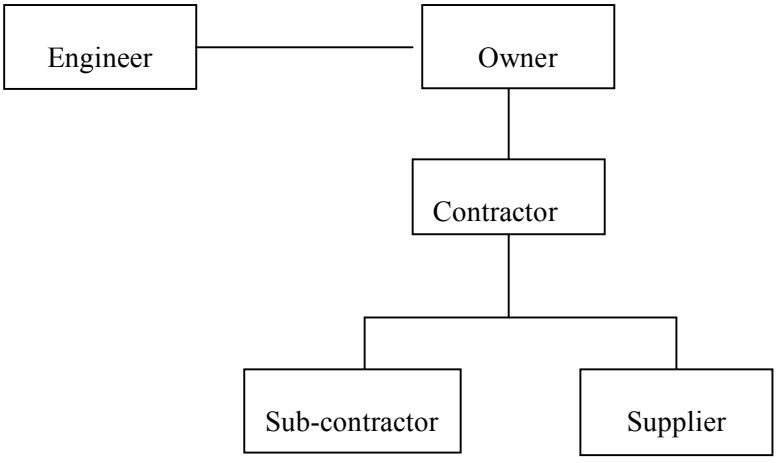


Fig. 2-1 Traditional Approach

The most outstanding character of DBB is that the procedure of the project construction has to follow the order of Design- Bid- Build. Only when the former one has finished, the later one can start.

Advantages of DBB:

The owner, contractor, and engineer are clearly assigned their own responsibilities and tasks.

Disadvantages of DBB:

The procedure is linear and the lifetime is too long. Also the corresponding between the constructors, engineers, and contractors is difficult. Finally, the pre-investment finance can be very high.

(2) Management Contracting Approach (MCA)

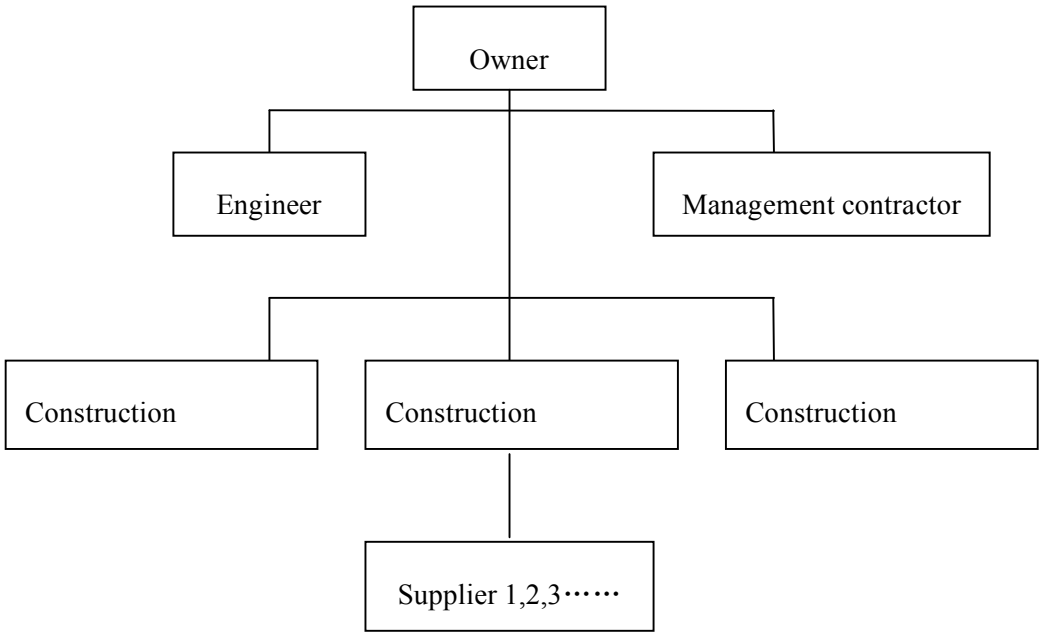


Fig.2-2 Management Contracting Approach

The management contractors are not in charge of the construction, they just have to manage the organization (See fig.2-2). The owner chooses this system because:

(a)The project is very large scale.

(b)The organization is complex. There are many tasks between different contractors to coordinate.

(c)The owner doesn't have the ability to manage the project organization.

Advantages of MCA:

(a) The contractor serves the whole organization as a team, which creates largest benefit for the owner.

(b) It's easy to alter the management organization to adapt to the project.

(c) This system has a great information flow between engineering and management.

Disadvantages of MCA:

(a)MCA doesn't have enough laws to guarantee the project will go on wheels.

(b) The owner chooses a management contractor means the owner has one more department to manage, which leads to an increase in overhead expenses.

(c) The different opinions between management contractor and engineering department will affect the coordination of the project.

(3) Engineering – Procurement – Construction (EPC)

EPC is the abbreviation for Engineering Procurement Construction. EPC is one of the global construction contracting models, and it is also known as the turnkey project service. It is a type of contract typical of industrial plant construction sector, comprising the provision of engineering services, procurement of materials and construction. The term “turnkey” indicates that the system is delivered to the client ready for operations. The outstanding feature of the EPC is that the ultimate price and time of the project have a great degree of certainty. The project is largely Contractor managed and the cost risk and control are weighted towards the Contractor and away from the Owner. Fig.2-3. shows the basic EPC mode.

In this project delivery system, the EPC contractor holds all of the responsibility. It includes the provision of engineering services, procurement of materials and construction.

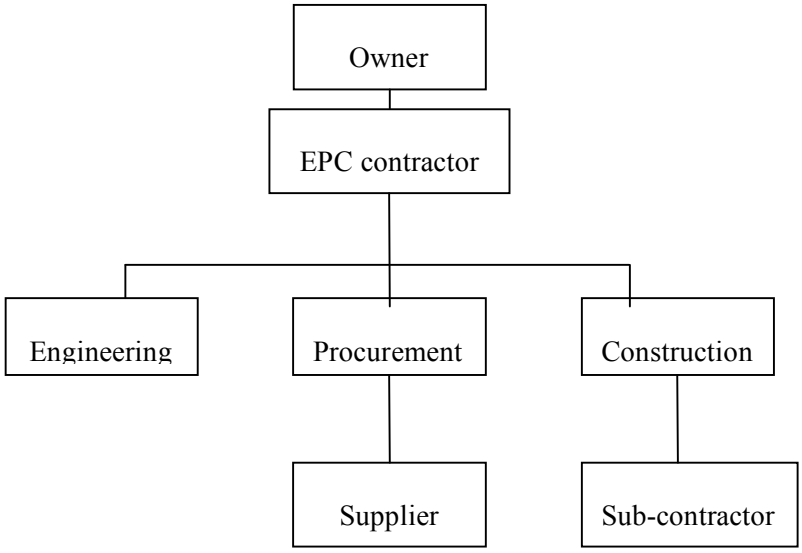


Fig.2-3 Engineering – Procurement – Construction

Advantages of EPC:

(a) Responsibility is divided clearly,

(b) The whole schedule can be cut down.

(c) Less stress because there are various managers.

(d) The owner knows the whole prices of the project.

Disadvantages of EPC:

(a)Because bidding happens before the engineering is complete, it is difficult for the owner to identify what the work exactly is.

(b)The owner's ability to control the project is low.

(c)The pre-tender stage cost can be very large.

(d)The tasks across E, P, and C call for more management skills.

(e)The EPC contractor holds greater responsibility so it is pivotal to have someone who has the right qualifications for the job.

(4) Build – Operate – Transfer (BOT)

If the government doesn't have enough money for the construction of the project, they will try to attain investors from home and abroad to help with the project. The government, as a concession grantor, gives the concession to a private project company. During the

concession period the company has to operate the project, then turn it back to the government.

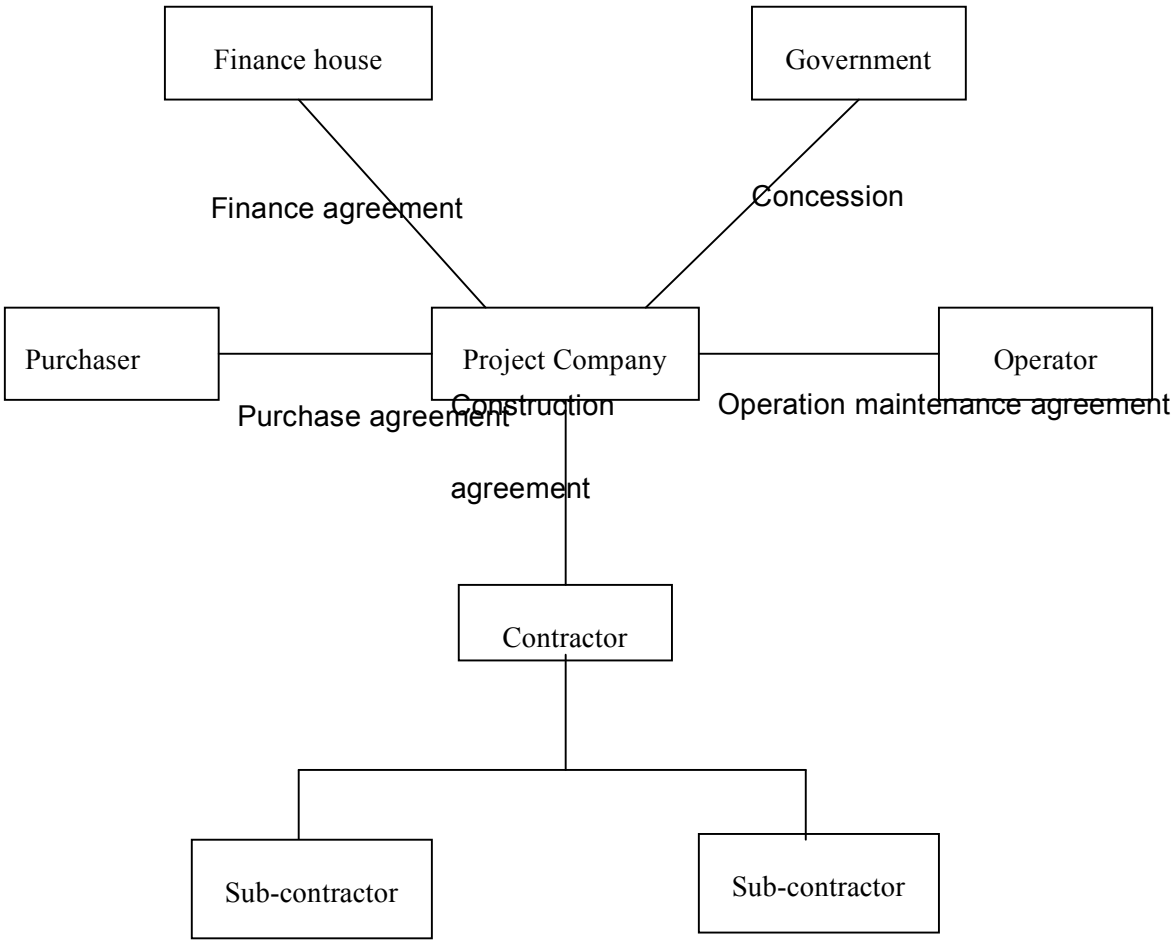


Fig.2-4 Build – Operate – Transfer

Advantages of BOT:

(a) The government is released from financial burden.

(b) The government can avoid large numbers of project risks. The investors share most of the risks.

(c) A BOT project is always operated by a foreign project team, which will input modern technology and management skills.

Disadvantages of BOT:

(a) The public department and private department will need a long time to adjust to each other. They need to research, communicate, exam, etc. These activities will increase the prophase finance.

(b) During the concession period, the government will lose the right to control the project.

The four basic project delivery systems are not independent but have close relationship with each other, even some of they can be employed at the same time. The only difference is the emphasis of the project organization and contract relationship. These project delivery system classifications help us to gain a good perspective of the rules involved in the project construction, and allow us to find ways to complete the project with high efficiency.

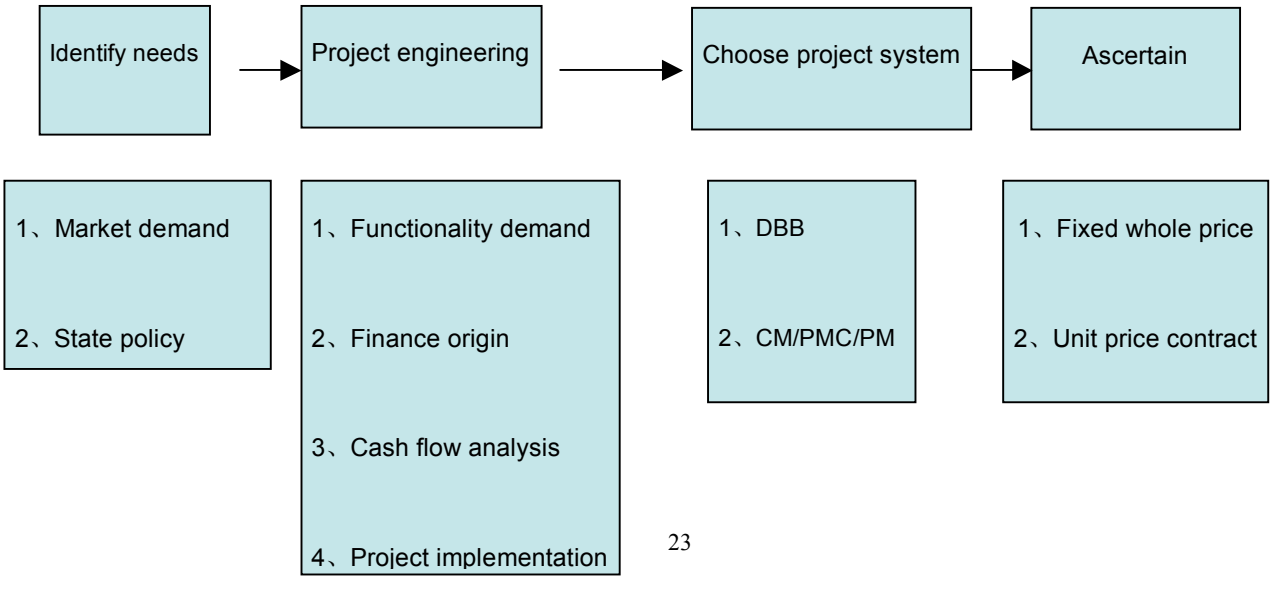


Fig.2-5 The procedure of project system engineering

2.2 Project contract life cycle

For construction contracts, from the contract formation to the contracts end; it usually takes a long period of time, sometimes even years, and it has many processes. Contract management must be carried out throughout the entire life period, and in different stages, contract management has different tasks and priorities. To common open tender projects, the construction contract usually goes through two main phases: the establishment of the contract and the implementation phase of the contract (See fig.2-6). The establishment of the contract phase has two processes. These processes are bidding and contract negotiations. The implementation phase of the contract also has two phases. These processes are the construction and the maintenance.

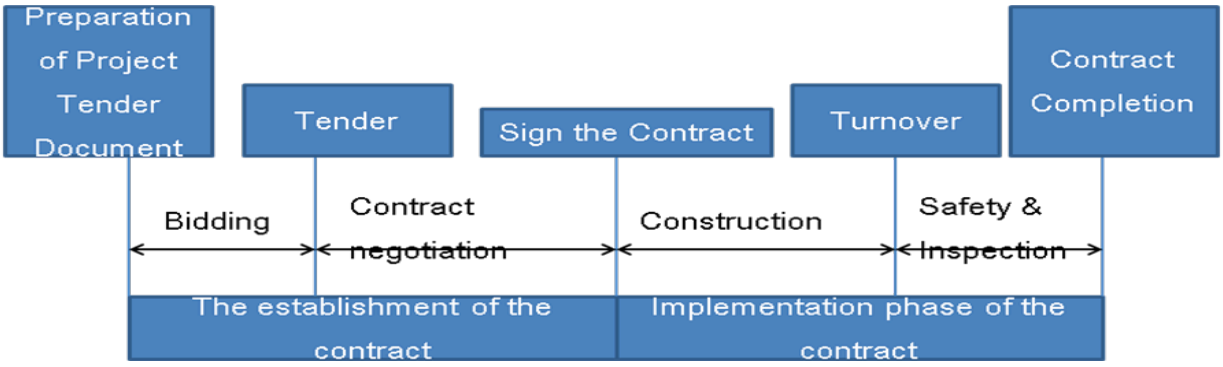


Fig.2-6 Life cycle of the contract

The establishment of the contract

(1) Bidding period

The bidding period is from the preparation of bidding documents to bid opening. It is the initial offer and acceptance between the owners and the contractors, meaning it is the initial period of construction contract.

(2) Contract negotiations

This period begins when a tender is made and ends when the contract is signed. This period can be divided into two stages:

(a) The initial evaluation of different tenders including declaring the unqualified tenders. Then do a comparative analysis among the contractors who offer reasonable prices and have the ability to construct the project. Finally choose the contractors.

(b) The owners and the contractors discuss the future of the contract and how they are going to go about completing it. Finally, the two sides sign the contractors.

The implementation phase of the contract

This period is from signing the contract to the contract end. In this period, engineering work, procurement work and construction work need to be finished. Contractors must complete the construction work and take responsibility of the warranty work based on the quantity, quality, schedule and technique requirements written in the contract. Of course, at the same time, contractors can receive the economic benefits according to the contract.

The purpose of this paper is to discuss the contract management of international EPC projects, and we mainly focus on the implementation phase of the contract, which can be divided into engineering (E), procurement (P), and construction (C) based on the process of EPC construction project. In the next part (2.3), contract management in the implementation phase of the contract will be discussed in detail.

2.3 Risk and Risk Management

Risk management has been widely applied in various fields such as economics, insurance, industries, and so on. While the word "risk" means that uncertainty can be expressed through probability, risk management is a structured process for the management of uncertainty through risk assessment. Project risk is based on a simple equation:

Risk = (Probability of Event) (Consequences of Event).

In other words, all risks must be evaluated in terms of two distinct elements: the likelihood that the event is going to occur as well as the consequences, or effect, of its occurrence.

Risk and opportunity are mirror opposites of each other. Opportunity emerges from favorable project circumstances and risk emerges from unfavorable events.

