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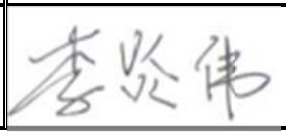
Author: Li Yanwei	
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Finally, I would like to thank my family and friends who have believe in me and support me with whatever "crazy" decisions I've made. With your love and supporting, I do not feel lonely wherever and whenever I am actually alone.

After 18 years full time studies as a student, one statement currently popular in China can finally apply to me at this moment as rewarding:

"*Mom won't worry about my study anymore*"

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Abbreviations

CI – Construction Industry

SC – Subcontractor

NN – Neural Network

JCT - Joint Contracts Tribunal

RSS – Rotary Steerable System

LWD – Logging While Drilling

MWD – Measuring While Drilling

TVD – Total Vertical Depth

MD – Measured Depth

CLD – Closure Distance

SLB – Schlumberger

BHI – Bakerhughes

HAL - Halliburton

NPT – Non-Production Time

CHAPTER 1. INTRODUCTION

Along with the rapidly changing environment of industry economy, each company is inevitably connected with each other directly or indirectly, and the inter-relationship among companies becomes more and more complex. A company can be both main contractor and subcontractor at the same time. As a main contractor, to maintain a long-term competitive advantage, companies have to constantly reorganize their value chains and focus on a few core activities and subcontract all other activities in which they do not have a world class status. Especially companies operating in volatile, high customized, or advanced technology fields find extensive subcontracting more attractive and strategically more critical for survival than before. In the meanwhile, as a subcontractor, a good understanding of the need of the main contractor is important for a company's success.

Subcontracting can be traced back to 1920s, first used in construction industry, prospecting in manufacturing industry, and finally spread into almost all industries, including oil industry. Subcontracting takes place when organizations moved jobs in fields such as accounting to other organizations that are experts. Magnezi, Dankner, Kedem & Reuveni (Magnezi et al., 2006) stated that subcontracting is the process of moving some activities to other organizations to achieve effective production. Khamanarong (Khamanarong, 2000)decribed the subcontracting process in the Northeastern region of Thailand, stating that subcontracting in the area is a process through which medium-sized or large industries subcontract some work to subcontractors who are local villagers. The main contractor provides technology and skills to the subcontractors in the village. When villagers have finished the training, the subcontractor provides raw materials or tools of production to the village to produce goods. When the village industry has finished the contracted work, the work is returned to the main contractor. A typical subcontracting process is illustrated by Fig.1 below.

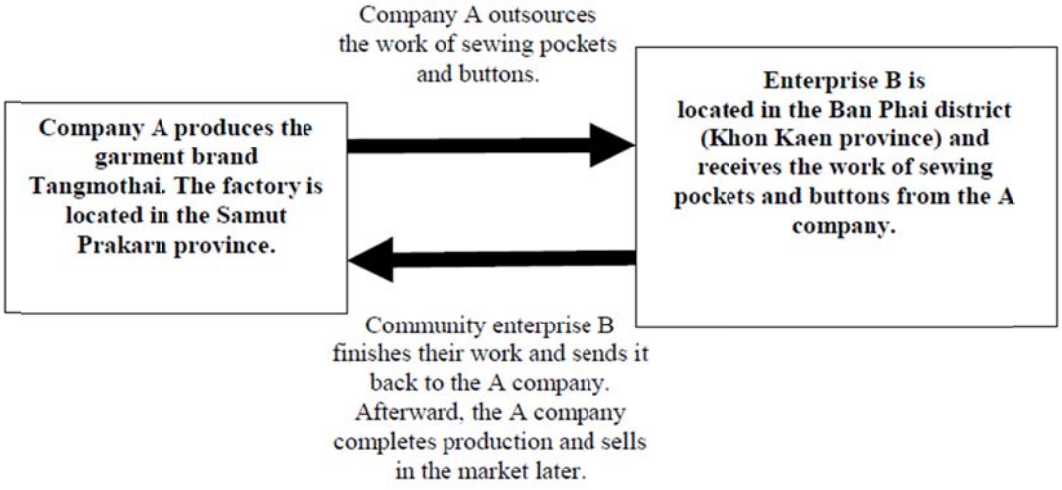


Fig.1. The outsourcing and subcontracting process (Khamanarong, 2000)

Directional drilling, as an important part of oil industry, is high-tech intensive. In China's domestic offshore oil drilling industry, COSL is the largest main contractor in directional drilling. But different from the situation of the other industry, due to lack of advanced technique in directional drilling such as Rotary Steerable Assembly and MWD/LWD system, in most projects COSL has to subcontract this part of service to some world class companies such as Schlumberge, Bakerhughes and Halliburton. On the other hand, when comes to worldwide oil industry, almost each oil company has its own main contractor in directional drilling department, to get the project, COSL has to qualify in the subcontractor selecting process. So how to manage these subcontractors in domestic market and qualify in the abroad market is critical for COSL's success.

1.1. Types of Subcontractor

A subcontractor is an individual or in many cases a company that signs a contract to perform part or all of the obligations of another's contract(2007). In other word, a subcontractor is like a person who is hired by a general contractor (or prime contractor, or main contractor) to perform a specific task as part of the overall project and is normally paid for services provided to the project by the originating general contractor. While the most common concept of a subcontractor is in building works and civil engineering, the range of opportunities for subcontractor is much wider and it is possible that the greatest number now operate in the information technology and information sectors of business.

The incentive to hire subcontractors is either to reduce costs or to mitigate project risks. In this way the general contractor receives the same or better service than the general contractor could have provided by itself, at lower overall risk. Many subcontractors do work for the same companies rather than different ones. This allows subcontractors to further specialize their skills.

In the United Kingdom economy, the need to respond to a rapidly changing environment and service a diverse infrastructure has encouraged flexibility and diversity in its subcontractor community with the majority of subcontractors now providing specialised skills to a wide range of companies.

The Joint Contracts Tribunal, also known as the JCT, produces standard forms of contract for construction, guidance notes and other standard documentation for use in the construction industry. According to JCT standard form contracts, three types of subcontractor(1998) are identified as below:

Domestic subcontractor

A subcontractor is who contracts with the main contractor to supply or fix any materials or goods or execute work forming part of the main contract. Essentially this contractor is employed by the main contractor.

Nominated subcontractor

Certain contracts permit the architect or supervising officer to reserve the right of the final selection and approval of subcontractors. The main contractor is permitted to make a profit from the use of nominated subcontractors on site, but must provide "attendance"

(usually the provision of water, power, restrooms, and other services to enable the nominated subcontractor to do his job). In effect the appointment of nominated subcontractors establishes a direct contractual relationship between the client and the subcontractor.

Named subcontractors
Effectively the same as a domestic subcontractor - A subcontractor who contracts with the main contractor to supply or fix any materials or goods or execute work forming part of the main contract. Essentially this contractor is employed by the main contractor.

1.2. Major Challenges Faced By COSL

Core technology in offshore directional drilling industry is owned by some international companies such as BHI, SLB and HAL, so subcontracting will be the choice and the only choice for Well-Tech COSL's directional drilling department. Dragged by this reality, it is hard for Well-Tech COSL's directional drilling department to be qualified in the overseas market.

1.3. Objective of The Thesis

In response to the high subcontracting proportion of directional drilling operation in COSL, the thesis will focus on how to manage the subcontractors to lower COSL's subcontracting cost in China's domestic market and maintain its competiveness in overseas market as well. At the end of the thesis, the author will be able to answer the following questions:

1) Why subcontracting and the benefit of subcontracting.
2) How to make subcontractor selection.
3) Give a general view of the subcontractor management system used by COSL in directional drilling department and find out the weakness of this system.
4) Introduce a factor-based weight sum method of subcontractor management used in EP project.

1.4. Methodology of The Study

1.4.1 Thesis Structure

The second chapter will firstly show us the shift of the relationship between subcontractor and contractor, and then use construction industry as an example to illustrate the benefit brought by subcontracting to answer the question why it is necessary to subcontracting and normally identified critical factor needed to consider when subcontracting.

The third chapter will start with general view of numbers of methods used to select subcontractor, and then show some detail of two specific methods such as NN method and WBSES method.

The fourth chapter will give a general view of the subcontractor management system used by COSL‘s Directional Drilling Department and point out the weakness of this system.

The fifth chapter will illustrate a factor-based weigh sum method of subcontractor management and use an example to illustrate the benefit it brought to Shenzhen base of COSL Well-tech directional drilling department in EP project.

The sixth chapter will discuss the research process of the thesis, including what the author had learnt and what can done further based on this study.

The Seventh chapter will offer conclusion of the study, recommendations will be presented and the limitations of the study will be explained.

1.4.2 Research Work Flow

Please refer to the diagram below for the work flow of the thesis.

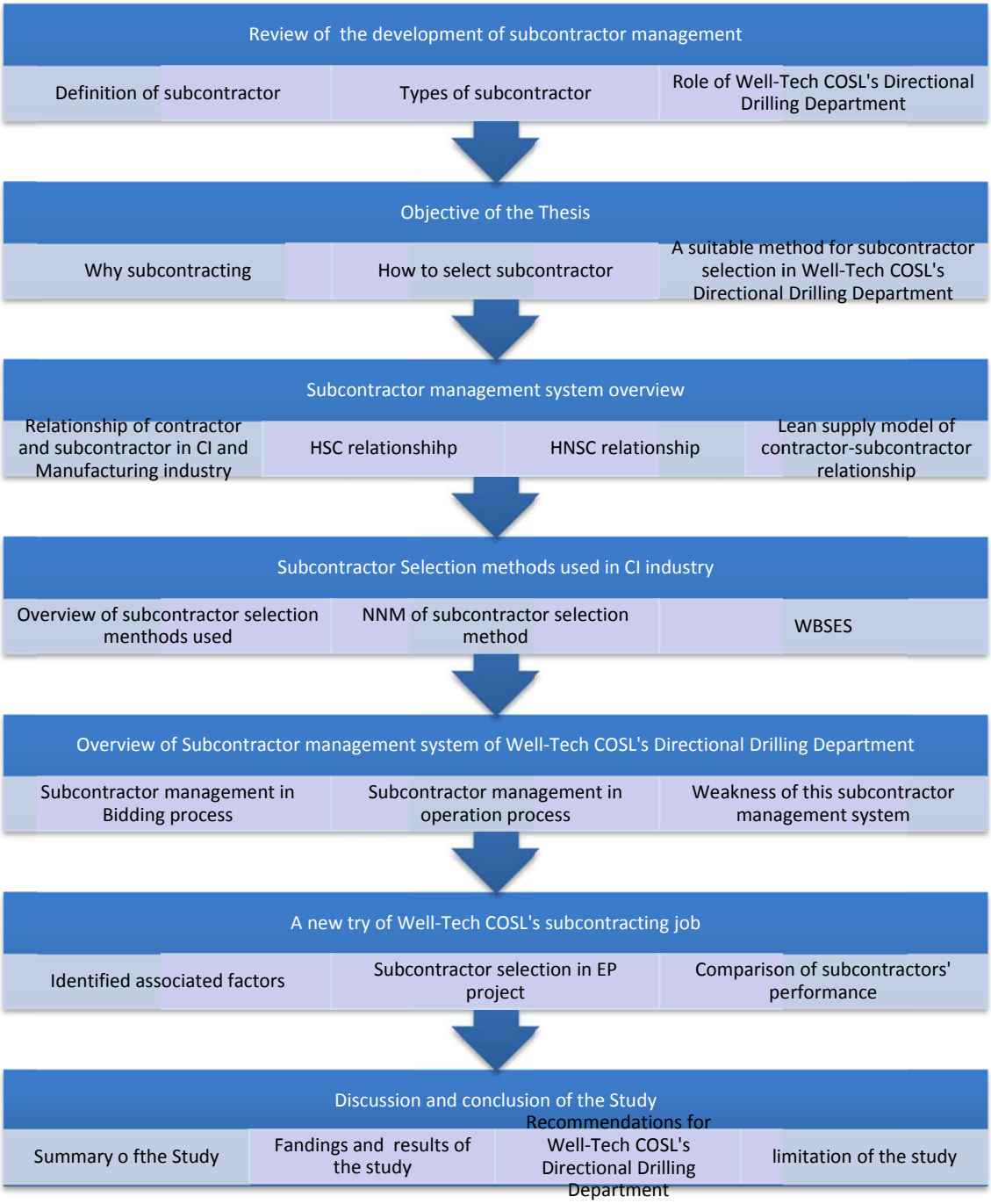


Table 1 Thesis research work flow (Khamanarong, 2000)

