Title  Risk Management Strategy of Construction Projects in China
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RISK MANAGEMENT STRATEGY OF
CONSTRUCTION PROJECTS IN CHINA

by

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A thesis submitted to the University of Bedfordshire, in partial
fulfilment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

Embarking on a construction project means taking a risk. Project risk management (PRM) provides an effective approach to improve decision making and minimise project risk. Project risks may not possess the same level of significance for different countries, markets and projects. Current research on PRM in China has been rather theoretical, addressing technology issues. Considering the current practice in the Chinese construction industry (CCI), the PRM needs understanding and support from the industry and a mature market environment. This research aims to establish PRM strategies for identifying and adopting the best practice to provide practical guidelines for the CCI, thus improving the PRM, motivating the reform of the Chinese construction market, and enabling the CCI to function in the competitive environment of globalisation.

An extensive literature review and a number of case studies for construction projects in China have been conducted, addressing issues closely related to the research. A systematic analysis is employed and developed for project planning and decision making. Contractual risks are considered as the first step and catalyst for improving the PRM in the CCI. Built on the findings from the case studies and analysis, the research puts forward a framework of contractual risk management to study the concept, identification and classification of contractual risks. Contract interfaces are analysed for contractual risk management under various project procurement routes (PPRs). The potentially large improvements to the PRM and reform of the Chinese construction market from the introduction and application of innovative PPRs and their contractual conditions are addressed.

Two mathematical models - a probabilistic analysis model and an effective information entropy model for key contractual risks - are presented. The validity and applicability of the models are demonstrated with sample data for the CCI. Detailed recommendations and guidelines for the implementation of the proposed strategies are suggested.
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Dedication

This work is dedicated to my wife, Jie Wang for her support and encouragement.
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Declaration

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of Bedfordshire.

It has not been submitted before for any degree or examination in any other University.

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Date: 18 Dec, 2006
CHAPTER 1 INTRODUCTION

1.1 THE IMPORTANCE OF THIS RESEARCH

Risk is inherent in all human activities, and in the construction industry no project is risk free. Embarking on a construction project means taking a risk. Risk is a measure of the probability, severity and impact of adverse events that may affect project objectives. Project risk management (PRM) provides an effective approach to improve decision making and minimise project risk. PRM is defined as a logically consistent framework to develop the process of risk identification, analysis, response and control. PRM basically utilises an understanding of uncertainty to plan and control projects. The main work of project management is project planning and project control. Project planning includes objective planning, organisation planning and contract structure planning while project control basically means controlling the investment, quality and duration. Project planning provides a foundation for project control. Traditional project management employs classical certainty analysis to manage projects and this is a major obstacle to achieving project control targets as it cannot respond readily to unpredicted events. PRM is advanced project management, which involves systematic technologies and approaches based on uncertainty analysis. Once risks are identified they may be managed efficiently. For example, risks associated with a project may be high but through risk identification and by careful development of project planning, a number of risks can be eliminated, transferred or insured against. Otherwise, the risks will enlarge and may result in severe consequences. Passive risk retention occurs through neglect, ignorance or absence of decision, e.g. if a risk has not been identified and handled, the consequences of the risk must be borne by the project participants. If this early stage of risk management fails, subsequent steps will be doomed and risk management cannot be effective. Therefore, risk identification is important as the first step of risk management.

PRM can reduce risk and increase the probability of the project achieving its cost, time and other objectives. In the Western construction industry, the subject of
project risk, its assessment, allocation and management have been developed and analysed on an increasing scale over the last 20 years. The benefits of PRM (PRAM Guide, 1997, by the UK Association for Project Management - APM) are that it:

- allows a comparison of the robustness of projects to specific uncertainties;
- increases understanding of the project, which in turn leads to the formulation of more realistic plans in terms of both cost estimates and time-scales;
- gives an improved understanding of the project through identifying the risks and thinking through response scenarios;
- makes the relative importance of each risk immediately apparent;
- produces a knowledge of the risk in a project which allows assessment of contingencies that actually reflect the risks and which also tend to discourage the acceptance of unsound projects;
- gives an understanding of how risks in a project can lead to the use of a more suitable form of construction contract;
- enables decision making to be more systematic and less subjective;
- contributes to the build-up of satisfactory information of historical risks that will assist in better modelling of future projects;
- improves incorporation experience and communication;
- increases understanding of the risks in a project and their possible impact which can lead to the minimisation of risks for a part and/or the allocation of risks to the party best able to handle them;
- allows for an independent view of the project risks which can help to justify decisions and enable more efficient and effective management of the risks;
- facilitates greater, but more rational, risk taking, thus increasing the benefits that can be gained from risk taking; and
- assists in the distinction between good luck and good management, and bad luck and bad management.

All of these benefits are very important and need to be understood in the Chinese construction industry (CCI), but which are the most significant for the CCI? The
author’s view is to give an evaluation of how understanding risks in a project can lead to the use of suitable conditions of construction contract based on the project procurement route (PPR). Contractual conditions and contractual form are used interchangeably by various professional bodies and practitioners, and this research uses contract conditions unless the context requires the use of contractual form. Also, the benefits may be achieved under a mature construction market and regulation environment. However, there is a long way for the Chinese construction market to travel to reach this aspiration. At present, how can the benefits of PRM for the CCI be obtained? This research will address this problem and other related issues. Project risks may not have the same level of significance for different countries, markets and projects. What is the major gap in the construction industry between China and the developed world? What are the particular issues that need to be solved to improve PRM? Such questions must be answered. China’s unique social and economic system, coupled with its rapid expansion into world markets, makes the observance of administrative procedures and regulations different from other developing countries. For example, the Chinese National Construction Law (National People’s Congress, 1998) uses project delivery formed under centrally planned economics instead of project procurement. The project delivery is generated from a centrally planned economy, and the project procurement from market economies. The main gap in the construction industry between China and the developed world is the issue of management, followed by technology and economics (Yan, 2001a). Therefore, the issue of construction market reform is crucial to develop the CCI and to provide a stimulus for promoting risk management in the CCI. Construction market reform should be in harmony with the construction administration system, management mechanisms and legalisation environment.

PRM is in its infancy in China and the participants of projects have little understanding and knowledge of this important area of management. The research to date on risk management has been rather theoretical, addressing specific technology issues and there are few systematic approaches developed in the area of planning and management of construction projects. This study, however, not
only puts forward models for quantitative analysis of project contractual risks for the decision making of construction projects, but also stresses a systematic methodology and practical steps based on project assessment and contract strategy, which can be implemented to gain maximum benefits for project participants. For the CCI, PRM needs the support from the industry and a mature market environment. At the industry level, this research examines the past and current performance of the CCI, presents an analysis of the development of the PPR and its function in the construction market reform, and the development of the industry to identify the causes of inefficiency, and seeks solutions to the problems. The potentially large improvements to PRM and reform of the Chinese construction market could result from the introduction and application of innovative PPRs and their contractual conditions. This study will provide an opportunity to analyse both production enhancement and process improvement of the CCI to deepen the reform of the Chinese construction market. The intention of this research is to develop an effective approach that suits the current situation of the Chinese construction market, and to provide a valuable insight into the Chinese PRM and how it might be improved.

1.2 PROBLEM STATEMENT

The research puts forward the framework of contractual risk management, studies the concepts of contractual risks of construction projects and systematically evaluates the contractual risks in combination with the project procurement route (PPR). Different project environments including the construction market need different risk management strategies. The main questions to be examined are:

Can project risk management (PRM) help provide a reliable approach to developing the Chinese construction industry (CCI)? The question may be divided into:

- What is the current situation of PRM in the CCI?
- What is the major gap in the construction industry between China and the developed world?
• What are the major problems to be overcome and the possible solutions to them in order to improve the Chinese PRM?

How can PRM be applied in the CCI? The question may be divided into:

• How is PRM understood with a systematic approach?
• What are the key issues which need to be addressed to enable PRM to be successfully implemented in the CCI?

In order to work out these questions, and make recommendations of practical guidelines for the successful development of PRM in the CCI, it is essential to investigate the status of PRM in China, and analyse the reform and development of the CCI. A survey is conducted in Chapter 3 to obtain an insight into the current practice of PRM in China, and find out the attitudes of Chinese project participants towards PRM. This will help identify the major problems that dictate the pace of the development of the CCI.

1.3 THE AIM AND OBJECTIVES OF THIS RESEARCH

The aim of the research is to present strategies and suggest recommendations for project risk management (PRM) in the Chinese construction industry (CCI), by identifying and adopting the best practice appropriate for the conditions operating in China. Specific objectives are

1) To understand risk characteristics in the construction industry and to review the theory and methodology of PRM.
2) To present a clear statement of the need of the research through a survey of the current practice and attitude of the Chinese project participants toward PRM in the CCI, and thus to determine the focus for the research.
3) To examine whether the current PRM methods and techniques can provide a reliable programme to be developed in the CCI by studying the major risk events in the CCI.
4) To develop a framework of contractual risk management based on the concept, classification, and identification of contractual risks.

5) To investigate the selection and applications of the project procurement route (PPR) and contractual risks associated with the PPR, thus developing a framework for PRM for the CCI.

6) To develop, test and evaluate quantitative analysis models for quantifiable contractual risks: an effective information entropy model for contractors to determine an optimum tendering price, and a probabilistic analysis model of contractual risks for use by clients or contractors.

7) To develop practical guidelines for the strategies of PRM for the CCI.

1.4 THE METHODOLOGY FOR THE RESEARCH

Project risk management (PRM) is a large subject for research, and the research employs a methodology consisting of systematic analysis, which emphasises micro (construction projects) management in combination with medium (construction industry) management, data analysis in combination with investigations (survey and case studies), and quantitative (quantifiable contract risks) analysis in combination with qualitative (non-quantifiable contract risks) analysis.

The overall research method is positivist in the sense that there are logical objectives but reflects post positivism as described by Denzin and Lincoln (1994) in that it is recognized with this complex topic that a full understanding will not be achieved. As set out above a variety of research methods are employed ranging from questionnaire surveys, case studies through to mathematical modelling. The qualitative approach adopted in the questionnaire survey presented in Chapter 3 is important. The survey needs to capture the complex interrelationships and these can be lost by removing an aspect for quantitative analysis thereby possibly eliminating associated variables which may be influential (Guba and Lincoln, 1994). The questionnaire survey and the case studies provide data that contribute to developing an understanding or theory as the research evolves – in essence a
grounded theory approach (Glaser and Strauss 1967, Strauss and Corbin, 1994). This involvement of both qualitative and quantitative techniques is appropriate in this project; indeed Crompton and Jones (1988) argue that quantitative data always rests on qualitative distinctions. This is clearly illustrated by the probabilistic analysis model for contractual risks presented in Chapter 7, where the mathematical model uses information generated by qualitative methods. This mix of qualitative and quantitative approaches is necessary in dealing with complex organizational structures. These complex organizational structures can be considered as systems.

System science emerged as an important field of study after the Second World War. It was originally rooted in biological and engineering sciences, only recently branching out to become involved with social and economical problems. Morris (1983) describes a system as 'an assemblage of people, things, information, organisation, etc. grouped together according to a particular system objective'. System analysis should focus on interrelationships of the component parts and their influence upon the effectiveness of the total process. What each of them achieves depends upon what the others do. In the view of system science, the construction industry, consisting of design firms, construction corporations, consulting companies and administrations, is understood as a system. The construction project consisting of people, materials, capital and information flow is recognised as a complicated open system. This research investigates the risk management of construction projects and concentrates on project planning, including contractual strategy and project procurement route (PPR), and contract risk management. This research has been done in a systematic approach involving six phases:

1) Literature review;
2) Survey and case studies – determine study framework;
3) Contract risk management;
4) Project procurement route and contract strategies (for qualitative analysis of contract risks);
5) Strategies of PRM for the CCI, based on qualitative contract risks;
6) Mathematical modelling for the quantifiable analysis of contract risks.

This research studies PRM at both project level (case studies) and industry level (survey) in the CCI. It seeks to identify the gap in practice between the CCI and the western construction industry, and main issues to be overcome in order to improve PRM in the CCI. This provides necessary guidance in formulating the framework of the research and developing the strategies of PRM for the CCI. Based on the analysis of the PRM process and the current situation of the CCI, the research proposes a framework for contract risk management in construction projects, covering the concept, classification, identification and management of contract risks. For non-quantifiable contractual risks, an exploratory analysis is carried out of the project procurement route (PPR) including its assessment, selection, application conditions and function in the Chinese construction market reform. These provide technical supports to develop PRM strategies for the CCI. For quantifiable contractual risks, the research focuses on mathematical modelling. Two quantitative analysis models are proposed to investigate the effective information entropy and contractual risk probability analysis.

1.5 THE STRUCTURE OF THE THESIS

This thesis consists of 8 further chapters. Chapter 2 provides an extensive literature review on project risk management (PRM) covering, the characteristics of project risks, relationship between risk and uncertainty, theories and methods.

Chapter 3 presents a survey of PRM in the Chinese construction industry (CCI). The survey provides an overview of the CCI and an insight into the understanding of the application of PRM in China by identifying the attitudes of Chinese project participants towards PRM.

Chapter 4 studies contractual risks of construction projects, and presents the concept, classification and identification of contractual risks and a framework of contractual risk management.
Chapter 5 considers the project procurement route (PPR) and the relationship between the contractual risk and the PPR. It provides a case study to illustrate the popular project management model in China to determine the major problems and possible solutions considering the special role of the PPR in improving the Chinese PRM.

Chapter 6 proposes an effective information entropy model for contractual pricing strategies. The model provides a new method for applying information entropy based on an effective information distribution.

Chapter 7 proposes a probabilistic analysis model of quantitative contractual risks. The model can be applied to determine the likely range of project risks for objectives such as duration, quality and cost.

Chapter 8 provides recommendations on the strategy to suit the current situation for PRM in China, based on the study of contractual strategies, the PPR and contractual risk management.

Chapter 9 concludes the research and proposes further research efforts.
CHAPTER 2 RISKS AND RISK MANAGEMENT IN THE CONSTRUCTION INDUSTRY

2.1 THE CONCEPT OF RISK

Human beings have a long history of struggle against risks. According to the Shorter Oxford Dictionary, one of the earliest definitions of risk (1719) is “the probability of hazard or commercial loss”. Nearly 300 years later, Project Risk Analysis and Management (PRAM) defined risk as “an uncertain event or set of circumstances that, should it occur, would have an effect on the achievement of the project’s objectives”. The PRAM definition introduced probabilistic analysis so that mathematical methods can be utilised in risk analysis. The definition of risk adopted in this thesis is described in British Standard No. 4778: Section 3.1 (1991) (Bunni, 1997) as a combination of the probability, or frequency of occurrence of a defined hazard and the magnitude of the risk as a situation that could occur during the lifetime of a product, system or plant that has the potential for human injury, damage to property, damage to the environment consequent on the occurrence. Based on the definitions, risk may be expressed in the form of a mathematical equation, as follows:

\[ R = P \times C \] (Bunni, 1997).

This mathematical expression seems simple but it indicates the properties of risk, which may be showed in Figure 2.1 where probability of hazard event is plotted against the consequence of the occurrence of the hazard event. So, curves 1, 2, 3, 4 and 5 indicate different risk levels from low to high. For example, the probability of an aircraft hitting a high building is very low though the
consequence is large. Therefore, it might be considered appropriate not to take this into account when designing high buildings as the risk is very low.

![Graph showing equal risk curves](image)

**Figure 2.1 Equal risk curves**

### 2.2 THE NATURE OF PROJECT RISK

Critical aspects of construction projects are uncertainties, such as quality, prices, duration and weather. Individual project may include project-specific sources of uncertainty that affect the project value. The purpose of project risk management (PRM) is to reduce uncertainties by employing uncertainty analysis. Project uncertainties are stimulated by many factors, such as political, economical, technical and natural factors.

Despite a detailed literature survey, it has been shown that no research to date has been found able to reveal the following information in connection with the nature, characteristics of project risk and relation between risks and uncertainties in construction projects. The essence of project risk is uncertainty, and the uncertainty contains the following three aspects:

- What time the adverse event will happen,
- How long the adverse event last, and
• The magnitude of risk consequences.

Risk to the project may be the sum of many subsidiary risks. For example, risk of project overrun could result from a number of adverse events such as weather and supply problem. Therefore, risk identification and analysis are critical in determining key project risks.

The characteristics of project risk are as follows:

• Uncertainty is the basic characteristic of construction projects because there are many uncertainty factors both inside and outside of construction projects from commencement to completion. It determines that the area of risk analysis is extensive and the target of risk management is complex. However, it is unnecessary to analyse all project risks, and it is important to determine the key project risks that may yield a great influence on the project decision making.

• The uncertainty or randomness (in mathematics) of construction projects determines that risk analysis by mathematical quantification is difficult, especially, for those risk events that possess low probability and high consequence, such as war, earthquakes and other force majeure.

• Generally, the construction phase is affected by risks including natural conditions of site, technical complexities of construction, contractor's experience and ability, the client's financial situation.

• A comparative analysis of the magnitude of the various risks to which a project is exposed can be used to decide whether to accept a particular risk or to take measures to reduce or transfer it.

• The risks of a construction project can only be managed by using a clearly written contract efficiently and fairly.

2.3 RISK AND UNCERTAINTY IN CONSTRUCTION PROJECTS

In terms of mathematics, there are differences between risks and uncertainties:
- A risk exists when a decision is expressed in terms of a range of possibilities that can be attached to the outcomes.
- An uncertainty usually refers to the random nature of a result, which exists when there is more than one possible outcome of a course of action but the probability of each outcome is not known.
- Generally, project risks associate with project objectives. However, there is no association between uncertainty and project objectives.

Generally speaking, uncertainty refers to the absence of relevant information for decision making during early stages of construction planning, such as the state of design completion before commencement of construction, past experience of a firm relative to the project, the impact of weather and the availability of labour for the project. The uncertainty of projects can be reduced through risk analysis and risk control.

### 2.4 THE PURPOSE OF THIS REVIEW

Risk management has developed over many years with its own process, tools and techniques, and with consensus over the major concepts and practices. Nevertheless, projects still fail to meet their objectives and businesses are deprived of the expected and needed benefits, despite the theoretical principle that risk management should contribute to project and business success (Charette, 2002). Project risk analysis and risk management have been commonly utilised for defence procurement, oil and gas, aerospace, civil engineering and construction projects. Baker et al. (1999) studied risk response on the choice and use of the most successful techniques within the oil and gas industry and compared them with the use of those chosen by the construction industry. The subject of risk, and its assessment, allocation and management in construction projects has been analysed and developed on an increasing scale over the last 30 years. However, there is little uniformity of approach to the topic of risk by those involved in the construction industry and surprisingly, only a few useful general applications on the topic of risk have been developed in the area of planning and
management of construction projects. The lack of uniformity relating to risk extends even to the definition of 'risk' and what is meant by it (Bunni, 1997).

An extensive literature review of issues that relate closely to this research is conducted on risk identification, classification and risk management process, and analysis techniques. The purpose of the literature review is to probe the gap between the understanding and establishing of the research carried out to date in the field of project risk management (PRM). It is also necessary to close the gap between the Chinese construction industry (CCI) and Western construction industry in this field, and find the key issues that must be overcome so as to improve PRM in the CCI. This provides useful guidance in formulating a framework of PRM and determining the focus in quantitative analysis of risk of this research.

2.5 RISK MANAGEMENT OF CONSTRUCTION PROJECT

The construction project consisting of people, materials, capital and information flow is recognised as a complicated open system as defined by general system theory, and project risk management (PRM) is a large subject for research. There are many uncertainty factors both internal and external from commencement to completion. There are also different parties in the construction industry such as project participants and administrative authorities. Meanwhile, construction projects involve many stages such as, planning, design and building. Defectiveness in any stage or by any participant will have negative effects on the project. This means that the area of risk management is extensive and the target of risk control is complex. For any individual construction project, it is important to determine the key risks in order to make an appropriate risk management strategy.

PRM uses the information collected during the risk analysis phase to make decisions on how to improve the probability of the project achieving its time, cost and performance objectives. PRM is the procedure in which risk management is carried out step by step, and is also defined as a detailed logically consistent framework to develop the process of risk identification, risk analysis, risk
response and risk control. Buchan (1994) took three processes, risk identification, risk analysis and risk response to account for risk management. Bostwicks (1987) took four processes including risk identification, risk evaluation, risk response and risk control for risk management in his paper, and five steps are presented by Nummedal et al. (1996). The five systematic steps are risk identification, risk estimation, risk evaluation, risk response, and risk monitoring. The five steps fit together into a circular procedure that yields a controlled risk environment. Both risk identification and estimation can be considered as risk analysis, and risk response and monitoring can be entitled risk control. The principal aim of PRM is to ensure that risks associated with a construction project are managed in the most efficient manner. PRM has been developed from the following classic models of Hertz and Thomas (1983), Cooper and Chapman (1987). More details about risk management can be found in the works of Flanagan and Norman (1993) and Smith et al. (1999). In recent years project risk management has been growing from a defined technical approach to system analysis. For example, Han et al. (2004) discussed the basic framework of risk management systems to integrate the process and the risk hierarchy of projects at the corporate level.

The process of PRM is described in simple terms as composed of two stages, risk analysis and risk management, as illustrated in Figure 2.2. The structure described in Figure 2.2 is based on Cooper and Chapman (1987).
The first stage of risk analysis as shown in Figure 2.2 begins with the identification and assessment of risk which is a qualitative process and this is followed by quantitative analysis, typically involving probabilistic analysis, allowing evaluation. This in turn informs the risk management which allows formulation of the management response. This will include both immediate responses and contingency responses.

For risk response, Raftery (1994) has identified four possible techniques: risk elimination, risk transfer, risk retention and risk reduction.

1) Risk elimination means risk avoidance. A contractor will not bid for a new project or a contractor will tender a very high bid.

2) Risk transfer can take two basic forms (Thompson and Perry, 1992):

- The property and/or activity responsible for the risk may be transferred, e.g. a sub-contractor is hired to work on a hazardous process;
- The property or activity may be retained, but the financial risk transferred, e.g. through insurance.
Different project systems have different project environments and risk structures. Clients and contractors can make use of PPRs that possess their own risk structure and contract conditions as major methods to transfer project risks. A construction contract is not only a lawful instrument for risk allocation, but also the legal document of project management.