Systematic risk management comprises of four distinct steps:

1) Risk identification – the process of determining the specific risk factors that can reasonably be expected to affect the project.

2) Analysis of probability and consequences – the potential impact of these risk factors, determined by how likely they are to occur and the effect they would have on the project if they did occur.

3) Risk mitigation strategies – steps taken to minimize the potential impact of those risk factors deemed sufficiently threatening to the project.

4) Control and documentation – creating a knowledge base for future projects based on lessons learned.

Project risk management is comprised of these four steps, and the feedback of the system is used to regulate the risk management performance (See Fig.2-7.).

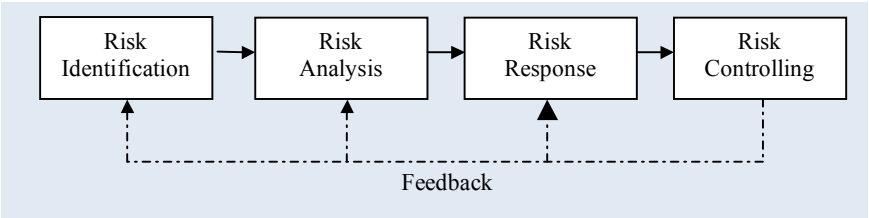


Fig.2-7. Risk Management process

2.4 Risk management methods

The theoretical study of global construction project risk is accompanied by the formation and development of the global construction project market. As early as during the Second World War, risk analysis techniques were being applied in the field of systems engineering and operations research. And risk analysis techniques for construction project management began in the 1950's. Along with the post-war reconstruction in Western societies,

especially in the economic recovery of Western Europe, a large number of large-scale space, utilities, energy and transportation construction projects were built in Europe. The huge investment made the project managers pay more and more attention to cost management, and the complex project environment made the project face a lot of uncertainty. How to identify and assess the uncertainty on the impact of project cost became a major problem of managers. Scholars have developed a variety of project risk assessment techniques, such as PERT (Program Evaluation and Review Technique), Sensitivity analysis methods, Simulation technology, etc. In the early study, we only used mathematical statistics and probability to describe and evaluate one-dimensional elements of the project objectives, such as time and cost effect. With the development of new evaluation methods, the global construction project's risk management becomes integrated, network-based, and multi-dimensional.

Project risk management methods are mainly qualitative or quantitative. Examples of qualitative risk analysis methods are risk checklists, project life cycles', decision trees, the intrinsic link table (WBS-RBS and RBS-CL), rating grids, etc. There are also three basic quantitative risk analysis methods: probability theory, multi-attribute preference theory, and fuzzy logic. Project risk management is comprised of four steps: identification, analysis, response and controlling. And the feedback of the system is used to regulate the risk management performance so the project's risk management is an active and dynamic way to manage the risk effectively.

Miller and Lessard have argued why large engineering projects should be carefully managed given that they are "high stakes games" characterized by substantial irreversible

commitments, skewed reward structures in case of success, and high probabilities of failure. Chun-Hui Wu et al. explored the relationship between project risk and project performance. Their analysis confirmed that project risk had a significantly negative impact on project performance.

Miller and Lessard dissected the risk into categories such as (1) market-related: demand, financial and supply; (2) completion: technical, construction and operational; (3) institutional: regulatory, social acceptability and sovereign [1]. Edwards and Bowen categorized risks into natural and human. S. Ebrahimnejad et al. made a detail RBS (See Fig2-8.). The proposed risk structure shows the risk groups, risk categories, and risk events at the lowest level. Project risks are divided into five groups, Management, Engineering, Procurement, Construction, and Commissioning.

WBS – Level 0	WBS – Level 0	The initial Risks		
Management	-	1- Project management disabilities	2- Lack of attention to law and regulations	3- Economical inflation
		4- Fluctuating currencies exchange rate	5- Increase in international crude oil price	6- Lack of attention to contract requirements
		7- Communication matters between consortium members	8- Weak clientele	9- Delay in paying and receiving project's invoices
Engineering	Basic Design	1- Inaccessibility to foreign design consultants	2- Design failures	3- Change in project specifications
	Detail Design	4- Failure in transmitting data from basic design to detail design	5- Lack of expert human resources	6- Lack of design quality

Procurement	Equipment and Bulk Material	1- International relations	2- Ambiguity in project cash injection	3- Inappropriate vendor list
	Long Lead Items Spare Parts	4- Incorrect long lead item time schedule	5- Imperfect data transmission to vendors	6- Lack of experience in inspection and forwarding
Construction	Site Preparation	1- Soil and site bed problems	2- Unsuitable weather conditions	3- Heavy lifting matters
	Camp Construction	4- HSE matters	5- Workers riots	6- Lack of communication between central office and site office
	Site Establishment	7- Change in construction scope of work	8- Lack of experienced workers	9- Contagious diseases
	Plant Construction	10- Subcontractor interferences 12- Delay in equipment delivery to site	11- Delay in paying subcontractors invoices	12- Deficiency in QA/QC inspections and audits
Commissioning	Pre-commissioning Commissioning	1- Non-consideration of pre-commissioning requirements	2- Lack of pre-commissioning materials quality	3- Non-consideration to commissioning procedures

Fig.2-8. Risk Breakdown Structure

In Liu Renhui and Zhai Fengyong's study, they constructed a risk management systematic framework, which includes five purchases: risk identification, risk assessment, risk analysis, risk handling, and risk monitoring. Then the input-output model of the risk management system has been based on the theory of identification model.

Robert. J. Chapman et al. examined the steps involved in conducting the identification and assessment process and how they may influence the effectiveness of risk analysis. It is commonly recognized that the risk identification and risk assessment sub stages for the overall process of the project risk analysis and management have the largest impact on the accuracy of any construction risk assessment.

V. Carr et al. used a hierarchical risk breakdown structure (RBS) as a model for qualitative risk assessment. Risk descriptions and their consequence can be defined using descriptive linguistic variables. Using fuzzy approximation and composition, the relationships between risk sources and the consequences on project performance measures can be identified and quantified consistently.

S. Ebrahimnejad et al. identified the significant risks in construction industry projects and introduced some effective criteria and attributes used for risk evaluation in the construction industry. Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and fuzzy LINMAP (Linear Programming Technique for Multidimensional Analysis of Preference) methods are presented to evaluate the high risks in the projects. They compare the modeling mechanisms of the two methods and their performances in modeling a set of project risk data.

Anli Sun and Cunbin Li proposed a new method on project risk evaluation based on the Markov Process. According to “non-aftereffect” of the Markov Process, a state transmission probability matrix is built to analyze and predict the future development state of the project. They also provide a quantitatively feasible method to analyze the project risk.

Trond E. Olsen et al. illustrated how to take the risk management of complex procurement projects in construction. They address the case of contract design and risk sharing in Norwegian offshore development projects to illustrate the implication of endogenous risk in construction. At the end, they gave a risk-sharing model. The findings

of the study revealed that there were two ways that can reduce the risk faced by the contractor: (a) by project design, and (b) by contract design.

Van Truong Luu et al. quantified schedule risk in construction projects using Bayesian belief networks. Delays on construction projects can cause great financial losses for project stakeholders. The findings of the study revealed financial difficulties of owners and contractors, contractor's inadequate experience, and shortage of materials are the main causes of delay in construction projects in Vietnam.

In Hsiaofan Wang and Feichen Hsu's study, they used the cumulative prospect theory to propose the individual risk management process (IRM), which includes risk analysis and risk response stages. The individual's risk level for the confronted risk can be identified from the risk analysis, while the response strategies can be assessed at the risk response stage. The proposed method provided is more useful and produces more pertinent information than the traditional method of the decision tree by using the expected monetary value (EMV).

Jiahao Zeng et al. presented fuzzy reasoning techniques to cope with risks in complicated construction situations. The application of fuzzy reasoning techniques provided an effective tool to handle the uncertainties and subjectivities arising in the construction process. A modified analytical hierarchy process is used to structure and prioritize diverse risk factors. By using the proposed methodology the risks associated with steel erection can be assessed effectively and efficiently.

Florence Yean and Linda Hoi take the risks faced by Singapore firms when undertaking construction projects in India as an example. The main risks include political and social risks,

high cost of financing, fluctuating currency exchange rates, and huge cultural difference between foreigners and Indians. The risk response techniques include having adequate insurances and careful planning and management.

Terry Lyons, and Martin Skitmore took a survey of the Queensland engineering construction industry. They found that risk identification and risk assessment are the most often used risk management elements ahead of risk response and risk documentation. Brainstorming is the most commonly used risk identification method. Qualitative methods of risk assessment are also frequently used. Risk reduction is the most frequently used risk response method, with the use of contingencies and contractual transfer preferred over insurance. Project teams are the most frequently used group for risk analysis, ahead of in-house specialists and consultants.

3 Methodology

This project was directed toward helping the Second Construction Company of Sinopec (SCCS) improve the way they manage contract risks in global construction projects through the use of management tools that help analyze, characterize, and manage contract risks. We interviewed company personnel and obtained a case study. With the analysis of this data we were able to formulate a strategic plan that will aid the Second Construction Company of Sinopec with the future improvement of their contract risk management.

The following Methodology section explains in greater detail how we accomplished these tasks through three objectives that built off each other. Each objective described below is introduced, and then followed by the hybrid (qualitative and/or quantitative) data that will be needed in order to accomplish the specific goal. This section explains how the necessary data was gathered.

Interview Related Company Personnel

In order to collect input from the users and the administrators, interviews and surveys had to be conducted. Seeing as it is impossible to interview Saudi Arabian workers, any interviews or direct inquiries we conducted were directed towards our contacts in the Second Construction Company of Sinopec. The information gathered from these managers was useful because it allowed us to understand a plethora more about what they felt were the most important underlying contract risks along with greater detail of each specific risk.

Along with the interviews that were conducted we also distributed a questionnaire that posed questions on six different topics: organizational structure risks, human resource risks,

contract management risks, contract process risks, contract management system risks, standard document risks. The purpose of this survey was to measure, on a scale of 0-9, what they believed the level of importance was of each specific category, along with what they believe is the current level of importance. This survey allowed us to gather qualitative data along with a quantitative measure of the importance of each topic asked in the questionnaire.

In addition to the interviews and questionnaire, we were also able to obtain a case study from the Saudi Arabia project. This was important to us because through this we were able to analyze the project, which helped identify risks through the actual project instead of just speculating about possible risks that can occur.

Analysis of Gathered Data

In order to successfully compile a list of recommendations to the Second Construction Company of Sinopec it was necessary for us to analyze a specific project and characterize the contract risks. With the acquired Saudi Arabia project we were able to do just that.

To begin our analysis we decided to separate the Saudi Arabia contract management into three sections that include the international EPC project process, Contract risk analysis, and contract management. We created a tri- axis structure that visually displays this. The information required in order to complete the EPC project process can be obtained through the company's methods of execution along with researching scholarly articles. For the contract risk analysis we have to gather information about all of the potential risks that exist within the contract process, both in the establishment phase and the implementation phase of the contract life cycle. This was done through the use of scholarly articles for general inquiries. These articles help us paint a general picture for what contract risk analysis process

is like, and we modified them to make it focus on our topic. In addition to that, we have contract management. For contract management we decided that we had gather information on six different aspects of contract management, which include financial management, HSE management, procurement management, quality management, human resource management, and schedule management. Through our research and company interviews we were able to determine that these six topics are crucial in the contract management process.

Developed Contract Management System

By the end of this objective, a system was developed that helped to make the Second Construction Company of Sinopec's (SCCS) contract management system easier which incorporated various methods that we determined would be of most use to the company, along with what we believed was feasible in incorporating. This part was crucial to our work because it is where we actually developed a plan for the company.

In order to begin laying out the necessary recommendations we had to first determine which aspects of the contract system needed changes were advantageous or desired. This information came from the results of our questionnaire along with the use of our researched information and the manager's feedback. This data was collected and critically examined in order to determine what to consider during the creation process. When it came to the creation of the contract management system is was important to adhere to the company's desires and limitations in order for the contract management system to be implemented.

4 Findings-Contract Management Process Analysis

Our aim of this part is to review the international EPC project process, to identify the risks during the contract implementation phase, and to discuss the methods used in contract management.

Contract management is a complex and dynamic system. We built a three-dimensional structure to analyze it (See fig.4-1).

(1) International EPC project process

According to the characteristics of the EPC project delivery system, it includes three parts: engineering management, procurement management and construction management.

For all the three parts, we explain the process in different ways. One is about the contract provisions of engineering, procurement and construction. The other is about the specific strategies the constructors use in the management work. Also some information about the real SABIC project is given and discussed.

(2) Contract risks analysis

During this part, we provide a brief overview about risks, which mainly focus on the project risk definition and risk categories. Then the risk analysis of the SABIC project is given. And the risks are divided into risks in the establishment phase of the contract and implementation phase of the contract based on the contract life cycle. Lots of specific and vivid cases are applied to make the risks clearer in this part.

(3) Contract management

The international EPC project contract management is completed by these six parts: finance management, HSE management, quality management, schedule management, human resource management, and procurement management. Professional knowledge is also very important. There is also some detail about the SABIC case in this part.

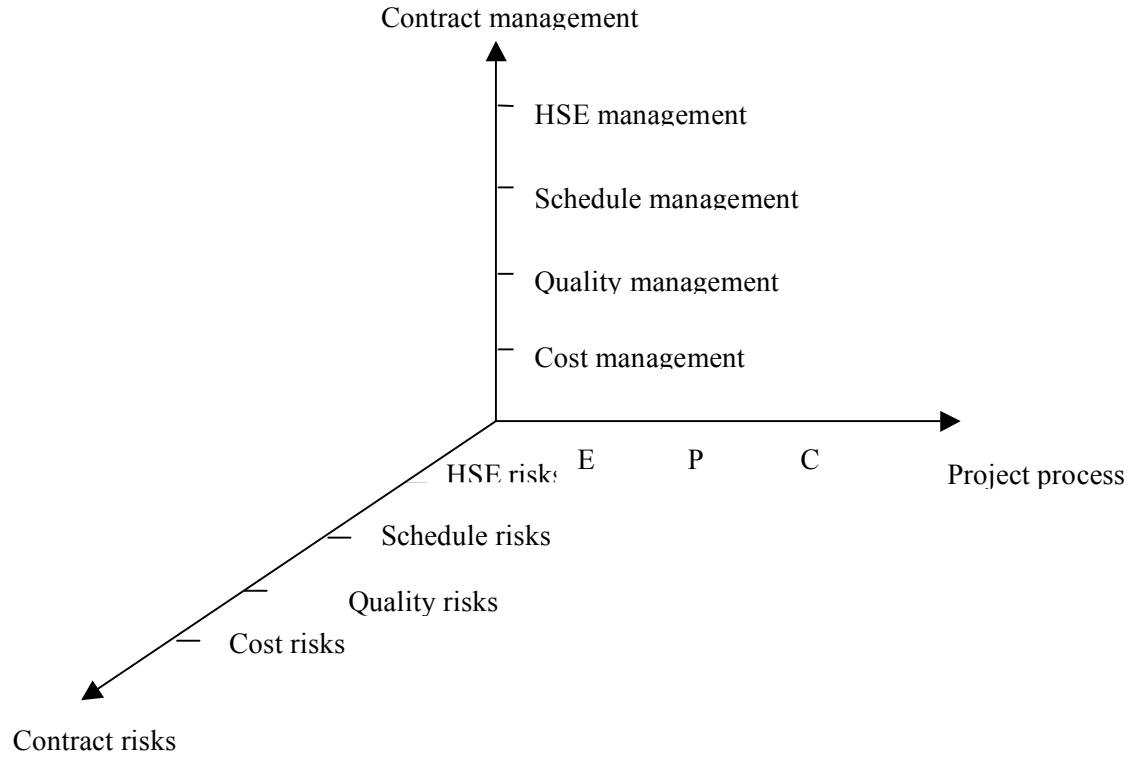


Fig.4-1 EPC construction contract management structure

4.1 International EPC project process

4.1.1 Engineering management

1. Brief introduction of engineering management

Engineering of construction projects is consists of many things. First, one needs to make an all-around and detail arrangement for technique, economy, resource, environment etc, which is needed to construct the project. It also needs integrated activity, which includes analysis, demonstration and compiling design paper.

According to the size and complexity of the construction project, engineering is divided into two or three stages of engineering. To the civil construction projects, engineering is divided into Preliminary Design and Working Drawing Design. For the industrial projects and complex infrastructure projects there is sometimes one more stage. Technical Design or Expended Preliminary Design is added between the above two stages.

2. Contract provisions about engineering

1) Design scope

According to how much preparatory work that owners did, the owners will have different strategies when they use the EPC contract. Sometimes there is very little preparatory work for the owners, in which case the contractor bears the design of large scope; if the owners did a lot of preparatory work or even completed the preliminary design, the scope of the contractor's design is limited to the construction design.

To EPC turnkey mode, FIDIC has the statement for the engineering work of both owners and EPC contractors. This is as follows:

(1) Owners complete the conceptual design, and put the design results into the "owner's request", which is a part of contract document. This shows the aim of the project, functional requirements, and technical standards. At this stage, the owner's design work is approximately 10% of the total design workload.

(2) In the bidding phase, contractors complete the preliminary design in accordance with the requirements of the tender documents, and send it to the owners as a part of the tender documents. As the depth of the specific design broadens, the owners should give the details of why to the bidders.

(3) In the process of project implementation, EPC contractors are responsible for completing the final design. This is divided into general arrangement drawing design and detailed drawing design.

2) Design basis and technical standards

Design is based on the design requirements of EPC contract, including:

(1) The outcome document of the owner's preparatory work.

(2) The country's technical standards where the project is located.

(3) Technical standards agreed upon in the contract.

(4) Construction and engineering-related laws, such as construction law, environmental law, product law, etc.

(5) Good engineering practice.

3) Design document inspection and approval

In the process of international EPC contract implementation, design document inspection and approval are the way that owners control design quality. International EPC contracts have the following provisions:

(1) Owners have the right to inspect any documents in connection with the project.

(2) If the contract requires that certain documents subject to the approval of owners, contractors should submit the document to the owners or PMC (Project Management Contractor), which is commissioned by the owners, to carry out examination and approval.