1.4.3 Data Resources

From the research work flow illustrated in Table 5, we can see that four kinds of data have been used by the thesis:

1) Data of subcontractor management within subcontractor selection process at construction industry.
2) Data of financial performance of Well-Tech COSL directional drilling department.
3) Data of subcontractor management within bidding and operation process at Well-Tech COSL directional drilling department.
4) Data of performance of some international enterprises such as SLB, BHI and HAL in previous and recently finished subcontracted projects.

1.4.4 Ethics, Validation And Reliability Of The Data

From the research work flow we can see that all the data being cited by the study are derived from credited literatures, or credited public data base that are open to everyone to use.

Meanwhile the research process are based more on industry practice review, it is not data critical but most qualitative and situate at industry overall level, therefore the conclusion and comments is validate and reliable to the industry in general in spite of limitations of the quantitative data being collected from different industries and geologic regions.

CHAPTER 2. WHY SUBCONTRACTING

2.1. Relationship Between General Contractor And Subcontractor

As mentioned in Chapter 1, the context in which most companies operate is undergoing radical changes. Companies are reorganizing their value chains and focusing on a few core activities, where they can achieve and maintain a long-term competitive advantage, subcontracting all other activities in which they do not have a world-class status. And there has been a clear shift towards long-term, commitment-based subcontractor-contractor relationships among the manufacturers. One study conducted by Ulla Lehtinen on Finnish manufacturers shows that the number of subcontractors whose production is based on long-term contracts increased from 66% to 83% between and 1996. And according to the study, an average of 42% of the sales went to the general contractor in 1996, while the same figure in 1988 was 38%. Especially companies operating in volatile, high customized, or advanced technology fields find extensive subcontracting more attractive and strategically more crucial for survival than before(van Weele and Rozemeijer, 1996).

2.1.1. Hierarchical Subcontractor-Contractor Relationship

This type of subcontractor-contractor relationship emphasizes synergistic problem solving, and is one important reason for the competitiveness of Japanese producers. It can be described as a tier structure (see Fig. 1); sub-sub-contracting in Japan may go down as far as five layers below general contractor. The first tier suppliers have been given responsibility for product development, systems undertakings and JIT deliveries. The second tier subcontractors are smaller, have less expertise, generally specialize in a narrower range of products, and work on production and/or processing. The third-tier subcontractors are given even less sophisticated in terms of competence and activities.

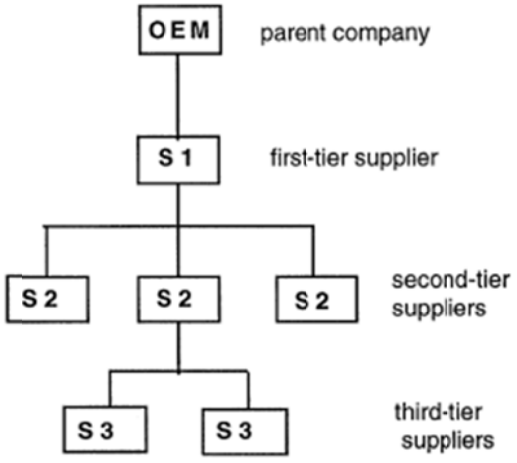


Fig.2. The model of a hierarchical subcontracting system (Lehtinen, 1999)

2.1.2. Horizontal Network-Type Subcontractor-Contractor Relationship

Along with the development of industry, a new type of subcontractor-Contractor partnerships is being adopted at an increasing rate by US and European companies. It can be described as a "network-type" organization, with cooperation between a wide range of business enterprises, including small to medium size firms, each with its own professional skills and expertise. The main features defining this partnership are exchange of ideas, information and benefits, joint problem solving, research and technology development based on long-term trust and faith.

Under this type of relationship, the core business of the subcontractor usually evolves gradually as presented in Fig. 3

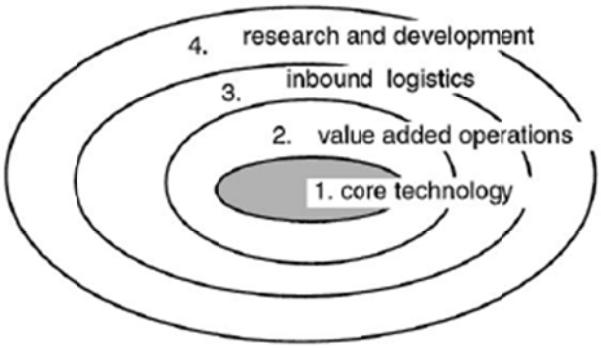


Fig. 3. The evolution of subcontractors' core business offered to the main contractor(Lehtinen, 1999)

In the first stage the subcontractor usually offers only limited number of operations to its general contractors. When the relationship between the subcontractor and the general contractor becomes successively more integrated with time, the subcontractor takes responsibility from production to system production as well as research and development. While a subcontractor evolves towards a system subcontractor, it starts to offer to the general contractors other value-added operations.

2.1.3. Lean Supply Model of The Subcontractor-Contractor Relationship

Lean thinking was born out of studying the rise of Toyota Motor Company from a bankrupt Japanese automaker in the early 1950s to today's dominant global player(Wikimedia Foundation, 2015). Lean is doing more with less. In other word, it means using least amount of effort, energy, equipment, time, facility space, materials and capital – while giving customers exactly what they want. The principles of lean thinking(Womack et al., 2013) are illustrated as below:

- Specify Value. Value can be defined only by ultimate customer. Value is distorted by pre-existing organisations, especially engineers and experts. They add complexity of no interest to the customer.
- Identify the value stream. The value stream is all the actions needed to bring a product to the customer.

- Flow. Make the value-creating steps flow. Eliminate departments that execute a single-task process on large batches.
- Pull. Let the customer pull the product from you. Sell one. Make one.
- Pursue perfection. There is no end to the process of reducing time, space, cost and mistakes.

Lean supply model of the subcontractor-contractor relationship is closely associated with enabling flow and the elimination of wasteful variation within the supply chain(Stratton and Warburton, 2003). It is initially developed in manufacturing industry.

Subcontracting operation to low cost overseas suppliers is an attractive lure in our global economy, but often undertaken without adequate regard for the market needs and the corresponding demands on the associated delivery systems. Products compete in different ways in different markets and delivery systems need to be designed with this in mind. Offshore supply offers attractive cost benefits, but the trade-off is often high levels of inventory to support a slower response capability. Thereby, lean supply model of subcontractor-contractor relationship emphasises the optimization on supply chain. Normally the physical flow in the supply chain can be simply described in the following scheme 1.

Scheme 1. Physical flow in the supply chain

To reach a lean supply model of subcontractor-contractor relationship, there are three things we should pay attention to.

a) Global logistic
   The global logistic is the biggest concern in such a supply chain as suggests the complexity of the physical flows. Costs and transit times attached to these flows are reduced as much as possible while keeping the same level of service. The two main areas of improvement are the packaging design and the distribution centre location. Packaging costs are minimized while respecting several constraints as shown in the following scheme.

Scheme 2. Packaging cost distribution

These costs are generally undesired since packaging yet necessary does not add any value to the product in accordance to customer needs.

b) Value stream mapping

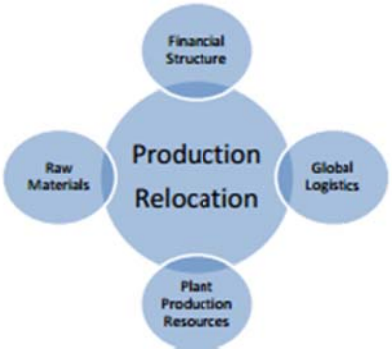
Under the lean model, as shown in the scheme, it considers the value added to the product throughout the supply chain processes and identifies the wastes mainly in terms of time and money.

Scheme 3. Value stream mapping

Every new opportunity must fit several constraints characterizing the business practices. Typical constraints are attached to fiscal, legal, political, commercial or operational aspects. Thus, multidisciplinary solutions are designed for increasing the supply chain performances.

c) Production planning

Given the plant locations and the market scale, it is crucial to produce locally as much as possible increasing thereby the performances of the supply chain by reducing mainly the transit times. Scheme 4 below shows the production planning.



Scheme 4. Production planning

Production opportunities are analysed while considering the most relevant constraints like the availability of raw materials, the plant production resources, the financial structure and the global logistics.

2.2. Benefits of Subcontracting

1) Subcontracting can greatly reduce main contractor's production cost. For example, if a company employs labourers itself, it will have a large amount of employment costs, such as wages per day and health insurance, but if a company choose to subcontract to other companies, it only need to pay for finished work, and if some work do not meet the requirement of quality, it can refuse to pay.
2) Subcontracting enable main contractors to receive a larger than designed order without expanding their facilities or buying more machines. Swenson (Swenson, 2005) explained that new production requires substantial investments, which small enterprises can rarely make. Thus, they will look for new business partners to produce for them or reduce their cost of investment.
3) Subcontracting enables itself to focus on its core business. Otherwise, if a company burdened by such non-core business, it would not even allow itself to break even. Through subcontracting, main contractor can focus on what they do best.
4) Subcontracting allow main contractor to finish an order on time even if it does not have access to a necessary amount of permanent workers. For example(Khamanarong, 2000), labourers in Northeast Thailand leave factories when it is time to grow crops, such as rice and corn. Consequently, factories in Northeast Thailand have a high turnover rate during the growing season.