3) Risk retention is the method of handling risks by the clients or contractors who have the ability to control them. The risks foreseen or unforeseen, are controlled by fulfilling the terms of the contract. There are two retention methods, active retention and passive retention (Carter and Doherty, 1974). Active retention is a deliberate management strategy after a conscious evaluation of the possible losses and costs of alternative ways of handling risks. However, passive retention occurs through neglect, ignorance or absence of decision making, e.g. a risk at the tendering phase has not been identified and handling the consequences of that risk must be borne by the contractor performing the work.

4) Risk reduction may be an action within the overall risk management, and it is because of the possible wider use of risk reduction that it has been categorised separately. The actual reduction of risks within these categories is confined to the improvements of a company’s physical, procedural, and educational and training devices (Flanagan and Norman, 1993).

2.6 RISK IDENTIFICATION AND CLASSIFICATION

2.6.1 Risk identification

Risk identification provides a foundation for risk management, and project objectives and their associated risks should be identified as early as possible during the project appraisal phase. Once a risk has been identified it is possible to take action to deal with it. Risk identification is achieved by the following well-known methods:

• Checklist,
- Delphi technique,
- Brainstorming, and
- Interviewing key members of the project team.

Risk identification is conducted by the selection of an overall approach combined with a specific technique such as the Delphi technique. The technique is a highly formalised method of communication that is designed to extract the maximum amount of unbiased information from a panel of experts. The Delphi method consists of four rounds, identifying the selection criteria, refining the selection criteria, obtaining utility factors (degree of suitability against each criterion) from experts, and refining the utility factors (Chan, 2001). The objective of the Delphi method is to obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires. The approach for risk identification is commonly either top-down or bottom-up. The top-down approach advocates a 'quick look and probe' method for construction projects. The bottom-up approach identifies risks at a low level of work breakdown. These methods are enhanced by the use of checklists. The checklists can be generated by reference to reviews of past project data, case based analysis and by using the personal experience of the risk analyst. A hierarchical structure of risk sources known as a risk breakdown structure (RBS) is recognised as a major tool for project risk identification. The RBS is a powerful aid to risk identification, assessment and reporting, and the ability to roll-up or roll-down to the appropriate level provides new insights into overall risk exposure on the project (Hillson, 2002).

2.6.2 Risk classification

A reasonable breakdown and categorisation of overall risk identification can be considered as risk classification. In order to manage risks it is necessary to classify project risks because in the construction industry the risk elements involved are diverse and varied. The purpose of risk classification is to cope with risks effectively, and the classification is helpful to identify risks. The industry has a history of attempts to identify and manage risks encountered.
• Carruth (1977) and McNulty (1980) identified some risk elements inherent in construction projects, which include site security, health and welfare requirements.

• Perry and Hayes (1985) and Mustafa and AI-Bahar (1991) identified a number of risk sources central to construction projects. These are environment, physical, design, financial, legal, political, construction and operation risk, etc.

• Cooper and Chapman (1987) classify risks according to the significance of the risks (their nature and magnitude) and sort risks into the two major groups of primary and secondary risks.

• Tah et al. (1993) used a risk breakdown structure based on origin and to the location of risks and their impact in the project.

• Wirba et al. (1996) adopted a symptomatic combination of the method of Tah et al. (1993) and that of Cooper and Chapman (1987), where the former was used to classify all risks in detail and the later to separate risks into primary and secondary risks.

• Bunni (1997) analysed construction risks on the basis of the effect they generate once they activate, and two basic types of risk could be identified. The first type incorporates the risks that can lead to damage, physical loss, or injury, and the second type delays the completion of the work and/or cost over-run of the construction project. Examples of the first type of risk include defective design, defective materials, defective workmanship, acts of God (e.g. hurricanes and earthquakes), fire, human errors and failures to take adequate precautions. Examples of the second type include late possession of the site, delay in receipt of information necessary for timely construction, changes in design, and variations to the original contract.

2.6.3 An example of risk classification

Each individual project has its own risk factors and risk structures due to its site, technical complexity, construction, management, design, material, subcontractor, etc. Project packages do not share the same risk level and each should be treated individually. Build-Operate-Transfer (BOT) projects possess the most complicated risk structure and risk factors that have the potential to concentrate all
known engineering risks onto a single project. Taking a BOT of state hydroelectric station in China as an example, its project risks include (Wang et al. 2000):

1) Political risk: confiscation, revocation, sequestration and exclusivity; adverse government action or inaction; reliability and creditworthiness of local parties; provision of utilities; increase in taxes (general and specific); political force majeure events; termination of concession by the government; and payment failure by the government.

2) Economic risk: inflation, interest, foreign currency exchange rate and foreign currency convertibility.

3) Legal risk: applied laws; ownership assets; security structure; insolvency (bankruptcy) of concession company; contract risk; lease property; and enforceability of security.

4) Market and revenue risks: insufficient fee income; fluctuating demand of power generated; transmission failure; problem in bill collection; power theft; fluctuation of cost and availability of fuel/coal; government restriction on profit and tariff.

5) Operational risk: government department default; concession company default; operator inability; termination of concession by concession company; environmental damage; operating force majeure events; labour risk; technology risk; prolonged downtime during operation; and condition of facility.

6) Construction risk: land acquisition and compensation; restriction on import; cost overrun; increase in financing; cost; time and quality risk; contractor default; default by concession company; scope of identified but related work and variations; environmental damage subsisting; and protection of geological and historical objects.

7) Unforeseen force (force majeure): earthquake, tornado, rainstorm, tsunami, nuclear pollution, collapse, subsidence, etc.

8) Special risks: war damage, armed intrusion, overthrow of government, etc.
The author considers two extra risk categories as listed in items 7 and 8 above. The risks of a BOT project include all risks associated with the construction project from inception through to completion. They have been classified as above according to the characteristics of risks. In order to manage effectively project risks, BOT projects employ mature technologies and are applied in non-competitive fields besides effective preliminary study and project assessment. BOT projects are a new project management model, an innovative project financing model and project procurement system which needs an advanced management system. Packaging of BOT projects demands effective management of risks associated with the complicated financial and legal relationship among a considerable numbers of the participants. One of the crucial factors to operate a BOT project successfully is effective risk assessment and reasonable risk allocation. As mentioned, the purpose of risk classification is to cope with risks effectively. For this purpose, the risks of a BOT project can be classified into three kinds as follows:

1) Country risk: political environment, economical environment, legal and regulation framework for the BOT project, government attitude towards private sector, realistic demand for the BOT project, etc.

2) Government risk: bidding procurement, availability of contractors, government subsidies of price to avoid social reaction, government guarantee against financial risk beyond the control of private investors, etc.

3) Project risk: monopoly condition for the service/product, foreign capital, sufficient return on equity/investment, the limits of construction, operation and maintenance, consistency with the environmental issues, technical factors, etc.

This method of risk classification for BOT projects is also beneficial to cope with the risks in international projects. The risk level varies from project to project and from country to country. For quantitative analysis of risk, the main approaches for BOT projects are the models based on the Monte Carlo simulation, multiple regression and net present value (NPV) method to assist in the negotiation of BOT contracts (Loh et al., 1997). NPV is an economic parameter for evaluating the investment efficiency of projects, which calculated by estimating future cash
flows and discounting them back to the present value using an appropriate discount rate.

2.7 METHODS OF RISK ANALYSIS

2.7.1 Qualitative methods of risk analysis

Different projects possess different risk structures and risk levels, and each project requires a particular risk management approach suited to it. Quantitative analysis of project risk requires a large number of calculations to be carried out based on historical data and statistical data, and hence a problem is how to get the data. If the data are not available and no experiment can provide the data, it will probably be necessary to use qualitative analysis methods, such as interviewing key members of the project team, checklist, Delphi technique and brainstorming. In most cases, the decision making in the construction industry must depend on the past experience and information obtained. Taking an international project as an example, the project risks should be analysed and assessed as macro risks (country and government risks), intermediate risks (construction market risks) and micro risks (project risks). A survey was conducted and twenty-eight critical risks were identified, categorised into three (country, market and project) hierarchical levels and critically evaluated and ranked (Wang, 2004). The market risks include: technological advantage over the local market, role of the construction industry in a foreign country’s overall economy, availability of construction resources, complexity of regulatory processes, attitude of the foreign government towards the construction industry, and financing opportunities (Shenkar and Zeira, 1987). There are three major models for the risk management of international projects.

1) Ashley and Bonner (1987) segregate political risk for international projects into two categories: political source and project consequence. They have defined project consequence variables as those variables that directly influence the project, such as labour restrictions, change in per-unit cost of labour, and strikes and labour – impacting delays. Political source factors have been defined as those variables that indirectly influence the project through their impact on the project.
consequence variables. The political source factors include variables such as the firm’s relation with the government, nature of the firm’s operations, government policies, nationalist attitude towards the firm, and influence of power groups. The political risk in this model is evaluated by subjectively assigning financial impact and probabilistic values to the potential risk generating project consequence variables and computing the expected value of impact. Although a valid approach, this model limits risk analysis to the impact of political events on the project and its consequences. Furthermore, it does not consider the indirect impact of political factors on the construction and other related market and the potential impact of market factors on the project.

2) The business environment risk information (BERI) model, views the country risk as the sum of political risk, operational risk, and remittance (allowance) and repatriation factors. The BERI model is an empirically based forecasting service founded to assist multinational firms in their business decisions. The service provides a framework to evaluate risk, make regular period updates, and forecast political and economic events. The BERI model has compiled risk indicators into three groups: (1) operating risk criteria, (2) political risk criteria, and (3) financial risk criteria (Haner and Ewing, 1985).

3) The macro sociopolitical (MSP) models approach risk from the macro level perspective. Most of the MSP models express the political instability factor as a function of various economic, ideological, and social forces. The assumption is that political events can affect the development of economic and business conditions in the host country. The complex array of development in the host country’s sociopolitical environment might lead to political instability, resulting in drastic changes in the business environment, including expropriation actions by the host government (Knudsen, 1974; Haner and Ewing, 1985; Ting, 1988). The major shortcomings of the MSP approach are: (1) they do not analyse the effect of political instability on the actual investment project, and (2) they lack specificity in relating the impact of expropriation. Macro risks, intermediate risks and micro risks should not be considered in isolation. The macro environment might trigger some of the risk indicators at the market and the project level, while market
environment might influence some of the project indicators. Apart from this, additional indicators might be triggered within each of the three levels due to their respective environments.

2.7.2 Quantitative methods of risk analysis

Risk analysis of construction projects has been the object of attention because too often risks are not dealt with satisfactorily and the industry has suffered poor performance as a result. The assessment of the level of risk is a complicated topic due to risk characteristics in uncertainty and vagueness. The risk assessment process requires an assessment of the probability or likelihood of both the damaging event and its impact. There is a proliferation of techniques and packages designed to provide risk analysis and management facilities but they have, for the most part, failed to meet the needs of project managers. These techniques are founded primarily in principles and methodologies derived from operational research techniques developed in the 1960s, and tend to focus on quantitative risk analysis based on estimating probabilities and probabilistic distributions for time and cost analysis (Tah and Carr, 2000). A range of studies including William and Heims (1989), Toakley and Ling (1991), Raftery (1994), and Akintoye and Macleod (1997) identified the current usage of risk management techniques in the construction industry. These include subjective probability, decision analysis, sensitive analysis, Monte Carlo simulation, fuzzy logic, stochastic dominance, risk premium, risk adjusted discount rate and decision trees. The application of all these methods is effective to a defined technical problem but is limited in practice. The construction industry is plagued by risk and has often suffered poor performance as a result (Tah and Carr, 2000). The approaches of quantitative analysis of project risk need sophisticated technologies that are introduced from other academic fields, and further developed in the construction industry. For example, fuzzy arithmetic and entropy measures have been introduced to analyse the collected data in terms of weightings and closeness indices from different respondents in two aspects: (1) the degree of importance for the four predetermined factors influencing site layout.
planning; and (2) the degree of closeness between the nine predetermined site facilities. In particular, the maximum entropy principle can be applied in the construction industry to deal with uncertainty problems (Lam et. al., 2005).

2.8 DISCUSSIONS

The nature and characteristics of the risks of construction projects and the relationship between risk and uncertainty have been analysed, which provides a basis for this research. An extensive literature review has illustrated that in the construction industry, risk analysis and management are found primarily in principles and methodologies derived from operational research techniques developed in the 1960s, and currently project risk management (PRM) focuses on limiting project losses. This perspective has produced a standard risk management process typically including risk identification, measurement and mitigation. Although this process provides some procedures and techniques to analyse and manage project risks, it tends to focus on quantitative risk analysis based on estimating probabilities and probabilistic distributions for time and cost. Software packages for PRM can deal with certain technical issues, such as duration prediction by the Monte Carlo simulation and cost calculation of construction projects. At the moment, there is no software package for the systematic analysis of PRM. As construction business competition becomes more intensive and changes more difficult to predict, the needs for risk management will become more intense.

Different from other countries, China's basic national and cultural state is in a period of transition moving from a centrally planned economy to a market economy, and the administration system under the centrally planned economy still largely affects the current practice in the Chinese constructive industry (CCI). In order to identify and adopt the best practice in PRM to suit the Chinese construction industry (CCI), and improve PRM in China, it is necessary to explore the practice of risk management in the CCI.
CHAPTER 3 CURRENT STATUS OF RISK MANAGEMENT IN THE CHINESE CONSTRUCTION INDUSTRY

The purpose of studying risk is to manage risks. However, risks may not have the same level of significance for different countries, markets and projects. In the Chinese construction industry (CCI), risk management is in its infancy and the participants of projects have little understanding and knowledge of this important area of management. At present, Project risk management (PRM) in the CCI needs industry support, powerful law environment and mature construction market. In order to develop the strategies of PRM in the CCI, it is necessary to understand the current status and the special issues to be solved in order to implement PRM and develop the CCI.

3.1 AN OVERVIEW OF THE CHINESE CONSTRUCTION INDUSTRY

3.1.1 The development of the Chinese construction industry

Since the ‘open door policy’ and economic reform commenced in the early 1980’s, China has been developing at a rapid pace. China’s economic development and the influence of economic globalisation have resulted in the need to join in the world market. In China, the construction industry was selected to be the first industrial sector to adopt international practices, and was recognised as an important independent and profitable sector of the national economy and no longer a subordinate activity of the state’s capital investment plans.

In 1982, the international tendering for the inlet channels engineering of the Xiaolangdi Hydroelectric Power Station on the Yellow River (a World Bank loan project) marked the first construction project utilising international practices (He, 1994). Since then there have been many examples that attest the adoption of international practices. It is significant that an industry so often considered as
slow to take up the advances in management in Western economies has been identified as the industry to be in the vanguard of a process that would affect the economic and social landscape of China. Currently the annual output of the Chinese construction industry (CCI) is approximately US$ 93 billion which accounts for more than 6% of the Gross Domestic Product (GDP) and has been growing at an average annual rate of about 10% since 1978 (State Statistical Bureau of China - SSBC, 2000 and 2001). In the view of author, this situation will continue for the next 20 years at least. With the development of the Chinese urbanisation during the period, more than a half of the total population will live in urban areas.

China has issued a unified construction law (National People’s Congress - NPC, 1998) and re-written the Economical Contract Law (NPC, 1999) that provide a rational framework of construction policies and regulations. The Ministry of Construction (MoC) of China has reviewed and issued the New Construction Contract Conditions (NCCC, 3rd Edition, 1999), which is the only construction contract conditions in China. Although it has adopted the principal clauses of the FIDIC (International Federation of Consulting Engineers) Red Book, the problem is that the Red Book fits in the unit price or re-measure contract, but the NCCC operates with the Lump Sum Contract. The Lump Sum Contract of the traditional project procurement route (PPR) is efficient for small and simple construction projects and is therefore limited in its use. The CCI has become familiar with Lump Sum Contracts and this prevents the Chinese project participants from adopting other PPRs where the design and construction phases are not separated.

As a consequence of entering the WTO, China’s construction market will open fully to foreign contractors and engineering consultants in 2006. It is axiomatic that the influx of foreign contractors into China will improve the management skills and undoubtedly facilitate the emergence of Chinese contractors as participants in a broader world front than that they currently enjoy. Commentators often view the internationalisation of a particular country’s industry as being achieved when competitors enter the home markets. Internationalisation is achieved equally by home industries entering the world markets. This will force
the Chinese contractors to review and improve their competence in the domestic and overseas markets and to ensure that they are fully conversant with international practices. It is noteworthy that the MoC has promoted a positive lead in this strategy (Yan and He, 2000). In 1984, the construction industry was selected as an experimental sector for the urban economic reform. A comprehensive regulatory framework with realistic implementation measures has been identified as necessary. At the central planning level, the government has introduced examples of regulations that constitute the ‘best practice’ from other economic systems to form the basic template. China’s policies for the construction industry have called for:

- the implementation of competitive bidding,
- the implementation of a new system of construction supervision, and
- the implementation of a new system of construction contractual management and a formal registration system for various professional engineers (such as civil engineers, architects and consultants as used in the International Federation of Consulting Engineers - FIDIC contract conditions and by the Institution of Civil Engineers - ICE, UK) in the industry.

Of all the areas identified as important to the development of the construction industry, competitive bidding was seen as a crucial measure and was tested in 1984. The success of this pilot was developed and approximately 50% of construction contracts were let through competitive bidding 10 years ago. In 2000, China issued the Law of Bidding and Tendering (NPC, 2000) and the Regulations on Qualification Administration of Project Tendering Agency (MoC, 2000). Currently, all government and public sector projects are required by law to employ bidding for contracts. Competitive bidding has been used not only in the field of construction and installation, but extended to project design, equipment purchase and construction supervision. In order to develop the construction supervision capacity, China started to implement a construction supervision system in the early 1990's. To develop a professional system and improve the standards of professional performance, regulations were made, including the
Regulations on Assessment and the Registrations for Project Supervision Engineers (MoC, 1992), and the Regulations on Assessment Systems for Project Costing Engineers (MoC and the Ministry of Personnel, 1996). In 1994, 1400 supervision agencies were established employing approximately 71,000 staff (He, 1994). The adoption of international practice has ensured that China develops the basic regulatory framework in place for its construction industry.

3.1.2 The main issues of the Chinese construction industry

Despite all the efforts and achievements, it must be admitted that the progress of implementation of the policies and regulations has been slow. While the causes are complex, the major reason is that the administration system under the centrally planned economy still largely affects the current practice. Law and regulations account for one aspect while providing conditions for innovation within the construction industry is another task. China’s basic national and cultural state is in a period of transition moving from a centrally planned economy to a market economy requiring a considered and deliberate direction.

Factors that dictate the pace of the development in the Chinese construction industry (CCI) include:

- The clients have traditionally managed construction projects themselves, especially infrastructure projects. This is one of the major reasons that China’s engineering consultants have not had the opportunity to develop their business. Meanwhile, it obstructs the implementation of new regulations and systems.
- The construction market is immature. In particular, the project procurement route (PPR) is unitary and the participants have become accustomed to the unitary Traditional PPR (design/bid/build - D/B/B) and to the Lump Sum Contract.
- The organisation structure of construction enterprises militates against the adoption of innovative PPRs and the mechanism of the construction market.
• Competitive bidding and contract management still need improvements to remove some of the difficulties, such as 'partial bidding' and 'triangular debts'. These are the major obstacles for the further development of the CCI.

• Supervision capacity is limited, particularly in engineering quality control. Systematic organisation, planning and co-ordination are often neglected.

• Traditionally, design and construction have been separated. Generally, the design firm is limited to the design work and the construction company carries out only the construction work. Therefore, engineering consulting is a new field and will require time to become accepted.

• In some projects, such as highways, bridges and civil buildings, the construction quality has been seriously compromised and is recognised as a critical problem (Yan, 2003).

At the construction industry level, it is hard to implement effectively PRM without solving these issues. It means that PRM needs the industry support and application environment. These issues cannot be solved one by one themselves because of their interaction with each other. However, the construction market reform is crucial to resolve these issues and to further develop the CCI. Also, the reform is essential to accelerate the internationalisation of the CCI. In 2000, the MoC chose Hebei province, and the Cities of Shanghai and Shenyang as experimental regions for construction market reform to achieve improvements in the administration system and management mechanisms. One of the tasks is to reform the organisation of construction projects and develop GEP. In March 2003, the Ministry published guidelines for the experimentation of General Engineering Packaging and the development of project management enterprises. The purpose is to deepen the reform and development of the Chinese construction market and to increase the competitive ability of the CCI.

A significant event in recent years for the CCI has been China’s entry into the World Trade Organisation (WTO). As a consequence, China’s construction market will open up furthermore to foreign contractors and engineering consultants. This will force the Chinese project participants to review and improve
their competence in the domestic and overseas markets and to ensure that they are fully conversant with international practice. It is noteworthy that the Chinese Ministry of Construction has promoted a positive lead in this strategy (Yan and He, 2000). Internationalisation is achieved equally by home industries entering the world markets. What is the major gap in project risk management (PRM) between China and the developed world? What are the particular issues needing to be solved to improve PRM for the Chinese construction industry (CCI)? Such questions must be answered in order to make recommendations of practical guidelines for PRM strategies for the CCI. Therefore, an investigation into the current status of risk management of construction project in China is necessary.

3.2 A SURVEY OF RISK MANAGEMENT IN CHINA

3.2.1 Introduction

This survey is conducted to obtain an insight into the understanding and application of risk management in the China construction industry (CCI), and to find out the attitudes of project participants towards risk management.

The objectives of the survey are to understand:

- the current situation of project risk management (PRM) in China
- the major risk events in the CCI
- the major gap in the construction industry between China and the developed world in terms of PRM
- the major problems to be overcome and possible solutions to them in order to improve the Chinese PRM

In China, there are three major types of contractor, namely, state-owned enterprises, urban and rural collectives and rural construction teams. State-owned enterprises usually operate at a larger scale in terms of production and employment than the others. Generally speaking, state-owned enterprises represent the most advanced management in the CCI. So all the samples of this
survey are from state-owned enterprises, including contractors, design firms (typically called design institutes in China) and building consulting firms and, therefore, giving an insight into the most developed sector of the CCI.

The survey was carried out over the period extended from January to September 2002. Questionnaires were distributed to 50 construction firms, 38 design firms and 40 building service firms, including the participants (state-owned construction enterprises) of the new campus of Shenyang Jianzhu University (SJZU), in March 2002 with a suggested date for return at the end of April 2002. The project participants provided extensive relevant information by answering the questionnaire of the survey.