(3) Within the required timeframe, owners should inspect the design document. If there are problems, owners can have contractors modify them.

(4) The drawings and documents shall not be used for the project before inspection and approval have occurred.

(5) If contractors want to modify the document, which is already approved by the owners, they still need to report to the owners for approval.

(6) The outcome document of the contractor's design should use the language stipulated in the contract.

4) Design responsibility

For an EPC contract, the contractors take charge of the design, so they take responsible for the design. However, because the owners did some preliminary design before the contract was signed, and usually put the design results into the contract, the owners also need to take part of the responsibility. Division of responsibilities and limitations between the two sides is as follows:

Responsibility and limitations of the owners:

(1) Cannot change the terms of the contract.

(2) Define the expected purpose of the construction project.

(3) Completion of test and performance standards.

(4) Make sure the contents that contractors put forth are able to verify.

(5) During the contract implementation process, if the norms or standards in the contract have changed, if the law has changed, or if the owners' provisions have new standards then the changes should be dealt with by the owners. The owners also need to bear the consequences as well.

Responsibility and limitations of the EPC contractors:

(1) Contractors take the responsibility to check the results of the owners' preliminary design.

(2) The contractors are responsible for the correctness of the results of owners' preliminary design.

(3) Owners' approval of the contractor design documents does not lift the responsibility of the contractor.

(4) If the contractor's design documents have errors, the contractors need to correct it at their own expense.

5) Compiling and submission of the completed documents and operation and maintenance manual

(1) Contractors compile the detailed completed document, and submit it to the owners in accordance with the terms of the contract.

(2) The contractor has to submit the completed drawings reviewed by the owners.

(3) The specifications of the completed drawings have to be permitted by the owners'.

(4) Before the completion of the project, contractors need to create a provisional operation and maintenance manual.

(5) Before obtaining the acceptance certificate, contractors must submit this formal operation and maintenance manual to the owners.

3. EPC contractor engineering management

1) Design organization and plan design organization

Department of project engineering is a temporary organization for completing the project design, and it is set up in two situations. If the EPC contractor itself is an engineering corporation, who is good at design, the project design manager can be chosen from their company, and the professional designers can be chosen form appropriate departments. If the contractor itself does not have the design ability he needs to hire an engineering sub-contractor, then the sub-contract should be signed and all the activities should be based on the requirement of the EPC contract. The sub-contractor is in charge of the design manager, but he must be subject to the EPC project manager.

The EPC contract of the Saudi Arabia polyolefin project is a joint venture company, which is made up by three corporations: AK, SSEC and SCC. Since each of the corporations has its own core competence, like AK is good at engineering, SSEC does well in procurement, and SCC is an outstanding construction company, each of the them take different parts of jobs and try to complete the project together. AK is in charge of the basic design work and the SSEC is in charge of the detailed design work.

Design plan

The design plan is worked out by the department of project engineering based on the overall implementation plan of EPC project, and it is the complement for the project implementation plan. Design plan includes:

(1) Research and understand the design requirement of the EPC contract, to determine the scope of the design work.

(2) Determining the design principles; mainly related to safety principles, economic principles, the principle of quality assurance, etc.

(3) Determining the overall design schedule according to the total duration of the project.

(4) Determining the workforce, facilities, and equipment input in the design phase.

(5) The workplace for the design work.

(6) The norms and standards adopted in the engineering design.

(7) Laws and regulations in the environmental protection area.

(8) Determining which divisions of the design work need sub-contractors.

2) Design control and design outcome document

Design control is to control the design work and correct the design work, which is deviated from the design plan based on all types of design procedures, documentation, and design work guide during the process of design implementation. Design control mainly includes schedule and quality. To the EPC contract, the design impact of the excessive costs should also be controlled.

The results of design output documents include drawings, calculations, data sheets, technical manuals, software, operating instructions, and many others. The documents are used to guide the contractor's procurement, construction, completion tests, and commissioning. FIDIC refer to the "construction documents" or "contractor's documents."

4.1.2 Procurement management

1. Brief introduction of procurement management

For international EPC projects, procurement is very important during the implementation of projects and it is also significant success of the projects. For most projects, particularly industrial projects, the total procurement cost of the contract is as high as 40% - 60%. In the international engineering EPC contracts, there are various provisions to the procurement, especially in recent years, the owners' intervention on the procurement process has become more and more popular.

In view of the procurement's important role in the implementation phase of the contract, it is necessary for the procurement department to have a good relationship with other departments. So it is crucial to make the responsibilities of the procurement department and working procedures clear.

2. Contract provisions about procurement

1) General responsibility for procurement

General contract provisions about procurement include the following aspects:

(1) Contractors should be responsible for all the materials needed such as raw materials, equipments, and other consumables.

(2) Contractors should have procurement departments that are in charge of procurement tasks and the coordination to make sure the work is efficient.

(3) Contractors should choose the transportation routes and make a distribution plan based on road conditions.

(4) If others claim for the bad transportation, contractors should make sure that owners will not suffer the loss and negotiate with the claimant and pay for the loss.

(5) Contractors should prepare procurement process documents according to the contracts requirements and submit them to owners to monitor the contractors' work.

2) Monitoring the procurement process

(1) Contractors shall prepare an overall procurement plan and submit it to the owners. Procurement plans should be consistent with the requirements of the project and contractors should pay special attention to significant equipment.

(2) Contractors should inform owners of the major plant that is going to be used including the plant name, dispatch point, loading port, unloading port, inland transportation, and point of arrival at site.

(3) For the main materials and equipment, their source should be limited to the list of suppliers appointed in the contract and other suppliers who have been approved by the owners.

(4) Contractors should carry out the supervision and management for the vendor, supplier, and manufacturer during the whole procurement process.

(5) For the significant equipment, contractors should supervise the manufacturing to control the quality and progress.

(6) Owners have the right to check the equipment and materials at a reasonable time including the inspection of the progress in manufacturing and during the quality testing process.

(7) Any equipment in the manufacturing process can be inspected as written in the contract.

(8) Owners have the right to request the contractors to provide non-priced supply contract for their inspection.

3) The assistance of the owners

For materials procurement, because of many legal proceedings, owners are often required to assist the contractors in some areas. The form of the assistance usually is the offer of L/G (letter of guarantee). For some special materials such as explosives and so on, owners are often required to get an Import Permit in the contract.

4) Employer Supplied Items

Employer supplied items are called free issue materials in FIDIC EPC contracts. Relevant EPC contract provisions are listed as follows:

(1) If owners are required to supply free materials to contractors in the contract, owners should pay for their charges at their own risk and transport the materials to the designated locations.

(2) Contractors should check the materials before receiving them. If there are any quality problems or quantity problems, contractors should inform the engineer. After receiving the notification owners shall immediately make up the volume and replace the defective materials.

(3) After the contractors' inspection s the of materials are transferred to the other contractors then it is their responsibility to look after the materials.

(4) If quantity problems and quality problems are not obvious and it is hard for contractors to find the problems then owners still need to be responsible for that after contractors receive the materials.

3. EPC contractor procurement management

1) The contractor's procurement organizations and plans

EPC procurement organizations,

The procurement department is often set up to finish the procurement work in EPC project organization structure. The procurement manager is recommended by the project manager and appointed by the company. For complex industrial projects, according to the nature of the entire procurement work, the procurement department can set up positions such as Purchasing Engineer, Expediting Engineer, Inspection Engineer, Traffic Engineer and

Coordination Engineer, in which inspection engineer can also be selected from the design department or the quality department according to project organization division. For construction projects, procurement positions are clear because the work is simple. The number of the positions can be determined by the procurement workload. For small projects, a person can also have many roles. Because the preliminary workload is heavy, the number of procurement members can increase.

EPC project procurement plan

EPC project procurement plans can be divided into two parts: the general plan and the schedule plan. The project general plan is a guidance document according to the project implementation plans.

The general procurement plan includes the following aspects:

(1) Determination of the scope of the project procurement.

(2) Formulation of the review rules for procurement documents.

(3) Formulation of manufacturer/supplier coordination procedures.

(4) The definitude of the procurement schedule and the cost objectives make sure that this objective is consistent with the objective of the project.

(5) Formulation of general procurement principles including the principle of schedule guarantees, the principle of quality guarantees, and the principle of security guarantees.

(6) Formulation of work procedures to be followed.

(7) Documentation of various procurement files and purchase order files.

(8) Formulation of procurement procedures for significant materials and significant equipment.

The procurement progresses plan is to make sure that all materials such as the main equipment, the main material, auxiliary, and the various consumables are purchased on time under the framework of the general plan. The procurement manager will be responsible for that by organizing the staff to finish it. It is finished based on the EPC project, construction material use plan, and procurement budget from the control department.

4.1.3 Construction management

1. Brief introduction of construction management

Construction is the core part of the EPC project. Construction is equal to the period from Commencement at Site to Substantial Completion or Mechanical Completion. In an EPC contract, construction schedule, construction method, construction quality, and construction safety are involved. The idea of construction in EPC contract is very broad. According to the contract, you can say every minute of the project needs construction management.

2. Contract provisions about construction

1) Relative regulations on construction in EPC contract

(1) The contractor shall follow the owner or the contract's opinion.

(2) The contractor should provide sufficient management personnel and send full-time project managers to be responsible for on-site management.

(3) Construction personnel must have appropriate skills and have good professional ethics.

(4) Construction equipment provided by the contractor, once transported to the site, are considered special construction equipment. Without owner's permission they should not be transported from the scene.

(5) During the construction period, contractors should keep the construction site in good order. When the project is close to completion, they should do a good job-site clean up.

2) Relative regulation on construction quality in EPC contract.

Construction quality in EPC contract covers construction engineering technology, methods, requirements, etc.

(1) The construction must be based on contracts, specifications, and other documents.

(2) During the construction, if various types of standard norms cannot agree with each other, they should follow the most stringent.

(3) During the implementation new standards appear, the owner has the right to request the contractor to follow the new standards, but the contractor should be compensated.

(4) The owner has the right to examine, test, and experiment the works that have been done. If the work has failed, the owner has the right to refuse acceptance, and order a redo. If the contractor insists on not correcting his mistakes, this could lead to the owners

terminating the contract.

(5) After completion, the project should achieve the required performance guarantee (Functional / Performance Guarantees).

3) Relative regulation on construction schedule in EPC contract.

(1) The contractor must complete the construction during the given period, together with the preparation of the different documents, as well as the test, otherwise the contract should bear a delay in compensation.

(2) When the contractor received the notice to start, they should start as soon as possible, and after that do the engineering, procurement and construction work at a reasonable pace.

(3) When the project starts, the contractor shall prepare and provide the owner a detailed implementation schedule for the project.

(4) If the owner thinks that the contractor's actual progress is too slow or the actual progress has lagged behind the progress of the project, the contractor is obliged to develop plans to speed up the work.

(5) The contractor should submit a Monthly Progress Report to the owner, sometimes even a Weekly Progress Report, and maybe even a Daily Journal Progress Report depending on what the owner wants.

4) EPC contract provisions relating to HSE

With the global economic development, the opinion of Health, Safety, and Environment (HSE) has raised more and more attention in the world.

(1) The contractor shall, at their own expense, take appropriate preventive measures to ensure the workers' safety.

(2) The contractor shall appoint a full-time staff to handle the issue of security and personal accidents to create preventive measures to avoid accidents.

(3) When infectious diseases occur, the contractor should comply with the host country's laws and instructions to deal with the diseases.

(4) The contractor shall comply with all applicable safety regulations.

(5) The contractor should take care of the right to enter the site, and the safety of all personnel.

(6) The contractor should strive to maintain good order at the scene, and to remove the obstacles so as to avoid a threat to the safety of people.

(7) Before the final test, contractors should provide site fencing, lighting, and security at the working site.

(8) If the construction affects the public as well as public security, the contractor must provide them the necessary facilities.

(9) The contractor should take all measures to protect the environment both inside and outside the scene and control the operation of its construction noise, pollution, etc., in order to reduce the public personal property damage.

(10) The contractor shall ensure that the emissions from their construction activities, sewage, and any other emissions do not exceed the emissions allowed by their surrounding laws.

(11) The contractor shall prepare for the implementation of the project HSE Management Handbook.

3. EPC contractor construction management

1) Schedule management of the contractor

(1) The progress of making a plan

Schedule of an EPC project can be shown as follows:

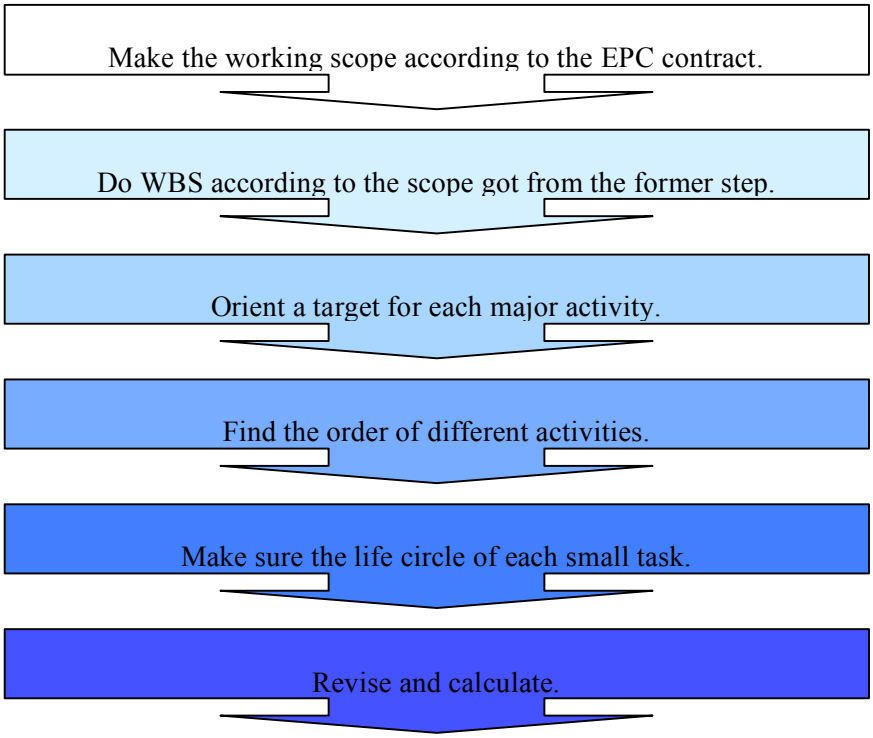


Fig.4-2 the Progress of making a plan

(2) Tracking the progress of the scheme, monitoring, and forecasting

After the completion of the schedule planning, it is necessary to establish criteria for measuring project progress and systems. The progress measurement system should be based on contractual requirements, according to the input of the workload or the achieved target of the progress to access the progress of the project. Most of the current international projects use Earned Value Technique to monitor the progress of the project. They use Planned Value, Earned Value, and Actual Cost analysis to compare the progress and costs.

(3) Progress status report.

The contractor will need to establish the project progress status reporting system, including a progress report on the general sub-Monthly Progress Report, the Weekly Progress

Report, as well as the Daily Progress Report. The contents of the report cover the overall progress of the project, the design progress, procurement progress, and the construction progress. The Monthly Progress Report includes the completion of the work this month, next month's plans, any problems, remedial measures, as well as the progress of the attached curve and human resources plans.

2) Quality management of the contractor

(1) Arrangement phase of the construction management

The main work of this phase includes:

1. Determining the of construction quality criterion according to the EPC contract. For quality test standards, norms should be written into documents as the basis for construction quality control.

2. Human resource arrangement. According to the project characteristics and the complexity of the requirements of various types of construction, train workers to special types of work to ensure that the quality of the construction meets the construction requirements.

3. Equipment arrangement. Construction machinery equipment should be prepared according to the workload and technology of the work.

4. Construction site arrangement. Complete the necessary checkpoints for availability of water, electric power, access roads, telecommunications, and site leveling.

5. Construction plan programming, including the Ministry of Construction setting up the

organization, management methods, construction planning, and technical arrangements. Sometimes these require the owner's approval.

6. Corresponding of the joint part of different technical interface. During this process, preparations should be made in case of any quality problems.

(2) Quality management of the construction phase

Quality control of the construction phase is divided into two levels: first, the owner takes charge of construction operations and control at the construction site in accordance with the contract; another level is the internal construction contractor quality management.

Quality control of the construction phase includes:

1.Determine the basis of quality control, including the EPC contract technical requirements, design documents, construction specifications, and quality standards.

2. Quality control consists of using internal inspection in contractor management, joint hearing, and on-site measuring. If necessary the EPC contract should combine with the owner to do the estimation and test.

3. An inspection process for the construction and materials. And to identify problems and feedback after the reform process, in particular, to strengthen the special processes and materials (Owner Supplied Items) control.

4. Handover process quality control.

5. Construction quality of statistics. Evaluation of the quality is very important in quality control.

(3) Final acceptance stage of quality management

Although the completion of EPC contracts can be different, the general understanding of the completion includes the final acceptance of the machinery stage, mechanical completion, operational acceptance, and a performance guarantee test to make sure the job meets the requirements.

3) HSE management of the contractor

In construction practice, the contractor should establish a general HSE management system, that is: according to the provisions of the contract and the law, combined with the specific characteristics of the project, develop a set of provisions in the health, safety, and in environmental protection. Then make a management handbook to monitor, record, and evaluate.

According to the scale of the project, the project organization can set an individual HSE management department, and it can be included in the construction department.

Health management

Health management includes prevention, health testing, labor protection supplies, health care measures, and first aid program.

Safety management

Safety management includes construction safety and society safety. Construction projects have way more risks involving personal safety than other types of projects.

Environment management

Construction will to some extent pollute nature. Make proper use of nature, reduce or avoid pollution, and stimulate sustainable development should be imperative when people balance the built environment and natural environment.

The contractor should pay more attention to protecting the environment during the construction in accordance with the contract and the provisions of the law. Contractor's responsibility includes water and soil conservation, noise control, control of dust pollution in the atmosphere, and vegetation protection around the construction site.