2.3. Factors Affecting Subcontractors' Performance

Managing subcontractors does not simply involve asking them to allocate resources (labour, material, and machinery/equipment) into the jobsite whenever an activity is scheduled, and then pushing them to speed up the work without a clear consciousness of risk. Following I'll present you some factors that can greatly influence the performance of subcontractors.

1) Uncertainty in Workload

The overall trend in almost all industries is to do the job faster and cheaper. So the subcontractor have to organise themselves to tackle this new context of tightened supply chain, which implies shorter but also more reliable delivery times.

A subcontractor must be able to suggest a price and a delivery date to its general contractor as soon as he receives a rough description of the expected order. And along with it is the truth that most of time, the subcontractor workload consists in a mix of certain orders (often corresponding to repetitive orders) and uncertain ones (corresponding to orders under negotiation).

Most of the time, delivery dates are suggested on the base of the production manager's expertise; this can be efficient in a stable and known context, but this stability is more and more rare in the industrial environment(Geneste et al., 2003). In order to achieve a faster response to the final customers' demand, the subcontractor's managerial focus should be on issues concerning material and information flow in the network and within the companies. In the future, more shared education and other mutual development projects are needed between the general contractors and subcontractors to overcome the problems in logistics management and to promote the development of subcontractors' business.

2) Labour Skill

As we all know, workers especially skilled/experienced workers may be unavailable when in the industry boom period. Each worker may have tens even hundreds of opportunities to work on numerous projects. So, most subcontractors have to recruit new workers to maintain the sufficiency of labour, but the quality of these newcomers is uncertain.

3) Field Coordination

The field coordination is considered the other most important factor. Some interface problems may arise during operation. Normally CPM (critical path method) is adopted by most general contractors to plan a project and evaluate the schedule of the project, and the critical path is always determined ahead of the project execution. But, when duration of the near-critical path is close to that of the critical path, the field coordination becomes particularly important. If the activities on near-critical or non-critical path are not planned properly, the duration of the project can be greatly affected which means longer project duration, more investment. Consequently, field daily coordination meetings are always needed to arrange the activities on the near-critical path.

4) Material Delivery

Though material delivery is considered least important among all factors, it can also lead to great uncertainty on project duration. Material delivery always goes along with uncertainty in work order. So here we consider both expected and unexpected material delivery.

As part of a project, material delivery is also determined when the plan of the project comes out. Doing a project, timely delivery of material generally is expected, otherwise, there will be extra float time on both critical and non-critical path. But, when the project

meets a sudden change such as something unexpected happen and the project cannot go exactly with plan, material delivery plan need to be changed either. Otherwise, the project may have to stop and wait for material, which means more non-production time and more money. In summary, how to manage subcontractors to timely delivery to both expected and unexpected work orders is an important part of subcontractor management.

CHAPTER 3. PREVIOUSLY USED SUBCONTRACTOR SELECTION METHODS

Subcontracting has been widely used in the construction industry (CI). SCs play an important role in the success of construction projects. The success level of these projects mainly depend on the philosophy of selecting “the right person for the right job”(Arslan et al., 2008).

Methods have been proposed using approaches such as multi-criteria utility theory models (Hatush and Skitmore, 1998), evidential reasoning (Sönmez et al., 2002), decision criteria (Russell and Skibniewski, 1988), fuzzy set theory (Singh and Tiong, 2005) and linear programming (Elazouni and Metwally, 2000). Rahman and Kumaraswamy (Rahman and Kumaraswamy, 2004) showed the importance of relational, trust and joint-responsibility-related factors for selecting different parties. Palaneeswaran and Kumaraswamy (Palaneeswaran and Kumaraswamy, 2000) focused on developing a model for contractor prequalification and bid evaluation in design and build projects. Moreover, Jaselskis and Russel (Jaselskis and Russell, 1992), Crowley and Hancher (Crowley and Hancher, 1995), RusselKumaraswamy (Kumaraswamy, 1996) and Alsugair (Alsugair, 1999) have identified commonly used criteria for prequalification and bid evaluation and have proposed methodologies for contractor selection.

Alarcon and Mourgues (Alarcón and Mourgues, 2002) proposed a contractor selection system that incorporates the contractor’s performance prediction as one of the criteria for selection. They developed a conceptual model that helps to identify information needed for a comprehensive evaluation and used it for the proposed contractor selection system. Russell and Skibniewski (Russell and Skibniewski, 1990) developed QUALIFIER -1, a computer program to aid decision makers in prequalification. Then, Russell et al. (Russell et al., 1990) developed QUALIFIER – 2 by adding some extra functions to QUALIFIER – 1.

Holt et al. (Holt et al., 1994) provided example applications of multi-attribute analysis for evaluating construction bidders. Furthermore, Holt (Holt, 1998) reviewed and analysed the use of different contractor selection methodologies and discussed the advantages and disadvantages of these methods.

Kumaraswamy and Matthews (Kumaraswamy and Matthews, 2000) showed how partnering principles can be profitably applied to the SC selection process. Maturana et al. (Maturana et al., 2007) developed an on-site evaluation method based on lean principles and partnering practices. The method supports SC selection based on their previous performance and allows MCs to help SCs improve their performance by providing them with periodic feedback.

In all, a large number of SC selection methods have been proposed. In this part the author will give some details of two methods: a neural network application to support management in SC rating and a Web-based subcontractor evaluation system.

3.1. A Neural Network Method In SC Rating

From a methodological point of view, the process of subcontractor selection can be schematized in three phases:

a). Selection of the rating parameters to be assessed;
b). Parameters evaluation;
c). Competitor comparison;

Main contractor trying to select a specialized firm to carry out part of a project, and this is normally based on the evaluation of both the bids received by the potential subcontractors and the competitors 'characteristics such as reliability, size, etc. But in this subcontractor selection process it is not always easy to recognize precise rules, but there is a coherent way to solve the problem. This coherence can be rooted in intuition, experience, common sense, or not explicitable rules. Then, subcontractor selection becomes a problem usually solved by subjective criteria, based on personal experience and belief. The complexity of subcontractor selecting, due to the uncertainty and ambiguity involved in the decision making process, requires a formalization aimed to reduce the experts 'subjectivity. In this recognition, Vito Albino (Albino and Garavelli, 1998) developed this Neural Network method to optimize this process. The NN method includes three phases:

1) Design of the NN. Usually this phase can be divided into two activities: the definition of the network architecture and the definition of the network internal rules;

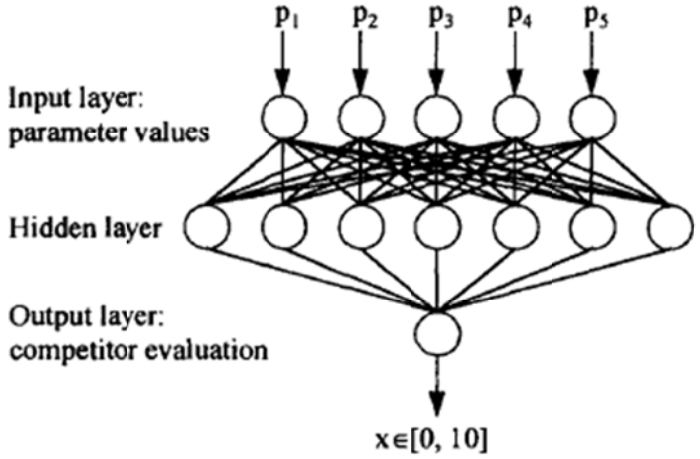


Fig. 4. A simple example of Neural network architecture (Albino and Garavelli, 1998)

2) Programming. This results in a training set of examples suitable to make the network learn the decision makers' behaviour. Furthermore, the network learns the way to provide a response to the information introduced by the users.
3) Testing. This means checking the network performance with a specific algorithm.

3.2. A Web-based Subcontractor Evaluation System

The Web-based subcontractor evaluation system was proposed by Gokhan Arslan and Serkan Kivrak (Arslan et al., 2008) aiming to select the most appropriate SCs for their relevant sub-works, speed up the selection process and gain time and cost savings during the bidding process in construction industry. Phases during a typical bidding process can be illustrated by Fig. 5.

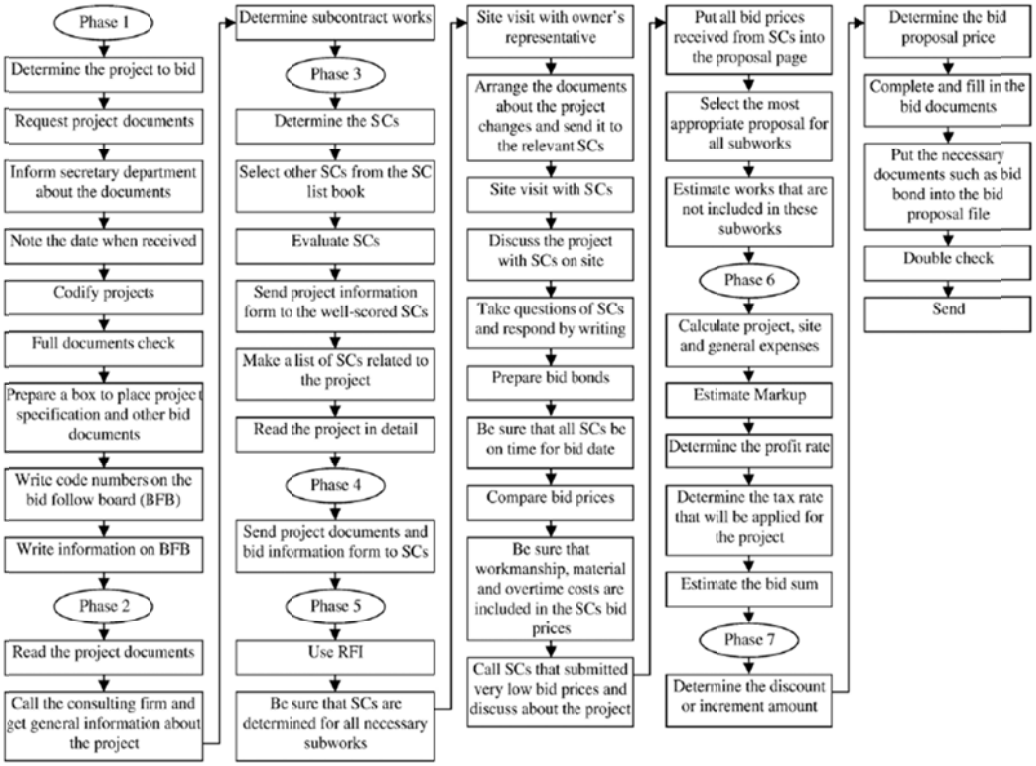


Fig.5. Phases during a typical bidding process(Arslan et al., 2008)

Bidding for construction projects is a critical decision for construction companies especially in the international construction market (Dikmen and Birgonul, 2004) as the amount of profit level is critically determined at this stage. A simplified SC selection during the bidding process is illustrated in Fig.6.