Questionnaire returns were received over the next five months, in some cases after telephone reminders. The response rate for completed questionnaires was 43%, i.e. fifty-five out of the 128 questionnaires were completed and returned eventually from individual architects, project managers and senior officers of the companies including construction firms, design firms and engineering supervision firms. The number of respondents is statistically sufficient for the purpose of the survey. The job titles of the respondents covered a wide range, and varied from assistant engineer to director. However, the majority of the respondents were project managers and engineers, and they were experienced with over 8 years in construction management. Most respondents were from state-owned enterprises and most respondents' firms were medium-size firms with about 1000 employees. From the characteristics of the diversity of the respondents and their firms, the sample provides a realistic profile, which can be used to present the general practices and status of risk management as well as the views on the use of risk management within the CCI.

3.2.2 Design of the survey

The survey was restricted to construction enterprises, design firms and supervision companies in Shenyang, which is the capital of Liaoning Province and one of the largest industrial cities in China. There are 436 construction enterprises
and 186 construction design firms in Shenyang. In 2000, the Ministry of Construction (MoC) of China chose Hebei Province, and the cities of Shanghai and Shenyang as experimental regions for construction market reform to achieve improvements in the administration system and management mechanisms. One of the tasks was to reform the organisation of construction projects and develop General Engineering Packages (GEP). The work was expected to complete by 2003 (Guidelines for the Reform of the Chinese Construction Market, MoC, 2000). However, this has not been achieved because the construction market reform is a very complicated process dealing with the structure of construction enterprises, administration system and regulation environment in the industry. Shenyang is typical of the current practices and mean development level of the Chinese construction industry (CCI).

The survey involved three stages:

(1) Questionnaire design,
(2) Selection of the samples, and
(3) Analysis of the responses.

The framework and details of the questionnaire used in the survey were designed to suit the particular needs of this research. The questionnaire contained 36 questions split into six separate sections (Appendix C):

(a) General questions about risk and attitude towards risk management,
(b) The major risk events in the CCI,
(c) The relationship between project risk management (PRM) and project management,
(d) General practice, strategies of risk management and major difficulties for applying risk management,
(e) The practice of project procurement route (PPR) and contract management, and
(f) The development tendency of risk management after China entering the WTO.
3.2.3 Method of the survey

In order to provide a statistical method for analysing the sample data for assessment of the risk probability and risk consequence, the scales presented in Table 3.1 and formulae are commonly adopted. Here, the scales in the table are relative values with four categories ranging from 0.2 (lowest), 0.4, 0.6, to 0.8 (highest). For similar scales with more categories (e.g., a scale of 0.1, 0.3, 0.5, 0.7 and 0.9), the outcomes (RS) are of different values, but the assessment consequences would be generally the same or very similar.

Table 3.1 Probability and consequence of risk

<table>
<thead>
<tr>
<th>Risk probability, $\alpha$</th>
<th>Low</th>
<th>Low-medium</th>
<th>Medium-high</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk consequence, $\beta$</th>
<th>Small</th>
<th>Small-medium</th>
<th>Medium-large</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

$$S_j^i = \alpha_j^i \beta_j^i$$

$$RS^i = \frac{\sum_{j=1}^{n} S_j^i}{n}$$

where $n$ denotes the number of persons investigated;

$S_j^i$: denotes the outcome of the $i$th risk event by the $j$th person investigated;

$\alpha_j^i$: denotes the probability for the $i$th risk event by $j$th person investigated;
\( \beta_j^i \): denotes the consequence for the \( i \)th risk event by the \( j \)th person investigated;

\( RS^i \): denotes the average outcome of the \( i \)th risk event.

### 3.2.4 Analysis of the survey

1) Important risks in the CCI

As seen in Table 3.2 the lowest responding percentage is 78\% of the five important risk events. So, the outcome of the survey may represent the major risk events in the CCI.

<table>
<thead>
<tr>
<th>Risk</th>
<th>No. of responses</th>
<th>%</th>
<th>( RS^i )</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Difficulty for contractors to collect debt from the clients</td>
<td>51</td>
<td>93</td>
<td>2.48</td>
<td>1</td>
</tr>
<tr>
<td>2. Client payment is not on time</td>
<td>53</td>
<td>96</td>
<td>2.41</td>
<td>2</td>
</tr>
<tr>
<td>3. Bidding under an unfair competition environment</td>
<td>46</td>
<td>84</td>
<td>2.37</td>
<td>3</td>
</tr>
<tr>
<td>4. Local conservation</td>
<td>43</td>
<td>78</td>
<td>2.26</td>
<td>4</td>
</tr>
<tr>
<td>5. Contractors have to pay construction costs instead of clients for a period of time</td>
<td>54</td>
<td>98</td>
<td>2.20</td>
<td>5</td>
</tr>
</tbody>
</table>

The survey shows that, the important risks found in the CCI are:

- Difficulty for contractors to collect the debt from the clients \( (RS = 2.48) \),
- Client payment is not on time \( (RS = 2.41) \),
- Bidding under an unfair competition environment \( (RS = 2.37) \),
- Local conservation \( (RS = 2.26) \), and
- Contractors have to pay the cost of construction instead of the clients for a period of time \( (RS = 2.20) \).
These five risks listed according to the value of RS, show that for contractors, the major risks come from the clients in the CCI. The effective approach for reducing these risks is to improve the contractual management of construction projects. It indicates that PRM in the CCI is different from other countries, and PRM should be based on contractual risk management (CRM). The key issue to overcome these problems is to develop and deepen the reform of the Chinese construction market. Otherwise, the sophisticated theories and approaches of PRM will not work effectively.

2) Major findings

General questions in the questionnaire about risks and attitude towards risk management include:

- What is risk according to your understanding?
- What is your understanding of project risk management?
- Do you think it is necessary to assess project risks at the project planning phase?
- Do you think it is difficult to implement project risk management in your company? If yes, give reasons, e.g. unavailability of time or finance or lack of expertise.
- Give as many methods as possible for project risk management, such as experience, mathematical models and insurance.

The analysis has concentrated mainly on the findings from the returned questionnaires. Let \( R = \frac{n_m \times 1}{n_n} \), where \( n_n \) denotes the number of answers to the question investigated, and \( n_m \) denotes the number of correct answers to the question investigated. The lowest responding percentage is 71% for the attitude towards risk management, and the outcome of the survey may represent the attitude towards risk management in the CCI as shown in Table 3.3.
Table 3.3 An analysis of responses: attitude towards risk and risk management

<table>
<thead>
<tr>
<th>Risk attitude</th>
<th>No. of responses</th>
<th>%</th>
<th>(n_m)</th>
<th>R %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Risk and risk management</td>
<td>43</td>
<td>78</td>
<td>3</td>
<td>6.9</td>
</tr>
<tr>
<td>2. Project risk assessment</td>
<td>53</td>
<td>96</td>
<td>5</td>
<td>9.4</td>
</tr>
<tr>
<td>3. Mathematical models for project risk management</td>
<td>52</td>
<td>95</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>4. Time to analyse and handle project risks</td>
<td>55</td>
<td>100</td>
<td>6</td>
<td>10.9</td>
</tr>
<tr>
<td>5. Ability to management project risks</td>
<td>51</td>
<td>93</td>
<td>5</td>
<td>9.8</td>
</tr>
<tr>
<td>6. Experience as method for managing project risks</td>
<td>39</td>
<td>71</td>
<td>35</td>
<td>89.7</td>
</tr>
</tbody>
</table>

The results of the survey reveal the following:

- The project participants have little understanding and knowledge of this important management area (R=6.9%);
- The risks of construction project are not being assessed in a formal and systematic way (R=9.4%);
- Most respondents are unwilling to utilise sophisticated mathematical models for risk management (R=0.0%);
- They feel that there is no time to analyse and handle project risks (R=10.9%);
- They are not confident in their ability to control risks, and they do not correctly understand the concepts of risk and risk management (R=9.8%); and
- The risk management is done by using the experience and judgement of the managers (R=89.7%).

The results of the survey indicate that basically, PRM has not been utilised by the sampled companies in the CCI and the risks of construction projects are not being assessed in a formal and systematic way. Both clients and contractors are unwilling to adopt sophisticated mathematical models for risk management. Most respondents do not think they have time to analyse and handle risks and they are not yet equipped to handle PRM. They are not confident in their ability to control
risks. The current method of risk management is based on the experience and judgement of managers. This has left many companies in a dangerous position for further development under the new competitive market conditions. The most common methods to guard against risks are to insure a project and to add a contingency sum, which is a fixed percentage figure to the estimated cost. The contingency figure is arbitrary and may not be appropriate for the specific project. The traditional contingency figure approach is reactionary in nature. In contrast, PRM provides a systematic and rational framework for identifying and assessing potential project risks and improving project performance. Meanwhile, the respondents of the survey have a positive attitude for applying PRM. Considering the China's entry into the WTO, they believe that the RPM will become more important in the future. This means that the industry may need further education to help recognise role of risk management of construction projects. In the CCI, people have become accustomed to employing personal experience to manage the uncertainties of construction project. The benefits of using PRM need to be made known to people, and education and training provided in using computer based decision support systems. This research investigates the risk management status in the CCI and the survey has provided detailed information for this research.

The questions about project procurement route (PPR) include:

- Do you know what project procurement route is?
- If yes, give an explanation of PPR and provide types of PPR.
- Which type of contract is most often employed in your company, Lump sum contract, Unit price contract or others?
- What is the major approach of project contracting (packaging) in your company?

Table 3.4 provides an analysis of the responses in the survey. Let $R = n_m \times \frac{1}{n_n}$, where $n_n$ denotes the number of answers to the questions investigated, and $n_m$ denotes the number of correct answers to the question investigated.
Table 3.4  An analysis of responses: Understanding of the PPR

<table>
<thead>
<tr>
<th>Risk attitude</th>
<th>No. of responses</th>
<th>%</th>
<th>$n_m$</th>
<th>$R$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The concept of PPR</td>
<td>49</td>
<td>89</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2. Understanding of PPR</td>
<td>49</td>
<td>89</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>3. Lump Sum Contract</td>
<td>52</td>
<td>95</td>
<td>52</td>
<td>100</td>
</tr>
<tr>
<td>4. Design/Bidding/Build (D/B/B)</td>
<td>39</td>
<td>71</td>
<td>33</td>
<td>85</td>
</tr>
</tbody>
</table>

It has been found in the survey that:

- The concept and principles of PPR is new in China, and the respondents were not aware of PPR at all ($R=0.0\%$);
- The respondents misunderstood the PPR as the method to buy construction materials and equipment ($R=0.0\%$);
- The respondents did not know other PPRs except the Traditional PPR ($R=100\%$); and
- The participants of construction project have become accustomed to the unitary Traditional PPR (Design/ Bidding/ Building) and Lump Sum Contracts respectively ($R=85\%$).

These questions covered most subjects regarding the survey objectives. For example, in this survey, it has been found that the project procurement route (PPR) is not well known except for the Design/Bid/Build (D/B/B) model, which has been used for about two hundred years. When the concept of PPR was first introduced in the 1970s, the PPR for the D/B/B model was viewed as the Traditional PPR in the construction industry. Most respondents misunderstand the PPR as a method to procure construction materials and equipment. This is not surprising because the participants of construction project have become accustomed to the unitary traditional method (Design-Bid-Build) and Lump Sum Contract respectively. An insight into the understanding and application of risk management in the CCI has been obtained by the analysis of returned
questionnaires. This survey illustrates current situation of PRM in China and the major gap in the construction industry between China and the developed world.

3.3 THE APPROACHES TO PROJECT RISK MANAGEMENT FOR THE CCI

The benefits of risk management (PRAM Guide, 1997, by the UK APM-Association for Project Management) in the Western construction industry are documented as:

- increasing the understanding of the project, which in turn leads to the formulation of more realistic plans in terms of both cost estimates and timescales,
- giving an improved understanding of the project through identifying the risks and thinking through response scenarios,
- enabling decision making to be more systematic and less subjective, and
- giving an understanding of how risks in a project can lead to the use of a more suitable construction contract conditions.

PRM may be reviewed as a logically consistent framework to develop the process of risk identification, risk analysis, risk response and risk control. The survey shows that for contractors, the major risks come from the client in the Chinese construction industry (CCI). An anecdotal saying in the CCI is “winning a bid depends on a low tendering price, and making profit is on claims”. It is likely to lead to contractual disputes rather than collaborative problem solving when difficulties arrive. The benefit of project participants is from project performance which is from effective project planning instead of either low tendering prices or claims. In the author’s view, project risk management (PRM) and project planning are two crucial issues to realise project objectives, and PRM is the foundation of project planning. In the CCI, project failures are essentially caused by the unawareness and neglect of project planning. Project planning mainly includes objective planning, organisation structure planning and contractual structure planning. Especially, contractual structure planning should be emphasised that
includes the choice of the PPR and contractual risk management. Planning is a major determinant of project success in the construction industry.

Under the centrally planned economy, many construction projects are state projects, and therefore, the CCI has not paid enough attention to project risks and their harmful consequences are usually borne by the government. The project participants are used to managing the project by using the experience and judgements of managers, and this has left many companies in a dangerous position under the new completing market environment. For example, because of a wrong decision making or poor risk management, a company has to suffer heavy losses even bankrupt, or face penalties associated with not meeting project objectives that could have a devastating impact on the company position.

An effective approach to reducing these risks is to improve the contractual management of construction projects. This research provides such an approach to improve project risk management for the CCI. Figure 3.1 illustrates the framework of the approach, where solid lines indicate a route map and the dashed lines a logic relationship. Table 3.5 summarises existing techniques and measures in PRM while Table 3.6 lists the techniques and measures proposed for this research. Control curves used in Table 3.5 allow a graphical representation of integrated probabilistic performance forecasts. For example, in forecasting both cost and duration, expected budgeted cost and planned duration can be obtained from the respective budget and duration distributions.
Figure 3.1 Project risk management process for this research

Table 3.5 Existing techniques and measures in PRM

<table>
<thead>
<tr>
<th>Risk identification</th>
<th>Risk analysis</th>
<th>Risk response</th>
<th>Risk control</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Interviewing</td>
<td>4. Monte Carlo simulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Decision Trees</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.6 Proposed techniques and measures for this research

<table>
<thead>
<tr>
<th>Risk identification</th>
<th>Risk analysis</th>
<th>Risk response</th>
</tr>
</thead>
<tbody>
<tr>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Contract interface</td>
<td>2. Information entropy method</td>
<td>2. Contract types and contract conditions</td>
</tr>
<tr>
<td>management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The investigation in this chapter shows that, it is significant to implement contract strategies including PPRs and contractual risk management as the best practice for the CCI in project risk management (PRM). Although Table 3.5 may be employed for any individual project, Table 3.6 presents specific measures selected as appropriate to improve PRM in China. Because the causes for project failure in China are usually poor project planning and contract management rather than project control, this research will not make a further study of risk control techniques. The research emphasises project planning, the PPR and contractual strategy, contractual risk management and quantitative risk analysis, presents a framework of contractual risk management covering the concept, classification and identification of contractual risks (Chapter 4), and studies the PPR and its functions for the Chinese construction market reform (Chapter 5). For quantifiable contractual risks, quantitative analysis models are proposed and discussed for tendering pricing using effective information entropy and for probabilistic analysis of contractual risks (Chapters 6 and 7).
CHAPTER 4   CONTRACTUAL RISK
MANAGEMENT OF CONSTRUCTION
PROJECTS

4.1 INTRODUCTION

In order to keep risks under control and thus to prevent the occurrence of their harmful consequences, risks must be allocated to the various parties in a construction contract. For simple or small projects, risk assessment and risk control are much easier than for large and complex projects like Build-Operate-Transfer (BOT) projects and international construction projects. However, for any project, risk management can be applied in developing clearer and more appropriate contract conditions, especially for the current situation in the Chinese construction industry (CCI). Therefore, it is important to study contractual risk and contractual risk management (CRM) in order to control project risks. The construction contract documents provide not only a lawful instrument for risk allocation, the legal document or code of project management, but also the track for project management.

Project risks can be managed, shared, transferred or accepted through a contract strategy in order to improve project performance. Contract risk management should be based on a reasonable risk allocation. The principle of risk allocation is that risks should be allocated to the party best able to control the risk, which is an international practice. The cost associated with each risk can be minimised if it is allocated to the party with the greatest ability to understand and control it. Project risks must and can only be ascertained by using an effective and impartial contract. Good examples are standard conditions of contract, for instance, FIDIC (International Federation of Consulting Engineers) contract conditions that include the Orange Book (1995), White Book (1995), New Red Book (1999), Silver Book (1999). Each standard construction contract condition has its own contractual risks and contractual risk structure. Without good contract conditions,
risks cannot be controlled and managed. Nevertheless, not all risks of a construction project can be foreseen and identified, and the risks involving unidentified hazards are extremely difficult to allocate or apportion between the project participants, such as economic and political risks. These risks are difficult to manage as their consequences cannot be accurately assessed. Then, statistical methods are available for taking into consideration the possibility of their occurrence and thus dealing with them. The project participants should understand what the contractual risks are, and how the risks change with a different project procurement route (PPR), contract type and contract conditions respectively.

4.2 CONTRACTUAL RISK MANAGEMENT

In essence contracts have to define the project objectives, qualified by the constraints. Despite many interfaces, the project as a whole has to be managed within a single coherent legal and contractual framework. Contracts are therefore viewed as adaptable tools for managing project risks. Contractual risks are a complex, multi-sided issue (Section 4.4 provides details). In China, contractual risks have not been adequately addressed. The survey and analysis in the research show that the reason for most disputes and claims is to do with the defects, neglects and unawareness of contractual conditions and contractual interface liabilities. Therefore, for the Chinese construction industry (CCI), contractual risk management (CRM) of construction projects should be considered as critical in the improvement of project risk management (PRM). CRM is a logically consistent framework to develop the process of contractual risk identification, analysis, and control. The purpose of CRM is to develop an appropriate, clear and impartial contract for a particular project, and therefore, provide a foundation for PRM. PRM cannot be carried out without contractual risk analysis and management. In order for this to happen this research provides a framework of contractual risk management to improve PRM for the CCI, depicted in Figure 4.1.
4.3 TYPES OF CONTRACT

According to Macneil (1978), contracts can be classified into three types: classical, neoclassical and relational contracts.

- Classical contracting covers all future contingencies, and transactions tend to be self-liquidating;
- Neoclassical contracting involves trilateral governance, where the third party is employed to provide the assistance in resolving disputes and evaluating performance;
- Relational contracting provides the means to sustain ongoing relations in long and complex contracts.
The option of contract type is based on the characteristics of the project. If specific investments are at stake, the continuity becomes more important. It is valuable to develop a sustainable relation contract.

A more useful method for contract classification is based on the payment approach of clients. There are numerous types of contract for different methods to share risks. In the construction industry, the typical six types of contracts are:

a) Fixed price (Lump Sum)
b) Unit price
c) Cost reimbursable
d) Target cost
e) Cost-plus
f) Guaranteed-maximum price

• Under a fixed price contract, the contractor accepts all risks by taking a fixed fee for the work regardless of the out-turn cost. It is assumed that the sponsor has completely specified the requirements, and as long as they do not change, the contractor can meet a given price. Traditionally, the contractor is charged a penalty if the duration is exceeded.

• Under a unit price contract, the sponsor accepts the change of the working amount, and the contractor only accepts the change of the unit price. It is different from fixed price contracts, in that the contractor must accept the change of both the unit price and working amount.

• Under a cost-plus contract, the sponsor finances the construction costs and pays the contractor a percentage of the costs as profit. The disadvantage is that while the contractor is still responsible for controlling cost, the higher the costs, the higher the profit. It is possible to adopt a strict change control, but the responsibility for controlling additional costs lies with the sponsor.

• Under a cost reimbursable contract, the contractor is paid the costs incurred plus a fixed fee or a percentage of the out-turn contract sum for management, overheads and profit. If the fee is expressed as a fixed sum, and the estimated prime cost is exceeded or it is less than the actual prime cost by more than
10%, the fixed sum can be adjusted. The contractor can also be motivated to control costs if paid a bonus for finishing under budget, or charged a penalty if the budget is exceeded.

- Under a target cost contract, the contractor is paid a fixed price if the out-turn is within a certain range, typically this is minus or plus 1 to 3% of the target cost but occasionally may reach 10%. If the cost goes outside this range, then the sponsor and the contractor share the risk in accordance with predetermined limits. A share formula is the prime means of introducing incentives into target contracts. For instance, if the actual costs were less than the target cost, the saving would be shared equally between the client and the contractor.

- Under a guaranteed maximum price contract, the sharing arrangement may be limited on the overrun side of the target costs by the use of guaranteed maximum price. If the costs raise to this point the contractor effectively reverts to a fixed price contract. Actual costs exceeding the maximum target are borne by the contractor.

Under the tradition project procurement route (PPR), the client would usually like to employ the Lump Sum Contract because the actual price the client pays for the project is likely to be close to the contract price. In theory, the project that adopts a Lump Sum Contract is completely designed before bidding and the construction, and risks are basically borne by the contractor in terms of both the scope deviation and the change of unit price. The risk allocation under this model is unbalanced between the client and the contractor. In order to overcome this inadequacy, other contracts have been developed and applied based on the Lump Sum Contract, such as guaranteed maximum price contracts and target cost contracts. If the project needs several years or more to complete, the unit price contract should be employed in order to shorten the construction period and to reduce the changes to the project execution plan. Cost reimbursable contracts are not popular with clients and are generally entered into only when there are no alternatives. The target of project control is the integration of project quality, duration and cost. FIDIC (International Federation of Consulting Engineers) General Contractual Conditions provide better standard conditions of contract to realise the integration
targets of projects. The problem is how to make a choice among the different types of construction contracts. However, in the CCI there is no choice because there is only one type of construction contractual conditions associated with the Traditional PPR. How to develop a series of contractual conditions to provide for a wide range of requirement for different construction projects is a challenge to the CCI.

With regard to contractual risk management, what are the contractual risks, and how are they identified and classified? How many contract interfaces are there, and who is in charge of the interface management? Despite a detailed literature survey, no literature has been found that deals with these issues. This research studies the concept, classification and identification of contractual risk, contractual interface risk and their management based on the PPR (Chapter 5 provides further details).