4.2 Contract risks analysis

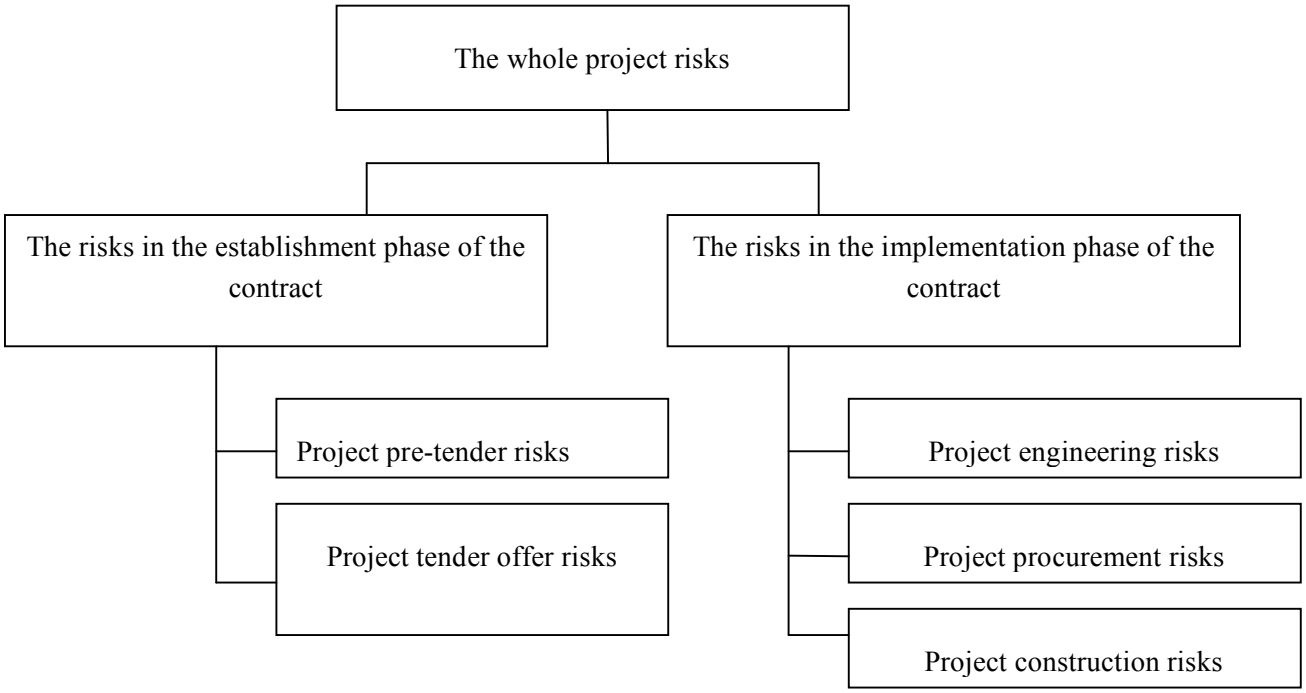


Fig.4-3 Sinopec-Saudi polyolefin project risks

Sinopec-Saudi polyolefin project has a variety of risks; according to the contract life cycle, they are risks in the establishment phase of the contract and implementation phase of the contract. In the phase of contract establishment, the risks can be divided into pre-tender risks and tender offer risks. In the phase of contract implementation, the risks include engineering risks, procurement risks and construction risks. For construction risks, we can divided them into quality risks, schedule risks, cost risks, security risks.

4.2.1 Risks in the establishment phase of the contract

(a) Pre-tender risks

The risks involved in it are as follows:

- Political risk, such as the relationship between two countries. The political situation in Saudi Arabia, they have to be careful of the possibilities of terrorist attacks, and policy continuity and stability in the country.

- Legal risk, such as the staff are unfamiliar with the local laws, and the legal system is different from China.

- Inaccurate information.

- Agents are unreliable.

- The situation in the host country is unclear.

- Unfamiliar with the market.

- Unfamiliar with the situation of competitors.

- Not enough risk analysis.

- Decision-making errors.

(b) Tender offer risks

The risks involved in it include:

- Inadequate preliminary work.

- The tender requirements are not clear.

- Shortage of basic information about design.

- Inadequate analysis about tender documents.

- Failure of check on-spot.

- Failure about the prediction of the implementation phase.

- Failure in the selection of joint venture partners or sub-contractors.

- Unfamiliar with the local taxes and fees and market price of various kinds of resources in Saudi Arabia such as labor force, materials, equipment machinery, etc.

- The risks caused by resource organization. Being unfamiliar with the resource transit from home concerning approach, procedure, cycle, difficulty level, and cost.

- The risks of the strain on the resources and the surge in prices caused by over-investment.

- Natural risks. Risks brought about by tough climates (high temperature), which mainly manifest themselves in labor cost increase.

- Exchange rate risks.

- Underestimating the bid of the quoted price.

4.2.2 Risks in the implementation phase of the contract

(1) Project engineering risks

(a) Risks caused by owners and project management companies.

(b) Risks caused by sub-contractors.

(c) Risks caused by contractors.

(2) Project procurement risks

We do analysis of procurement risks from the sources of the risks. The risks are divided into four aspects mentioned bellow.

(a) Risks caused by owners and project management companies.

(b) Risks caused by suppliers.

(c) Risks caused by fund.

(d) Risks caused by sub-contractors.

(3) Project construction risks

(a) Risks caused by engineering and procurement.

(b) Risks caused by the coordination situation of partners.

(c) Risks caused by natural and social circumstances in Saudi Arabia.

(1) Project engineering risks

(a)The risks caused by owners and project management companies.

- Are the owners and project management companies satisfied with the project? Do theyhave any special requirement?

- Project standards that are required by the owners and project management companies.

- The absenteeism of owners and project management staffers will constrain the progress of the project.

(b)The risks caused by sub-contractors

- Unfamiliar with project conditions, sub-contractors still use the standard used in home.

- Understaffed of sub-contractors, the staffers have a lack of the technical knowledge

- Misuse of design regulations.

- Unfamiliar with local conditions and practices.

(c)The risks caused by contractors

- The contractors' capability of engineering management.

- Misuse of design regulations.

- Unfamiliar with local conditions and practices.

(2) Project procurement risks

(a) Risks caused by owners and project management companies

- Product designated by owners and project management companies are not available in Saudi Arabia.

- Owners and project management companies do not agree with the color or quality of the raw materials.

- Preference of owners and project management companies to suppliers leads to a shortage of raw materials and a delay in time.

(b) Risks caused by suppliers

- Expensive material prices

- In April 2006, the price of argon was 65 Saudi Arabian riyals, however in December 2007, the price climbed up to SAR 350. The price increased four times in 20 months.\

material name	price（SR）		increase in the percentage
	4/2006	12/2007	
Concrete	300	420	40.00%
Rebar	2100	2700	28.57%
carbon steel material	6.5	10	53.85%
stainless steel welding material	50	100	100.00%
Argon	65	350	438.46%
Nitrogen	25	50	100.00%
Galvanized	1200	2100	75.00%

Table 4-1 Material price changes

- Shortage of materials and labors, due to unexpected market overheating, will affect the production period.

(c) The risks caused by funding.

- Suppliers in Saudi Arabia usually sign a contract with a 30%-60% down payment. Sometimes a contract comes into effect after the supplier receives the full payment.

- Suppliers decline contract terms of paying margin quality.

- Delivery cycle usually ranges from two months to four months, which means buyers should settle the related payment in advance.

(d) Risks caused by sub-contractors

- Sub-contractors' attitudes

- The construction units (construction companies) held negative attitudes toward the suppliers. Local suppliers asked for demand plans one week in advance and make confirmations two days before, however the construction companies did not provide accurate demand plans and they sometimes canceled their demand plans without informing the suppliers. The suppliers complained a lot about that and expressed their unwillingness to cooperate.

- Sub-contractors' procurement abilities

- With the construction decoration works going on, the number of procurement staff in the construction companies was not enough and their abilities were poor. After August 2007 their procurement tasks for decorating materials were in a state of suspension.

(3) Project construction risks

(a) Risks caused by engineering and procurement

- Design modification

- The number of concrete and rebar needed exceed the budget due to the design

modifications, the original estimate for rebar is 4,400 tons, and the actual amount is 6,000 tons. The original estimate for concrete 30,000m3, the actual amount 40,000m3; design modification is still underway.

- Material selection

- SCC encountered the problem of alternatives of galvanized pipe when implementing CONTROL BULLDING and PP/PE SUBSTATION indoor materials procurement. EMT CONDUIT was chosen based on Saudi specification, but EMT was inconsistent with the real situations.

(b) Risks caused by coordination situation of partners

- Engineering, procurement and construction don't combine with each other well.

- When it is not prepared well, the construction design is required to be made as soon as possible, which may exceed the budget.
- Procurement of steel. A manufacturer is expected to make out the production schedule and sign a contract for the supply of steel. However, because of the delay of the engineering, the steel may fail to supply in time, the whole project will be put off.
- Engineers are not familiar with the norms and standards in Saudi Arabia. Even though they are familiar with API, AMST, ASME, but they are accustomed to the domestic way of thinking. This will delay the project, and increase costs. A 60% Model PE device audit found four more serious problems.

(c) Risks caused by natural and social circumstances in Saudi Arabia

- Natural conditions in Saudi Arabia is tough

- Geographical and climate conditions in Saudi Arabia are tough. The temperature is above 40 degrees Celsius throughout the year in Saudi Arabia and the highest temperature is about 52 degrees Celsius. Furthermore, the temperature in the construction site is far more than this temperature. The surface temperature of steel, which is directly exposed to the sun, exceeds 80 degrees Celsius. It is hard for the domestic workers to get used to the climate conditions in Saudi Arabia. Many domestic workers suffered from heat stroke when they arrived in Saudi Arabia.
- The weather with wind and sand is common in Saudi Arabia from August to October which impacts the lifting work in the construction site and even affects the whole work schedule.

- Religious issues

- Saudi Arabia is a religious country, the birthplace of Muslim. Saudis spend a lot of time praying. Although non-Muslims are not required to do that, the Chinese behaviors may be in violation of the Muslim law because they do not understand the religion.

(1) A small number of Chinese employees made much noise in the neighborhoods of Yanbu in Saudi Arabia in the period from April to June in 2006. Local residents complained about it to the religious police and the Royal Commission. In the end the Chinese employees were fined twice.

(2) In August a Chinese worker carried wine with him when he reached Jeddah Airport and it was found by Customs. The worker was then fined for this.

(3) In September posters with naked people on them were found in one Chinese worker's baggage when he reached Jeddah Airport. In the end the worker was fined.

(4) In October 2006 (during Ramadan), a worker was found smoking a cigarette in a car. The worker was arrested upon the site of him smoking. After enormous effort, the worker was released.

(5) Early in October 2006 a non-Saudi worker touched a local Saudi inadvertently when he was shopping in the street. The Saudi insulted and assaulted the employee immediately, and then quickly run away. The employee ran after the Saudi. When the employee caught up with the Saudi he pushed the Saudis from behind, the Saudis fell to the ground. Other Saudis called the police. The police took the two people to the police station. After transcripts the Saudi was released, but the non-Saudi worker was arrested and fined 3,000 Saudi Arabian Riyal.

4.3 Contract management

In an international construction project's contract management someone needs to take charge of the signing of the contract, the implementation of the contract, and finally the termination of the contract in order to guarantee the project runs smoothly and they receive the final expected result.

Contract management plays a significant role in an international project management system. The contract determines the safety, quality, schedule, and cost goals, which is the contractor's main basis for project control.

Characteristics of international engineering contract management:

(1) Entire process. Contracts lifetime can be very long because an EPC project usually takes some time to be completed. Different types of contract forms come and go in an EPC project, therefore, contract management should be continually carried out throughout the project life cycle.

(2) Consistency of objectives. Goals of HSE management, quality management, cost management, schedule management, and human resources management should follow the goals of the overall objective.

(3) Systemic. An international project has various types of contracts, large numbers of terms, and complex circumstances. The relationship between different parts should be really complex so all aspects should be considered, and resources optimizing is necessary.

(4) Strictly performed. The general value of international projects is usually very high. One small mistake can lead to complete project failure, which leads to a huge loss in money.

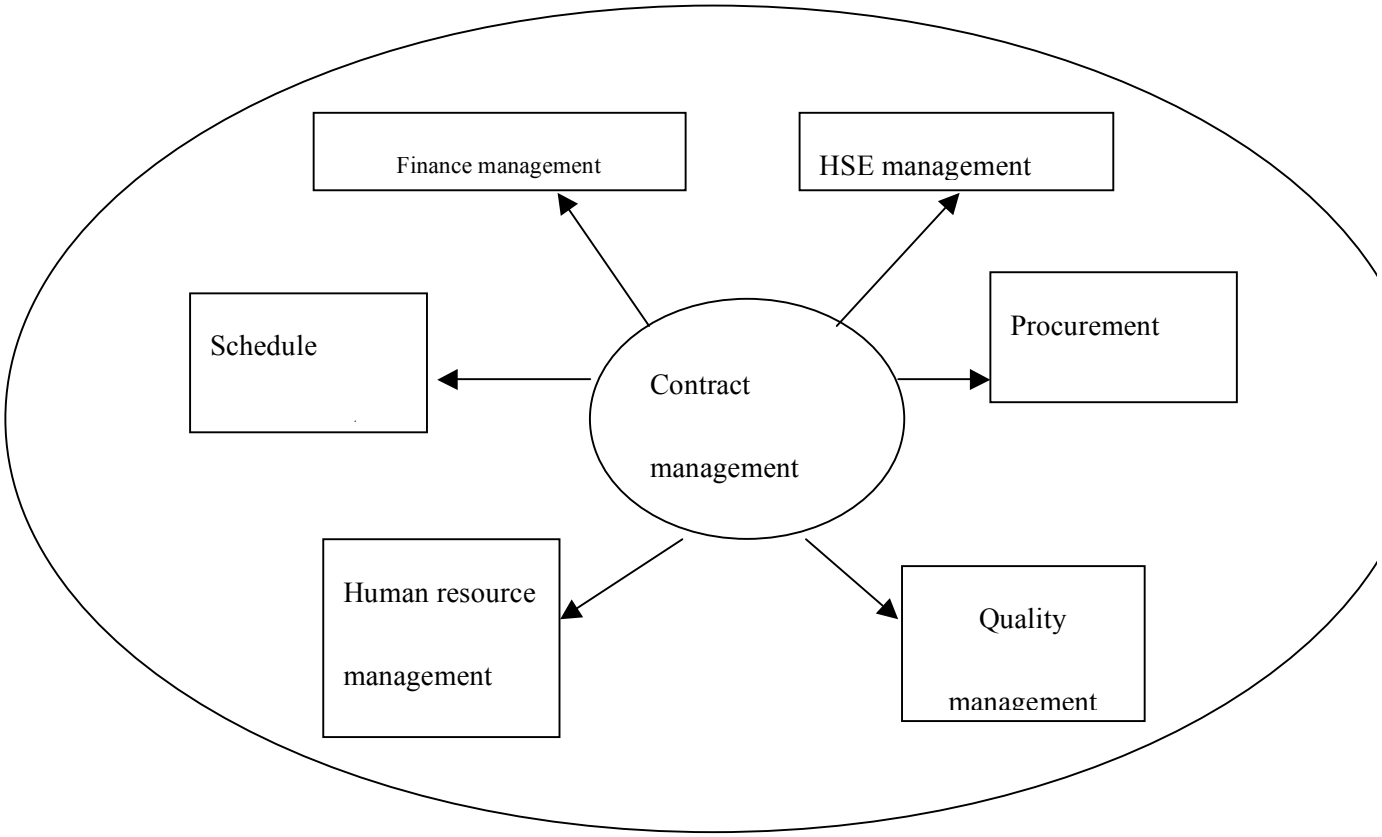


Fig.4-4 Contract risk management structure

An international EPC project contract management can be considered from these six parts: finance management, HSE management, quality management, schedule management, human resource management, and procurement management. Professional knowledge is also very important.

4.3.1 HSE management

1. Brief introduction

HSE stands for health, safety, and environment. The target of HSE management is to guarantee people's health and safety, protect nature, reduce pollution, and stimulate sustainable development.

The requirements of the health, safety, and environment protection are different in different countries. If they just follow the domestic requirements without paying attention to the local requirements, this may cause the project to fail when examined.

2. Methods

In order to reach the targets above, methods can be taken as follow:

(A) Set up an HSE management system.

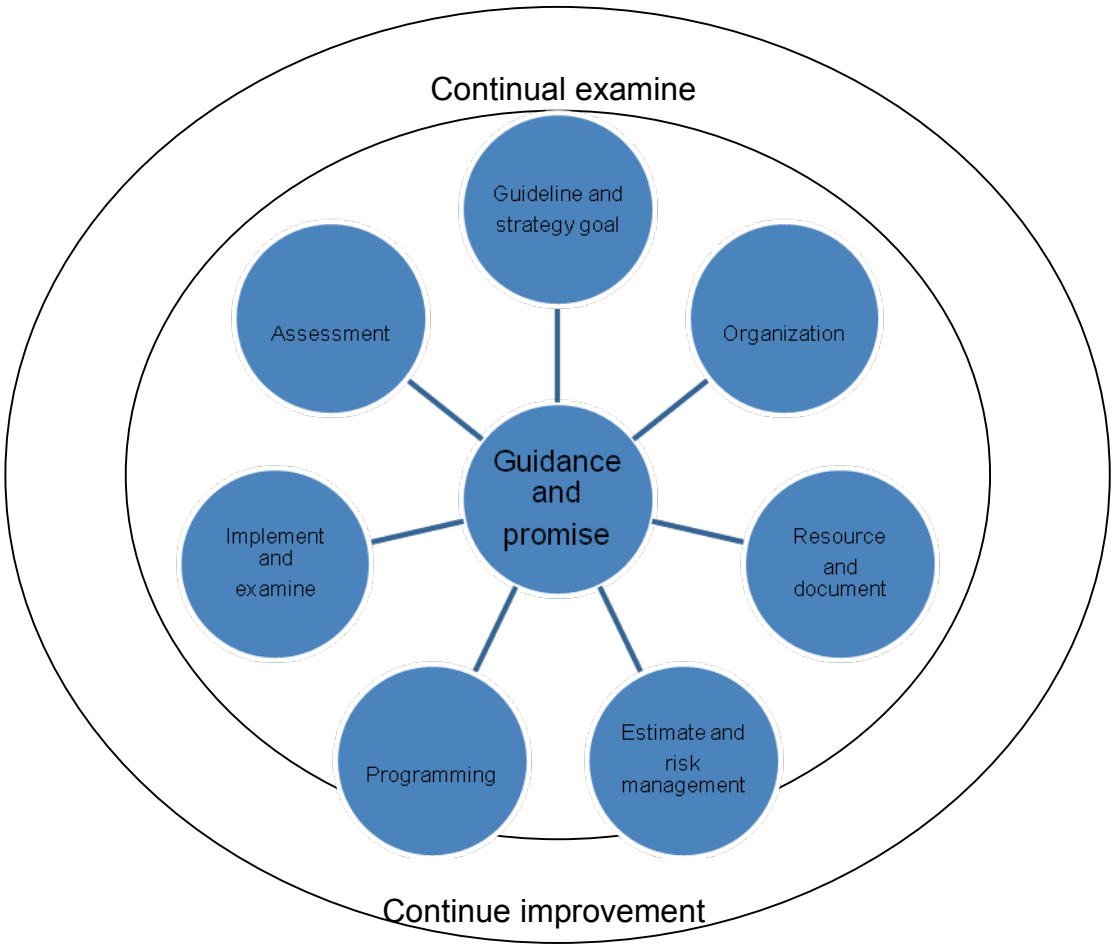


Fig.4-5 HSE management system

An HSE management system has eight major elements. They are guidance and promises, guidelines and strategy goals, organization, resource and documents, estimation and risk management, programming, implementation and examination, and assessments. Every element is a criterion that HSE management has to reach. Guidance and promise is the core part of the management system. Other elements circle around the core and are carried out through activities. The eight elements circulate the work, making the system work and avoid HSE accidents.