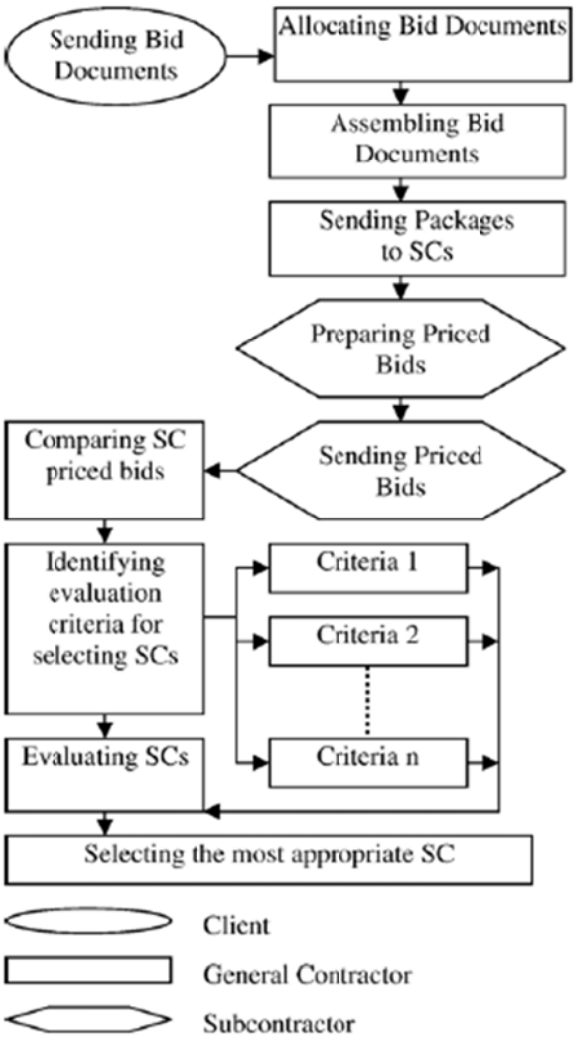


Fig.6. Simplified sub-contractor selection during the bidding process (Arslan et al., 2008)

Normally, the lowest bid price is usually the key determinant factor for selecting SCs in traditional approaches (Tserng and Lin, 2002). But Arslan and Serkan Kivrak pointed out that companies should implement a systematic evaluation process in the selection of the right SCs for the right job. Thus, the web-based sub-contractor evaluation system was developed.

The web-based sub-contractor evaluation system was based on the IT technology. It contains the following procedure.

a) Identify the factors that should be considered in the subcontractor selection prcess: the criteria may include the quality of production, efficiency, employment of qualified members, reputation of the company, accessibility to the company, completion of the work on time, etc.

b) Data collection: collecting related data as much as possible to form a database, MySQL, which is a database management system that can handle large volume of data, and provide fast search and short processing time.
c) Set SC evaluation criterion: cost, quality, time and adequacy and so on. It can be illustrated by Fig7.

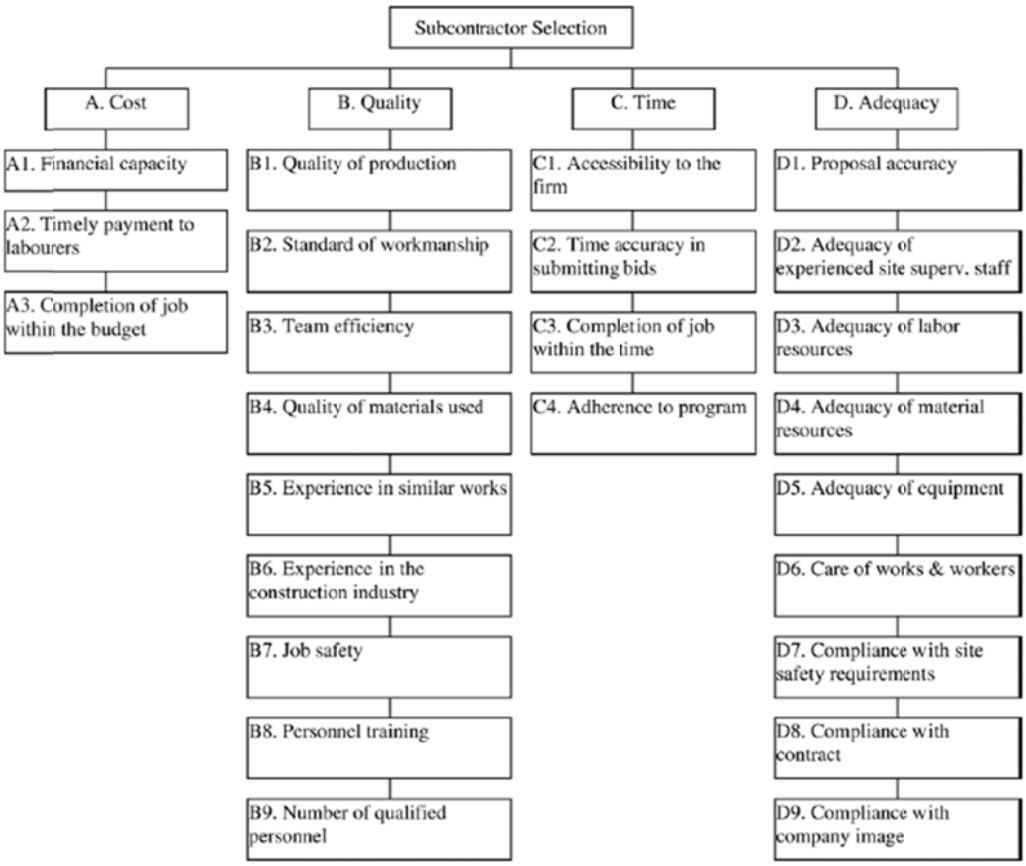


Fig.7. Evaluation criteria for subcontractor selection (Arslan et al., 2008)

d) SC evaluation in WEBSES
In WEBSES, SCs can be evaluated according to the sets of evaluation criterion which are grouped under these headings: cost, quality, time and adequacy. In Fig.8, the evaluating process is illustrated.

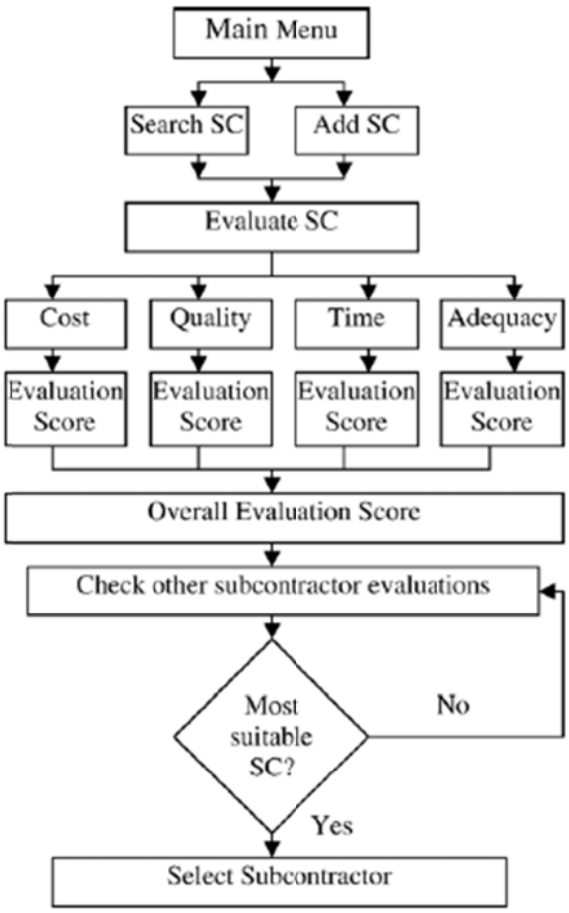


Fig.8. Evaluating and selecting sub-contractor using WEBSES (Arslan et al., 2008).

The WEBSES provides us a fair and objective assessment. It eliminates the dependence on lowest bid price by considering a combined criterion. It can speed up the sub-contracting process and improve the decision quality. It can also reduce costs of the selection process. It may become an effective way in the selection of the right SCs for the sub-contract works of the construction projects.

CHAPTER 4. GENERAL VIEW OF SUBCONTRACTOR MANAGEMENT SYSTEM OF COSL

From chapter 1-3 we have a full view of all aspects of subcontractor management. We get to know what subcontractor management is, how to manage subcontractor, and most important is what benefit an effective subcontractor management can bring to general contractor. COSL Directional Drilling Department, taking advantage of its state-run background, has been experiencing a rapid expanding, and now is the biggest general contractor of offshore directional drilling operation in domestic offshore directional drilling market. But due to the lack of RSS and LWD/MWD package, it has to subcontract more than 90% of its projects (see Table 1). From the table, we can see that under the currently used subcontractor management system, the profit rate get lower when the subcontract rate gets higher. In China, COSL get a lump-sum contract from CNOOC, and then subcontract the project to the other directional drilling companies. In this mode, subcontractor gets paid according to daily service rate, so the profit rate mainly depends on the performance of the subcontractor, higher performance level, higher profit rate. This chapter will give us a detail view of COSL's subcontractor management system.

Table 1
Financial condition in recent three years of COSL

Year	2012	2013	2014
Subcontract Rate	93.37%	88.99%	94.88%
Profit Rate	11.24%	11.42%	10.90%

According to COSL's QHSE manual, its subcontractor management system covers two aspects: one is management on Bidding, the other one is management on subcontracted operation.

4.1. Subcontractor Management Regulation On Bidding & Bid Invitation

4.1.1. Purpose of Regulation on Bidding & Bid Invitation

This procedure is hereby formulated to avoid commercial risks, specify the rights and obligations of the bid inviter and bidder during the bidding process, and ensure the Division can provide the service meeting the requirements of bid documents and reasonably utilize existing resources of the division.

4.1.2. Terms and Definitions

4.1.2.1 Category of Bid Documents

a) The Division-level bid documents: means the bid documents of the Division's overseas market, emerging market and emerging business or the bid documents led by the Company or authorized by the International Business Market Dept. and having important significance for the Division.
b) Regional-level bid documents: means domestic non-interregional bid documents for mature customers, the service contents therein are in the range of service area of operation unit.

4.1.3. Responsibility and Authority

4.1.3.1. General Manager

The general manager of the division is responsible of the examination and approval of evaluation comments of the bid documents at division level.

4.1.3.2. Marketing Dept.

a) Marketing Dept. is the Division's centralized management department for bidding of operation service projects, and shall be responsible for organizing, coordinating and guiding the bidding work of all bases and overseas project teams, and for reporting to the Division's leaders in charge the progress of major bidding projects, etc.
b) To be responsible for the following work of division-level bid documents: conduct initial review, fill the Preliminary Review Form of Bid documents; organize all functional departments for joint review of bid documents involving huge operation income and major influence, and form the minutes of meeting. Preparation and delivery of bid documents;
c) Be responsible for the urging and management work of bid documents of regional level.
d) The information of all bid documents shall be subject to statistics and tracking.

4.1.4. Operation and QHSE Dept.

The operation & QHSE dept. is responsible for the preparation and review of QHSE related articles of the bid documents.