4.4 THE CONCEPT OF CONTRACTUAL RISK

Basically project risks may be entitled contractual risks, because most risks must be allocated to the various parties eventually through the contractual documents of the construction project. These risks must be ascertained by using a clearly written contract efficiently and fairly. Otherwise, disputes will arise among the contractual parties. Several studies (Strassman and Wells, 1998) have been conducted to identify the various risk categories in construction projects and to determine the "ownership of risk". From a client’s perspective, these risks include: unpredictable cost escalation and faulty structures needing frequent repairs, and the project will simply be abandoned and partially paid for but incomplete. Similarly, from a contractor’s perspective the risks include: inclement weather, delays in site availability, unforeseen subsoil conditions, inadequate detailed drawing, late material deliveries, unanticipated price changes, faulty subcontracting and unproductive labour and strikes.

Contractual risks are relative to the contract, and the risks arise from the legal relationship between the project participants, and from the contract interfaces
between different contracts, such as construction contract and design contract. The contractual risks of the Lump Sum Contract based on the Traditional PPR do not include the feasibility stage, design stage and operation stage, because these stages are beyond the scope of the construction contract while BOT projects include all those stages. The concept of contractual risk is

1) based on the legal connection produced by contracts including the contractual type and condition. Many complex cases are reported exposing the difficulties in drafting contractual provisions that readily identify the risk carrier when a disaster occurs.

2) ongoing relationship created by the interaction of the project participants during the design, construction and other phases of the project. The documents of construction contracts not only are a lawful instrument for risk allocation, the legal document or code of project management, but also form the track for project management.

3) from the interfaces between different contracts. The unawareness and neglect of interface management may result in disputes and claims between project participants. Each PPR possesses its own particular interfaces and interface structure.

In order to manage efficiently construction projects, project risks including interface risks must be unambiguously allocated to project participants. Project risks, foreseen or unforeseen, are controlled by the client or contractor that fulfills the conditions of the contract. In order to manage contractual risks, it is necessary to study the classification of contractual risks and the interface risks of contracts.

4.5 THE CLASSIFICATION OF CONTRACTUAL RISKS

Contractual risks may be classified into two sorts:

1) Non-quantifiable (qualitative) contractual risks, and

2) Quantifiable contractual risks.
4.5.1 Non-quantifiable contractual risks

Generally, non-quantifiable contractual risks cannot be readily calculated with mathematical methods although they may be estimated by statistical probability. They include natural risks, political risks, economical risks, legal risks, organisation and co-ordination risks, and finance risks. These risks can only be recognised through the contract structure and contract provisions. Non-quantifiable contractual risks are the basis and major concern for the contract strategy, and they can be managed, shared, transferred or accepted through a contract strategy. By analysing non-quantifiable contractual risks, this research studies the interface risks of contracts, selection of the PPR, conditions for applying the PPR and evolution and development of the PPR (Chapter 5).

4.5.2 Quantifiable contractual risks

Quantifiable contractual risks refer to those that may be more readily calculated and analysed by a mathematical or statistical method, including design risks, construction risks, duration risks and installation risks. These risks are usually foreseeable, identifiable and controllable hazards, such as soil foundation condition and design change. It is impossible and unnecessary to calculate all quantifiable risks for a construction project. However, it is necessary to analyse, prioritise and calculate important quantifiable risks based on the project environment, project characteristics and bidding documents. By studying quantifiable contractual risks, this research puts forward an effective information entropy model and a probabilistic analysis model for the analysis of key quantifiable contractual risks. Chapters 6 and 7 describe respectively the two models with illustrative examples.

4.6 IDENTIFICATION OF CONTRACTUAL RISKS

Risk allocation seems simple but is far from straightforward as many complex cases are reported exposing the difficulties in drafting contractual provisions which readily identify the risk carrier when the disaster occurs. Therefore, it is
important to study the identification of contract risks in order to control the risks. Contract risks can be identified from three aspects: 1) the PPR related risks involving the risk structure for different PPRs and their contractual interface risks (discussed in Section 5.3); 2) contract type related risks; 3) Contract conditions (General Contract Conditions and Special contract conditions) related risks.

4.6.1 Contract type related risks

In terms of contract type, the following risks may be identified:

- Political risks: The risks need special contractual clauses, such as war, revolution and inconsistency of regulations (e.g. for Build-Operate-Transfer or international projects). If a Cost reimbursable contract or Guaranteed-maximum price contract is employed, it is necessary to enclose these clauses in Special Contractual Conditions.

- Financial risks: Extension of bid validity period. Each contractual type needs a bidding model. For example, for a Cost reimbursable contract, the Negotiation bidding is employed instead of the Open bidding, and the bid validity period is dependent on the negotiation.

- Legal-contract risks: Direct liability, liability of other participants, local law and codes, and contractual clauses. Different contract types possess a different contractual risk structure, e.g. under the Lump Sum Contract, the liabilities of the participants (client and contractor) are different from those of other contract types such as the Unit price contract and Cost reimbursable contract.

- Design risks: Incomplete design scopes, availability of information, innovative applications, new technologies, likelihood of change, interaction of design and construction. Any General Engineering Packaging (GEP) PPR such as Design/Build (D/B) PPR and Engineering Procurement Construction (EPC) PPR (Section 5.1.1 provides details) always employ a Lump Sum Contract. Taking D/B PPR as an example, the contractor of the D/B PPR basically control all aspects of the design that are not constrained by the performance criteria, and the contractor may have less need to create detailed drawings in
order to execute the design and may seek to reduce design costs by converting many "design details" into the methods and means of construction. Therefore, the design risks under the Lump Sum Contract associated with D/B PPR are different from that of other contract types and other PPRs.

- Construction risks: Weather; availability of equipment and spares; extent of change; ground condition, and inadequate site investigation; insufficient time to prepare bid or tenders; damages during construction due to negligence of any parts; vandalism and accidents. Taking inadequate site investigation as an example, according to international practices, contractors cannot request to adjust the tendering price due to inadequate site investigation (for Lump Sum Contract). For example, the bidding documents of a construction project employing a Lump Sum Contract may indicate that there are sands around the site for the contractor to use, which means savings on transporting sands, but the client will not take liabilities for the contractor’s tendering price if the sand is not suitable for the project. If a Cost reimbursable contract is employed, the contractor does not need to consider the issue.

It is important to emphasise that contract type related risks are basically determined by the PPR because the contractual type is based on the PPR, and each PPR possesses its own contractual risk structure and interface risks (Chapter 5).

Under the Lump Sum Contract of the D/B PPR, a close working relationship is developed between the engineer, the contractor and the client. For example, during the design stages of the project, both the designer and contractor can search for alternative materials and construction methods, taking into account the budget and schedule. However, under the Traditional PPR, a design error discovered later can mean months of lost time for waiting for design revisions.

4.6.2 Contract conditions related risks

Different from the contract type related risks, contract conditions related risks can only be identified from Special Contractual Conditions. For any contractual type, the responsibilities for dealing with these risks must be included clearly in the
Special Contractual Conditions. Generally speaking, some contractual clauses in the General Contractual Conditions (or standard contract form, such as the FIDIC Red Book) may be amended, supplemented or refused by the Special Contractual Conditions but these changes must be consistent with the General Contractual Conditions. Otherwise, some risks are translated from the client to the contractor. For example, the responsibilities for the postponement of site occupation may be removed by the client. By assessing contract conditions, the following risks may be identified:

- **Political risks:** Customs and trade restrictions and procedures, inconsistency of regulations within the country or organisations, requirements for permits and the procedure for their approval. Constraints on the availability of labour, requirements for joint ventures with local organisations, requirements to use local labour or organisations.

- **Financial risks:** Cash flow of client, cash flow problems for contracts; loss due to default of the contractor, sub-contractor, supplier and client; adequate payment for variations; availability and fluctuation of foreign exchange, repatriation of funds; local and national taxes, business disruption.

- **Legal-contract risks:** Legal differences between countries, liquidated damages, maintenance, change to ‘expected risk’, such as revisions of General Contract Conditions by the client, which are inconsistent with the General Contract Conditions or international practices.

- **Design risks:** Level of detail required and accuracy.

- **Construction risks:** Delay in possession of site; supply of manufactured items; quality, availability and productivity of sub-contractors; unforeseen problems; theft; poor design and shop drawings.

Besides the risks mentioned in this section, the liabilities and responsibilities of the project, e.g. special contractual provisions for environment issues, are allocated to each participant through the special contract conditions. An appropriate, clear and equitable conditions of contract based on a suitable PPR is critical for the success of the project, meeting the specific requirements and
objectives. It is an effective method to study and employ suitable contractual conditions based on the PPR to improve PRM in China. Chapter 5 discusses the contractual risk structure of popular PPRs. The PPR is the foundation of the contractual strategy, and it is noteworthy to study the introduction and application of innovative PPRs for the Chinese construction industry (CCI).

4.7 INTERFACES OF CONSTRUCTION PROJECT

Risk management must consider interface risks. Ganah et al. (2000) investigated the interface problems in the construction industry, and found that the problem counts for 67% in electrical assembly, 64% in mechanical assembly and 82% in pipe fitting assembly. For the Chinese construction industry (CCI), the interface problems not only affect project performance but also result in numerous disputes and claims because of the neglect of interface management. So, interface risks must be stressed in project planning and the design stage in order to reduce interfaces and determine the responsibilities for interface management. Interfaces are the major source of organisation and co-ordination risks. Effective interface management may avoid the unawareness and neglect of the responsibility for managing interfaces. Due to the influence of the traditional construction model of Design/Bid/Build (D/B/B), contractual interface risks are often neglected in project risk management (PRM) in the CCI.

4.7.1 Interface

An interface is universal in the world, and it means either the separating faces that different parts in a system, process and entity, or combining faces that connect different parts in a system, process and entity according to the characteristics of the system, process and entity. A system embraces many subsystems, and the interfaces among them are not only the connection of the subsystems but also the separation of the subsystems. In the view of systems science, interfaces exist not only in macro world and micro world, but also between the system and its outside environment. From the organisation theory’s point of view, there are horizontal and vertical interfaces in an organisation structure. The two types of interface
produce an effect on the organisation hierarchy and the efficiency of information flow. Interfaces may be formed in accordance with the characteristics of a material, entity, system and process, and they can be nominated as material interface, entity interface, system interface and process interface respectively. These interfaces may explain the attributes of the system and process, and indicate the combinative state of two systems and the relationships between them.

### 4.7.2 Interfaces of construction projects

Interfaces of construction projects are multifarious forming an open system consisting of material flow, fund flow, information flow, etc. In order to effectively analyse and manage interfaces, it is practicable to categorise them into three types: physical, organisational and contractual interfaces.

1) Physical interfaces

Physical interfaces exist in the implementing process of a construction project, including interfaces in different design phases (such as interfaces between layout design and preliminary design), interfaces between the stages of the construction process and interfaces between equipment setting and the building work. The number and complexity of physical interfaces depend on the design and the project procurement route (PPR).

2) Organisation interfaces

Organisational interfaces exist in the relationship between the participants of a construction project, and there are two interfaces. One is the interface with a contract relationship, for instance, the interface between the client and contractor, and another is the interface without a contract relationship, for instance, the interface between the engineer and contractor. There are various organisational interfaces for different PPRs, such as the organisation interfaces in the Traditional PPR and organisation interfaces in the Design/Building (D/B) PPR.
3) Contractual interfaces

Contractual interfaces exist between various contracts, such as the interfaces between design and construction contracts, between construction and supply contracts, and between subcontractors (Yan, 2005b). There is a correlation between the three kinds of interface, and a PPR establishes its contractual interface structure that contains the number of interfaces and interface responsibilities. The contractual interface and its interface structure further determine the organisational interfaces and their structure, as well as the major physical interfaces. Each interface has its own characteristics, and it is necessary to employ different methods to manage these interfaces. For physical interfaces, process management is an effective approach, which utilises the principle and programme of total quality management. The other two types of interface rely upon the PPR (discussed in Section 5.3).

4.7.3 Case study of Beijing Xinwanshou Hotel

This is the first typical case of a contractual dispute and claim between the client and contractor in the CCI, the Beijing Xinwanshou Hotel (investment of CNY 400 million or approximately £30 million) claim in the middle of the 1980s because of poor building quality (Li, 1995). This was a complicated claim event that took more than two years to settle. The author’s purpose is to analyse the cause for the dispute and claim rather than to describe the complex process of the legal case.

Due to the poor quality of the heat exchangers, the tap water in the hotel was of red colour, thus the dispute being referred as the ‘Red Water Event’. The hotel was in operation with a very low number of customers. The client was unhappy and discounted the contractor’s payment including part of the construction cost. In fact, the quality of the eight heat exchangers involved all the project participants including the client, contractor and supervision engineer, and it was unclear who was in charge of the interface management. The contractor thought nothing was wrong with its work according to the construction contractual conditions and technical standards, and refused to take the responsibility for the poor quality of
the heat exchangers. The contractor pointed out that when the client decided to procure a new type of heat exchanger, the supervision engineer agreed with the client, but the contractor had a different idea and suggested to select the popular type of heat exchanger because of its proven quality and the small price difference between the two types of heat exchanger. However, the client insisted that the contractor had to take the responsibility for the poor quality of the heat exchangers and refused to pay for the work done by the client. Disputes took place between the client and contractor. The contractor was well reputed in construction quality and contractual document management in the CCI, and thought the responsibility for the poor quality of the heat exchangers was on the client and the supervision engineer. The building was built in accordance with the Traditional PPR, and therefore, the client had a great power to manage and control the project. The contractor claimed the payment from the client. However, the client claimed that the contractor had to take the responsibility, and refused to pay the remaining bill for the project. There was no choice for the contractor. At last the contractor employed a famous construction lawyer from Shanghai, and took legal steps to seek proper compensation via Beijing Supreme Court, which judged that the contractor won the claim and the client had to pay CNY 4.3 million as the remaining bill for the project.

In China, it is very hard for a contractor to win a claim, and in this case, the major reasons for the contractor’s success were that firstly, the contractor employed a well-qualified construction lawyer, and secondly, the contractor could provide all documents and records for the construction project. Without these two factors, the contractor could not have won the claim. The case illustrates:

- The reason for the poor quality of the eight heat exchangers in the hotel was the lack of awareness of interface management of the construction contract, equipment supply contract and supervision contract. However, the source resulting in unclear responsibility for the interface management was that the client took the power to procure project equipment instead of the contractor. Had the contractor been given total responsibilities for managing the construction project including equipment procurement or had the project
employed the Turnkey or Engineering Procurement Construction (EPC) PPR, the dispute would not have happened. Therefore, contract strategy is a vital issue to improve PRM in the CCI.

• Different from developed countries, quality problems in Chinese construction projects are often initiated from management defects. The heat exchanger problem was a management issue. Had the responsibilities for managing the contractual interfaces been ascertained clearly in the contractual clauses, the claim event would not have happened. In the CCI, project risks are often associated with defects, neglects and unawareness of contractual clauses and contractual interface liabilities. Interface management is not only the source of management efficiency, but also the assurance to achieve management objectives (Yan, 2005b).

• Under the current practice in the CCI, the client had a great power to manage and control the project. However, the ability of the client to manage the contract is much weaker than that of engineers or contractors. The project performance was greatly affected because of the poor contractual risk management. In order to improve the project performance, Chinese clients should understand how to operate a project according to market mechanisms, instead of a bureaucratic method existing under the planned economy, and how to manage the project according to contract documents instead of the client’s arbitrary decision.

4.7.4 Case of a provincial museum

Chinese Construction Daily (2004) reported a contractual dispute between the designer and contractor for a museum project. A provincial museum (CNY 300 million, or approximately £23 million) in China was opened in 2001. However, during the rainy season, water leaked through the roof of the museum building. Disputes took place between the contractor and designer as to who should take the responsibility for the poor quality of the roof. The designer claimed that the poor quality of the roof was caused by construction faults and the contractor should take the responsibility, but the contractor argued that the construction was carried
out according to design documents and standards and nothing was wrong. The contractor insisted that the responsibility was with the designer. The disputes went on, and the client was unhappy for being involved in the dispute. The roof design adopted a new structure and construction materials including waterproof material, but there were not any clauses in the special contract conditions for specific technical and interface management issues such as the new roofing structure and materials. The contract documents of the project were defective, and therefore, it was impossible to judge who should take the liability between the designer and contractor. The issue was not resolved because of the contract defects and unsuitable PPR employed. Both the designer and contractor were disappointed, and the client was the victim for the poor quality of the roof.

The Lump Sum Contract of the Traditional PPR is efficient for small and simple projects, but is it efficient for this kind of large and new construction project? Under the Traditional PPR, the client procured the design, construction and materials separately, and the designer completed design according to the client's requirements and layout design and the contractor completed the construction according to the design documents. Nothing was wrong but who was in charge of the interface management between the design and construction? This case shows that the cause for the roof quality was the interfaces and the poor management of the construction contract, design contract and material supply contract. There is no way to solve interface issues under the Traditional PPR with subcontracting (Section 5.3.2 provides details). For large complicated construction projects, had the Design/Build (D/B) or Turnkey PPR been employed, any dispute and claim would not have happened. D/B or Turnkey contractor takes total responsibilities for design and construction, and the D/B or Turnkey PPR is geared towards delivering high building quality at the lowest possible price to prevent future claims and liability. Under the D/B model, a close working relationship is developed between the engineer, the contractor and the client. For example, during the design stages of a project, both the designer and contractor can search for alternative materials and building methods, taking into account the budget and schedule. The case did not seem complicated, but the consequence was really
destructive, indicating that contractual risks may initiate from an unsuitable PPR and the interfaces between different contracts.

Though the contract dispute happened between the designer and contractor, this case is similar to that described in Section 4.7.3. The client employed the same PPR, the Traditional PPR and Lump Sum Contract. The two cases happened in 1986 and 2001 respectively, and the time gap was 15 years. The problem is why the interface issues are still a major reason for quality defects. This research suggests that the effective approach to solve interface problems is to implement contract risk management (CRM) through a suitable contract strategy and employing a General Engineering Packaging (GEP) PPR, such as D/B, Turnkey or EPC PPR. This case shows:

- Interface management is a critical approach to improve the Chinese PRM. However, it is not easy to solve the problems of the interface management. In the CCI, there is only one kind of construction contractual conditions (General Contract Conditions), Lump Sum Contract based on the Traditional PPR. The project participants have become familiar with the unified Lump Sum Contract and the Traditional PPR. The situation prevents the Chinese employers from adopting other forms of PPR where the design and construction phases are not separated.

- The clients in the CCI have traditionally managed projects by themselves. This is one of the main reasons that China’s engineering consultants have not had the opportunity to develop their business. Employing innovative PPRs and General Contract Conditions of construction projects is an effective method to improve the Chinese PRM.

4.8 CONTRACTUAL RISK MANAGEMENT FOR THE CCI

The principle of risk allocation is that risks should be allocated to the party best able to control them, which is the key factor in contractual risk management (CRM). The cost associated with each risk can be minimised if it is allocated to the party with the greatest ability to understand and control it.
The Chinese construction market including the regulatory environment is still immature. It is likely to lead to contractual disputes rather than collaborative problem solving when difficulties arrive. The benefit of project participants is from project performance, which is from the effective PRM instead of either low contract prices or claims.

The New Engineering Contract (NEC) (Appendix D) is a latest development of the Construction Contract Conditions by the ICE (the Institution of Civil Engineers, UK). The NEC stimulus to good management, lays a great emphasis on communications, co-operation and programming and the need for clear definitions at the outset of various types of information. The research considers the development of the NEC and proposes the following principles to improve CRM for the CCI.

1) Effective risk management is based on the recognition of mutual benefits and a win-win arrangement through co-operation relationships between the participants. It must be understood that risks may be transferred from one party to another, but the purpose is to reduce project risks due to the party best being able to control them;

2) Positive behaviours are needed in managing contractual risks. Contractual risks can be mitigated by the appropriate choice of contract conditions. Duties and responsibilities of contracting parties should be allocated clearly in optimal contract conditions, along with necessary provision for flexibility in filling the gap between General Contract Conditions and Special Contract Conditions.

3) Better relationships, mutual understanding and strong co-operation among the contracting parties are very important for the CCI.

These principles provide a foundation to improve project performance, and they are extremely significant to develop the CCI. Construction projects involve many complex processes and many uncertainties. Considering the current situation of the CCI, it should be stressed that CRM for construction projects is critical. The
research suggests that before entering a contract, the contracting parties need first to determine:

- their requirements and objectives,
- the characteristics of the construction project, and
- the major risk factors and interface structure of the construction project.

Then, the parties need to select:

- the most suited project procurement route (PPR), and
- contract types that contain necessary mechanisms for addressing disagreements towards negotiation and organisational arrangements.

4.9 CONCLUSIONS

The following conclusions can be drawn from the study presented so far:

1) Appropriate, clear and impartial contract conditions are invaluable to project success, helping meet specific requirements and objectives of the project. This is particularly suitable and imperative for the current Chinese construction industry (CCI). Many disputes and claims between project participants take place because of the defects, neglects and unawareness of contract conditions.

2) Contractual risk management (CRM) should be based on reasonable risk allocation. The principle of contractual risk allocation is that the risks should be allocated to the party best able to control the risks. The cost associated with each risk can be minimised if it is allocated to the party with the greatest ability to understand and control it. Otherwise, the level of risks will dramatically increase, which will result in more disputes and claims. Therefore, it is necessary to study and employ mature standard forms of contract based the project procurement routes (PPR) to improve project risk management (PRM) for the CCI.

3) Under the current situation in the CCI, the major contract risks come from the client. Therefore, mutual benefits and win-win arrangements are very
important in managing contractual risks. Also, this shows that the Chinese construction market is still immature, and needs improvement and development.

4) In the CCI, basically, the contractual risks can only be identified from the assessment of contract conditions. The reason is that there is only one conditions of contract in the CCI. The Ministry of Construction of China has reviewed and issued the New Construction Contract Conditions (NCCC, 3rd version, 1999; 2nd version, 1995; 1st version, 1991), which is the only contract conditions of construction projects in China. With the reform of the organisation of construction projects and the development of General Engineering Packaging, China should issue its own comprehensive standard contract conditions in parallel to those by the major professional bodies in the world, e.g. the American Institute of Architects (AIA) and the Institution of Civil Engineers (ICE), UK.