(B) Set up HSE management system assessment standards, and check regularly. The assessments should include whether the HSE management system matches the target, and whether the HSE management system worked effectively.

(C) Set up an HSE management department, and appoint qualified people in charge of the HSE management. Every manager's duty has to be clearly described and put into documents. When something happens someone has to answer for it.

(D) Staff training. This will make sure they know the HSE management system.

(E) In charge of the sub-contractor's HSE management. Even though this is not our responsibility, we worked as a team with the sub-contractor. Their performances play important roles in the whole project.

4.3.2 Schedule management

1. Brief introduction

Schedule management makes sure certain tasks are finished at certain times. In order to finish the project on time, schedule management is very important. Tasks in schedule management include schedule making, project follow-ups, schedule updates, and reports. These tasks usually take place in the control department, and are assorted into the engineering department, the procurement department, the construction department, and the quality department.

An international project schedule usually can be divided into three levels.

The first level is management planning. The upper managers make sure of the start point and end point, as well as the major tasks. They take charge of monitoring and guiding. If the scope of the contract changes, this level will still remain the same.

The second level is major task planning. This level is more detailed than level one. The control department takes charge of monitoring and controlling. CMP is the major method used in this part.

The third level is detail control planning. This level can also be called construction planning. This has the most details out of the three. The construction department takes control of this part. During this time, planning updates frequently.

2. Cause of schedule risk

(A)The schedule was designed beyond capacity.

(B) Nature reasons.

(C) Mistakes in management, such as a lack in communication between different departments.

(D) Engineering changes.

(E) Financial reasons.

(F) Material and equipment supply delays.

3. Methods to solve the schedule problem

(A) Change the consecution of different tasks.

(B) Increase working resources, such as labor and machines.

(C) Redistribute resources.

(D) Outsource.

(E) Increase work efficiency, such as training and motivation.

(F) Decrease the working amount, even cancel one or two units.

The SCCS has set up its own schedule planning of the Poly project. LEVEL ONE is a general schedule. LEVEL TWO and LEVEL THREE show the detailed tasks that have to be done at certain times.

4.3.3 Quality management

1. Brief introduction

Whether the quality of a project is good or not depends on the satisfaction of the clients. It can also be measured by the contract. The requirements of the project quality should meet the contract documents, engineering documents, and technique criterion.

2. Quality management process model

Project quality management process model shows:

- Project manager should get to know the requirements through management responsibilities.

- Identify and apply the necessary resources through resource management.

- Create and implement a procedure through the process of making products and providing services.

-Measure, analyze, and improve the results.

- Through management and feedback document the shortcomings.

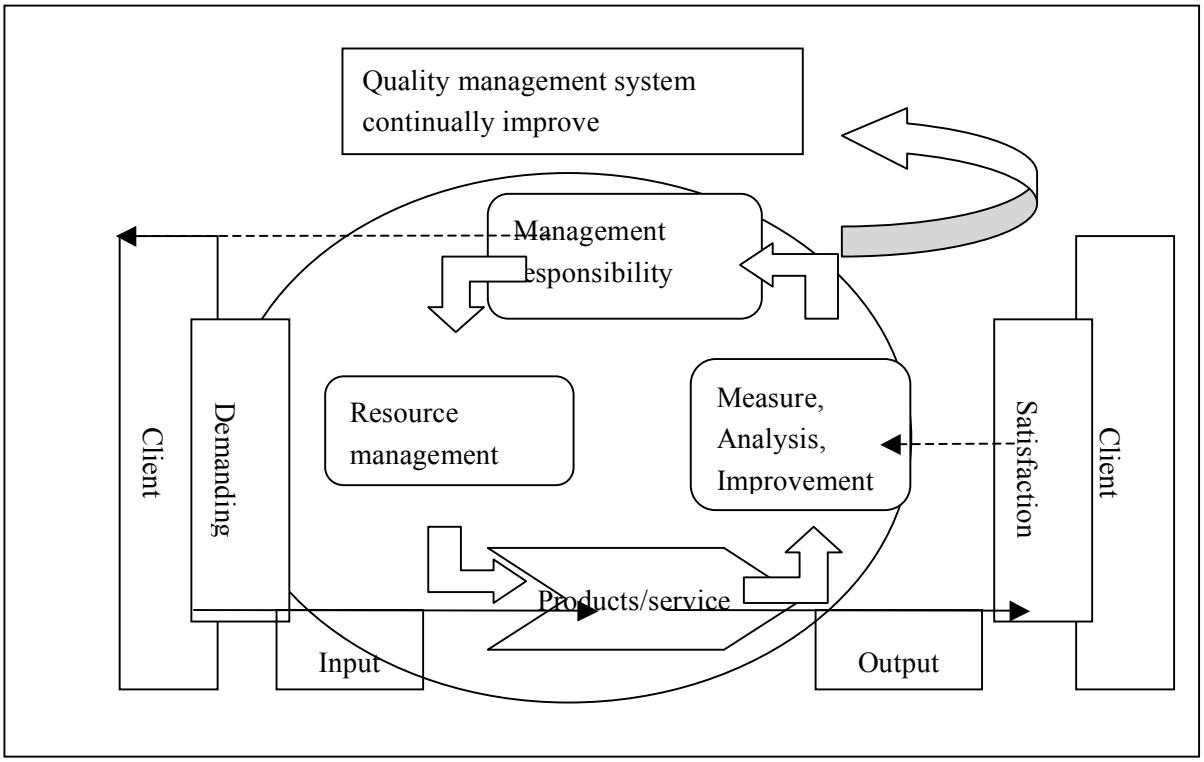


Fig.4-6 Quality management system

As in the figure shown above, the project organization should know what the clients really want. After the products and services are provided, see the satisfaction of the clients. Then we can know whether the project has achieved its goal or not.

In order to set up a sufficient quality management system, some tasks have to be properly done. Quality handbook, quality plan, procedure document, quality record should be included in these tasks.

The Quality management system has to be examined regularly. An assessment system should be set up to monitor quality management system.

A building has to be casted at one time. If it is not successful, everything has to be put down and start from the very beginning. The cost and waste will be large. Because it is such a

huge error, something was not under control. The owners refused to sign the contract accepting the project, they said the quality of the construction did not meet the standards. Later through many inspections it was proved to be safe. The owners then accepted it. Make award and punish documents on safety and quality management. Strictly stick to them. Responsibility should be handed down to a certain person, and he should be held responsible for it, especially when something wrong happens. Meet and assess regularly. Staff from upper class to lower class should pay attention.

4.3.4 Finance management

1. Brief introduction

Economic benefit is a major point in estimating whether a project is worthwhile in the long run. According to the cost planning, measures would be taken to correct any deviations that are bound to occur. Financial management, assorted by human resource management and materials management can both be utilized to help maximize the financial benefit for the firm.

2. Procedure of finance management

The main tasks of financial management include resource planning, cost estimation, cost planning, and cost control. The procedure of financial management is shown below:

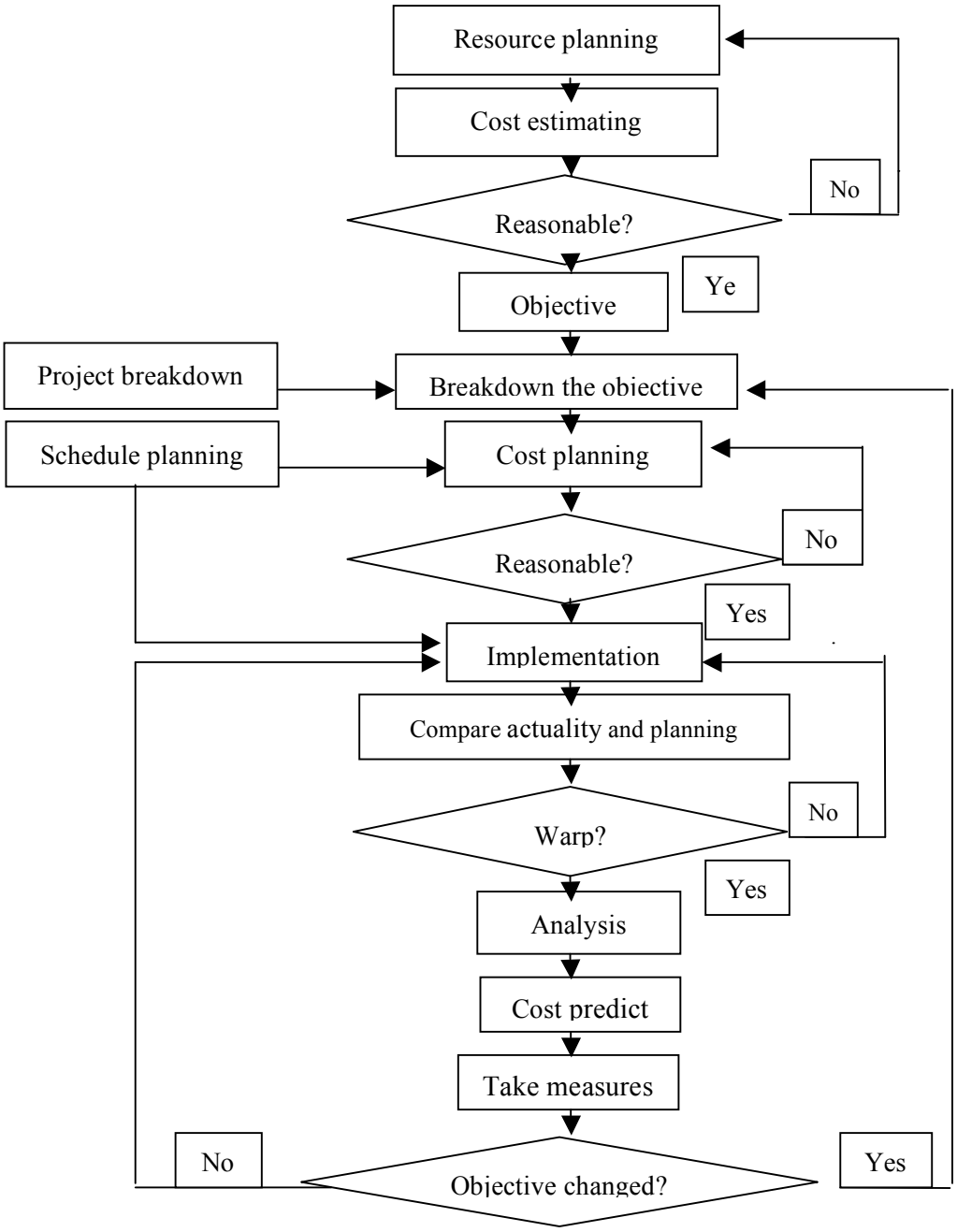


Fig.4-7 Procedure of finance management

Special circumstances to be taken into account are:

-Working out the financial planning

-Working out financial arrangement planning

-Advanced payments

-Scheduled payments

-Schedule planning

Before signing a contract, everything possible has to be taken into account, to assure that every party has their own responsibilities lined up more specifically their financial obligations. Converse with the owners, and the company who is in charge of the project's management to make sure that they will pay for the procurement in advance, or will pay when the order bill is sent out.

For example, the predicted price is 300 SR (Saudi Riyal). The highest possible price can be as much as 500 SR, and the lowest price can be as much as 200 SR giving us an actual average price is 400 SR. If a price prediction system is set up, the financial waste can be reduced. Especially in the Saudi Arabian project, since the price of steel and concrete change is very volatile. Because of the engineering changes, there were 1,000 tons steel that were stored which resulted in a lot of waste.

4.3.5 Procurement corresponding

1. Brief introduction

In international EPC projects, different companies from different countries join together to work on a specific task. Considering the various standards of the material, complex procedure, broad origin of the resources, volatility of the material prices, and great risks in

the global environment, whether the E, P, or C can correspond with each other play an important role in the implement of the project.

2. Corresponding between procurement and engineering

(A) Do the procurement and engineering at the same time. Engage in purchasing materials in advance, which will shorten the whole life cycle.

(B) Software that electronically manages the project, improving communication and overall effectiveness of the management process.

(C) Reduce waste; shorten schedule delay caused by supply delay.

Important things to remember:

(A) Not all key materials have to be bought from the best supplier, procurement should be done in local places as much as possible. Thus procurement costs can be greatly reduced. Procurement department should inform engineering department about the market of equipment and materials.

(B) Analyze type and capacity of the material, this can make the planning more reasonable, and decrease costs.

(C) Technique staff and manufacturers should communicate consistently to make sure the materials are correct.

3. Corresponding between procurement and construction

(A) The procurement department should give input as soon as possible, so that the construction department can make the necessary changes in time.

(B) As to huge and important equipment, procurement department should be informed in advance.

(C) Construction department should keep in touch with procurement: tell them the demanding in time, in case of shutdown.

4. Case

Supply life cycle problem: material demand is proposed when the need arises.

Solution: Being fully aware of the practice of engineering in Saudi Arabia, make planning in advance, do the procurement before the implementation. If the arrangement is not proper, adjust between departments.

Design, product selection problems 1: CONTROL BUILDING and PP / PE SUBSTATION indoor materials procurement, the galvanized pipe encountered maintenance problems, the design based on SABIC SPECIFICATION selected EMT CONDUIT, however, thin-skinned EMT pipe tube sets can only be used to connect live card sets of silk thread and cannot connect.

Solution: By understanding the practice of engineering in Saudi Arabia and put forward materials instead, use RSC instead of EMT.

Design, product selection problems 2: the types of indoor lighting switches given in the contract were too general, and difficult to confirm. Different suppliers hold different brands and agents. If the proposed were approved, they can’t be changed easily.

Solution: different suppliers should provide samples. In the approval, not only real products but also photographs and documented information of the product should be included.

Design, product selection problems 3: SABIC SPECIFICATION a form of a small number of standard requirements and drawings, but the engineers and the owners cannot decide whether or not to use it.

Solution: make a prediction, and procure some in advance, thus a lot of time can be saved.

Design and procurement: When the steel suppliers have the capacity to produce, the blueprint was not ready. When the blueprints were ready, the suppliers already got to work doing another task. It has passed the dead line of the contract, so the suppliers don't have to carry out the contract. SCC paid 60——70million more to persuade them to produce the steel.

The upper procurement and lower procurement: AK has to do the procurement, while the supplier was really busy and didn't have spare people to do the work. Finally, SCC mobilizes more than 100 people from china to Saudi. Because of this the whole project has been delayed for nearly 6 months.

4.3.6 Human resource management

1. Brief introduction

Besides all the aspects that are considered in human resource management, international projects have their own specific characteristics. One example is the different cultures and background. People need time to adapt to the politics, culture, and laws of a new country.

Language is the biggest challenge. Especially when signing a contract, it will be very serious if the two parts can't get the same opinion about one certain item. Cases will be shown below.

2. Problems

Some sub-contractors' management abilities and professional abilities cannot be shaped to meet the needs of site management. During the project implementation process they don't have the necessary skills, which results in confusion. Skills and quality of several construction objects cannot meet requirements. People cannot adapt to the host country's religious laws, traditions and harsh natural environment. Some sub-contractors do not pay on time or as planned, especially on these special days such as New Year's Day and Spring Festival.

3. Methods to improve the situation:

It is necessary to carry out regular contract management training. This is a basic method to improve managers' management skills and improve staff's awareness of contract management.

Enhance staff training and education before going abroad, especially the language, law, culture and religion. Also something has to be done for the nature environment difference.

Everyone should get to know the risks caused by the difference of the religion, customs, and so on. For example: in the Islamic countries, the prohibition of eating pork, drinking, during the month of Ramadan in public places. In addition, staff should sign an agreement before leaving to remind them all the time of the forbidden.

Strive to create a better working and living environment for the staff. Have pamphlets that show the work force places where they can go socialize and relax. Finally family visits should be included in the worker's contract.

4. Case

- From April to June, 2006, some Chinese employees were naked and made much noise. They were fined at last.

- September, 2006, items traveled from China to Saudi Arabia, which included playing cards in which naked people were printed on the cards. This resulted in a fine.

- October, 2006 (during Ramadan), a staff member smoked a cigarette in a car. He was arrested and released three days later.

- At the beginning of October, 2006, a non-Saudi staff touched a local Saudi person inadvertently in the crowd; the Saudi man immediately beat him, and then quickly escaped. The Saudi man fell on to the ground while the non-Saudi man pursued him. Passer-by called for police. The man was arrested and fined.