4.1.5. Planning and Financing Dept.

The Planning & Financing Dept. is responsible for the review on fund guarantee, payment terms, and contract clauses on payment, insurance and tax, etc.

4.1.6. Operation Unit

Each operation unit shall be responsible for initial evaluation of local regional-level bid documents, fill the form of initial evaluation on bid documents and deciding on bidding or not, and for the preparation, mailing, filing and tracking of bid documents.

4.1.7. Oversea Project Team

a) After the overseas base obtains the bid documents, it shall positively communicate with the corporate's local overseas institution and the Division for initial evaluation thereof and decide on bidding or not.

b) To be responsible for preparation and delivery of local bid documents under the assistance of Marketing Dept. and local overseas institution.

4.1.8. Flow Chart

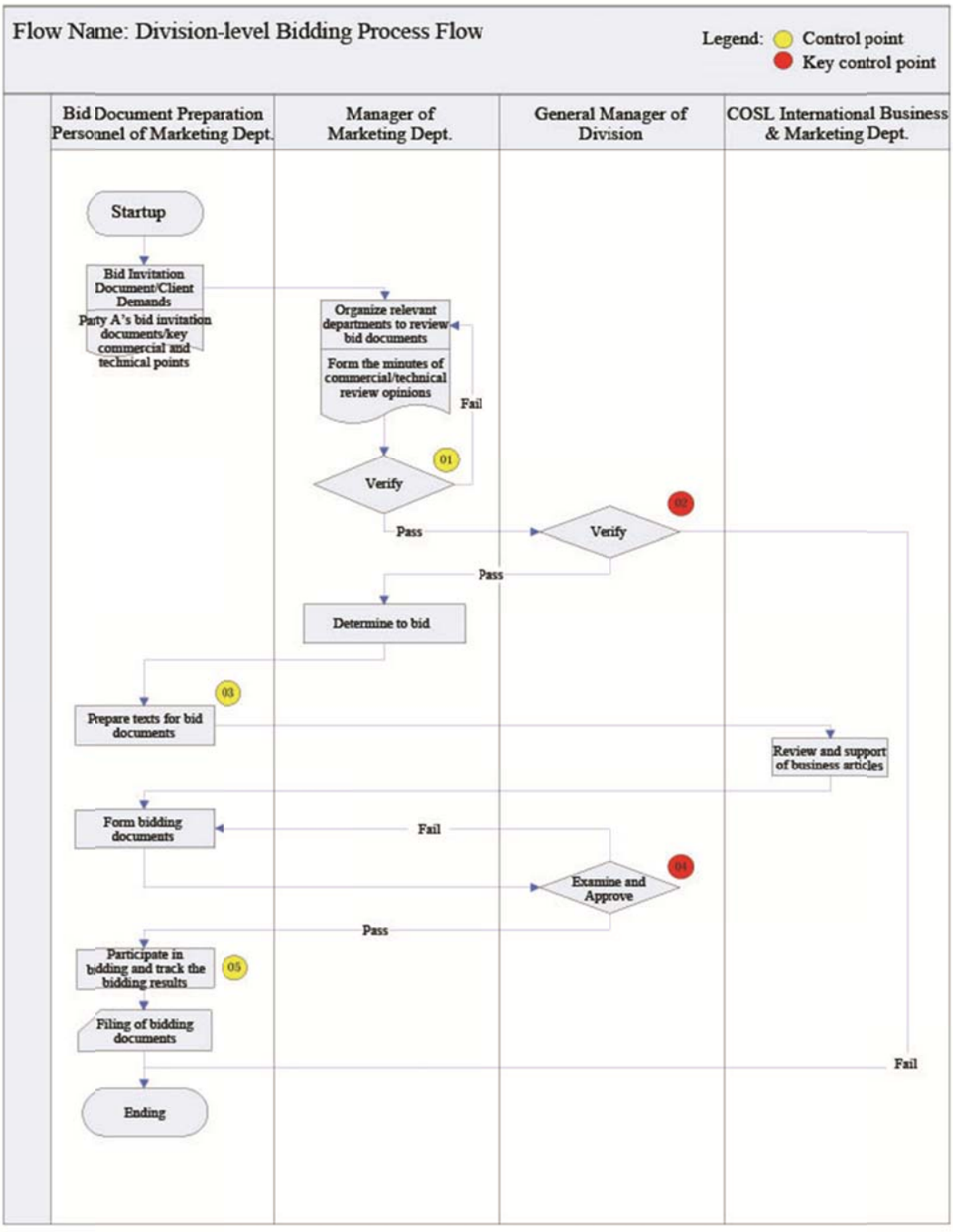


Fig.9. Division-level bidding flow chart(COSL-WellTech, 2014)

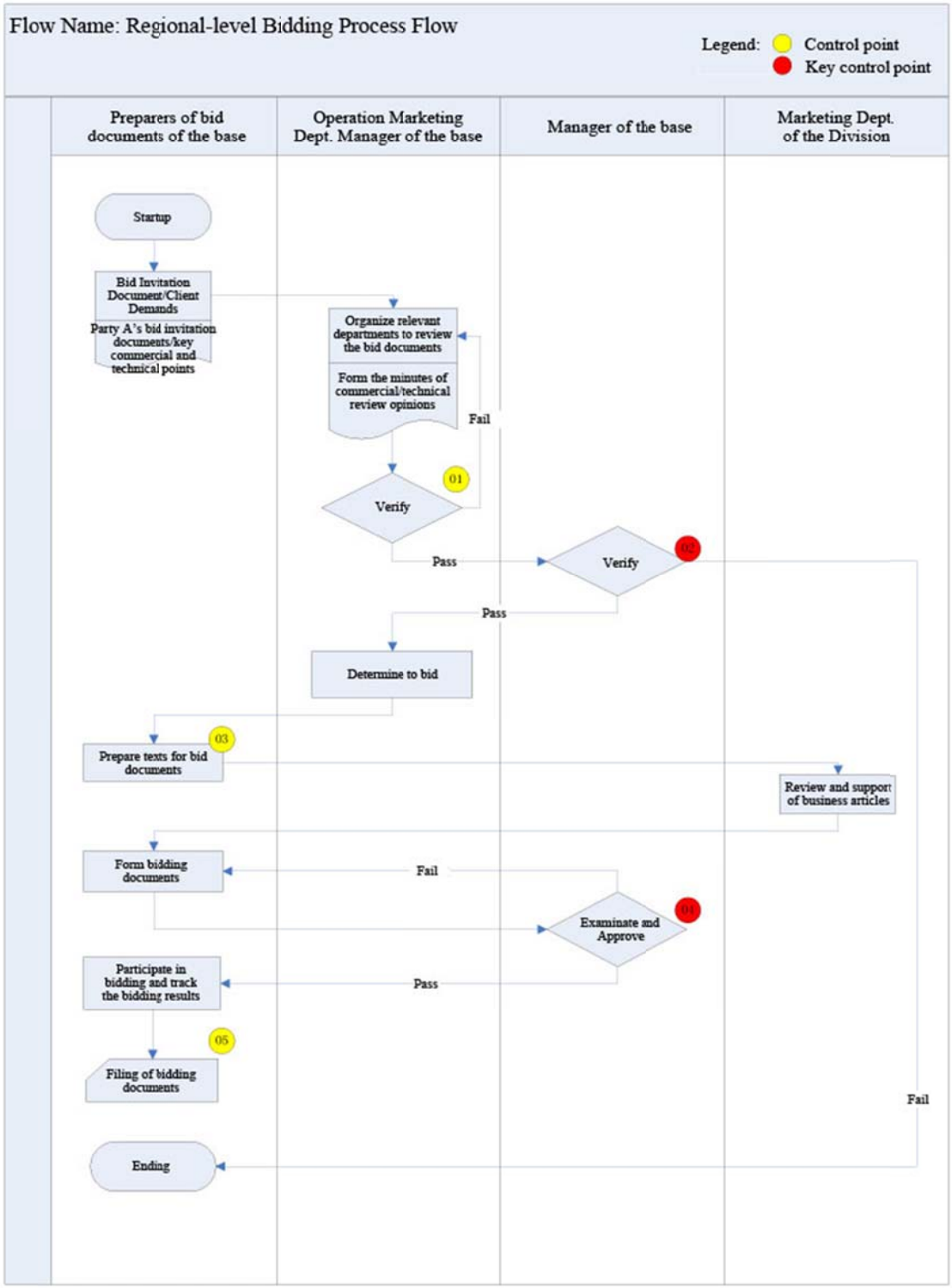


Fig.10. Regional-level bidding flow chart(COSL-WELLTECH, 2014)

4.1.9. Working Procedure

4.1.9.1 General Principles

a) The Division adopts review classification system of bid documents and territorial management principles.

b) The Division-level bid document will be uniformly managed by the Marketing Dept.. After receiving any Division-level bid document, any unit shall promptly submit to the Marketing Dept. the electronic version thereof, furnish relevant background information, and attach relevant information and treatment remarks. Marketing Dept. will fill the initial review form of bid documents, and decide on bidding or not; for bid documents involving huge operation income and major influence, it shall organize all functional departments for joint review and form the final opinions.

c) Each operation unit shall be responsible for the management of regional-level bid documents. After receiving the regional-level bid documents, any unit shall promptly conduct initial evaluation thereof, fill in the initial evaluation form, and submit it to the Marketing Dept., and work out the bidding strategy under the coordination of Marketing Dept.. To be responsible for preparation, delivery, archiving and tracking of regional-level bid documents.

d) All bidding activities in China shall be carried out in the name of COSL.

e) The bidding in overseas market adopts the principles of the company's international business and Market Department centralized management.

4.1.10. Selection Of Evaluators Of Bid Documents

For bid documents of different levels, relevant review units shall decide on the composition of review personnel according to their contents, and shall ensure the specialized skills of review personnel meet the requirement.

4.1.11. Bidding Documents Evaluating

4.1.11.1 Response Before Bidding

a) After receiving the bid invitation, any unit of the Division shall promptly report to the Marketing Dept.. Marketing Dept. and operation unit will conduct analysis and evaluation in combination with relevant information in view of the customer's bid invitation; when appropriate, persons can be specified to track the customer so as to collect more market information, and corresponding customer care activity shall be implemented according to the Division's Customer Information Management Procedure.

b) According to the information collected from the above activities as well as the type of bid invitation documents, Marketing Dept. of the Division shall designate persons or authorize relevant units to make preparation for bidding and carry out relevant market planning, and set up the project team when necessary.

4.1.11.2. Evaluation Preparation

a) After receiving the bid invitation documents, Marketing Dept. shall communicate with the base or overseas project team and the functional departments of the Division involved therein, and decide on bidding or not according to the communication results, and when necessary, report to the leaders in charge for examination and approval.

b) After bidding is decided, relevant units will be respectively organized/authorized to evaluate the bid documents according to their nature. When necessary, relevant units shall form special bidding team to organize and coordinate relevant activities.

c) For any clause with ambiguity or dispute in the bid invitation documents, Marketing Dept. or other units shall specify persons to promptly clarify with the customer.

d) When necessary, according to the requirements of bid invitation documents, the commissioned bidding may be handled, and the cooperative parties or subcontractors shall be sought to conduct joint bidding.

e) The departments or individuals participating in evaluation of bid documents should carefully read relevant contents of bid invitation contents, and make their own evaluation comments (the comments should be filled into Evaluation Form of Bid Documents), and attend evaluation meeting if necessary.