5) The CCI is familiar with the Lump Sum Contract associated with the Traditional PPR, which prevents the Chinese clients from adopting other PPRs where the design and construction phases are not separated. The Lump Sum Contract of the Traditional PPR is efficient for small and simple construction projects and is therefore limited in its use. This is one of the main reasons that many projects fail to meet their objectives. Therefore, it is necessary to study and employ other forms of contract based the PPR to improve PRM for the CCI.

6) Contractual strategies can utilise many project features to manage project interfaces and uncertainties, and therefore achieve project objectives. It must be understood how to choose an alternative conditions of contract or how to make use of a contract strategy to improve PRM. The PPR is the foundation of contractual strategy, and therefore, it is significant for the CCI to employ innovative PPRs to motivate the reform of the Chinese construction market and to improve PRM in China.
5.1 INTRODUCTION

Contractual risk management (CRM) is based on the contractual strategy, and the contractual strategy based on the project procurement route (PPR) because the PPR determines the legal relationships produced by contracts and contractual interface structure. So, the PPR plays a key role in improving PRM for the Chinese construction industry (CCI).

The level and maturity of a market development can be indicated by the approaches of goods exchange. The evolution of commercial exchange from goods by goods to electronic purchase testifies to the development of market economy and social progress. Since construction projects are a particular kind of good, their procurement route is different from other commercial purchases. The construction market is a unique trade market with its own particular regulatory environment, market conditions and administration system. In the Western construction industry, the PPR has become a fashionable term with the practitioners and researchers. The PPR determines the overall framework and structure of responsibilities of project participants within the building process, and is a key factor contributing to overall client satisfaction and project success. The selection of the most suitable PPR is a critical factor for both the client and contractor. The PPR is becoming an important and contemporary issue within the building industry (Love et al., 1998). Sir Michael Latham (1994) described the PPR as ‘formulation of a project strategy by the client’ as well as ‘the first building block to a successful and cost effective scheme’.

In the international construction market, there have been various PPRs in addition to the Traditional PPR (i.e. Design/Bid/Build or D/B/B), such as the Construction
The phases of the scope in the figure are:

1. Preparatory work
2. Design preparation
3. Design
4. Construction preparation
5. Construction management
6. Installation and commissioning
7. Operation management or Property management

In order to introduce innovative PPRs into the CCI and provide a practicable plan for their applications, it is necessary to study the development of the PPRs, selection of the PPRs, and the conditions for applying them. This chapter investigates these issues, explains major problems to be overcome and some possible solutions, and possible strategies for the introduction of innovative PPRs in CCI are proposed.

5.1.2 Evolution and development of PPRs

Design/Build (D/B) is not historically a new idea or method. In ancient times, buildings were built with the D/B method because one person or party as the master builder had a single-source responsibility for design and construction. At
that time, the level of production and technology was very low, and the building professionals such as the engineers and contractors were not separated. Architects acted as master builders who were responsible for a project from conception to completion and controlled all phases of the work. With the development of production and the increase of the construction scale, the construction structure and technology became more sophisticated, and the master builder was not suitable for the needs of further construction development. The master builder gave way to the conventional tripartite structure of the owner, engineer (architect or consultant) and contractor. Speciality separation in the construction industry was introduced and the civil engineer, architect, consultant, surveyor, and contractor gradually entered the construction field. The construction industry then experienced an evolution from integration to separation. Speciality engineers then engaged in individual technical jobs such as architectural design, structural design, surveying and so on and contractors engaged in construction work. Based on the professional separation of the construction industry, the tradition model of projects (Design/Bid/Building or D/B/B) was formed step by step. It is a system that was established in the early nineteenth century and has continued (Franks, 1998). The traditional model has lasted for two hundred years and still works well because people in the industry have experience with the established standard forms of contracts. FIDIC Conditions of Contract for Works of Civil Engineering Construction (The Red Book, 1987) is a typical pattern of the contract conditions (re-measure contract) of the Traditional PPR. The origin of the FIDIC Red Book is ICE Conditions of Contract (the Institution of Civil Engineers, UK), and the New Engineering Contract or NEC (Appendix D) is the newest development of the ICE Conditions of Contract.

Towards the end of the 1960s, alternatives to the traditional system evolved. The main reasons for the changes were the failure of the construction industry to satisfy its clients' needs. Too many projects ran over their contract periods and cost significantly more than clients anticipated (Franks, 1998). The emergence of the D/B approach as a popular PPR is one of the most significant recent trends within the construction industry. The D/B PPR has advanced merging of
technology, economics, management and regulations, which is an important means to realise the clients' needs for the best integration of cost, quality and time. In response to the demand, the Joint Contracts Tribunal (JCT) in London published its contract conditions for D/B in 1981. The ICE published its Conditions of Contract for D/B in 1992. In response to the international demand, FIDIC introduced the 1st version of the Conditions of Contract for D/B and Turnkey (Orange Book) in 1995, and the 1st version of the Conditions of Contract for Engineering Procurement Construction (EPC) / Turnkey Projects (Silver Book) in 1999. Different from the Red Book, the Orange Book and Silver Book are intended to be a fixed Lump Sum Contract. The emergence of D/B approach as a popular PPR reflects the most significant trend within the construction industry in the past 30 years. Within a decade, the D/B PPR had spread from being a novelty to the normal so that by the end of the 1980s, as much as 40% of all new building work in the UK was procured by the D/B system (Eggleston, 1993).

As construction projects became more complex, and the needs of clients become more extensive, new project procurement systems had to be introduced and applied in order to meet the requirements. In the 1970s, the construction management (CM) model (fast-track construction management) was developed and applied in the USA. In 1984, the Build-Operate-Transfer (BOT) model was first coined by the former Turkish Premier, Turgut Ozal (Walker and Smith, 1995). In the international construction market, there have been various PPRs, such as the CM approach, MC method, D/B Model, D/M model and BOT model. Different PPRs introduced some radical innovations in the perception, setting and management of the relationships between clients, designers, builders and suppliers.

The principle of BOT projects is not new. The first construction project financed through such an arrangement was the Suez Canal that was completed and opened for international navigation in 1869. The concession agreement in that case was for a period of 99 years. A similar approach was later adopted for the construction of the Panama Canal. Since the 1970s, there have been major global shortages in funding the ever-growing need for infrastructure projects around the world. This has led many governments to reconsider their policy of self-financing such
projects. Although the traditional methods of financing a project represent the main methods used today, the concept of involving private finance in infrastructure projects is becoming more popular. The use of private finance is expected to rise to an estimated 15% of infrastructure projects implemented worldwide (Bunni, 1997).

Any PPR is not a rigid model. Taking a BOT project as an example, there are different BOT project, including:

- Design-Build-Finance-Operate (DBFO),
- Build-Own (BO),
- Build-Own-Operate-Transfer (BOOT),
- Build-Own-Operate (BOO),
- Build-Rent-Transfer (BRT), and
- Build-Lease-Transfer (BLT).

The BOT is an international term for projects employing private finance. The two key factors for the success of a BOT project are project risk allocation and project financing. In the late 1980s, the British Conservative government encouraged public sector projects like hospitals to be financed, built and operated by private capital. In 1992, the British government proposed a Private Finance Initiative (PFI) construction model. The PFI in the UK received major boosts during 1989 and 1992 when the British government sought to involve the private sector in public projects to a greater extent than before. Both BOT and PFI work on the same principle. Private capital investments in the public sector projects form the basic attribute of BOT projects. These new project procurement systems mean that many organisations have to rethink their approach to the ways in which risks are treated within their projects and companies.

There is some relationship or connection between different PPRs. BOT project is a special D/B PPR. Turnkey contracts typically include the provision of design, construction, fixtures, fitting and equipment to the extent defined in the contract documents. Turnkey contracts are often financed by the contractor and may
require the contractor to operate the works for a few months’ commissioning period, or for some years’ operation on a BOT basis (Bunni, 1997). The evolution from the D/B PPR to Turnkey PPR, and then to BOT projects, indicates a great change, which develops the emphasis from the initial cost of procuring a building to the life cycle cost of providing accommodation together with all services through its usable life. Chinese construction enterprises need to comprehend this development and rethink their approach to the package building process within their projects.

5.1.3 The selection of PPR

A different project procurement route (PPR) merely provides a different way of packaging the building process. The question is which PPR is the most suitable for a particular project. At the project planning stage, it is important to choose a suitable PPR to reduce the uncertainties. Several studies have considered how this “better” individual procurement method may be identified by reference to a set of project characteristics, attributes or criteria (e.g. NEDO, 1985). The most advanced of these are those of Skitmore and Marsden (1988) and Singh (1990), who proposed a procedure involving factor weightings and priority rating for project attributes. One problem with this, however, is that the factor weights cannot be obtained easily by objective means and must be elicited from practitioners in the field, who have found difficult in reaching a consensus on such matters (Hamilton, 1987). Nahapit and Nahapit (1985), however, found the main factors affecting the choice of procurement method to be project characteristics, suggesting that similar clients with similar project requirements may have similar and consistent priority ratings. Existing project procurement selection systems are shown in Table 5.1.
Table 5.1 Existing procurement selection systems (Tucker and Ambrose, 1999).

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Description</th>
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<tbody>
<tr>
<td>NEDO</td>
<td>1985</td>
<td>Rating system using client’s priority for nine key areas.</td>
</tr>
<tr>
<td>Skitmore and Marsden</td>
<td>1988</td>
<td>Two systems: multi-attribute based on the NEDO model with a rating system and weighting of client priorities; and discriminate analysis technique utilising variances in procurement characteristics under certain criteria.</td>
</tr>
<tr>
<td>Brandon et al.</td>
<td>1988</td>
<td>A computer expert system called ELSIE, determining a suitable procurement system, based on project characteristics and client requirements.</td>
</tr>
<tr>
<td>Bennett and Grice</td>
<td>1990</td>
<td>A system based on the NEDO and Skitmore and Marsden models and allows clients to weight specific criteria multiplied by set utility ratings for various systems.</td>
</tr>
<tr>
<td>Liu</td>
<td>1994</td>
<td>An organisational behaviour-based model utilising an act-to-outcome process governed by organisational goals, which in turn are subjective to moderators, which determine the goal/performance relationship.</td>
</tr>
<tr>
<td>Chan et al.</td>
<td>1994</td>
<td>A model utilising Bennett and Grice model, but uses a different procurement category developed for the Australian construction industry.</td>
</tr>
<tr>
<td>Franks</td>
<td>1998</td>
<td>Simple rating system based on client’s performance requirements.</td>
</tr>
<tr>
<td>Dell’Isola et al.</td>
<td>1999</td>
<td>Decision matrix-based model that rates the performance of each procurement system for selected issues and their relative importance on a client/project profile.</td>
</tr>
<tr>
<td>Tucker and Ambrose</td>
<td>1999</td>
<td>A three-dimensional interaction matrix that provides a procedure to evaluate the appropriateness of a procurement system for a particular project and the need of the client.</td>
</tr>
</tbody>
</table>

The research on the selection of PPR has been continuing, such as the fuzzy membership functions for procurement selection criteria proposed by Ng et al. (2002), the rethinking on the multi-attribute utility approach based procurement route selection techniques by Chang and Ive (2002), a case-based procurement advisory system for construction by Luu et. al. (2003). However, innovative PPRs are new to China. The author discussed the potential for more innovative PPRs in the CCI and proposed that the large improvement to PRM and reform of the Chinese construction market could result from the introduction and application of innovative PPRs and their contractual conditions (Yan, 2001b). During the early
stages of the application of the PPRs, it is important to find key issues needing further investigation and possible solutions to them (Section 5.2).

PPRs can be understood as a model of organising a project, which impacts specific project attributes such as speed, quality, cost and contract management, and therefore, a PPR constitutes the overall framework of project management and structure of responsibilities for the participants. Sir Michael Latham (1994) described ‘formulation of a project strategy by the client’ as ‘the first building block to a successful and cost effective scheme’. Each PPR has been developed to meet particular client needs, and there is no universal system (Franks, 1998). A PPR is in some senses better than all others for an individual project, but no one is likely to be better than others for all projects. An experienced engineer employed by the client would not employ the same procurement system for all projects. Therefore, a PPR cannot be used indiscriminately on all types of project. The choice of the project procurement method depends on the characteristics and attributes of the project. A recommended route for a client to take is (Franks, 1998):

- Satisfies the need for a building;
- Makes an internal assessment which considers benefits, risks and financial constraints;
- Ranks options in order of benefits and feasibility; and
- Makes a decision in principle as to whether the project is necessary and feasible.

All clients require their building to be completed on time, within budget and to be of the highest quality. However, some clients stress that some criteria are more important than others. NEDO (1985), Skitmore and Marsden (1988) and Singh (1990) suggest employing the following criteria to establish a profile of the client’s requirements:

- Speed (during both design and construction),
• Certainty (price and stipulated time and knowledge of how much the client has to pay at each period during the construction),
• Flexibility (in accommodating design changes),
• Quality (contractor’s reputation, aesthetics and confidence in design),
• Complexity (the client may specify particular subcontractor, or construct ability analysis),
• Risk allocation/avoidance,
• Responsibility (completion of programme, price, product quality, design and construction),
• Price competition (covering such issues as value for money, maintenance costs and competitive tendering), and
• Disputes and arbitration.

The certainty of being on time, cost and achieving value for money are the primary concerns of the client. A comprehensive list of client’s requirements can be found in the work of Bennett and Flanagan (1983). Other procurement selection models (e.g. NEDO, 1985) used similar selection criteria and Table 5.2 provides a summary.
Table 5.2 Criteria for PPR selection

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<tbody>
<tr>
<td>1. Speed</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>2. Certainty</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>3. Flexibility</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>4. Qualitative</td>
<td>✓</td>
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<tr>
<td>5. Complexity</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>6. Risk avoidance</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>7. Price completion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>8. Responsibility</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>9. Disputes and arbitration</td>
<td></td>
<td></td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>10. Accountability</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<tr>
<td>11. Innovative advice from consultant</td>
<td>✓</td>
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</tbody>
</table>

5.2 CASE STUDIES

In implementing innovative project procurement routes (PPRs) in China, some crucial issues should be emphasised. This section investigates these issues, explains major problems to be overcome and possible solutions to them.

5.2.1 Selection of the PPR

Based on the building practice of a construction project in Pudong New District of Shanghai, Wang et al. (2002) have qualitatively compared the effects on the project objectives of three types of PPR: the Traditional PPR, Construction Management (CM) route and Turnkey approach. The conclusion is that the Traditional PPR is more suitable than CM or Turnkey PPR. The main reason is:
Traditionally, the education and training of Chinese engineers and contractors are often limited to a specific technical sector. There is no special profession to provide CM managers in the Chinese construction industry (CCI).

It is inconsistent with current Chinese construction regulations that the construction will not commence until all design documents are completed. In other words, it is illegal to commence a construction project while designing.

Turnkey PPR needs the contractor to possess the ability of integrating technology, economics, management and regulations and project financing for the client. However, there is a big gap in the integrating ability and project financing between Chinese contractors and western contractors. Therefore, there are few qualified contractors for the turnkey packaging of projects.

So, the project employed the Traditional PPR. The case shows:

Like other innovative PPRs, CM route and Turnkey approach are new to the CCI. In the CCI, the project participants have become accustomed to the sole Traditional PPR. Not only clients but also consultants prefer to use the Traditional PPR instead of an innovative PPR, wherever feasible because they have better experience with the method. It is difficult to abandon their established working practice of always contracting with contractors, Consequently, there is a big gap in the PPR between the CCI and the Western construction industry.

In China, the study on the PPR is in its early stages, and the selection and assessment of PPRs are based on experience and the qualitative judgement of project participants. In order to introduce innovative PPRs and improve contractual risk management (CRM) of construction projects in the CCI, it is necessary to provide guidelines and strategies including the priority, selection and application conditions of the PPR.

For the purpose of introducing and employing innovative PPRs, a particular example is chosen in order to understand in detail the popular project
management model in the CCI, and investigate main problems in Chinese practice and possible solutions.

5.2.2 New campus project of Shenyang Jianzhu University

1) Project background

In 2000, the Ministry of Construction of China (MoC) chose Hebei Province, and the cities of Shanghai and Shenyang as experimental regions for construction market reform to improve the administration system and management mechanisms (Guideline for the Reform of the Chinese Construction Markets, MoC, China, 2000). Shenyang, in north-eastern China, basically represents the current practice and mean development level of the Chinese construction industry (CCI). The new campus of Shenyang Jianzhu University (SJZU) is a typical project that indicates the popular project management model in China, i.e. the client employs the Traditional PPR and Lump Sum Contract by subcontracting. Chinese clients always contract with contractors or subcontracts for the construction or supply of raw materials, and manage the construction by themselves, and most construction projects employ the Traditional PPR and Lump Sum Contract. Therefore, the project of SJZU can illustrate the current practice and popular project management model in the CCI, and find major problems need to overcome for implementing innovative PPR. The planned construction area of the project was 340000 m² located in Dongling District of Shenyang. The total budget was approximately CNY 620 million (about £44 million, the figure from the client committee of SJZU) as of September 2001. This mainly comprised design, construction, supervision and project management, and the procurement of utilities and equipment. The cost came from resource exchange (making use of the big price gap between urban centre and suburban land), i.e. the western campus of SJZU located in an urban centre area was sold, and this yielded more than a half of the project cash needed (including purchase of suburban land).

2) Project management model

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A special project management approach was employed that includes:

- The client committee took on both the roles of contractor and consultant. The committee consisted of architects, civil engineers, cost engineers and planning engineers. It had to consider how to integrate all of the various fundamental disciplines involved in the project so that all issues from planning, design to construction could be taken into account early in the project life cycle.

- The committee developed an outline design using their own team of consultants, to a level at which significant planning issues and inter-department relationships had all been determined, and requested tenders to submit a conforming bid based on the outline design. The basic requirements, technical issues, alternative designs and tendering price were evaluated.

- This method gave great control to the client while preserving the advantages of time saving in design and building. It means that the client takes most project risks which are usually taken by contractor.

- All contracts were signed between the client and the subcontractors, designers and suppliers, and the total number of contracts was more than 100. The contracts were drawn up on a Lump sum basis with a milestone payment system.

- With the increasing complexity of building process, the committee enhanced co-ordination and communications between designers, subcontractors, managers and other professionals involved in the project.

- The organisation structure of the project is shown in Figure 5.2, which is different from that of the traditional project model shown in Figure 5.3. The subcontractors in the two figures also include material and equipment suppliers. The solid lines indicate a contractual relationship and the dashed lines a working relationship.
Under the Traditional PPR (Figure 5.3), according to international practice the engineer (architect or consultant) work includes the control over the cost, quality and duration of the project, contract and information management, and the coordination between project participants. They are employed by the client, and play a key role in managing the project. However, the supervision engineer (Figure 5.2, such as Liaoning Zhifa Supervision Company) was only in charge of quality management of the SJZU project, and the client itself acted as the engineer in managing the project.

3) Construction phase

Through international bid for tenders, Shenzhen Zhongyin Design Company won and then produced the plan and preliminary design of the new campus. The Northeastern Institute of Architectural Design and the Design Institute of SJZU together carried out the structure design of buildings for teaching, administration, accommodation, etc. The plan and all design work were completed through the
period from June 2000 to September 2001. The total building work was divided into four sections including 20 buildings for teaching, laboratory and offices, connected by a two-story, 750-metre long corridor. Beijing City Construction Group, Northeast Jincheng Construction Corporation and another two companies were selected in parallel as subcontractors through unlimited bidding. The building work started on 8 August 2001. Liaoning Zhfa Supervision Company, the supervision firm of the Lumei Design Institute and the supervision firm of SJZU were selected through unlimited bidding and were in full charge of the project supervision. The buildings mentioned above have been completed as well as the dormitories, library, landscape and sport centre.

4) Key points of the project management

• The condition of the management approach was that SJZU possessed all professional staff in various fields.
• The characteristics of the project determined that the objectives for cost and time did not have to be so strict as those of contracted projects due to the client's role as both the contractor and consultant, i.e. although the consequence of duration and/or cost overrun is negative, the client did not need to pay penalties.
• The order of priority of the project was quality, function, aesthetics, time and cost, instead of cost, quality and time which is the normal ranking.

5) Analysis of project objectives

• The major objectives of construction projects are quality, duration and cost, and the three objectives are correlative. However, the client of SJZU had the power to determine and change the objectives of the project because the client took on both the roles of contractor and consultant. For example, the period of the project was postponed for half a year, due to the delay in selling the western campus. Generally speaking, any duration delay of construction projects can cause dramatic effects on the reputation and, of course, the net present value (NPV) of the project. For a commercial project, if delay occurs,
competitors could use the situation as an opportunity, and the client may lose its customers. Meanwhile, any change made during the building phase would be very expensive and could cause additional delay. Different from international practices, the project employed estimated project objectives instead of exact project objectives.

- Basically, the quality of the new campus was controlled as expected by the client, but a few qualitative issues still exist, such as rain leakage from the roof of the junctions between the main corridor and sub-corridors and some junctions between buildings, and the faults in the air conditioning system. These issues in the project were related to the interfaces among the subcontractors including suppliers. Managing and co-ordinating numerous subcontractors was a major risk for the client.

- Although the construction cost was controlled to its budget, the operation cost will increase due to the qualitative issues during the project life cycle. The total cost of the project life cycle is the sum of the construction cost and operation cost. However, project participants in the CCI normally want to control construction cost but neglect project running cost. The major reason is related to the PPR. If the Engineering Procurement Construction (EPC is a standard PPR in the FIDIC Conditions of Contract for EPC/Turnkey Projects, 1st edition, 1999) or BOT PPR were employed, the EPC contractor or the project company managing the BOT project had to consider both of the construction cost and operation cost.

- The objectives and management model of the project determined that the project management was based on the client's experience and judgement instead of project planning and management.

6) Major findings

- The project management model is a kind of D/B/B PPR in China, and the client directly subcontracted subcontractors. It is a popular management model of construction projects without the assessment and selection of the PPR.
In China, the model of construction project management is different from the Western countries where it is against construction regulations for the client to take on both the roles of contractor and consultant. However, in the CCI, clients have traditionally managed construction projects by themselves and they may take on both the roles of contractor and consultant. In projects where clients act as managers there are fewer checks and balances and more opportunity for improper financial practice. It is helpful to change the situation to introduce and apply innovative PPRs that provides a foundation to develop Chinese engineering consulting industry, by managing construction projects based on engineering consultants, instead of organising a project management team by the client. China's unique social and economic system makes the major project risks and risk management different from the Western countries. The main gap in the construction industry between China and the developed world is the issue of management, followed by technology and economics.