- If the staff was more educated in the customs of Saudi Arabia most of these matters can be avoided.

- Language is another challenge, inaccurate interpretations leads to mistakes.

- For example the word 'unit' can be interpreted in different ways. Different cultural backgrounds, companies, and people have different understanding of the word 'unit'. In order to get the exact definition of unit, more than ten people discussed it a whole day. Then

came to the conclusion: from the E (engineer) to packaging is a complete unit. Also, translations of the phrases ‘Twice a day,’ ‘Once two days,’ and ‘Twice one day’ were another misinterpretation. In American English, British English, and other English-speaking countries these phrases all have different understandings.

- Translation mistakes——Double handing / second handing

- The translation of Chinese words ‘double handing’ was also a major problem. The Chinese people thought it meant two times but it actually meant transport for the second time.

- What is a ‘Loop’? Price is measured by loop, but loop cannot be defined exactly.

5 Recommendations-Contract Management System

For recommendations, the project team has suggested a brief idea of contract management system (See fig.5-1), which includes six part: law system, organization, contract management process, contract controlling process, contract risk management and contract management performance evaluation.

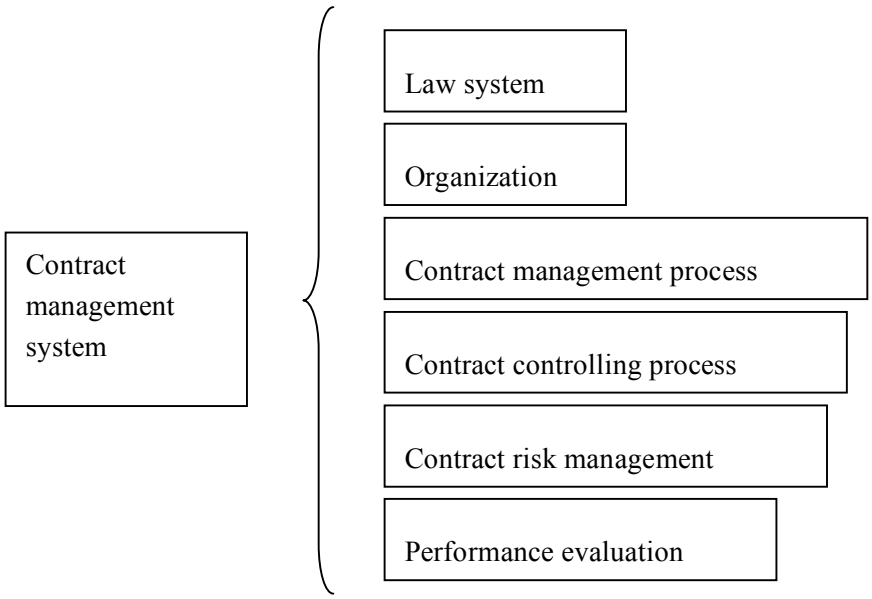


Fig.5-1 Contract management system structure

5.1 Law system

Status quo:

（1） Employees' awareness of the law of contract lags behind.

（2） Contract management system lags behind.

Sinopec Headquarter has a law department, which takes charge of the domestic and international projects.

SCCS has its own contract management system, but it could use improvements and sometimes it doesn't work. Meanwhile they never put them into documents. SCC has a legal office. Since the Saudi polyolefin project is the first time for SCC to hold an international project they don't have abundant experience. Staffs have limited knowledge about international contract and international laws. Most of the consultations have to be carried out through other counseling company.

Recommendations:

(1) Personnel. Recruit or train law professional personal, who have to know international laws and regulations about international projects especially international contract well.

(2) Organization. Set up a legal department.

(3) Training. To increase their knowledge of international law, especially international contract law, by training.

5.2 Organization structure

Status:

There is no contract management department nor are there full-time contract managers. Relative departments control contract schedule, quality, and cost. This causes the responsibility of each division to be unclear. When accidents happened it's difficult to find who should answer for it.

Recommendations:

(1) Personnel. Recruit or train professional contract management personnel. As professional

contract management personnel, he must have the knowledge of laws and regulations, and the ability to use legal tool to protect, also the claim procedures, and the capacity of project management, cost management knowledge and practical ability to apply it.

(2) Organization. Setting up a contract management department. Place special position as in the chart shown above to follow the management process including contract, negotiation, drafting, signing, implementation, alternation, convey, dispute management till the end of the contract.

(3) Training. Contract management staff should have training where they learn about relative contract documents and contract management skills.

The contract manager, contract management engineer, contract administrator, and project manager jointly supervise the implementation of the contract.

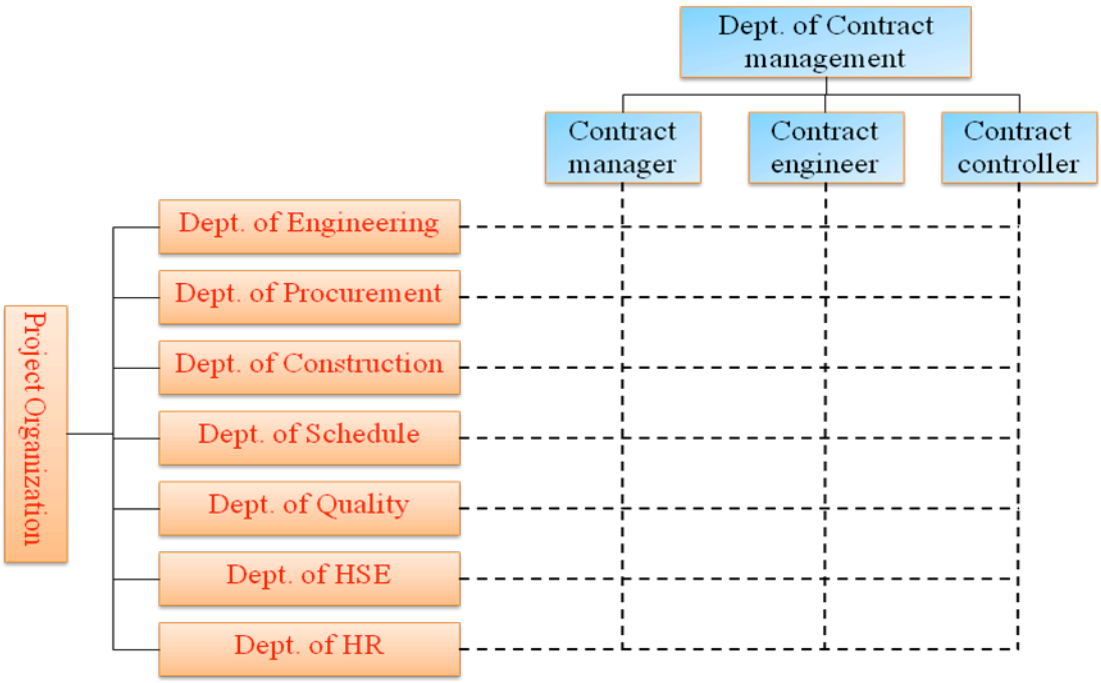


Fig.5-2 Contract management organization structure

	Project management	Contract management	Contract engineer	Contract controller
Contract form phase				
Contract negotiation and signature	E	C	P,D	D
Contract perform phase				
Contract analysis and inform		E,C	P,D	
Contract alternation		E,C	P,D	D
Contract convey		E,C	P,D	D
Contract compensation		E,C	P,D	D
Payment		E,C	P,D	D
Contract ending phase				
Performance estimate	D	D	D	
Documentation			P	D

P-plan, E-make the decision, C-check, D-do

Table 5-1 Contract management function breakdown

The table 5-1 showed above is a matrix of contract management function breakdown. Contract management is divided into three phases, the contract form phase, the contract perform phase, and the contract-ending phase. And main tasks will be assigned to certain members, so to reflect the responsibilities division.

5.3 Contract Management Process

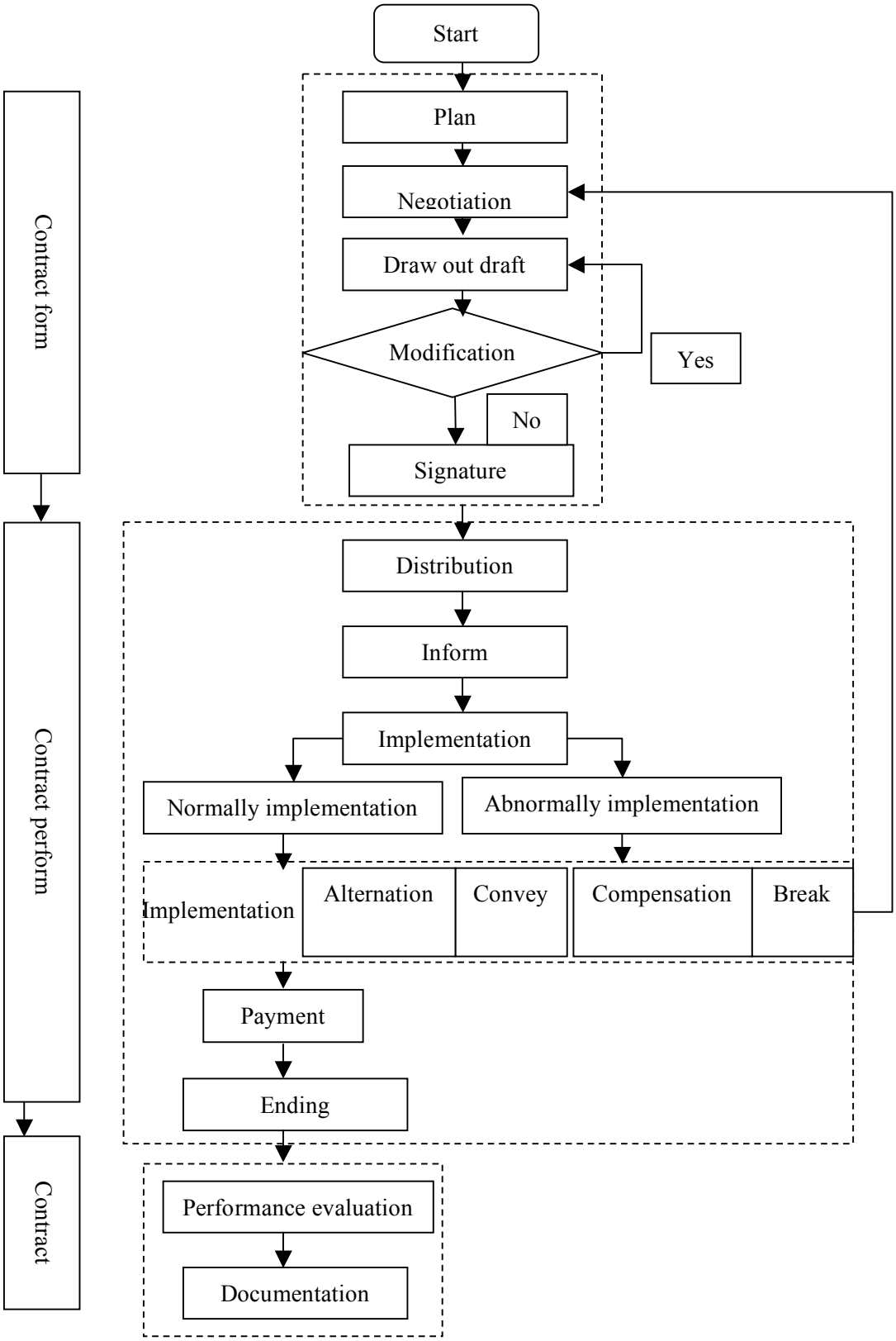


Fig.5-3 Contract management process

According to contract life cycle, the entire process of contract management can be cut down to three phases, namely the contract form phase, the contract perform phase, and the contract-ending phase.

(1) Contract form phase. At the beginning of the project, planning should be made, then negotiate with the owners on the contract content, draw the contract drafts and after modifications the final contract will come out.

(2) Contract perform phase. Distribute certain tasks to the appropriate departments according to the contract requirements, and inform relative staff about the detail requirements of the contract. During this phase, negotiations are still needed if the contract has to be altered, conveyed, or if compensation is acquired. The last one is the payment.

(3) Contract ending phase. Contract performance evaluation is needed. Lessons learnt and recommendations should be put into documents. This is good for the further improvement and development.

5.4 Contract controlling process

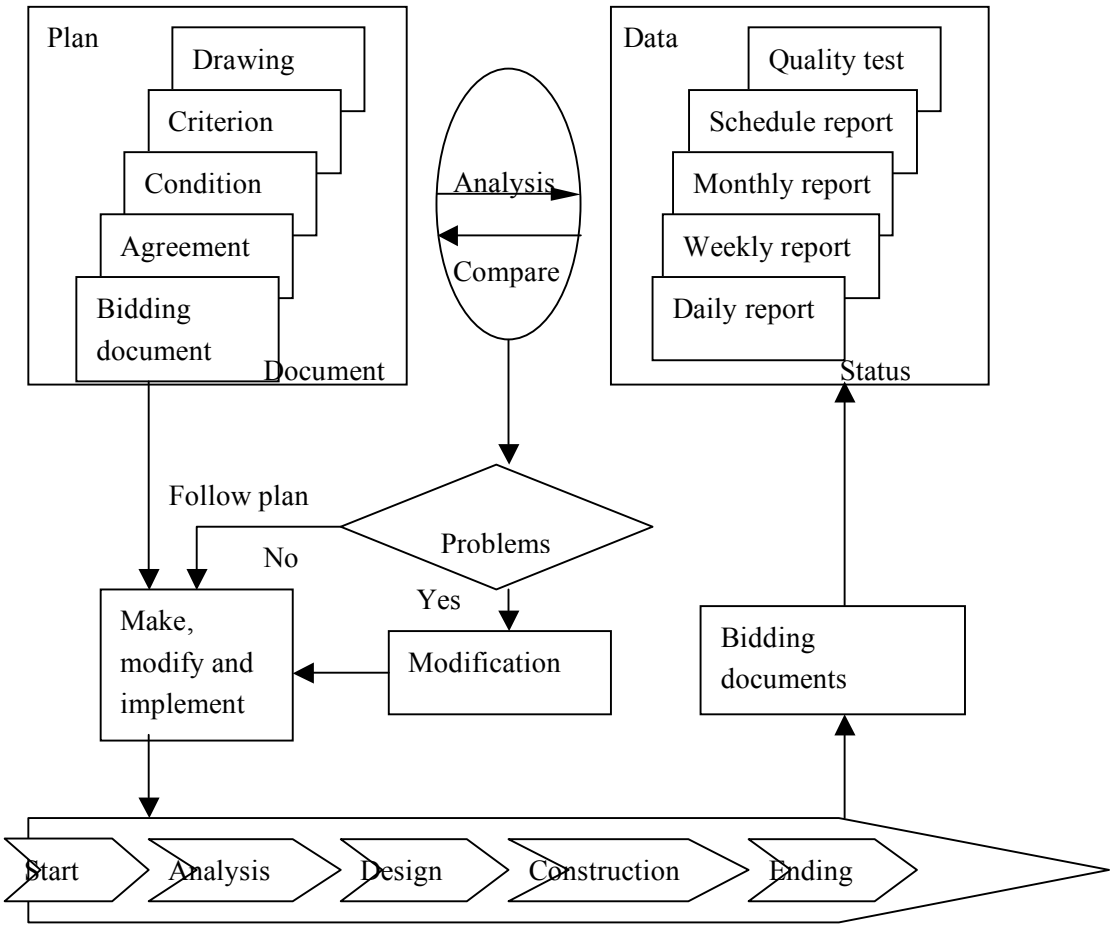


Fig.5-4 Contract control process

It is necessary to control the contract properly if we want to fulfill the project goal. Supervision, inspection, comparison and correction need to be done over the whole implementation process based on the planning.

Contract control process is a dynamic contract management process. Comparing the contract documents and planning with the actual state, finds problems that exist. Then decides whether to adjust the original implementation plan or make some modification.

Contract documents reflect the implementation plan, and the actual state through data collection.

5.5 Risk management suggestions

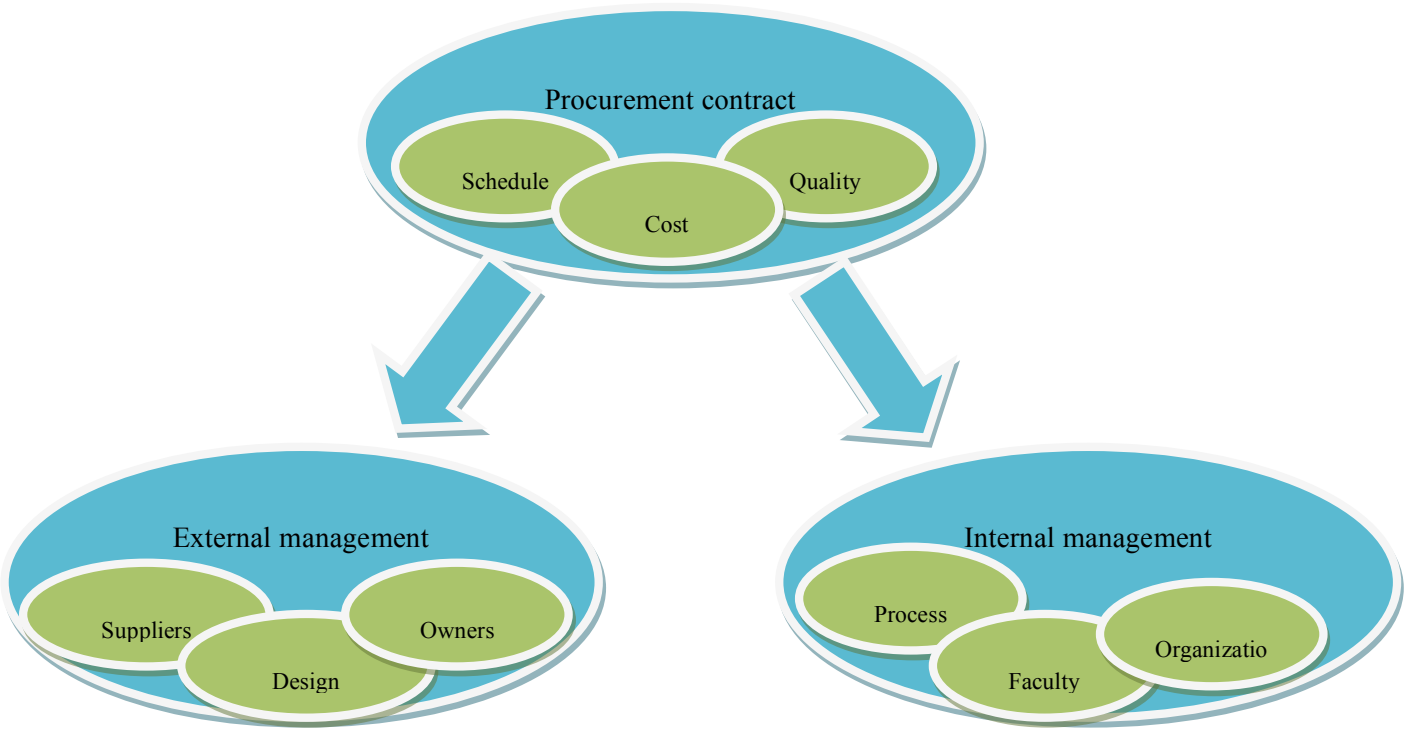


Fig 5-5 Risk management structure

EPC project procurement risk prevention measures

Internal management:

1、 To improve the system of reminders:

(1) For the intensive construction projects, the contractors should have full-time professional reminders to meet the schedule and quality needs of goods.