4.1.11.3. Evaluation of bid documents

a) Implement Article 6.2 of Management Methods for Bidding and Contract Review of the company.

b) Bid documents/ contracts are generally reviewed by a meeting, under special occasions; countersignature can be adopted for review. No matter which mode is adopted in review, it shall ensure:
   1) The contract/ bid document scope and requirements have been clearly defined.
   2) The service/product requirements have been clearly defined.
   3) The company has the capability to satisfy the requirements specified in the bid documents.
   4) Comply with related legal requirements or stipulations.
   5) Specified purpose or known expected mandatory requirements could be satisfied although not explicitly indicated by the client.
   6) Any additional requirement specified by the company.

4.1.11.4. Treatment of Evaluation Results

Important opinions in the above review conclusion shall be put into the bidding documents as the disputes over the contract (normally including 3-5 articles).

4.1.11.5. Preparation of Bidding Document

The biding documents shall be prepared through full communication with relevant units and considering the following contents; when

necessary, the leaders or departments in charge can be reported or requested for instruction. The bidding documents shall be prepared in strict accordance with the forms required in the bid documents.

a) Analysis on the bidding technical and equipment advantages and disadvantages of the Division;
b) The bidding strategies to be taken in order to give into play the Division's advantages;
c) Analysis on Conditions of Co-operators;
d) Advantages, risks and responsibilities of cooperative bidding;
e) Possible biding equipment of the competitors and its main technical performance;
f) The distribution of equipment or technical strength of competitors and the possibility of their bidding;
g) Minimum bidding price of competitors, the most possible price and market price;
h) The depreciation and amortization of the proposed bidding equipment of the Division, replacement and renovation cost allocation, mobilization/demobilization expense allocation, interwell displacement expense allocation, foreign employee cost allocation, hazardous article import and export expenses, personnel cost, etc.;
i) Minimum price for the bidding equipment/technical service.

4.1.11.6. Evaluation of bidding document

After the bidding documents are prepared, the review organizing department/unit shall organize relevant persons to review these documents, and ensure they fully meet the requirement of bid invitation documents.

4.1.11.7. Delivery of Bidding Document

The bid document preparing unit shall complete the preparation of bidding documents within the specified period, bind and seal the bidding documents as required by bid documents, and submit them to the client designated address before specified deadline for submission of bidding documents. Relevant record should be made when delivery.

4.1.11.8. Information tracking after bidding

Each operation unit of the Division shall fill each month the Summary of Bid Documents according to the requirements of market information management, and submit it to the Marketing Dept. after approval of its leader in charge.

4.1.11.9. Document management and others

a) Marketing Dept. and other units of the Division shall archive the bidding documents according to corporate documentation management provisions and ensure their completeness. The circulation of bidding documents shall be done according to corporate provisions on confidentiality, and irrelevant persons shall not involve in the quotation and commercial parts.

b) The subordinate units of the Division shall submit before the 5th day of each month the local Summary of Bid Documents.

4.2. Regulations On Subcontracted Operation

4.2.1. Purpose

Effectively control subcontracted service quality, occupational health/safety and environment pollution, and strengthen management of personnel and equipment from subcontractor side during implementation of sub-contract.

4.2.2. Terms And Definitions

1) Subcontracted service

   Due to resources or technology problem, relevant party has to be entrusted with part or all of an operation or it has to be completed through joint efforts.

2) Subcontractor

   Relevant company that is qualified to provide directional drilling service.

4.2.3. Responsibility And Authority

1) Marketing Dept.

a) Arrange subcontractor qualification review and verification.

b) Arrange verification and signing of sub-contract and supervise its implementation.

2) Operating Unit

a) Operating unit is responsible for review of subcontractor technical scheme and examination of personnel qualification;

b) Logistic person of COSL is responsible for the transfer of subcontractor's equipment;

c) On site team leader from COSL is responsible for management of subcontractors and their on site contract implementation.

4.2.4. Working Procedure

4.2.4.1 General principle

a) Select suppliers on the basis of their ability and reputation.

b) Operation unit shall appoint the person in charge of project or operation team leader to take charge of the communication and coordination between subcontractors and clients as well as onsite supervision of sub-contract implementation.

4.2.4.2 Sub-contract

a) Qualification management

Equipment & Procurement Dept. shall manage the credit standing of eligible subcontractors according to Implementation Rules for Management of subcontractors in the Division's Implementation Rules for Material Purchase Management.

b) Subcontractor selection

Marketing Dept. and operation unit shall organize the bidding, contract negotiation and conclusion of a contract according to the Service Purchase Management Procedures in the Division's Implementation Rules for Material Purchase Management.

c) Qualification items

1) Having met all business registration formalities;
2) With the capability to perform the contract (including service capability, technical level, human resource and facilities etc.);
3) With market access permit for relevant region (as required in some region);
4) Those have successful history in the projects of the same or similar kind;
5) Those have engineering operation permit as required;
6) Those have QHSE management system recognized by the Division;
7) Those have a good reputation and have no records of fraudulency or bad practice;
8) Those whose service quality is recognized by end-clients;
9) Other qualifications as required by the company and the Division.

4.2.4.3 Marketing Dept. and Directional Drilling Operating Unit shall report to the company the detail of the sub-contract, and the sub-contract should:

1) Comply with China's Contract Law, and relevant regulations on contract management of the company and the Division;
2) Have relevant legal clauses;
3) Nail down service contents;
4) Nail down requirements on personnel, equipment, technology and data for operation service for both parties;
5) Nail down both parties' responsibilities, rights and obligations;
6) Nail down requirements on management of subcontractors;
7) Stipulate handling of contract change;
8) Stipulate other necessary requirements.

4.2.4.4 Transfer of sub-contract

1) The Marketing Dept. has distributed the copies of the contract signed to all operation units.

2) The Operation Marketing Dept. shall organize and plan the contract implementation, and make divided communication of contract when necessary, to ensure the effective implementation of the contract.

4.2.4.5 Verification of Contract Implementation Qualification

When sub-contract arrives at operation unit, Operation Marketing Dept. shall arrange relevant operation line personnel for verification of technical scheme for subcontracted project. Examination contents

a) Basic information. Whether tasks carried out by project comply with the contract;
b) Whether standards and technical data requested by operation quality satisfy clients' requirements;
c) Whether technical scheme matches operation site environment and well conditions;
d) Whether operation personnel and equipment comply with the contract;
e) Whether operation risk analysis and quality/safety commitment are included;
f) Control measures for ensuring quality and safety;
g) Emergency identification and emergency plan;

4.2.4.6 Personnel qualification inspection

Operation Marketing Dept. shall inspect personnel qualifications provided by the subcontractors. The inspection content includes:

a) Basic information: staff member name, gender, age, educational level, nationality and religion etc.;
b) Relevant work experience, technical training and skills certification;
c) Health certificate, and "Five Sub-certificates";
d) When necessary, provide radioactive operation permit, blasting work permit, and anti-H2S, well control, emergency rescue certifications etc.

4.2.4.7 Quality Inspection and Acceptance of Equipment

After the supplier's equipment reaches the operation unit, the operation unit should organize the operators for quality inspection and acceptance. Requirements shall include:

a) Check packing and equipment appearance and quantity against the contract;

b) Equipment specifications.

c) Technical performance standard of equipment.

d) Technical report for conforming of equipment (demarcated).

e) Flaw detection, equipment and tool inspection reports made by third party and

tool dimensions.

f) For lifting tools and ropes, provide effective qualifications (lifting basket, container and slings shall meet Safety Management Regulations on Tying & Tied Objects).

g) Relevant descriptions and effective credentials for transportation and use of hazardous articles etc., train our personnel providing assistance when necessary

h) When necessary, make scale or demarcation in workshop in base.

4.2.4.8 Mobilization and Demobilization of Equipment and Personnel

a) When the supplier's equipment and parts arrive at designated places, the supplier shall appoint a person to check the quantity before sailing off, which can be sent to operation site after the person in charge of project signs for confirmation. Equipment demobilized from operation site shall be sent to the suppliers after checkup by both parties in operation unit.

b) Subcontractors shall handle relevant formalities and certificates (including radioactive substance dose inspection certificate, neutron source container inspection certificate, radioactive substances operation permit etc.) for hazardous substances (e.g. neutron source) transportation and operation, and shall provide supercargo during transportation. Each operation unit should be responsible for customs declaration and providing other assistance according to the demands of the project.

c) Foreign operation personnel from subcontractors' side shall have work permit issued by Chinese government, and offshore personnel shall also have offshore operation safety training certificate and health certificate for offshore operation. The supplier shall provide all operation personnel's resumes, which shall be reported to the person in charge of the project for confirmation.

d) Operation unit should be responsible for the mobilization and demobilization of suppliers' equipment and personnel from the base to operation site according to the clients' requirements and project schedule.

e) Each operation unit shall require to package and mark the equipment of the supplier according to Production Protection Control Procedure.

4.2.5. Onsite Coordination and Supervision Management

4.2.5.1. General Principles

Person in charge of project/onsite operation team leader shall strengthen onsite management of subcontractors. General requirements on management:

a) Maintain effective communication between the clients, the operation unit and the supplier's operator, as well as effective communication of work instruction, and operation site regulations (especially safety management and emergency exercise system, emergency plan, and escape route);

b) According to Procedure for Exerting Influence on Relevant Parties, inform the Division's relevant requirements on QHSE management system to onsite operators from the supplier side.
c) Supervise the supplier's operators to effectively execute the instructions of the client;
d) Supervise the service quality of the supplier's technicians, and assess the supplier's onsite service according to Measuring & Monitoring Control Procedure;
e) The statistics of effective working time of persons, equipment mobilization and demobilization as well as equipment shall be done according to the contract requirement, and the service contents shall be confirmed;
f) Any accident or incident shall be promptly reported; in case of any emergency, the subcontractor's personnel shall be notified of evacuation.

4.2.5.2. Operation control

During operation process, the supplier's onsite engineer shall send yesterday's onsite equipment running report by fax (or by email) to the person in charge of project/ onsite operation leader before 8:00 every morning.

a) During operation process, if the supplier's equipment have any fault or abnormality, onsite engineer must contact the person in charge of the project/ operation team leader immediately, explain the situation, make a judgment for the fault, work out handling method and estimate the time needed, report to the person in charge of the project and the supplier's operation coordinator respectively after getting a consensus, and communicate and explain to the supplier's operator through the person in charge of the project/ operation team leader.

b) The subcontractor's onsite operation personnel shall know beforehand the contents and requirements of the service to be furnished, and shall seek the consent of the customer via the operation team leader or person in charge of project before the use of devices in the optional service items.

c) The person in charge of the project and the supplier's operation coordinator shall be notified of onsite material demand and equipment return etc. in writing or by email immediately.

d) After the operation, the supplier shall submit data and operation report timely as specified by the contract, and the quality of data and report must be recognized by the client.

e) The information, data and report should be communicated in the sequence of the supplier—the contractor—the client. Without prior permission, the supplier must not disclose the client's operation and reservoir data. For any different ideas or technical difficulty that may require communication with the Operator, the contractor shall arrange a three-party discussion.