SJZU possessed a full range of expertise in construction, and all issues from planning, design to construction could be taken into account early in the project life-cycle. With the increasing complexity of building process, the client of SJZU had the abilities to enhance co-ordination and communications between designers, subcontractors, managers and other professionals involved in the project. However, this kind of management approach is also employed in other large construction projects whose clients, however, do not share SJZU's major advantage. Under this situation, the following questions must be considered:

a) How can the project objectives be guaranteed? Of course, at the project level, this will be one of the major risks to the project client.

b) Which PPR and which type and conditions of contract should be adopted? These are not a technique issue but a management issue.

c) How much money is wasted due to employing the same construction model for different projects (Yan, 2003)?

There is no single PPR that is likely to be better than others for all projects, and a PPR cannot be used indiscriminately on all types of project. At the level
of the CCI, careful consideration needs to be given to the most appropriate PPR for the project in question.

- The introduction and application of innovative PPRs may change the situation of the unitary Traditional PPR and the Lump Sum Contract in the CCI, and provide a foundation to manage construction projects according to contract conditions instead of the client’s experience and judgement.
- PPR is very important to improve PRM, develop the Chinese construction market and engineering consulting industry. Therefore, the application of innovative PPRs is a breakthrough to improve contractual risk management (CRM) and speed up the reform of Chinese construction market.

5.2.3 A project with the EPC PPR

In 2002, a power plant project in Jiangshu Province in China, built with the Engineering Procurement Construction (EPC) PPR was unsuccessful (Yan, 2004b). During the operation of the power plant, faults in the generators often happened and the faulty structures needed frequent repairs. Therefore, the amount of electricity produced was below the level specified in the design. Then, contractual disputes and claims took place between the client and contractor of the project. According to the contractual document of the power plant project, the EPC contractor had to take all responsibilities for the poor quality of the generators. The client was unhappy although it won the claim. The client’s purpose in investing in the project was to obtain an excellent power plant, rather than winning a claim.

The direct cause of the project failure was a technical issue, but the author’s purpose is to analyse the management problem, i.e. the cause of the contractual disputes and claims rather than the complicated technical issue and the claim process. The EPC is a standard PPR in the FIDIC Silver Book (FIDIC Conditions of Contract for EPC/Turnkey Projects, Silver Book, 1st edition, 1999). Different from FIDIC Orange Book (FIDIC Conditions of Contract for D/B and Turnkey projects), the EPC is specially suited for complicated industrial projects such as
energy and chemical plant projects. Accordingly, the EPC PPR was suitable for this power plant project, but why was this project unsuccessful? The basic condition for the application of the EPC PPR is that the EPC contractor must possess the ability for integrating technology, economics, management and regulations, and for contractual interface management. In the EPC, the engineering includes design, design optimisation and equipment option, and the construction also includes some technology issues such as equipment setting and testing. For this project, the technology issues mainly include the design of the power plant, the selection and procurement of power generation equipment, equipment setting and the construction. Simply, the EPC contractor should take all responsibilities for the engineering, procurement and construction. So, traditional contractors who mainly engage in the construction stage are not qualified as an EPC contractor. The EPC contractor in this project did not possess the ability, and this was the major cause for the project failure. The poor ability of the EPC contractor to manage the contractual interfaces between design and equipment supply, design and construction, and construction and equipment supply, resulted in the failure and the disputes and claims. Turnkey and EPC models possess a similar risk structure, and require the contractor to have more advanced speciality and ability to integrate and co-ordinate every resource, and therefore improve project performance. The case indicates:

- EPC PPR has advanced merging of technology, economics, management and regulations, which is an important means to realise the clients' needs for the best integration of cost, quality and time for complicated projects. However, the success of EPC projects largely depends on the ability of the EPC contractor. In the CCI, there are many contractors, but only a few are qualified EPC contractors. Therefore, the major risk to the client of EPC projects is the failure to choose a qualified EPC contractor.

- According to international practice, specialist design firms are often employed as the EPC contractors because of their expertise and management ability. However, for Chinese design firms to take the role of EPC contractors needs a transition from a design firm to a qualified consultant, which requires
practitioners to engage not only in the design work, but also in various management activities such as project planning, project assessment and contractual management. It is an internal stimulus in the construction industry to develop the engineering consulting industry to improve Chinese contractors’ abilities to apply EPC and other innovative PPRs.

• So far, the interface problem has not been effectively solved, and interface management is a big challenge to the contractors of General Engineering Packaging (GEP) in the Chinese construction industry (CCI).

5.3 CONTRACTUAL INTERFACE RISKS OF PPR

5.3.1 Contractual interface structure of PPR

For the implementation of a construction project, clients have a wide variety of contractual arrangements to choose from various contracts required to initiate and implement the construction project. For any contractual strategy, risks are the prominent criteria that will determine the selection of PPRs.

Generally, each PPR has its own contractual risk structure, and different contract types suit different PPRs. For example, the Design/Build (D/B) PPR, Turnkey PPR, Engineering Procurement Construction (EPC) and Build-Operate-Transfer (BOT) projects employ a fixed price contract for the project, but the Traditional PPR may employ a fixed price contract, a unit price contract or a cost reimbursable contract. A PPR cannot be used indiscriminately on all types of projects. Therefore, it must be understood how to choose an appropriate construction contract or how to make use of a contract strategy, and the structure of contractual interfaces to improve project risk management (PRM). Different PPRs possess a different interface structures that contain a different number of interfaces and interface responsibilities. Each PPR possesses its own contractual interface and organisational interface, and the two interfaces further determine the major physical interfaces. Figure 5.4 indicates main contractual interfaces in a project life cycle, where the phases are listed in Figure 5.1.
5.3.2 Contractual interface risks of the Traditional PPR

In the traditional project procurement route (PPR), i.e. the Design/Bid/Build (D/B/B) PPR, the owner hires an architect or consultant, who may spend several months to create working drawings. Additional weeks, even months are spent in a bidding process to hire a general construction contractor. The architect or consultant and contractor must complete their respective phase for the project before they can hand the project to the next stage. The major difficulties of the traditional procurement method are schedule slippage, high bids and the interface between design and construction that may cause conflicts and communication gaps among the participants. These difficulties are particularly obvious for large and complex projects that require advanced management systems.

The principal characteristics of the Traditional PPR are that the design/bid/build process is linear. The linear characteristics result in the duration of the project being longer than other type of PPRs. The designer finalises the entire design before the construction contract is put out for bidding, and the contractor has no early input into the design process. So, there is a noticeable interface between the designer and the contractor, which is the major reason for potentially high engineering variation and claims. The client takes the responsibilities for managing most contractual interfaces including interfaces 1, 2, 3, 5 and 6, and the contractor has only the responsibility for managing contractual interface 4 (Yan, 2005b). It is a big challenge for the client to manage the contractual interfaces. The major risk of the D/B/B system is that the project building according to the
plan and specifications may not perform as the client expected. The main contractual interface risks of the Traditional PPR are as follows.

- The whole process of design and construction is characterised by discovering interdependencies that make the uncertainties. The problem with the centralised model for co-ordinating design, construction and supply is that it is often ineffective for the client to manage the interdependencies because the management abilities of the client are much weaker than that of engineers or contractors.

- Issues of the interfaces and interdependencies are exacerbated by the traditional rigid separation between the project participants (client and contractor; designer and contractor; contractor and supplier). The boundaries of several activities need to be redrawn in order to prevent the emergence of interface issues, and the organisation of the project needs to be redesigned in order to facilitate the exchange of information between the relevant parties.

- Co-ordinating the complex work of a construction project through legalistic contracts offers some participants the chance of making money at the expense of others, but is likely to lead to contractual disputes rather than collaborative problem solving when difficulties arise. This contract is geared more towards preventing future claims and liability than delivering high quality building at the lowest possible price.

- The designer may not be fully aware of all the complex interdependencies that exist between different aspects of design and construction. The designer may also fail to understand the implication of design choices for construction methods, or for materials, and so the contractor has to find or improvise solutions on site.

- Under the Traditional PPR, the contracts tend to be highly detailed in terms of specifying responsibilities, liabilities, and above all, penalties if either party is responsible for delays that affect the interests or performance of the others. Everyone is working on the basis of what the plan centre specifies, rather than on the basis of what is actually needed by the user of the work. For example, in the structure of an office building, the contractor may find itself installing a
cladding system specified by the architect which requires expensive facing to the structure components specified by the structural engineer, when the cladding supplier and contractor together could have specified a much cheaper system to do the same job.

5.3.3 Contractual interface risks of the D/B PPR

The Design/Build (D/B) PPR simply means that a single entity is responsible for the design and construction. The single entity may be a D/B firm that has fully integrated in-house architectural and engineering capabilities, or a joint venture that may subcontract the design work or construction work. The owner deals directly with the D/B contractor. Therefore, in the D/B PPR, a close working relationship is developed between the architect/engineer, the contractor and the client. For example, during the design stages of the project, both of the designer and construction professional can search for alternative materials and construction methods, taking into account the budget and scheduling constraints. Whereas, under the Tradition PPR, a design error discovered later in the project can mean months of lost time.

Eggleston (1993) presents the design risks of the D/B contract, including:

- The contractor is responsible for the integrity and workability of its design.
- The contractor warrants that its design will satisfy the employer’s requirements. Accordingly, the contractor takes the risk on inadequate design and under-specification.
- The contractor is responsible for the selection of materials and specialist subcontractors and takes the risk on their suitability.
- The contractor is responsible for the performance of the design team. Therefore, the contractor takes the risks of late supply of design information, mistakes, revisions to details and co-ordination.

Although the risks are shared between the client and contractor, the balance of risk-taking is generally shifted towards the contractor under the D/B contract.
Under the D/B PPR, the client takes the responsibilities for managing contractual interfaces 1, 2, 5 and 6. The contractor takes the responsibilities for managing major contractual interfaces 3 and 4 that include the interfaces between design contract and construction contract, design contract and supply contract, and construction contract and supply contract. The contractor’s greatest benefit is to control and co-ordinate the project design and construction, which naturally leads to the contractor’s greatest risk, the expanded responsibility for design and construction. The D/B PPR adopts the Lump Sum Contract, and the contractor bears the main project risks. However, the contractor usually has much more experience and ability than that of the client to manage these contractual interfaces (Yan, 2005b). The major risks of contractual interfaces of the D/B PPR include:

- Under the D/B PPR, and for both of the client and D/B contractor, the key risk or critical area of risk allocation is the working scope because the detailed drawings of the project have not been completed at the bidding stage. Disputes about the working scope are not surprising. The contractor’s lack of critical information about the working scope at the contracting time may also lead to budget and scheduling disputes. For example, if the designer is not ordinarily held to strict schedules that may be on the critical path in a D/B contract, scheduling risks may arise.

- Only the largest and most sophisticated D/B firms have the united ability to design and build the project without subcontracting. In the Traditional PPR, the client approves the completed design. In contrast, the D/B contractor essentially controls all aspects of the design that are not constrained by the performance criteria. Under the D/B PPR, the contractor may have less need to create detailed drawings in order to execute the design and may seek to reduce design costs by converting many “design details” into methods and means of construction. Therefore, the design quality is possibly influenced by the contractor’s preferred design. The benefit to the client is that it will not be subjected to the designer and contractor competing claims of “design errors” and “unwillingness to construct".

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For Turnkey and Engineering Procurement Construction (EPC) projects, the contractor takes the responsibilities for managing main contractual interfaces 3, 4 and 5, and the client takes the responsibilities for managing other contractual interfaces 1, 2 and 6 (Yan, 2005b). The risk structure and risk responsibilities of both projects are similar to those of D/B projects, but the contractor of Turnkey or EPC projects takes the responsibilities for managing one more interface (interface 5) than that of the contractor of D/B projects. So, the contractor must possess dedicated ability for integrating technology, economics, management and regulation, interface management and various resources.

5.3.4 Risks of the BOT project

For BOT projects, a reasonable concession period nowadays would be 10 to 40 years. BOT project companies take all responsibilities for managing all contractual interfaces. All project risks concentrate on a BOT project, including construction risk (e.g. cost over-run of the project and delay in completion of the works), production risk (technological faults, materials in short supply), market risk (project products that do not sell, raw materials in short supply), finance risk (inflation, foreign currency interest, currency exchange), politics risk (policy change both nation-wide and locally, change of law and regulations), and unforeseen force risk (war, natural disaster). The BOT project possesses the most complicated risk structure and risk factors. As mentioned previously, the risks of BOT projects have been grouped into 8 types. The two crucial factors of BOT projects are project financing and fair risk allocation on a sound contractual basis. Successful project financing depends on ascertaining and implementing a fair allocation of the financing risk. The basic risks of the BOT project can be divided into three stages:

- risks in the development phase of a BOT project,
- risks in the pre-production phase of a BOT project, and
- risks in the production and operating phase of a BOT project.
The purpose of risk analysis for a BOT project is that project risks should be reduced to the level that can be accepted by the project promoter, local government and all project participants. In order to do so, the risks must be allocated to the party best able to control the risk.

- Construction risk and production risk should be allocated to the project company;
- Political risk and unforeseen force risk should be allocated to national or local host government;
- Generally, financial risk is assigned to the host government but sometimes the risk is assigned to the project company if the currency exchange or inflation changes is in a minor way that is determined by the concession agreement;
- Market risk is basically assigned to the government that guarantees the minimum price of the project product in the concession agreement;
- The risk for supplying raw materials is assigned to anyone who provides the materials.

5.3.5 Risk allocation between client and contractor under different PPRs

Project risks must ultimately be shared between the client and contractor. Figure 5.5 shows qualitatively risk allocation between the client and contractor under different PPRs. The categorisation of PPRs has been provided in Section 5.1.1.
For the Traditional PPR, under a fixed price contract, the contractor accepts all risks by taking a fixed fee for the work regardless of the out-turn cost. The contractor is charged a penalty if the duration is exceeded. Under a unit price contract, the sponsor accepts the change of the working amount, and the contractor only accepts the change of the unit price. Accordingly, the contractor takes less risks than that under a fixed price contract. However, under a cost reimbursable contract, the contractor is paid the costs incurred plus a fixed fee or a percentage of the out-turn contract sum for management, overheads and profit. Therefore, the client takes more risks under a cost reimbursable contract than under a fixed price contract or a unit price contract. The explanations for General Engineering Packaging (GEP) PPR are provided in Section 5.3.3. For engineering management PPR, the client takes more risks than that under GEP PPR, because the client fully authorises the CM manager or consultant to manage the construction project.
5.4 CONCLUSIONS

Innovative PPRs are new to the Chinese construction industry (CCI), and previously there has been only the one standard set of construction contract conditions, the Traditional PPR. In March 2003, the Chinese Ministry of Construction (MoC) issued guidelines for the experimentation of General Engineering Packaging (GEP) and the development of project management enterprises. The purpose is to deepen the reform and development of the Chinese construction market, and increase the competitive capability of the CCI. The introduction and application of innovative PPRs should provide a great market opportunity to develop the engineering consulting industry and construction contracts, and improve the risk management of construction projects. Therefore, the introduction and application of innovative PPRs is a breakthrough to improve PRM and speed up the reform of the Chinese construction market. This research has carried out an exploratory analysis of the PPRs and their functions for the reform of the Chinese construction market, which may provide guidelines for their application in the CCI.

Based on the above analysis, the key points are extrapolated as follows:

- For each PPR method, interfaces are the major source of organisation and coordination risks, and interface management is a big challenge to project managers in China. For the CCI, the ability of the Construction Management (CM) manager is a crucial issue for managing the interfaces between design, bidding and construction at different project building stages to project success.

- Innovative PPRs will need to be implemented progressively as expertise develops and it is important to select the most appropriate PPR for the project under consideration. First the design/build (D/B) PPR should be applied in the CCI. Secondly, the Turnkey PPR, Engineering Procurement Construction (EPC) PPR and Build-Operate-Transfer (BOT) PPR can become practicable.

- The introduction of the engineering management PPR depends on the reform of the CCI. For example, the CM model does not suit the current situation in the CCI. There are two major reasons. Firstly, the current Chinese
construction regulations require that all design documents have to be completed before construction, that means it is illegal to construct a project while designing. Secondly, there is currently a lack of Construction Management (CM) expertise in the CCI. According to international practice in the construction industry, the role of CM managers is usually taken by contractors who possess advanced abilities for managing construction projects. However, in the CCI there are few contractors who are qualified as CM managers because most contractors lack the experience for implementing the CM model and the management abilities for integrating technologies, economics, management and regulations. Therefore, it will take a considerable period of time to develop the CM model in China, and this will depend on the reform of the Chinese construction market and the development of the Chinese consulting industry. The objective of the reform is to build a mature construction market and develop an effective consulting industry. However, the management contracting (MC) model is suited for the current CCI, and it is an effective approach to manage construction projects based on consultants, instead of organising a project management team by the client. For this purpose, the vital issue is to develop the Chinese consulting industry and provide qualified engineering consultants.

- Under the Traditional PPR, the client takes all responsibilities for managing almost all interfaces, but the client's capability to do so is much weaker than that of qualified consulting engineers. Therefore, it is an internal stimulus in the industry to develop the engineering consulting industry for the application of innovative PPRs and the enhancement of consulting service.

As stated in Chapter 2, uncertainty is the basic characteristic of construction projects because there are many uncertainty factors both inside and outside of construction projects from commencement to completion, such as political, economical, technical, natural and other factors. However, it is impossible to eliminate all uncertainties of construction projects. The purpose of PRM is to reduce uncertainties, and a general method to do so is project planning that includes project organisation planning, target planning, contract structure planning,
etc. For the CCI, what are the important issues to reduce project uncertainties? The survey and case studies reveal the importance of improving decision making and contract risk management of construction projects including project interface management. This research studies interface risks and the relationship between interface risks and PPR, and presents the approach to improve interface management. Through project planning, the determination of a suitable PPR forms the basis of contractual risk management. During the planning stage, interface risk and its management should be stressed with the PPR selection, so as to reduce interfaces and determine the responsibilities for interface management, thus improving project performance.

The case studies illustrate that in the CCI, the causes for project failure are mainly poor management, such as wrong decision making, incorrect PPRs employed and the negligence of interface management. Generally speaking, for the CCI, the principle and procedure of PRM are more important than specific techniques for quantitative risk analysis. Therefore, this research emphasises on project planning, PPRs and contract risk management aiming to achieve optimal project performance (maximum function/cost or minimum project life cycle costs which consist of the construction and operation costs).

However, project participants in the CCI normally want to control the construction cost but neglect the operation cost, and they are accustomed to the Traditional PPR and the Lump Sum Contract. For the Traditional PPR, the interface between design and construction may cause conflicts, communication gaps among the participants, and uncertainties. The problem with the Traditional PPR for coordinating design, construction and supply, is that each project participant only considers its own work and benefits, and neglects the overall project performance. It is therefore necessary to employ General Engineering Contracting (GEC), such as Engineering Procurement Construction (EPC) and Build-Operate-Transfer (BOT).

Building on the findings from the survey analysis and case studies, this research has put forward the framework of contractual risk management, covering the
concept, classification and identification of contractual risks. For non-quantifiable contractual risks, contractual interfaces have been analysed under various PPRs, and the categorisation, selection and application of PPRs studied with cases in the CCI. The work provides a foundation and practical guidelines for PRM strategies in the CCI. However, quantitative risk analysis is also crucial in informing project decisions in PRM. The research proposes two models to analyse quantifiable contractual risks. For contractors to identify risks at the estimating and tendering stage with the purpose of determining tendering price strategies, an effective information entropy model is developed in Chapter 6. A realistic estimate of project contractual risks is important to both clients and contractors for project planning, and a probabilistic analysis model is proposed in Chapter 7 to qualitatively analyse contractual risks.
CHAPTER 6  EFFECTIVE INFORMATION ENTROPY METHOD FOR TENDER PRICING

6.1 INTRODUCTION

The motivation for searching for a new way of modelling is driven by the desire to mitigate the risks that continue to threaten the successful implementation of projects. Risk identification is the first step of risk management process before risks can be analysed and a necessary response can be determined. For contractors, risk identification is at the tendering and estimating stage, and the objectives are to identify the influencing factors in the contractor’s decision making as whether to bid or not for a project, and also the influencing factors in the contractor’ mark-up decision. Bajaj et al. (1997) reported that the major factors influencing a company’s decision whether or not to bid are the tender, type of project, finance, contract and management, and the tender and type of project are the most important factors. The type of project includes suitability of project to the company business plan, and tender related issues including the tendering procedure, number of tenders, time to tender and tender selection criteria.

In a competitive tender, and under the regulated environment of the worldwide construction market, contractors often use pricing strategies to win a bid. Generally, in the construction industry, the traditional way of pricing a tender is to use the cost plus mark-up method. The contractor calculates the direct and indirect costs for site facilities, labour, equipment and materials that will be used in the project. To follow, the contractor marks up the estimated cost by a certain percentage to cover its office overheads, contingencies and profit (Shash, 1993). Since Friedman’s (1956) work about competitive bidding strategies was published, many experts have explored tendering theory as a strategy for bidding. The significance of a single bid auction is that the single bid is assumed to express both the private valuation of the contract and the strategy employed to achieve
success (Kagel et al., 1987). However, at the present time, tendering decisions are still largely based on the contractor’s experience and bias, which simulate the pricing strategies in a simplified manner. Clearly, there are risks in such pricing strategy for they cannot be assessed quantitatively. At the moment, there are currently very few practical methods that can be applied in order to quantify the risks of pricing strategies. So, contractors are constantly facing the dilemma of submitting a high price to maximise profits with the probability of failing to win the bid and thereby suffering a shortage of work.