(2) It is necessary for the project team to develop detailed plans for the procurement of goods and take the initiative to participate in the manufacturing plan. For the critical thing

which will constraint the schedule, reminders need to report it to the project team and try their best to help suppliers solve the problem?

(3) Reminders need to strengthen management work for sub-contractors. Although EPC contractors have a direct relationship with suppliers, the situation of sub-contractors can affect the delivery of goods. Reminders not only need to understand the situation of suppliers but also need to keep track of the delivery status of sub-contractors.

2、 Improve the ability of procurement workers.

(1) It is good for procurement workers to join the regular training classes about procurement work.

External management:

1、 Choose reputable suppliers.

Supplier management cannot be ignored because supplier's selection can directly affect the quality of engineering materials, which affects the success or failure of EPC project. It plays a vital role in reducing costs and increasing the speed of procurement.

In order to do a good job in the management of suppliers, the important thing is to make a good choice about suppliers. Supplier's management includes the following four important aspects:

(1) The establishment of a supplier database.

(2) The development of perfect supplier selection indicators.

(3) The establishment of a supplier evaluation system.

(4) The implementation of the above aspects. For EPC projects there are many risks in the procurement section, it is important to choose reputable suppliers according to the

database so as to reduce costs and risks.

2、 Strengthen communication with owners and management companies to reach a consensus.

In the procurement of goods, the contractors need to take full account of requirements and recommendations of the owners, otherwise when the project is completed, owners raise objections such as the material doesn't meet the requirements. Then it will bring huge risk for the project.

5.6 Performance evaluation based on Fuzzy-AHP

AHP (Analytical Hierarchy Process) was invented by a well-know operation research expert, professor Shatti in the early 1970's. It is a simple but practical and effective method to deal with multi-objective, multi-criteria, multi-factor, and multi-level comprehensive evaluations. It is an analysis method combining qualitative and quantitative methods. Combined with multi-level fuzzy comprehensive evaluation, AHP can be used to evaluate the performance of contract management.

(1) Comprehensive evaluation index system of contract management

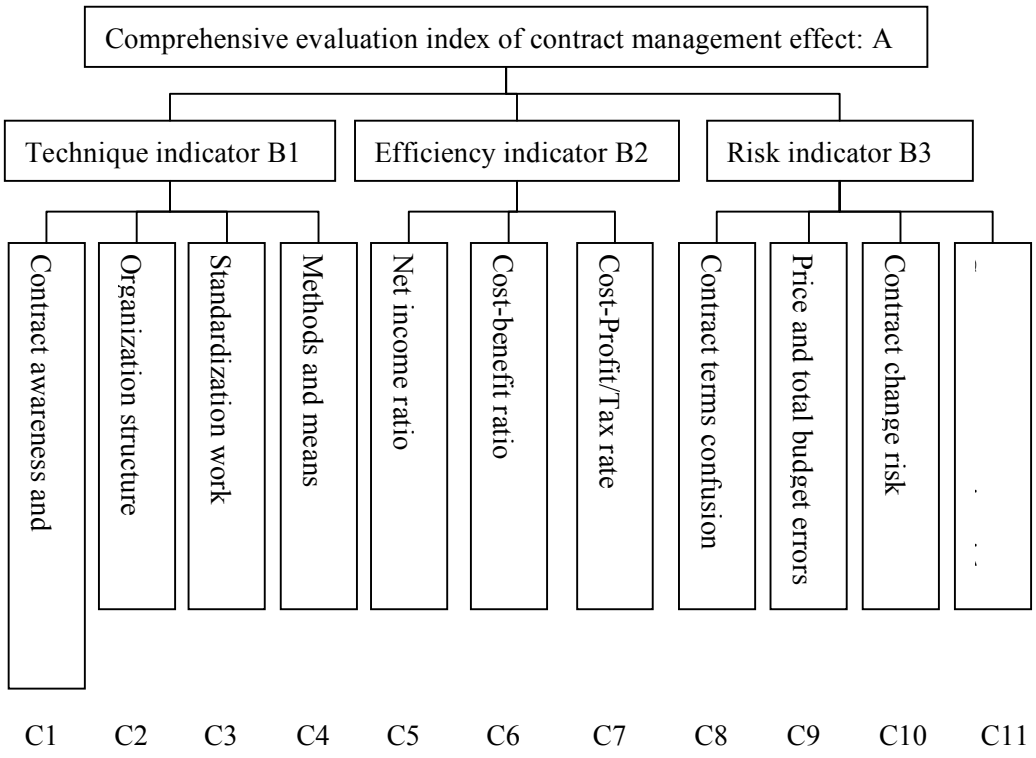


Fig.5-6 Comprehensive evaluation index

(2) Establish the judgment matrix

NO.	The importance of grades	aij
1	i and j are equally important	1
2	i is a little more important than j	3
3	i is more important than j	5
4	i much more important than j	7
5	i is definitely more important than j	9
6	i is a little less important than j	1/3
7	i is less important than j	1/5
8	I much less important than j	1/7
9	i is definitely less more important than j	1/9

Table 5-2 Judgment matrix

Notice: aij={2, 4, 6, 8, 1/2, 1/4, 1/6, 1/8} means that the importance of grade is between aij={l, 3, 5, 7, 1/3, 1/5, 1/7, 1/9}.

For example to level A,

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

Suppose:

To level A:

$$A = \begin{bmatrix} 1 & 2 & 1/4 \\ 1/2 & 1 & 1/5 \\ 4 & 5 & 1 \end{bmatrix}$$

To level B1:

$$B1 = \begin{bmatrix} 1 & 1/2 & 1/4 & 1/7 \\ 2 & 1 & 1/3 & 1/5 \\ 4 & 3 & 1 & 1/3 \\ 7 & 5 & 3 & 1 \end{bmatrix}$$

To level B2:

$$B2 = \begin{bmatrix} 1 & 3 & 1 \\ 1/3 & 1 & 1/3 \\ 1 & 3 & 1 \end{bmatrix}$$

To level B3:

$$B3 = \begin{bmatrix} 1 & 1/3 & 4 & 3 \\ 3 & 1 & 7 & 5 \\ 1/4 & 1/7 & 1 & 1/2 \\ 1/7 & 1/5 & 2 & 1 \end{bmatrix}$$

(3) The biggest latent root and latent vector

To level A:

$$A = \begin{bmatrix} 1 & 2 & 1/4 \\ 1/2 & 1 & 1/5 \\ 4 & 5 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 5.5 & 8 & 1.45 \end{bmatrix}$$

$$\begin{bmatrix} \frac{1}{5.5} + \frac{2}{8} + \frac{0.25}{1.45} \\ \frac{0.5}{5.5} + \frac{1}{8} + \frac{0.2}{1.45} \\ \frac{4}{5.5} + \frac{5}{8} + \frac{1}{1.45} \end{bmatrix}$$

$$\begin{bmatrix} 0.604 \\ 0.354 \\ 2.042 \end{bmatrix}$$

$$0.604 + 0.354 + 2.042 = 3$$

$$W_A = \begin{bmatrix} \frac{0.604}{3} \\ \frac{0.354}{3} \\ \frac{2.042}{3} \end{bmatrix} = \begin{bmatrix} 0.201 \\ 0.118 \\ 0.681 \end{bmatrix} = (0.201, 0.118, 0.681)^T$$

$$\lambda_{max} = \frac{1}{3} AW_A = 3.025$$

The same as:

$W_{B1} = (0.066, 0.110, 0.569)^T$ $\lambda_{max} = 4.059$

$W_{B2} = (0.429, 0.143, 0.429)^T$ $\lambda_{max} = 3$

$W_{B3} = (0.255, 0.571, 0.063, 0.110)^T$ $\lambda_{max} = 4.058$

(4)Consistency check:

CI（coincidence indicator）

RI（random consistency index）

CR（consistency ratio）

CR=CI/RI

$$CI = (\lambda_{max} - n)(n - 1)$$

RI table:

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

If CR<0.10, the matrix has the consistency. If not, we have to change the matrix and do it again.

To matrix A:

$$CI = (\lambda_{max} - n)(n-1) = \frac{(3.025-3)}{2} = 0.0125$$

CR= CI/RI=0.0125/0.58=0.022<0.10. So it has the consistency, and the weight of each index is $W_A = (0.201, 0.118, 0.681)^T$

Same as W_{B1}，W_{B2}，W_{B3}

Then:

$$W = （W_1，W_2，W_3，\ldots，W_{11})$$

$$= (0.201 \times 0.066，\ 0.201 \times 0.110，\ 0.201 \times 0.255，\ 0.201 \times 0.569，$$

$$0.118 \times 0.429，\ 0.118 \times 0.143，\ 0.118 \times 0.429，$$

$$0.681 \times 0.255，\ 0.681 \times 0.571，\ 0.681 \times 0.063，\ 0.681 \times 0.110）$$

$= (0.013, 0.022, 0.051, 0.114, 0.051, 0.017, 0.051, 0.174, 0.389, 0.043, 0.075)$

(5) Factors judgment sets

R=（excellent, good, average, below average）

	excellent（r1）	**good**（r2）	**average**（r3）	**below average**（r4）
C1	Strong awareness and excellent competence	Good awareness and competence	Average awareness and competence	Poor awareness and competence
C2	Excellent organization and function	Good organization and function	Average organization and function	Poor organization and function
C3	Scientific, comprehensive, reasonable	Good standardization	Have the standardization, but not so good	No standardization
C4	Advanced, effective and innovative	Advanced and effective	Not much used	Never be used
C5	leading level in the same industry	leading level in the same industry	Average level in the same industry	poor level in the same industry
C6	leading level in the same industry	leading level in the same industry	Average level in the same industry	poor level in the same industry
C7	leading level in the same industry	leading level in the same industry	Average level in the same industry	poor level in the same industry
C8	Clear terms, clear powers and responsibilities	Terms, powers and responsibility are almost clear	Terms, powers and responsibility are not so clear	Terms, powers and responsibility are unclear

C9	Exact price and total budget	Good price and total budget	price and total budget are not so good	price and total budget are wrong
C10	Almost no changes, and the change process are clear	Not many changes and the change process are kind of clear	Many changes and the change process are not so clear	A lot of changes and the change process are unclear
C11	a high success rate of claims	Parts of claims are successful	A little parts of claims are successful	little parts of claims are successful

Table 5-3 Judgment index and membership grade

(6) Expert evaluation

$$D = \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} \\ d_{21} & d_{22} & d_{23} & d_{24} \\ \cdots & \cdots & \cdots & \cdots \\ d_{111} & d_{112} & d_{113} & d_{114} \end{bmatrix}$$

$$d_{ij} = \frac{m_{ij}}{n}$$

n: the number of the people who participate in the evaluation

m_{ij} to the indicator i, the number of the people who choose the membership grade j

(7) Comprehensive evaluation

$$A = WD = (W_1, W_2, W_3, \ldots, W_{11}) \times \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} \\ d_{21} & d_{22} & d_{23} & d_{24} \\ \cdots & \cdots & \cdots & \cdots \\ d_{111} & d_{112} & d_{113} & d_{114} \end{bmatrix}$$

$$= (k_1, k_2, k_3, k_4)$$

Suppose:

A=（0.16，0.35，0.31，0.18）

$$\mathrm{Max}(k_1,\ k_2,\ k_3,\ k_4) = k_2$$

So: at last, the evaluation of the contract is “good”.

6 Conclusions

The work of the project team centralized the information about the Saudi polyolefin project. In the very short period of time the project team was able to identify and analyze the contract risks that occurred during the project and was able to find several possible areas where the SCCS can be improved. The project team has provided a comprehensive recommendation for SCCS as they move forward with the contract management system. According to the case study, the contract management system is a worthwhile idea for the company to participate in international competition.

In completing this project there were a few constraints and limitations that the group had to over come. Since two of the group members were from America and three of the group members were from China, there was a language barrier. The interviews the group had with the company were done in Chinese and the two members from America were unable to understand the conversations. The group overcame this by recording the interviews and the Chinese students would later translate the conversations for the American students. Another constraint was the short amount of time the group had to complete the project. The group had only four weeks to analyze the company's problems, and then create a solution to satisfy the company's needs. This constraint was overcome through hard work and determination.

There may be a few possible challenges in implementing our system for the company. It will take some research and time for the company to get properly acquainted

with our newfound ideas. They may also have to hire people with contract risk management experience and possibly train some of their current employees.

This project has contributed in a major way to the company. This project was done at a perfect time for the company because they are merging with an engineering company. They were already a top-notch company but signing with an engineering company makes them even more prosperous and proper contract risk management is going to be vital for them because the larger their company gets the more risks they are going to endure. Before this project, the company did not have a steady contract risk management system in place. But now they can take our project, analyze it, and implement some of our ideas.

Future work from this project would consist mainly of documentation. As the company goes from project to project and contract to contract they can document what has worked and what has not worked. This will allow them to have the most sufficient system possible.

Appendix A: Record of the first interview in SCCS

Questions and topics prepared:

1) Tell us something about your EPC construction model. Talk about the characteristics, advantages and others.

2) Which aspect of the project do you think were the most worthy to research on: procurement risk, design risk, or financial risk?

3) What is the biggest risk of the Saudi Project? How did you manage to solve these problems? What do you think is the biggest difference between domestic projects and overseas projects?

4) Do you have a case study for a domestic project so that we can compare with the overseas project?

5) Does your company have a normal procedure to manage and control risk?

6) How to coordinate the relationship between E, P, and C?

7) What do you think is the major reason for project delay?

8) Do you have a system to control the project schedule?

9) What's the total price of the project, and what was the share between 3 companies?

10) What's the actual cost and profit?

11) What's the origin of the project finance?

12) Do you have a system to control the expense?

13) Where do you get the material, from the locally or overseas?

14) What do you do when the type, quality, and quantity problems happen?

Appendix B: Record of the second interview in SCCS

1. Political risk

(a)Please comment on the current political conditions in Saudi Arabia and their impacts on foreign investments.

(b)What are some actions that Chinese firms can undertake to reduce political risks in Saudi Arabia?

2. Procurement risk

(Labor)

(a) Are skilled construction workers easily available in Saudi Arabia?

(b) If the skill level is low, what are some of the measures that are undertaken to find better quality workers?

(c) What is the production level of Saudi Arabian workers?

(Plant and equipment)

(a) Are plants and equipment easily available in Saudi Arabia?

(b) Are they properly maintained?

(Materials)

(a) Are construction materials easily available in Saudi Arabia?

(b) What is the quality of the construction materials in Saudi Arabia?

(c) Taxes imposed on imported materials would jack up the cost of construction. How is this problem addressed in construction projects in Saudi Arabia?

3. Financial and economic risk

(a) How is the risk of currency fluctuation of construction projects managed?

(b) Where are the likely sources of finance that are available to china contractors and consultants?

(c) Are construction delays frequent in Saudi Arabia? How are these delays overcome or handled?

(d) How are materials shipped, and what are the costs of the different types of transportation (whether its ships, trucks, or planes)?

(e) What is your market environment?

(f) What was your planned cost for the project compared to the actual cost of the project?

(g) If there a difference in the planned cost compared to the actual cost, what caused this?

4. Design risk

（a）Are architects in Saudi Arabia prompt in issuing drawings?

（b）Are design changes frequently made?

（c）What are the usual practices to reduce design risk in Saudi Arabia?

5. Construction related risk

(a) How are the following risks managed in Saudi Arabia (weather; soil conditions; equipment failure; accidents)?

(b) What is the timetable for the completion of the project (planned timetable compared to actual timetable)?

(c) If the project was not completed as planned, what caused the delays?

6. Cultural risk

(a) Is there a big cultural difference between China and Saudi Arabia?

(b) Do Chinese firms have difficulties in placing Chinese staff in Saudi Arabia?

(c) Is the culture difference between both countries improving?

(d) With the difference in culture, what are some of the communication methods undertaken to ensure that work can be done effectively and efficiently?

Time: 2009-7-2

Place: Second Construction Company of Sinopec

People:

Wu Guohua

Wang Jingyue

Jiang Lizhong

Wang Shaohua

Mi Tongling

Ryan（SEU）

Shelly（SEU）

Young（SEU）

Cristian (WPI)

Kyle (WPI)

Schedule:

9：15——11：30 Interview

12：30——14：00 Additional Interview

14：30——15：30 Plant Tour

Record material collection (case):

1, Teller: Wang Jingyue

Different understanding of language ——Understanding of ‘unit’

Different cultural backgrounds, companies, people have different understanding of the word ‘unit’. In order to get the exact definition of unit, more than ten people discussed a whole day. Then came to the conclusion: from the E (engineer) to packaging is a complete unit.

2, Teller: Wang Jingyue

Different understanding of language ——Understanding of ‘Twice a day’

‘Once two days’ or ‘twice one day’, American English, British English, and other English-speaking countries, share different understanding.