4.2.5.3. Modification and Extension of Subcontract

For contract modification and renewal, Marketing Dept. shall arrange evaluation,

and modified version shall be verified and signed by the company's department in charge.

4.2.5.4. Modification and Extension of Subcontract

a) Person in charge of project/ operation team leader of operation unit is responsible for confirmation of workload and service quality and signing of Contract Settlement Note, which shall be submitted to Operation & QHSE Dept. for approval after being verified by assistant manager in charge of operation in operation unit.

b) Planning & Financing Dept. of operation unit shall settle accounts according to the contract and Contract Settlement Note.

4.2.5.5. Recording and Filing of Subcontract

Relevant subcontract records shall be made according to the provisions of Company and Division on contract management, and relevant records shall be kept for 5 years.

CHAPTER 5. A NEW TRY OF SUBCONTRACTOR MANAGEMENT IN EP PROJECT

From chapter 4, we see that COSL's Subcontractor Management System is not a systematic one. Though it covers the bidding and operation processes, it ignores the most critical part of subcontractor management, subcontractor evaluation and selection. Given that its three subcontractors are all international enterprises, all of which are capable to do a project separately, we can come to a conclusion that this subcontractor management system focuses only on price. But, from chapter 1 to 4, we know that there are several factors need be considered when subcontracting a project, so this system is not the most suitable one. We need to improve it.

Aware of the weakness of this subcontracting management system, the author, as a project manager, work out a factor-based weight sum method trying to make this subcontractor management system more efficiency, more beneficial for COSL, and make use of this method in EP project in which the author was named project manager.

5.1. Factor-Based Weight Sum Method For Subcontractor Selection

The proposed model, factor-based Weight Sum method, considers the project and each subcontractor as a whole. It tries to work out the most suitable subcontractor for the project. It includes three steps: evaluation of the difficulty of the project, evaluation of the capability of the subcontractors and the selection of the subcontractor.

The first step, evaluating the difficulty of the project, is quite simple. It's just a mathematical thing, like 1 adding 2 equals three and the average is 1.5. For a directional drilling project, it normally has more than 10 wells, and each well has a well-path plan. After we import the plan into the directional drilling software, COMPASS, it will give us a difficulty index value according to the Total Depth, Vertical Depth and the needed Dogleg. What we need to do is just averaging these difficulty-index values. The result of this step is a series of values, N(1), N(2) … N(n).

The second step, evaluating the capability of the subcontractors, is the most critical one. In this step, we need to answer the following questions: who do the evaluation, what factors we need to evaluate and how to make sure the result of the evaluation fair to each subcontractor. The result of this step is a series of factors F(1), F(2) … F(n) and a specific value for each factor FN(1), FN(2) …FN(3).

The third step, selection of the subcontractor, is the decision made step. In this step we need to do the following two activities: qualitatively estimating the extent to which each factor influences the project and getting a final score for each subcontractor. The subcontractor getting the highest score qualifies in the subcontracted project.

5.2. Illustrative Example

5.2.1 Project Description

EP project is carried out by Shenzhen Base of COSL-WellTech, and it includes three sub-projects, HZ25-8, EP24-2 and XJ24-3B. These three sub-projects are planned to be carried out separately at the same time. At the bidding phase of the project, after the wellpath were planned, we gather the general information of the project, the workload and the difficulty index of these three sub-projects, which are showed in Table 2.

Table 2.
Workload and Difficulty Index of HZ25-8&EP24-2&XJ24-3B

Sub-project	Well Amount	Total Footage	Average Footage	Difficulty Index
XJ24-3B	10	33422	3342.16	5.93
EP24-2	17	47401	2788.26	6
HZ25-8	12	48437	4036.41	6.3

From table 6, we can see that the most difficult one is HZ25-8, and the workload of it is HZ25-8 as well, with the EP24-2 project the second and XJ24-3 the third one.

Until now except XJ24-3B which was finished on April. 2, the other two, HZ25-8 and EP24-2, are still going on. But, from the data we already have, we can see that the performance of subcontractor has got a great improvement compared with projects conducted previously.

5.2.2 Subcontractor Capability Evaluation

As we mentioned before, in this phase of subcontractor selection process, we need to answer the following three questions:

1) Who do the evaluation?
2) What factors we need to evaluate?
3) How to make sure that the result of the evaluation is fair to each subcontractor?

To deal with the first question, we organised an evaluation committee, the 20 members of which are from both Well-Tech COSL Directional Drilling Department and Geological Department, and the portion is 50% to 50%. Though the membership of the evaluation committee is not that large enough, the result of the evaluation can reflect both the drilling and the geological needs of the project.

For the second question, we all know that a project is associated with lots of factors, but we also know that for a specific project, only some specific factors are critical, and these critical factors usually determine the future of the project. In EP project, to make the evaluation process easy to control and easy to understand, we identified the following four critical factors:

1) Capability of key equipment

In a directional drilling job, the equipment we care most is: RSS、MWD and LWD. In this process, the members of the committee were asked to evaluate the capability of the three equipments based on their experience respectively, using a number 0 to 5 with an interval 0.5. And the result of the evaluation can be seen from table 3.

Table 3.
Evaluation of key equipments'capability

	Key Equip.		
Subcontractor	RSS	MWD	LWD
SLB	4	4.5	5
BHI	5	4.4	4.8
HAL	5	4.3	4.6

2) Experience

Experience is important for the success of a project, but we all know it is difficult to measure it, just like we would rather say someone has a lot of experience than someone has 100 experience. So, to make the evaluation process easy to control, we here use an integer for experience, 1 means the subcontractor had drilled 1 well in a specific district. According to this method, we get the score for each subcontractor showed in table 4.

Table 4.
Experience of each subcontractor.

Subcontractor	SLB	BHI	HAL
HZ25-8	1	2	4
EP24-2	1	4	1
XJ24-3B	5	1	1

The score set in the table comes from statistic data. For example, 1 in row 2, column 2 means that Schlumberger have drilled one exploration well in the HZ25-8 district.

3) Timely delivery

As discussed in Chapter 2, timely delivery is critical to the success of a project. It reflects the ability of the subcontractor to meet both expected and unexpected needs. It is especially critical in offshore oil drilling industry as it includes thousands of activities in a project. Any changes on these activities may lead to unexpected needs or changes on delivery plan. The same as in evaluation of key equipments, we asked the evaluation committee members to give score on the delivery performance of the subcontractors according to their work experience with these three subcontractors, and the result can be found in table 5.

Table 5.

Timely delivery of the subcontractors.

Subcontractor	SLB	BHI	HAL
Timely delivery	4	4.5	4

From table 9, we can see that BHI was said to do better in material delivery than the other two subcontractors, Schlumberger and Halliburton. In author's opinion, this is partly because of the policy that BHI always prepare 150% tools that needed according to the plan.

4) Price

Among all four factors, the price of directional drilling service of these three subcontractors is thought to be the most important one, because it directly determines the total cost of the project. Here we use the historical data to calculate the price. For example, we use the recently completed project LH4-1 which was subcontracted to Schlumberger as the data source of Schlumberger. According to financial data of Well-Tech Shenzhen Base, the total subcontracted value of LH4-1 project is $5516827， and the total footage of LH4-1 project is 25242.12 meter. Divided total subcontracted value by total footage, we get the cost per meter is $218.56. The cost per meter of all three subcontractors can be found in table 6.

Table 6.

Cost per meter of the subcontractors.

Project	Total Cost ($)	Total Footage (m)	Cost per meter ($)	Subcontractor
LH4-1	$ 5,516,827.00	25242.12	$ 218.56	SLB
PY35-2/1	$ 5,270,000.00	31020.9	$ 169.89	BHI
PH13	$ 6,270,000.00	23597	$ 265.71	Halliburton

As we all know, if all nominated subcontractors have the ability to do the project, then the lower the price, the higher the probability is that a subcontractor to qualify in the subcontractor selection process. So, here aiming to simplify the calculation, we use the minimum one of the price as a bar, divided it by the price of the other two subcontractors. Then we get the final score of the price of the subcontractor showed in table 7.

Table 7.

Price of the subcontractor.

	SLB	BHI	HAL
Price	0.77731	1	0.88424

5.2.3 Sensitivity Of Each Factor To Project

After identified the factors that critical to the project, we asked the same evaluation committee to provide quantitative estimates of the sensitivity of each factor for each sub-project, with the sum of these estimates come to 1. Given that the three sub-projects were

near to each other and took use of the same project team, we set the same value to the experience, timely delivery and price, with 0.2, 0.1 and 0.2 respectively.

Then for the key equipment, we further estimated each one's sensitivity for each sub-project base on the workload of the project, the needed dogleg and the pay zone thickness. First we asked each member of the evaluation committee to give a specific value to the sensitivity of a specific equipment to each sub-project, then, made an average. For example, S(RSS, HZ25-8), the raw value given by the committee can be found in Appendix A, and the average of them is 0.175.

Table 8.
Sensitivity to the identified factors

Project	Key Equip.			Experience	Timely Delivery	Price	Total
	RSS	MWD	LWD				
HZ25-8	0.175	0.15	0.175	0.2	0.1	0.2	1
EP24-2	0.17	0.185	0.145	0.2	0.1	0.2	1
XJ24-3B	0.14	0.185	0.175	0.2	0.1	0.2	1

5.2.4 Subcontractor selection

After we identified all the critical factors and get the sensitivity of each factor to the project, it came to the project team to match the subcontractor to the sub-project. In this factor-based subcontractor management method, we use the following formula to finally rank the subcontractors.

Formular (1):

Final Score(HZ25-8, SLB)=Experience(HZ25-8, SLB) * Sensitivity(HZ25-8, SLB) + Timely Delivery(Timely Delivery, SLB) * Sensitivity (HZ25-8, Timely Delivery)+ Price(Price, SLB) * Sensitivity (HZ25-8, Price) + Key Equip. Performance (SLB, RSS) * Sensitivity (HZ25-8, RSS) + Key Equip. Performance (SLB, LWD) * Sensitivity (HZ25-8, LWD) + Key Equip. Performance (SLB, MWD) * Sensitivity (HZ25-8, MWD) = 2*0.2 + 4*0.1 +0.777307*0.2 + 4*0.175 + 4.5*0.15 + 5*0.175 = 3.20546

Use the same formula, we get the final evaluation value of each subcontractor to each sub-project, the result can be found in table 9.

Table 9.
Final score of each subcontractor to each sub-project.