Construction projects consisting of people, material, capital and information flow are recognised as a complicated open system as defined by general system theory. Entropy as a state parameter, its important function is to reveal the characteristics of a system. Different from other techniques, entropy provides an approach to study the characteristics of a system, rather than analysing special technical issues. Despite a detailed literature survey, no literature has been found on applying entropy to project risk management (PRM) in the construction industry. This research demonstrates a new method for determining the optimum tendering price based on effective information entropy. The model may be applied under open bidding and the Lump Sum Contract. The major purpose is to reduce the risk for contractor tender pricing with the application of information entropy in the construction industry. The concept of entropy can be used in many fields and is further discussed in Section 6.2. It is necessary to emphasis that there are no single methods for determining the tendering price because it is influenced by many factors. For the satisfactory application of this method, various assumptions are necessary:

1) The contractor has some experience of tendering price and a certain amount of accumulated historical data of tendering price of its competitors;
2) The probability of winning a contract may be estimated from previous encounters and the appropriate strategy is to maximise the expected profit of the bid;
3) The tendering prices of the competitors are independent of each other; and
4) The environment of the construction market is mature and regulated, i.e. fair bidding is the condition for the application of the method (Yan, 2004a).

After the contractor’s pre-qualification, the tendering price is a crucial factor for winning a bid. Let $A$ be the contractor’s estimated cost and $B$ the tendering price. Then, the direct tender profit $I$ can be expressed as

$$ I = B - A $$

6.1.1

Only after winning a bid, can the contractor make the profit; otherwise, $I = 0$. Therefore, when deciding a tendering strategy, the predicted profit should be used as the criterion. If the probability for winning a bid is $P$, then the predicted profit is the expectation value $E(I)$ of direct tender profit $I$ where there can only be two possibilities and $E(I)$ can be expressed as

$$ E(I) = P 	imes I $$

6.1.2

where $E(I)$ can be interpreted as the contractor’s average benefit of similar construction projects at the same tendering price, which is the contractor’s target profit for a long period of business. So, $E(I)$ is more reasonable than $I$ for making tender price strategies. In the next sections, an effective information entropy method for deciding tendering price strategies with an example of tendering price using “effective distribution” of information is presented.

6.2 INFORMATION ENTROPY AND EFFECTIVE INFORMATION DISTRIBUTION

General system theory grew out of research in a number of disciplines, including Shannon’s (Shannon and Weaver, 1949) work on information theory and Wiener’s (Wiener, 1948) Cybernetics which all looked at concepts of entropy, feedback and interactions between components. The systems approach is valuable because generalisations developed by observing one kind of system often have application for another, often very different kinds of system. The ideas from other
subjects have the potential to help us understand the construction system. PRM has been developing from a defined technical approach to a system analysis for the purpose of improving decision making and project performance.

Since the concept of entropy was originally introduced by R. Clausius in 1865 (Shen, 1965) in thermodynamics, entropy has been applied widely, for example, in the fields of chemistry, biology, decision and information theory, and even social and economical sciences. As a state parameter of systems, entropy may indicate the characteristics of the system. In the field of physics, entropy has an accurate physical meaning that indicates the state of a thermal system and the characteristics of a thermal process, expounds the rule of energy inequality during energy conversion that is a natural law. In statistical physics, entropy is a mathematical function that may be used to measure the quantity of micro-states in a system.

### 6.2.1 Information entropy

In 1877, Boltzmann (Shen, 1965) realised that the entropy of a system may be related to the number of possible micro-states consistent with its thermodynamic properties. Boltzmann then postulated that $S = k \times \ln Q$, where $k$ is the Boltzmann constant (universal constant), $Q$ is the thermodynamic probability that can be defined as the number of micro-states without macroscopic difference and $S$ is entropy (Garber, 1995). With $Q = 1$, $\ln Q = 0$, and $S = 0$, there is no uncertainty in the system. This postulate may be regarded as the foundation of statistical mechanics because it relates a microscopic property of the system ($Q$) to one of its thermodynamic property ($S$). The most important property of entropy is to reveal the uncertainty of a system. Uncertainty of a system depends on two factors: one is the number of states ($n$) of the system and the other is their probability, i.e. $p(x_i)$ ($i=1,2,3,.....n$). For example, the number of states for a coin could be considered as two ($n=2$) and the probability of the two states is $p(x_1)=p(x_2)=1/2$. In information theory, if the probability of each state in a system is equal, such as the probability for winning a bid after pre-qualification, the uncertainty of the system
may be expressed as $\log_a n$, called information entropy, and the probability of each state is $p(x_i)=1/n$. Then, the entropy for any state can be expressed as $-(1/n) \log_a n = (1/n) \log_a (1/n)$. If there are $n$ independent states in a system, and their probabilities are $p(x_1), p(x_2), \ldots$ and $p(x_n)$, the information entropy of a system may be expressed by equation 6.2.1, i.e. the statistical model of Shannon entropy (Wiley, 1988).

$$H(X) = E[J(X)] = -K \sum_{i=1}^{n} p(x_i) \log_a p(x_i) = K \sum_{i=1}^{n} h_i \quad 6.2.1$$

where $X = \{x_1, x_2, \ldots, x_n\}$ denotes a series of $n$ random variables (e.g. all the factors that could affect the bidding system, including duration, quality, labour, etc) and $p(x_i)$ is the probability of $x_i$, noticing that $\sum_{i=1}^{n} p(x_i) = 1$; $J(X)$ denotes original information relating to $X$; $H(X)$ is the information entropy, i.e. the average information quantity of a system expressed by $E[J(X)]$; $h_i = -p(x_i) \log_a p(x_i)$ is the contribution of variable $i$ to the entropy; $K$ is the information constant for any given case and is just a choice of measurement unit; the base $a$ is usually set to 2 or $e$, for which $K$ is set to 1, where the information entropy is measured in “bits” or “nats” respectively.

Therefore, the information entropy (Shannon entropy) expresses the average quantity of information in a system. From equation 6.2.1, the properties of the information entropy can be derived as follows:

- The entropy possesses a probabilistic property;
- The entropy of a system is always positive because $0 \leq p(x_i) \leq 1$;
- If there is only one state for a system, then $H(X) = 0$, and there is no uncertainty for the system;
- As the number of states increases, the entropy of the system will increase;
- If the system has $n$ states and the probability for any state is the same (i.e. $1/n$), the entropy reaches the largest value (Yan, 2002).
6.2.2 Obstacle for the application of information entropy

Since information entropy $H(X)$ may express the average information quantity in a system, it therefore can be applied to systematic analysis and other engineering fields. This research develops a new approach to the application of information entropy to quantitatively analyse contract risks. However, the major difficulty is the interpretation of the meaning of information entropy for its application in engineering fields. While there is no problem in calculating quantitative information entropy, the problem is how to determine the quality of the information. In other words, the information from $J(X)$ possesses certain meaning but the same quantity of information entropy may possess a different meaning. Shannon did not decipher the qualitative meaning of information entropy when he presented the statistical model of information entropy. So, the utilisation of information quality must be further studied. For example, what is the function and effect of the information entropy by equation 6.2.1 in order to win a bid under different tender prices? Obviously, the question cannot be answered with only the quantitative information. It is necessary to determine the information entropy both quantitatively and qualitatively by the introduction of effective information distribution in order to illustrate the characteristics of a system. Recent research stresses systematic methodologies and practical steps based on project assessment in order to gain maximum benefits for project participants, and a shift of project management has been growing from defined technical issues to a system analysis for the purpose of improving decision making and project performance. In particular, the maximum entropy principle can be applied in the construction industry to deal with uncertainty problems (Lam et al., 2005).

6.2.3 Effective information entropy and effective information distribution

In order to overcome the obstacle for the application of information entropy, this research puts forward the concept of effective information entropy and the effective information distribution, and it may be demonstrated by the matrix equation 6.2.2. Let $V (V = \{v_1, v_2, \ldots, v_n\})$ denote the effective information distribution, which represents the effective level of information entropy on event
6.2.2

X, i.e. the qualitative factor (a kind of weighting). The value of each element of effective information distribution \((V)\) is specified in a range from 0 to 1, where the *median* value is set at the maximum value 1.

\[
S^* = \begin{bmatrix}
X \\
V \\
P
\end{bmatrix} = \begin{bmatrix}
x_1 & x_2 & \ldots & x_n \\
v_1 & v_2 & \ldots & v_n \\
p_1 & p_2 & \ldots & p_n
\end{bmatrix}
\]

Once again, \(X = \{x_1, x_2, \ldots, x_n\}\) denotes the series of random variables and \(P = \{p(x_1), p(x_2), \ldots, p(x_n)\}\) denotes the probabilistic distribution of event \(X\). From the matrix in equation 6.2.2, the effective information entropy can be obtained. Let \(I(P,V)\), which denotes the effective information entropy, be defined by equation 6.2.3.

\[
I(P,V) = -K \sum_{i=1}^{n} \nu_i p(x_i) \log_a p(x_i) = K \sum_{i=1}^{n} \nu_i h_i
\]

6.2.3

where \(\nu_i \geq 0\) and the other denotations are the same as for equation 6.2.1. Taking a coin as an example, the entropy \(H(X) = -(p(x_1) \log_2 p(x_1) + p(x_2) \log_2 p(x_2)) = -(1/2 \times (-1) + 1/2 \times (-1)) = 1\).

If \(\nu_1 = \nu_2 = \ldots = \nu_n = 1\), i.e. no weighting is considered for the system variables, then

\[
I(P,V) = -K \sum_{i=1}^{n} p(x_i) \log_a p(x_i) = H(X)
\]

6.2.4

From formula 6.2.4, it can be concluded that the average information quantity described by Shannon entropy is a particular case for calculating effective information entropy, \(I\). Meanwhile, it explains the reason why Shannon entropy is limited in practical engineering applications. Effective information entropy, \(I\) is a combined model of the distribution of objective information, \(H\) (historical data) that indicates the information quantity of a system, and the effective information
distribution (heuristic data), V that defines the quality of the system information. It is important to determine the effective information distribution for the application of effective information entropy. At the moment there is no unified mathematical method that can help establish the effective information distribution. The only way to establish the effective information distribution is dependent on experience, from accumulated factual data and the characteristics of the practical system under consideration. For example, the decision for tendering pricing strategies must change according to the number of competitive tenders. The optimum tender price for winning a bid and predictive profit will reduce with the increase of competitive tenders. This must be considered when producing an effective information distribution for tender pricing strategies. However, it is very difficult to precisely quantify the data to obtain effective information distribution for increasing the competitive advantage. A possible way forward would be to conduct a survey with a well-designed questionnaire for carefully-selected experts to answer. The questionnaire would consider the factors that affect the effective information distribution, such as the number of tenders, the tendering prices and the corresponding probabilities. The selection of experts would not be easy as it would be difficult to set the criteria appropriate to the specific industry. Although this research has not had an opportunity to conduct such a survey, an example based on the author's experience and understanding is provided in the next section to illustrate the application of the effective information entropy.

6.3 APPLICATION OF THE EFFECTIVE INFORMATION ENTROPY MODEL TO DECIDE TENDER PRICING STRATEGIES

6.3.1 An example application

Let \( m \) be the number of the tenders which pass the pre-qualification stage. First, a reasonable tendering price must be determined according to the predictive profit. Therefore, it is necessary to collect sufficient tendering information including different tendering prices and their probabilities for winning a bid. In order to achieve success, it is necessary for the contractor to ensure that its own tendering
price is lower than that of the competitors. Based on the contractor’s estimated tendering price \( B \), its competitors’ tendering price \( B_i \) (\( i = 1, 2, ..., m-1 \)) and the corresponding probability, a range of probabilities for \( B/B \) can be calculated using data collected and statistics (refer to Table 6.1).

Considering the lack of tender information in the Chinese construction industry (CCI), the data in Table 6.1 extracted from Qian et al. (1995) (where \( A \) = estimated contractor’s cost, \( B \) = tendering price, \( P \) = probability for winning a bid) is employed in this research. The table contains statistical historic data recorded, and it reveals the correlative relationship between tendering price, probability for winning a bid and the number of competitors. Therefore, the data can be employed as compared with the outcome of the effective information entropy method.

**Table 6.1  Probabilities of winning a bid (data from Qian et al., 1995)**

<table>
<thead>
<tr>
<th>( B )</th>
<th>( m = 1 )</th>
<th>( m = 2 )</th>
<th>( m = 3 )</th>
<th>( m = 4 )</th>
<th>( m = 5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75A</td>
<td>1.00</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>0.85A</td>
<td>0.98</td>
<td>0.960</td>
<td>0.941</td>
<td>0.922</td>
<td>0.904</td>
</tr>
<tr>
<td>0.95A</td>
<td>0.95</td>
<td>0.903</td>
<td>0.857</td>
<td>0.815</td>
<td>0.774</td>
</tr>
<tr>
<td>1.05A</td>
<td>0.85</td>
<td>0.723</td>
<td>0.614</td>
<td>0.522</td>
<td>0.444</td>
</tr>
<tr>
<td>1.15A</td>
<td>0.60</td>
<td>0.360</td>
<td>0.216</td>
<td>0.130</td>
<td>0.078</td>
</tr>
<tr>
<td>1.25A</td>
<td>0.40</td>
<td>0.160</td>
<td>0.064</td>
<td>0.026</td>
<td>0.010</td>
</tr>
<tr>
<td>1.35A</td>
<td>0.20</td>
<td>0.040</td>
<td>0.008</td>
<td>0.002</td>
<td>0.000</td>
</tr>
<tr>
<td>1.45A</td>
<td>0.05</td>
<td>0.003</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>1.55A</td>
<td>0.00</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

If there are \( m \) tenders, which have passed pre-qualification among all the competitors, and each tendering price is independent, then

\[
P = \prod_{i=1}^{m} p_i = p_1 p_2 ... p_m
\]  
6.3.1
In order to simplify the analysis, let \( p(x_1) = p(x_2) = \ldots = p(x_m) \), then

\[
P = \left[ p(x_i) \right]^n
\]

6.3.2

The contractor can obtain data similar to that of Table 6.1 from the tender information accumulated. By using equation 6.2.1 (where \( K = 1 \) and \( a = 2 \)) and the data in Table 6.1 for \( m = 1, 2, 3, 4, 5 \), the information entropy (Shannon entropy) can be expressed as:

\[
\begin{align*}
H(X)_1 &= 0.029 + 0.070 + 0.199 + 0.442 + 0.529 + 0.464 + 0.216 = 1.949 \\
H(X)_2 &= 0.057 + 0.133 + 0.338 + 0.531 + 0.423 + 0.186 + 0.025 = 1.693 \\
H(X)_3 &= 0.083 + 0.191 + 0.432 + 0.478 + 0.254 + 0.056 + 0.000 = 1.494 \\
H(X)_4 &= 0.108 + 0.241 + 0.490 + 0.383 + 0.137 + 0.018 + 0.000 = 1.377 \\
H(X)_5 &= 0.132 + 0.286 + 0.520 + 0.287 + 0.066 + 0.000 + 0.000 = 1.291
\end{align*}
\]

It is hard to comprehend the meaning of information entropy \( H(X) \) for winning a bid because the values of \( H(X) \) are too high for tendering price, and the \( H(X) \) cannot indicate the quality of the information entropy. Therefore, it is necessary to determine the effective information distribution to obtain the quality of the systematic information.

In the view of systems science, the data in Table 6.1 may be understood as an optimum tendering price system for winning a bid under different tendering prices and number of competing tenders. As mentioned in Section 6.2.3, effective information entropy is a combined model of the distribution of objective information (historical data) that indicates the quantity of the system information, and subjective information (heuristic data) that defines the quality of the system information. Therefore, if the probabilities of winning a bid in Table 6.1 are employed, effective information entropy can predict or provide the information as optimum tendering prices under different numbers of competing tenders. The approach to establish the effective information distribution is mainly dependent on the knowledge and experience of experts, and the characteristics of the practical system under consideration. For instance, the decision for tender pricing strategies
must change according to the number of competitive tenders. The optimum tender price for winning a bid and predictive profit will reduce with the increase of competitive tenders. This must be considered when producing an effective information distribution for tender pricing strategies, but it is difficult to precisely quantify the data (effective information distribution) for increasing the competitive advantage. In this example, the quantitative decision made for the effective information distribution is based on the author’s project management experience and heuristic analysis described below.

According to the tender experience and mean profit level of Chinese contractors, and considering 1.25A, 1.15A and 1.05A, for \( m = 1, \ 2 \) and \( 3 \) in Table 6.1, in order to specify the effective distribution of system information, values in the region of \( B = 1.15A \) could be used as the typical tendering price. Therefore, for \( m = 1 \) and \( B = 1.15A \), the corresponding element of the effective information distribution is set to the median value of 1, the maximum value for the qualitative factor as stated in Section 6.2.3. For a tendering price higher or lower than 1.15A, such as \( B = 1.25A \) or \( B = 1.05A \), the value of the corresponding element of the effective information distribution should be lower, e.g. set to 0.75. For \( B \) higher than 1.25A or lower than 1.05A, such as \( B = 1.35A \) or \( B = 0.95A \) (in relation to the distribution of the tendering prices in Table 6.1), because 1.35A as a tendering price is too high for winning a bid and 0.95A means the contractor’s profit is negative, the value of the corresponding element of the effective information distribution should be reduced significantly, e.g. set to 0.45. Furthermore, for a tendering price higher than 1.35A or lower than 0.95A, the value of the corresponding element of the effective information distribution should further reduce, e.g. set to 0.25. Therefore, the effective information distribution for \( m = 1 \) and, by extension, \( m = 2 \) and 3 can be expressed as: \( V_1 = V_2 = V_3 = (0.25, \ 0.45, \ 0.75, \ 1.00, \ 0.75, \ 0.45, \ 0.25) \). It should be noted that, when \( B = 0.75A \) or \( B = 1.55A \), the corresponding contribution (\( h_0 \)) is 0 and therefore there is no need to consider these values for effective information, leaving just 7 elements in the distribution.

In the light of the experience of tender pricing, it is well known that the optimum tendering price and predictive profit will decrease with the increase in the number
of competitors. When \( m = 4 \) and \( 5 \), the tendering price should be lower than \( B = 1.15A \), i.e. the corresponding element of the effective information distribution could be set to the median value of 1 for \( B = 1.05A \). Other elements of the effective information distribution may be dealt with by using the above principle and, thus, \( V_4 = V_5 = (0.45, 0.75, 1.00, 0.75, 0.45, 0.25, 0.00) \). Therefore, the effective information distribution for \( m = 1 \) to 5 can be expressed as follows:

\[
\begin{align*}
V_1 &= 0.25, 0.45, 0.75, 1.00, 0.75, 0.45, 0.25 \\
V_2 &= 0.25, 0.45, 0.75, 1.00, 0.75, 0.45, 0.25 \\
V_3 &= 0.25, 0.45, 0.75, 1.00, 0.75, 0.45, 0.25 \\
V_4 &= 0.45, 0.75, 1.00, 0.75, 0.45, 0.25, 0.00 \\
V_5 &= 0.45, 0.75, 1.00, 0.75, 0.45, 0.25, 0.00
\end{align*}
\]

6.3.4

Applying data in Table 6.1 and in formulae 6.3.3 (i.e. \( h_i \)) and 6.3.4 (i.e. \( v_i \)) to equation 6.2.3 (i.e. \( I(P,V) = -\sum_{i=1}^{n} v_i p(x_i) \log_2 p(x_i) = \sum_{i=1}^{n} v_i h_i \), where \( n = 2, K = 1 \) and \( n = 7 \)), the effective information entropy \( I(P,V) \) for \( m = 1 \) to 5 is calculated as follows:

\[
\begin{align*}
I(P,V)_1 &= 0.007 + 0.032 + 0.150 + 0.442 + 0.397 + 0.209 + 0.054 = 1.290 \\
I(P,V)_2 &= 0.014 + 0.060 + 0.254 + 0.531 + 0.317 + 0.084 + 0.006 = 1.265 \\
I(P,V)_3 &= 0.021 + 0.086 + 0.324 + 0.478 + 0.190 + 0.025 + 0.000 = 1.124 \\
I(P,V)_4 &= 0.049 + 0.180 + 0.490 + 0.287 + 0.062 + 0.005 + 0.000 = 1.072 \\
I(P,V)_5 &= 0.059 + 0.215 + 0.520 + 0.215 + 0.030 + 0.000 + 0.000 = 1.039
\end{align*}
\]

6.3.5

For a tender pricing system, the \( I(P,V) \) may be used as optimum tendering prices, i.e. when \( m = 1, 2, 3, 4 \) and 5, the tendering prices, \( B \) are 1.290A, 1.265A, 1.124A, 1.072A, 1.039A respectively, and the predicted profits are 0.290A, 0.265A, 0.124A, 0.072A and 0.039A respectively.

6.3.2 Comparative analysis

Entropy may indicate the characteristics of the system, and information entropy
may express the average information quantity in a system. Furthermore, effective information entropy indicates both information quantity and quality of a system. The effective information entropy model provides a new approach to analyse tender pricing risks, based on the characteristics and effective information distribution of a system, rather than dedicated techniques. Therefore, the method possesses different properties and characteristics, and it is not practical to compare it with other approaches. However, the application outcome of the effective information entropy for tender pricing strategies can be checked through a comparison with conventional tender prices and predicted profits. Based on the data in Table 6.1, the predicted profits of conventional tender prices may be obtained for \( m = 1, 2, 3, 4 \) and 5. For instance, when \( m = 1 \), the maximum predicted profit is given by \( 0.25A \times 0.40 = 0.100A \). The optimum tendering prices and predicted profits for \( m = 1 \) to 5 are shown in Table 6.2. Using the probability \( P \) in Table 6.1 and the linear interpolation method, the probability \( P \) and predicted profit \( E(I) \) for tendering price (1.290A, 1.265A, 1.124A, 1.072A and 1.039A) lower than competitors are worked out respectively as shown in Table 6.3. For instance, when \( m = 1 \), the probability for \( B = 1.290A \) is between 0.40 and 0.20, i.e. \( (0.40 - ((0.40 - 0.20)/10)*4 = 0.40 - 0.08 = 0.32) \).