3, Teller: Wu Guohua

Translation mistakes——Double handing / second handing

We translate the Chinese words as ‘double handing’ as usual. But actually it means transport for the second time, not two times.

4, Teller: Wu Guohua

Loop

Price is measured by loop, but loop cannot be defined exactly.

5, Teller: Wang Jingyue

When the steel suppliers have the capacity to produce, the blueprint was not ready, when the blueprints are ready; the suppliers already got other work to do. It has passed the dead line of the contract, so the suppliers don't have to carry out the contract. At last SCC paid much more to persuade them to produce the steel.

6, Teller: Wang Jingyue

AK has to do the procurement. While the supplier was really busy and don't have spare people to do the work. Finally, SCC mobilizes more than 100 people from china to Saudi. Because of this the whole project has been delayed for nearly 6 months.

7, Teller: Wang Jingyue, Wu Guohua

The major method to solve dissension is negotiation. Seldom ask for help from legal method.

8, Teller: Wang Jingyue

A building has to be casted at one time. If it were not successful, everything has to be put down and start from the very beginning. The cost and waste will be large. Because it is such a huge one, something is not under control. At last the owners refused to sign the acceptance, they said the quality of the construction did not meet the standards. Later through many

checkouts it was proved to be safe. Then the owners accepted it.

9, Weather

Control room, wall paint, painting dozens of times.

10, Teller: Wu Guohua

Price risk

Predict price 300

Highest price 500

Lowest price 200

The actual average price 400

Price= labor costs (stable) + materials fee (change all the time)

11, Teller: Jiang

They have to speed up the work when delay happened. They set a joint fund to mitigate the influence of the risks?

Appendix C: Record of the third interview in SCCS

Questions and topics prepared:

Did you analyze the environment before bidding?

How did SCCS outbid the competition?

What are the detail responsibilities in the project?

Do you have a HSE management department? What are their responsibilities?

How to control the quality, schedule, expense, human resource, HSE, procurement risks through the contract?

Do you have a contract management department?

Do you think it's necessary to set up such a department?

What do you think is the major role of a contract?

Time: 2009-7-16

Place: Second Construction Company of Sinopec

People:

Wu Guohua

Wang Jingyue

Jiang lizhong

Ryan（SEU）

Shelly（SEU）

Young（SEU）

Schedule:

10:00——11：30 Interview

1, Process change. If the owners proposed the change, they will pay additional.

2, procurement procedure

Demand analysis

Supplier select

Price

Bidding

Selection

Manufacture

Transportation

Clearance

Site reception

Site management

3, Control department takes the control of costs and progress, but only monitoring not implementation. The implementation will be taken care of by other departments.

4, Reminder group, reminds of Quality Supervision.

5, Ice-making machine, drinking water is provided to keep the staff cool.

6, The most vulnerable accident is fall from high.

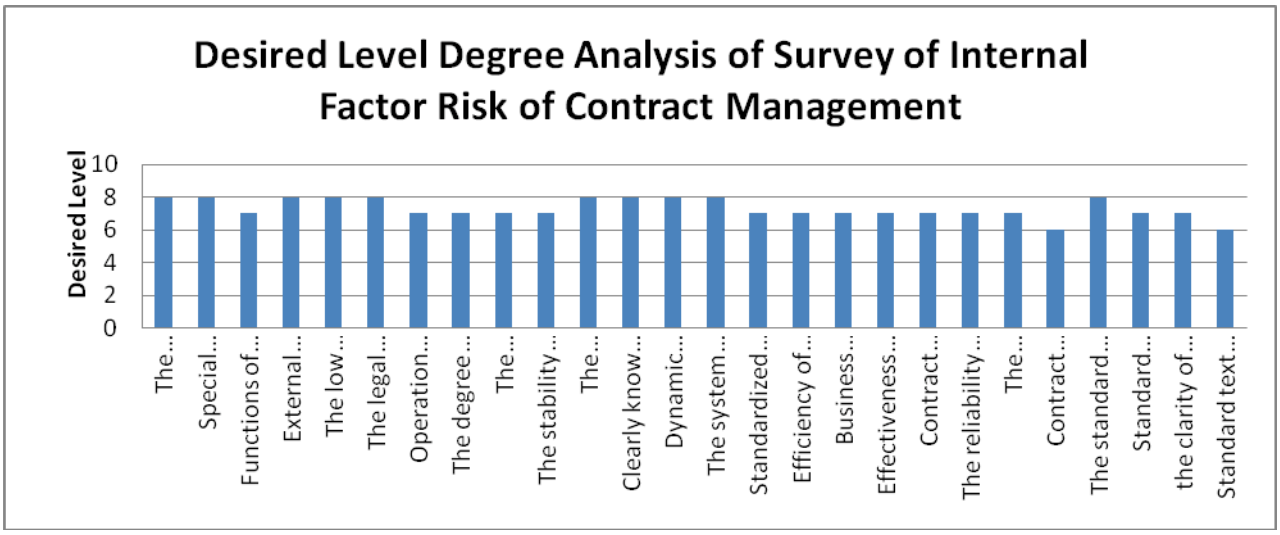
Appendix D: Questionnaire

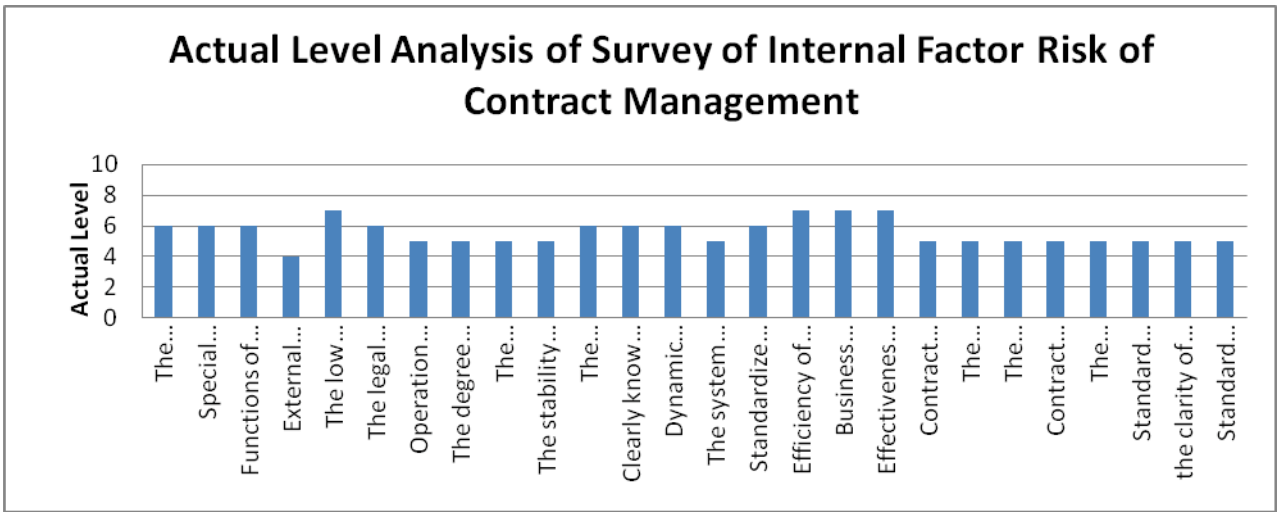
Survey Demonstration of Internal Factor Risk of Contract Management

Category	NO.	Contents	Desired Level	Actual Level
1 Organization structure risks	1	The adaptability of the contract management system	8	6
	2	Special contract management agency settings	8	6
	3	Functions of contract management department	7	6
	4	External Corporate Counsel / Lawyer's ability	8	4
2 Human resource risks	1	The low sense of the company responsible persons	8	7
	2	The legal knowledge and experience of legal work of the responsible persons in contract management department	8	6
	3	Operation ability of contract managers	7	5
	4	The degree of support for the law work from relevant departments	7	5
	5	The sufficiency of the legal stuffs	7	5
	6	The stability of the legal team	7	5
3 Contract management regulation risks	1	The robustness of the system	8	6
	2	Clearly know the regulation	8	6
	3	Dynamic adjustment of system	8	6
	4	The system of harmony（the system does not exist contradictory situation）	8	5
4 Contract process risks	1	Standardized business processes	7	6
	2	Efficiency of business processes	7	7
	3	Business Process operability	7	7
	4	Effectiveness of business processes	7	7

5	Contract management system risks	1	Contract information is delivered in time	7	5
		2	The reliability of the sources of contract information	7	5
		3	The usefulness of the contract information for decision-making	7	5
		4	Contract information network security	6	5
6	Standard document risks	1	The standard document is to cover the area of all transactions	8	5
		2	Standard document clarity	7	5
		3	the clarity of the scope of application of Standard document	7	5
		4	Standard text on the applicability of the practice of contract management	6	5

Items	1	2	3	4	5	6	7	8	9
Desired Level	Not important at all	Not important	Less important	Not very important	Average	A little important	Important	Obviously important	Extremely important
Actual Level	worst	Very bad	worse	bad	Average	good	better	Very good	best


Desired Level Degree Analysis of Survey of Internal Factor Risk of Contract Management
Desired Level
10
8
6
4
2
0
The...
Special...
Functions of...
External...
The low...
The legal...
Operation...
The degree...
The...
The stability...
The...
Clearly know...
Dynamic...
The system...
Standardized...
Efficiency of...
Business...
Effectiveness...
Contract...
The reliability...
The...
Contract...
The standard...
Standard...
the clarity of...
Standard text...


Actual Level Analysis of Survey of Internal Factor Risk of Contract Management
Actual Level
10
8
6
4
2
0
The...
Special...
Functions of...
External...
The low...
The legal...
Operation...
The degree...
The...
The stability...
The...
Clearly know...
Dynamic...
The system...
Standardize...
Efficiency of...
Business...
Effectivenes...
Contract...
The...
The...
Contract...
The...
Standard...
the clarity of...
Standard...


Actuality of the contract management
50
40
30
20
10
0
Organization structure risks
Human resource risks
Contract management regulation risks
Contract process risks
Contract management system risks
Standard document risks
Desired Level
Actual Level

Appendix E: Information about the Saudi Arabia Project

1、Introduction of the project

Owner: Saudi Basic Industries Corp (SABIC)

PMC: FW (Foster Wheeler)

Patent owner: DOW CHEMICAL &SABIC

Location: Yanbu Industry City

Content: (1) 400,000(500,000) t/y (ton/year) LLDPE (low density polyethylene)

(2) 400,000 t/y PP (Polypropylene).

(3) Package handling unit (PHU).

Contract period: 31.5 months (including engineering and procurement), 2005/7/20-2008/3/5.

Contract budget: about 750 million US dollars, in which about 350 million US dollars belong to SCC.

2、Responsibilities of the Commonwealth of the parties (PP & PE)

AK: in charge of the basic design and equipment procurement, completion and delivery;

SSEC: detailed design and other equipment and materials procurement, construction support;

SCC: All construction management and construction, also include the following:

All the construction / building materials procurement

Steel procurement

Anti-corrosion / insulation materials procurement

Customs clearance of imports of equipment and materials, hoisting transport

3、PHU execution mode

General principles:

Commonwealth to implement project management

Responsible for themselves

AK and SINOPEC sharing risk and profit by 50:50

Specific division of labor:

Design:

1, AK is responsible for the basic design (in addition to process systems) and the corresponding site design services

2, SSEC is responsible for the detailed design (in addition to process systems) and the corresponding site design services

3,responsible for the design process

Procurement:

1, AK and SINOPEC choose suppliers together.

2, AK provides the procurement services in the phase of the basic design.

3, SSEC is responsible for the procurement services in the phase of detailed design.

Construction:

1, AK and SCC implement the construction management together.

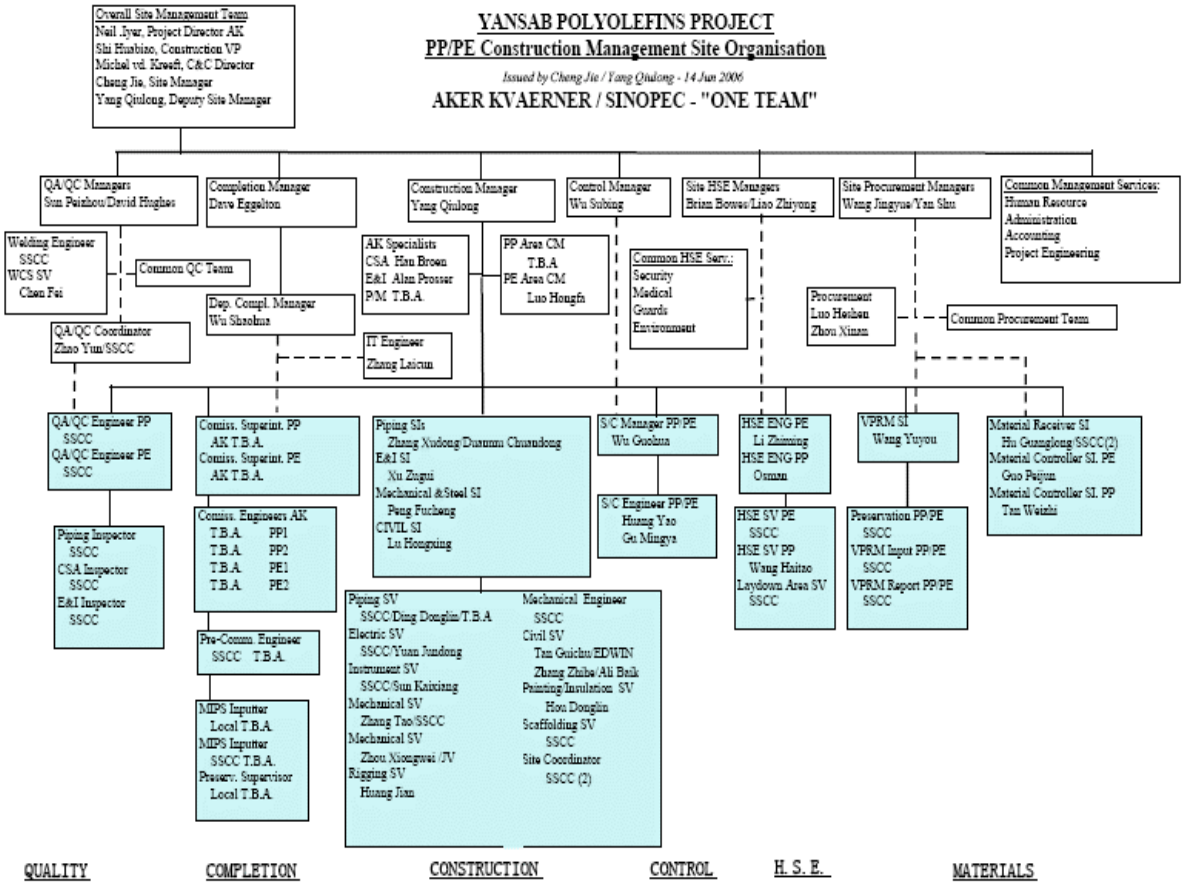
2, co-selected sub-contractors

3, SCC provided the temporary offices, as well as some storage materials, equipment.

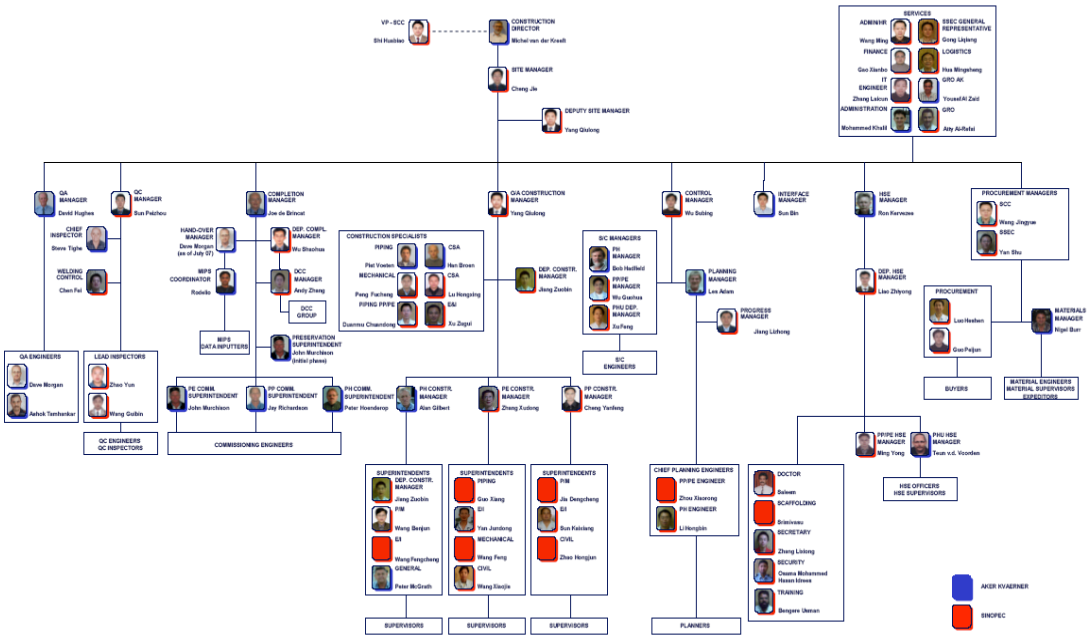
4、YANSAB Complex Project

The project is to construct the following production units in a self contained Petrochemical Complex located at a grass-roots site in the Industrial City of Yanbu.

Olefins Plant	1300 Kta	Technip
Ethylene Glycol Plant	700	Toyo
SHD / Butene-1Plant	50 Kta	SW
MTBE Plant	15 Kta	UOP
BTX Extraction Plant	250 Kta	SW
Polyolefins LLDPE Plant	400 Kta	AkerKvaerner / Sinopec
Polyolefins PP Plant	400 Kta	AkerKvaerner / Sinopec
Polyethylene HDPE Plant	400 Kta	SW
Utilities / Offsite Facilities	400 Kta	Fluor



YANSAB Polyolefins Project
Construction Management Organisation Chart – AKSI "One Team"
PEP Section IX – Att. F – revised 01-04-2007



ONE TEAM

Document Owner: M. v.d. Kreeft

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