Project	SLB	BHI	HAL
HZ25-8	3.20546	3.1875	**3.35185**
EP24-2	2.99296	**3.2325**	2.20685
XJ24-3B	**3.42296**	2.3825	2.17685

From table 12, we see that subcontractor Halliburton get the highest score on sub-project HZ25-8, with BHI and Schlumberger on sub-project EP24-2 and XJ24-3B respectively. According to this final score, we made the final decision, subcontracting sub-projects HZ25-8, EP24-2 and XJ24-3B to Halliburton, BHI and SLB respectively.

5.2.5 Performance Comparison

Up to now, XJ24-3B and EP24-2 were completed, and HZ25-8 will be completed in one month. From the collected data we already get, we see a great improvement on performance in EP project comparing to the projects each subcontractor completed before. Here we select the LH4-1 project to make the performance comparison of Schlumberger to XJ24-3B, and PY35-1/2 of BHI to EP24-2 and PH-13 of Halliburton to HZ25-8. The detail data can be found in table 10, table 11 and table 12 as below.

Table 10.
Performance comparison of SLB.

Project	Total Run Time / hrs	NPT / hrs	Work Efficience
LH4 -1	1986	108	94.56%
XJ24-3B	2360	89	96.23%

Table 11.
Performance comparison of BHI.

Project	Total Run Time / hr	NPT / hr	Work Efficience
PY35-1/2	5023	123	97.55%
EP24-2	3061	59	98.07%

Table 12.
Performance comparison of HAL.

Project	Total Run Time / hr	NPT / hr	Work Efficience
PH-13	4860	213	95.62%
HZ25-8	3864	91	97.64%

The calculated improvement rate can be seen from table 13.

Table 13.
Improvement rate of the three subcontractors.

Subcontractor	Improved rate
SLB	1.67%
BHI	0.52%
HAL	2.03%

5.2.6 Financial Analysis of Factor-Based Weight Sum Method

From the performance data above, we can come to a conclusion that the factor-based checklist method can exactly match the subcontractor and the project. This perfect match can greatly let the subcontractor take use of its advantages, further, improve its service quality. In this part, we'll see the cash value of this performance improvement. According to the data of 2014, we can see the workload of the three subcontractors in South China Sea from table 14 below.

Table 14.
Workload distribution of the three subcontractors.

Subcontractor	Work load per year /hr
SLB	15608
BHI	13000
HAL	5349
In Total /hr	33957

If we multiply the workload in table 14 and the improvement rate of each subcontractor in table 13, we can get the saved time per year, and the result can be found in table 15 below.

Table 15.
Saved time per year.

Subcontractor	Saved time /hr
SLB	260.1666342
BHI	67.76394739
HAL	108.4586554
In Total /hr	436.389237

If we further make a hypothesis that the operation taken jack up oil facility and DPP each weight 50% of the total workload, and the daily cost of these two facilities are 2.5 and 1 million per day respectively, we can easily get the cash value of the performance improvement.

Table 16.
Cash value of the performance improvement.

Oil Facility	Daily Cost / million	Portion	Saved cash value/ mil.$
DPP	1	0.5	9.091442438
Jackup Rig	2.5	0.5	22.72860609
In Total			31.82004853

CHAPTER 6. SUMMARY OF THIS STUDY

In this thesis, we have firstly reviewed the subcontractor management system widely used around the world; it covers several phases, subcontractor evaluation, rating, selection, and subcontractor-main contractor relationship management and performance evaluation and so on. After a study on some critical phase of the widely used subcontractor management, we get to know that an efficient subcontractor management system is critical to the success of main contractor. Well-Tech COSL, as a main contractor on offshore oil drilling service, subcontracts more than 90% its projects to other world-class companies such as SLB, BHI and HAL each year due to the lack of some advanced technology. But after we have a review on the subcontractor management system Well-Tech COSL uses, we further find that there are a lot of weaknesses in it, and the lack of an efficient subcontractor selection is one of the weaknesses. With the finding we establish the research objectives of the thesis as to firstly identify critical factors associated with the subcontractor selection of directional drilling project. Finally work out an effective way of subcontractor selection.

We have set our discussion scope mainly on subcontractor management in offshore directional drilling industry where the critical technology is hold in some three international enterprises. This is different from the other industry, and main contractors like Well-Tech COSL have no other choice than subcontracting. Therefore we firstly have a look on the subcontractor management system widely used in other industry. Then have a general view of the currently used subcontractor management system used by Well-Tech COSL and identify the weakness in subcontractor selection phase. Finally work out the factor-based weight sum method for subcontractor selection which is absent in Well-Tech COSL's currently used subcontractor management system. This method can be further divided into three parts.

Critical factors identification: For a directional drilling project, the most important factors are the difficulty index of the project, experience, and price, and timely delivery which reflects the capability of subcontractor to meet emergency, capability of key equipment such as RSS, LWD and MWD which is directly related to difficulty index.

Sensitivity of each factor to the final decision: we know that projects are different from each other, different TVD, different TD different CLD. So, given a specific project, we have to identify to what extent each factor impact the successful execution of the project.

Subcontractor comparison: to make the final decision, we only need to multiply each factor and the sensitivity of it to the project, and make a sum of them. After we get the final score of each potential subcontractor on the same project, we can make the final decision.

6.1 What The Author Had Learnt

With the broaden coverage of the research topics being went through, the author had obtained theoretical knowledge and practical methodologies mainly as the follows:

1) **Types of subcontractor**: the three identified subcontractors are domestic subcontractor, nominated subcontractor and named subcontractor according to Joint Contracts Tribunal based on the relationship between clients, main contractor and subcontractor.

2) **Relationship between subcontractor and main contractor**: Hierarchical Subcontractor-Contractor Relationship, Horizontal Network-Type Subcontractor-Contractor Relationship and Lean Supply Model of Subcontractor- Contractor Relationship.
3) Several critical factors affecting subcontractor's performance: uncertainty in workload, labour skill, field coordination and material delivery and so on. So, we should consider these factors when subcontracting a project.
4) Method used to evaluate subcontractor's performance in construction industry.
5) Well-Tech COSL's currently used subcontractor management regulation. Reviewing this regulation, we find that there are some weaknesses on in and an effective subcontractor selection method is one of them.

6.2 What Can Be Done Further Of This Study

At the end of this study, author had believed that in the COSL Directional Drilling Department, more attentions should be addressed specifically to how to evaluate subcontractors 'capability and subcontractor selection in order to ensure that the right subcontractor could be qualified for a specific project to get a better performance. Therefore further studies could be conduct to find out how to identify the most mattered factors in subcontractor selection process.

Through the data collection process, the author had found that it's difficult to take into account the time value of the cost of the project when make the performance comparison. For example, the project HZ19-2 selected to evaluate the price of Halliburton was conducted 6 years before when the price of Directional Drilling Service was significantly lower than that is in 2014, while the project PY35-1/2 selected to evaluate the price of Bakerhughes'was conducted recently in 2013, so it is to some extent unfair for Bakerhughes. When there are lots of factors identified, the time value of investment may have limited effect on the final result, but we should pay more attention on it when only limited factors are identified to evaluate subcontractor. So, working out a systematic and effective way to mitigate such unfairness could be a meaningful topic for further study.

6.3 Challenges Faced During The Thesis Writing Process

Major challenges are the following:

1) Offshore directional drilling industry is greatly different from the manufacturing industry and electronic industry in which main contractor focuses on their core business and subcontracts the other parts of the job. In directional drilling industry, the core technology is owned by only three international enterprises, and Well-Tech COSL as the named subcontractor has to subcontract the job to finish the project. Therefore, the most important part of this subcontractor management system lies in

subcontractor selection and performance control because in the lump sum model a better than expected performance means more profit for the main contractor. Lack of experience data, the author has to learn from the experience of the other industry. To make this study more related to directional drilling industry, the author has to identify the useful experience, and it is a large amount of work.

2) To make the result of the study reflect the true condition, the statistic data should be as large as possible. Therefore we should get as much data as possible when doing this study especially determining the price of potential subcontractors. But author had been struggling a lot to get all the data because that it is against Well-Tech COSL's privacy policy.
3) Basically this thesis has covered subcontractor management system used in several industry, such as construction, manufacturing, electronic and so on, this wide coverage has actually somehow challenged author with his limited knowledge and experience.

7 CONCLUSIONS

7.1 Findings And Conclusions Of This Study

From the discussion in the previous chapters, we found that offshore directional drilling in oil & gas industry hold different methodologies compare to the other industries such as manufacturing and construction, major findings and conclusions are listed below:

1) Subcontractor management is critical for a main contractor's business success and there are a large amount of factors need to be considered when subcontracting a job.
2) Industries such as construction and manufacturing have been aware of the importance of subcontractor management and have some well-known theories and effective practices to control the subcontracting process.
3) Though Well-Tech COSL has a more than 10 years' experience of subcontracting but its currently used subcontractor management system has some weaknesses and the absence of an effective subcontractor selection method is among them. To improve Well-Tech COSL's performance in directional drilling it is necessary to make some change this system.

7.2 Recommendations For Directional Drilling Department Of COSL

Two Roles for COSL

On one hand, COSL is subcontractor of CNOOC. An important piece of background information is that COSL Directional Drilling Department is a subcontractor to largely one customer CNOOC that accounted for 90% of its revenues with other customers both in China and abroad account for only 10%.

On the other hand, COSL directional drilling department is the one and the only one general contractor in China's offshore drilling area.

To maintain a long-term business success in directional drilling department of Well-Tech COSL

For a 5 years' term, the currently used subcontractor management system will have a more positive impact on Well-Tech COSL's business success if we make some improvement on its subcontractor selection process. But for a long term view, the most important factor for the directional drilling department of Well-Tech COSL's business success is the development of core technology in directional drilling.

7.3 Limitation Of This Study

Limitations of this study are listed below:

1) Not all the data used in the study are got first hand data directly from Well-Tech COSL due to the data collection is a resources consuming process which the author

is not capable to do it. Therefore some second hand data and references from other literatures have been used.

2) The subcontractor management system used in Well-Tech COSL is not a typical one due to the difference from the other industry. But as far as I know, Well-Tech COSL has reached some improvement in new technology related to directional drilling and this will have great impact on this system. For the long term development, what Well-Tech COSL needs is a combination of the subcontractor management system discussed in this study and the typical management system used in other industry such as manufacturing industry. The study has not addressed that part because that involve much larger research context which is out of the author's capability.
3) One note for this study is that all the financial data used here doesn't take into account the time value of the money. Even for a lump sum contract, Well-Tech COSL gets paid several times, if considering the time value, there would be a large amount of data collecting and processing work which is out of the author's capability.

APPENDIX A.
Raw evaluation data of the sensitivity of key equipment to the project from evaluation committee.

	HZ25-8			EP24-2			XJ24-3B		
	RSS	MWD	LWD	RSS	MWD	LWD	RSS	MWD	LWD
	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2
	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2
	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2
	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2
	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.2
	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1
	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1
	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1
	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1
	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1
	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.2
	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2
	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2
AVG	0.175	0.15	0.175	0.17	0.185	0.145	0.14	0.185	0.175

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