Table 6.2  Conventional optimum tender prices and predicted profits

<table>
<thead>
<tr>
<th>No. of Competitors</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendering prices</td>
<td>1.25A</td>
<td>1.15A</td>
<td>1.15A</td>
<td>1.05A</td>
<td>1.05A</td>
</tr>
<tr>
<td>( E(I) )</td>
<td>0.100A</td>
<td>0.054A</td>
<td>0.032A</td>
<td>0.026A</td>
<td>0.022A</td>
</tr>
</tbody>
</table>

Table 6.3  Probability and predicted profit for tendering prices lower than competitors

<table>
<thead>
<tr>
<th>No. of Competitors</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P )</td>
<td>0.320</td>
<td>0.142</td>
<td>0.319</td>
<td>0.436</td>
<td>0.480</td>
</tr>
<tr>
<td>( E(I) )</td>
<td>0.093A</td>
<td>0.038A</td>
<td>0.040A</td>
<td>0.031A</td>
<td>0.019A</td>
</tr>
</tbody>
</table>
From Table 6.3, for \(m = 1\) to 5, the tendering prices are 1.290A, 1.265A, 1.124A, 1.072A and 1.039A respectively. The data shows that the effective information entropy method specifies the characteristics of the tendering price, i.e. the tendering price reduces with the increase of competitors.

In order to demonstrate the validity of the effective information entropy method employed, a comparison has been made between the calculated results with the effective information entropy method in Table 6.3 and the historical data (optimum tender prices and predicted profits) in Table 6.2. The data in Table 6.2 is obtained from the statistical historic data recorded in Table 6.1, and therefore, can be employed to compare with the outcome of the effective information entropy method. The differences of the predicted profits between the \(E(I)\) in Table 6.2 and the \(E(I)\) in Table 6.3 are -0.007A, -0.016A, 0.008A, 0.005A and -0.003A, and the largest relative diversity is -0.296, i.e. \((0.038A - 0.054A)/0.054A\), which is 30%. For the profit prediction of tendering price, the diversities are small enough and, therefore, the model can produce reasonable and practical solutions. In Table 6.2, the tendering prices are historical data and the predicted profits for different numbers of competitors are determined from the profit level and the probabilities of winning a bid (historical data in Table 6.1). In Table 6.3, the method to determine the predicted profits is the same as that for calculating the predicted profits in Table 6.2. However, the tendering prices are determined through the analysis of tendering information (probabilities of winning a bid in Table 6.1) applying the effective information entropy method. Therefore, effective information entropy can be used to predict system information based on both quantity and quality of information, as optimum tendering prices under different numbers of competing tenders.

6.4 CONCLUSIONS

In today’s highly competitive construction market, only with suitable methods and strategies established is the bidder likely to succeed in bidding for a construction project and making the necessary profit. The research has explored the effective
information entropy and its application in tendering price strategies. The main conclusions are as follows.

- The effective information entropy model provides an approach to determining the optimum tendering price, which is the relationship between the maximum profit and probability of being the lowest tendering price.
- Different from conventional tendering pricing, the principle of the effective information entropy lies in the fact that the results calculated are dependent on the information (probability of winning a bid) of the tender pricing system rather than the predicted maximum profit and tendering price, and are not influenced by the division of the tender pricing into equal intervals used in the conventional tender method (Yan, 2004a).
- The example application employing the effective information entropy model has verified the model’s applicability according to the tendering information of contractors in the Chinese construction industry (CCI). However, for other countries such as developed countries, because estimated contractor’s, tendering price and the probability for winning a bid will be different from that of the example application in this research, the predicted profit of contractors will change resulting in a different effective information distribution.
- With historical data and the effective information distribution, the effective information entropy model could be applied in other engineering fields. A major task is how to determine the effective distribution of information according to their system characteristics.
- Information entropy may specify the uncertainties of a system while uncertainties are the basic characteristics of project risks. Risk management basically utilises uncertainty analysis to plan and control construction projects. Therefore, the effective information entropy model presents a new idea for applying information entropy to dealing with project risks.
CHAPTER 7  PROBABILISTIC ANALYSIS MODEL FOR QUANTIFIABLE CONTRACTUAL RISKS

7.1 INTRODUCTION

Project risk management (PRM) utilises uncertainty analysis to manage the project. Probabilistic analysis enables quantitative assessment of risks and their impact on achieving project objectives such as duration, quality and cost. Quantitative analysis of project risks is a crucial activity in informing project decisions. However, it is nearly impossible to develop a precise mathematical model for quantitative analysis of risks because risk factors are non-linear and random. Therefore, non-mathematical models have been developed to quantitatively describe project risks, such as the Monte Carlo technique and the artificial neural network method. There are a number of techniques available for quantitative risk analysis and the main approaches are described below.

7.1.1 Fuzzy logic

Fuzzy techniques are an approximation that can be used to model decision processes for which mathematical precision is impossible or impractical. The concept of fuzzy set was introduced by Zadeh (1967) and he pioneered the development of fuzzy logic. Fuzzy logic provides a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria rather than the presence of random variables. Fuzzy project scheduling has interested several researchers. In the last 20 years, about 20 papers have been published on the topic. Most of them are very theoretical and cannot be implemented in real-life situations (Bonnal et al., 2004). Fuzzy logic methods can be used for both qualitative and quantitative assessment of project risks. The main objective of using fuzzy logic is to evaluate the risk exposures considering the consequences in terms of time $T$, cost $C$, quality $Q$, and safety $S$ performance.
measures of the entire project, based on fuzzy estimates of the risk components. For a single risk event, the risk may be expressed as

\[ P \times M_{PE} = E_p \]

\[ C \times M_{CE} = E_c \]  \hspace{1cm} 7.1.1

\[ E = E_p \cup E_c \]  \hspace{1cm} 7.1.2

where \( P \) denotes the probability of the risk event occurring, \( C \) denotes the consequence of the risk event occurring, \( M_{PE} \) denotes the correlative matrix of risk probabilities, \( M_{CE} \) denotes the correlative matrix of risk consequences, and \( E \) denotes the risk.

If there are \( m \) risk events, then

\[ E = E_1 \cup E_2 \cup \ldots \cup E_m \]  \hspace{1cm} 7.1.3

The traditional fuzzy technique for calculating the total changes to \( T, C, Q \) and \( S \) is to perform a fuzzy union of the changes from the individual risks. Therefore, the traditional fuzzy technique has a tendency to produce average results so that it is not suitable for risk analysis in practical risk management.

Tah and Carr (2000) proposed a methodology to use a hierarchical risk breakdown structure to develop a formal model for qualitative risk assessment and evaluate the risk exposure, considering the consequences in terms of time, cost, quality and safety performance measures of a project based on fuzzy estimates of the risk components. In the model, the value of \( T, C, Q \) and \( S \) from the risk which has the greatest impacts are used, such as \( T_{\text{max}} = \max(T_1, T_2, \ldots, T_m) \) and \( T = \zeta T_{\text{max}} \). The use of the greatest risk is a good starting point based on an assumption of pessimism within the system. Given this starting point, the effects of the remaining risk factors can be used to modify it by \( \zeta \) which is defined as the modification factor. Then
\[ E_{\text{max}} = \max(E_1, E_2, \ldots, E_m) \]

\[ E = \zeta E_{\text{max}} \]

If \( C_i, Q_i, T_i \) and \( S_i \) indicate the effectiveness of \( E_i \) on \( C, Q, T \) and \( S \), then

\[ E_i \times M_{CE} = C_i \]
\[ E_i \times M_{QE} = Q_i \]
\[ E_i \times M_{TE} = T_i \]
\[ E_i \times M_{SE} = S_i \]

\[ C = C_1 \cup C_2 \cup \ldots \cup C_m \]
\[ Q = Q_1 \cup Q_2 \cup \ldots \cup Q_m \]
\[ T = T_1 \cup T_2 \cup \ldots \cup T_m \]
\[ S = S_1 \cup S_2 \cup \ldots \cup S_m \]

\[ C_{\text{max}} = \max(C_1, C_2, \ldots, C_m) \]
\[ Q_{\text{max}} = \max(Q_1, Q_2, \ldots, Q_m) \]
\[ T_{\text{max}} = \max(T_1, T_2, \ldots, T_m) \]
\[ S_{\text{max}} = \max(S_1, S_2, \ldots, S_m) \]

\[ C = \xi C_{\text{max}} \]
\[ Q = \xi Q_{\text{max}} \]
\[ T = \xi T_{\text{max}} \]
\[ S = \xi S_{\text{max}} \]

The major disadvantage of the method is that it is difficult to determine the value of \( \zeta \). To find an appropriate method for computing \( \zeta \) is currently a subject for further investigation.
7.1.2 Monte Carlo technique

The Monte Carlo technique, often called the Monte Carlo simulation, has been one of the most popular probabilistic risk analysis techniques. It is a process for developing data through the use of a random number generation. It should be used for problems involving random variables with a known or assumed probabilistic distribution. Computer programs often make use of this technique in conjunction with a model simulation. In other words, a computer program forecasts the entire range of results possible for a given situation through the Monte Carlo simulation. For example, the duration and cash flow of a project can be simulated through Monte Carlo technique.

The key issue for the Monte Carlo simulation is how to determine the probabilistic distribution and sampling methods. For example, a triangular distribution (optimistic, normal and pessimistic) should be selected for the simulation of cash flows.

7.1.3 Artificial neural network (ANN) method

An artificial neural network (ANN) is an interconnected assembly of simple processing elements, units or nodes, whose functionality is loosely based on the animal neuron [Gurney, 1997]. ANNs are systems that can learn, be trained on a set of input data. ANNs for decision support have been widely applied in system control, economical prediction and so on. Applications of ANN in the construction industry date back to the early 1990s and cover a range of topics. Adeli (2001) grouped the applications of ANN into four main categories: construction schedule and management, construction estimation, resource allocation and construction litigation. Dikmen et al. (2004) developed a neuronet model as a decision support tool that can classify international projects with respect to attractiveness and competitiveness based on the experiences of Turkish contractors in overseas markets. The model can be used to guide decision makers on which type of data should be collected during international business
development and further help them to prepare priority lists during strategic planning.

Under some circumstances, the ANN method is a powerful tool to handle uncertainty problems. For example, there are many factors in the bidding process in the construction industry, but only some of them are important with regard to the bidding results. However, it is difficult to identify these core factors. A factor selection approach in the bidding process using ANNs may eliminate redundant factors. Then, the initial factors are reduced to a few core factors, and new bidding model may be developed with the factors as input. With the increased availability of computerised calculating programs, the application of ANN techniques will increase in the construction industry.

7.1.4 Probabilistic analysis

Probabilistic analysis is perhaps the most common method for performing a quantitative risk analysis, which specifies a probabilistic distribution for each risk factor and then considers the effect of the risk factor in combination. There are a number of techniques for probabilistic analysis of risks and each requires the specification of crucial project variables and their corresponding distribution.

The Critical Path Method (CPM) is the simplest method for modelling the execution of a project. The project is broken down into activities or packages, and a probabilistic distribution for each activity at risk must be selected. For example, Xu and Feng (1998) established a schedule risk analysis model of network planning. Based on a simulation method, the schedule estimate and statistical distribution of the project are given, and then the risk distribution of the total duration is obtained.

7.1.5 Limitations of the existing methods

The methods mentioned above are established primarily on the principles and methodologies derived from operational research techniques developed in the
1960s, and tend to focus on quantitative risk analysis based on estimating probabilities and probabilistic distributions for scope deviation and changes to the project execution plan. As probabilistic analysis for quantitative risk depends on historical data, the problem is how to get the historical data. If historical data is not available and experiments cannot provide the data, it will probably be necessary to use a qualitative technique or experts' experiences.

The exacting method (e.g. the schedule risk analysis model of network planning) is only applicable to defined technical problems that can be specified in advance. However, there is no guarantee that the basic assumptions will be true, and it is likely that the future will deviate from the assumptions because project risk factors involved are diverse and varied. For example, once the network plan changes (which is unavoidable), it is hard for the schedule risk analysis model of network planning to follow the change.

The traditional fuzzy technique has a tendency to produce average results so that it is not suitable for risk analysis in practical risk management. For Tah and Carr's model (Tah and Carr, 2000), the major problem is that it is difficult to determine the value of the modification factor, $\zeta$, which is a subject for further investigation.

The ANN method for quantitative risk analysis requires a large number of samples for training and calculations to be carried out. It usually takes a lot of time, and unfortunately, sometimes the training process is not converging.

7.2 THE PROPOSED PROBABILISTIC ANALYSIS MODEL FOR CONTRACTUAL RISKS

As discussed in the previous section, no mathematical model is suitable for all practicable applications in the construction industry and each has its advantages and disadvantages. A model is usually insufficiently realistic if it simplifies too much for a complex application, and on the other hand, it may be nearly impossible to establish a very complex model to fully represent the application. This research puts forward a probabilistic analysis model for the quantitative
analysis of contractual risks. The model is defined so that, for each risk factor, its consequence $r_i$ and probability $p(r_i) \ (i = 1, 2, \ldots n)$ are provided by the subjective judgement of experts based on their expertise and experience if there are no historical data available. The consequences of risk factors and their probabilities in combination can then be analysed and calculated. According to probabilistic distribution theory, a graphical representation of project risk levels under different risk consequences and their probabilities (risk curve) can be plotted for the construction project. The calculation procedure of the model is provided in Section 7.2.1.

The model can be applied to determining the likely range of project outcomes including not only the duration, but also cost, quality and safety. The calculation procedure of the model is much simpler than that of the schedule risk analysis model of network planning. The model can be modified easily to test the changes in basic estimates and assumptions about risk ranges. Therefore, the method and its applications provide a novel idea for risk management and decision supports for construction projects.

The major assumption made in the proposed model is that the risk factors are independent. This allows a simple additive model. In mathematical terms, the risk factors of construction projects are non-linear and randomness, and therefore, it is too difficult to consider the complex correlativity between risk factors for mathematical modelling. Meanwhile, it also avoids the need to correlate individual components of a complicated model that do not behave independently. Statistical independence means that if activity A is a predecessor of activity B, and if A is early or late, the duration of B will not be affected. It does not mean that the date when activity B is completed will not be affected. If A is late, B is also likely to be late, but the time required to accomplish B, its duration will not be affected. Although this assumption is acceptable for practical purposes due to the small degree of dependence among the risk factors as described above, care should be exercised in identifying the risk factors so as to minimise the degree of dependence among them. For example, the degree of dependence among site condition, technical complexity of construction project, contractor's experience
and ability, and the client's financial situation, is so small that they may be considered as independent risk factors in the mathematical modelling.

7.2.1 Calculation procedure of the model

Quantitative contractual risks can be illustrated by Figure 7.1.

Figure 7.1 Bar chart illustrating incorporation of contractual risks

Figure 7.1 shows that risk factors that could result in risks occurring do not affect project activities directly but do so through risks. For example, the risk of duration overrun could be caused by risk factors such as weather, site condition and force majeure, and ultimately, these risk factors affect the project through duration risk. The risk evaluation process requires an assessment of the probability of risk event and its impact. In the proposed model, the quantitative contractual risk, can be expressed as a matrix composed by $E(R)$ and $P(R)$ in formula 7.2.1 where $E(R)$ denotes the expectation of consequence of the contractual risk occurring and $P(R)$ denotes the probability of the contractual risk occurring.

$$R=(E(R), P(R))$$

7.2.1
For a construction project, the quantitative contractual risks can be seen as a matrix composed by the time, cost, quality and safety risks, such that

\[
R = \begin{bmatrix}
E(R_t)P(R_t) \\
E(R_c)P(R_c) \\
E(R_q)P(R_q) \\
E(R_s)P(R_s)
\end{bmatrix}
\]

7.2.2

where, for a single risk factor \(i\), \(R_t, R_c, R_q\) and \(R_s\) denote duration risk, cost risk, quality risk and safe risk, and the contractual risk for risk factor \(i\) can be expressed as \(R_{ti}, R_{ci}, R_{qi}\) and \(R_{si}\), such that

\[
R_t = \begin{bmatrix}
R_{ti} \\
0 \\
0 \\
0
\end{bmatrix}
\]

7.2.3

If there are two risk factors and their consequences and probabilities are \(r_1, p(r_1)\) and \(r_2, p(r_2)\), there are 3 probabilities for \(R\), where \(R = \{r_1, r_2, r_1 + r_2\}\), thus

\[
p(r = r_1) = p(r_1)
\]

\[
p(r = r_2) = p(r_2)
\]

\[
p(r = r_1 + r_2) = p(r_1) \times p(r_2)
\]

7.2.4

Let there be \(n\) risks. For a single risk factor to happen, there will be \(C_n^1 (r_1, \ldots, r_n)\) (i.e. \(C_n^1 = n\)) consequences; for two risk factors to happen, the number of consequences will be \(C_n^2 (r_1+r_2, r_1+r_3, \ldots, r_1+r_n, \ldots, r_2+r_3, \ldots, r_2+r_n, \ldots, r_n+r_1, \ldots; \) and for \(n\) risk factors to happen, there will be \(C_n^n (\sum_{i=1}^n r_i)\) (i.e. \(C_n^n = 1\)) consequence. Thus the calculation program can be expressed as

\[
R = \{r_1, \ldots, r_n, r_1+r_j, \ldots, r_1+r_j+r_k, \ldots, \sum_{i=1}^n r_i \} \quad (i \neq j \neq k \ldots)
\]

7.2.5
\[ P = \{ p(r_1), \ldots, p(r_n), p(r_i + r_j), \ldots, p(r_i + r_j + r_k), \ldots, p(\sum_{i=1}^{n} r_i) \} \quad (i \neq j \neq k \ldots) \]

where

\[ p(r = r_i) = p(r_i) \]

\[ p(r = r_n) = p(r_n) \]

\[ p(r = r_i + r_j) = p(r_i) \times p(r_j) \]

\[ p(r = r_i + r_j + r_k) = p(r_i) \times p(r_j) \times p(r_k) \]

\[ p(r = \sum_{i=1}^{n} r_i) = p(r_1) \times p(r_2) \ldots \times p(r_n) = \prod_{i=1}^{n} P(r_i) \] 7.2.6

The total number of elements in \( R \) and \( P \) is \( N = \sum_{i=1}^{n} C_i = C_1 + C_2 + C_3 + \ldots + C_n \).

In order to draw the risk distribution curve (probability against consequence), it is necessary to rearrange the data in formulae 7.2.5 and 7.2.6 according to the magnitudes of the data in formula 7.2.5 (i.e. descending order of the risk consequences). Thus

\[ R' = \{ r'_1, \ldots, r'_N \} \quad (r'_i < r_{i+1} \text{ and } i=1, 2, \ldots, (N-1)), \]

7.2.7

\[ P' = \{ p(r'_1), \ldots, p(r'_N) \} \]

7.2.8

where \( N' \) is the total number of risk consequences after the rearrangement and \( N' \leq N \). If all risk consequences in \( R = \{ r_i \} \) \((i=1, 2, \ldots, N)\) are different, \( N' = N \); otherwise, \( N' < N \). For the same risk consequence under different probabilities, because they are independent, the probabilities should be added up as the overall probability for the risk consequence.

Finally, for probabilistic analysis of each risk consequence considering other risk consequences happening at the same time, its overall probability is the sum of probabilities of all the risk consequences that are larger than it, including itself, i.e.
Based on formulae 7.2.5 to 7.2.8, different contractual risks and their associated probabilities can be calculated under various conditions of the project environment.

### 7.2.2 Applications of the model

A realistic estimate of the final duration of a project is required as early as possible. All potential risks can affect the estimate, and act as constraints on the project. The main objective of the model is to assess the probability of meeting the project completion milestones and quantitatively analyse risks affecting the project schedule. The importance of duration risk analysis is:

- The project participants want to verify the schedule to ensure that the probability of meeting the object due date is high;
- Any duration delay can cause dramatic effects on the reputation and, of course, the net present value (NPV) of the project. For example, if delay occurs, competitors could use the situation as an opportunity, and the clients may lose their customers;
- Any change made during the construction phase would be very expensive and could cause additional delay.

An explicit example follows. For an infrastructure project in China with an estimated cost US$ 30 million and a total duration of 2 years, considering the experience of similar projects and through interviewing key members of the project participants, 3 project managers, 2 consultants and 2 professors (common in the CCI), the four risk factors are determined respectively for 1) natural site condition, 2) technical complexity of construction, 3) contractor’s experience and ability, and 4) the client’s financial situation. Meanwhile, the risk of duration delay and the probability of the four risk factors are determined according to the

\[
p'(r'_i) = \sum_{i=1}^{N'} p(r'_i) \quad (i = 1, 2, \ldots, N')
\]

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experience of similar projects and the justification of these experts, as shown in Table 7.1.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration delay (days), C</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Probability of risk events P</td>
<td>3%</td>
<td>1%</td>
<td>4%</td>
<td>4%</td>
</tr>
</tbody>
</table>

According to the data in Table 7.1 and formulae 7.2.5 and 7.2.6, then,

\[ R = \{3, 4, 7, 9, 10, 12, 13, 16, 14, 19, 20, 23\} \]

\[ P = \{0.03, 0.01, 0.04, 0.04, 0.0003, 0.0012, 0.0012, 0.0004, 0.0004, 0.0016, 0.000012, 0.000012, 0.000048, 0.000016, 0.00000048\} \]

For the same risk outcomes under different probabilities, because they are independent, the probabilities should be added up as the overall probability for the same risk outcomes. For example, the probability for a 7-day delay is 0.0403 (i.e. 0.04+0.0003). Rearranging \( R \) and \( P \) using formulae 7.2.7, 7.2.8 and 7.2.9,

\[ R' = \{3, 4, 7, 9, 10, 11, 12, 13, 14, 16, 19, 20, 23\} \]

\[ P' = \{0.03, 0.01, 0.0403, 0.04, 0.0012, 0.0004, 0.0012, 0.0004, 0.000012, 0.001612, 0.000048, 0.000016, 0.00000048\} \]

\[ p(3) = 0.12518848 \]
\[ p(4) = 0.09518848 \]
\[ p(7) = 0.08518848 \]
\[ p(9) = 0.04488848 \]
\[ p(10) = 0.00488848 \]
\[ p(11) = 0.00368848 \]
\[ p(12) = 0.00328848 \]
\[ p(13) = 0.00208848 \]
\[ p(14) = 0.00168848 \]
\[ p(16) = 0.00167648 \]
\[ p(19) = 0.00006448 \]
\[ p(20) = 0.00001648 \]
\[ p(23) = 0.00000048 \]

Based on the above data, the duration risk curve can be drawn as shown in Figure 7.2, which provides a support to decision making for project management. In the figure, \( P \) denotes the probability of duration risk occurring for the project, and \( C \) the consequence of the duration risk occurring.

![Figure 7.2 Probability curve of contractual duration risk](image)

From the probabilistic analysis for quantitative contractual risk and Figure 7.2, the following conclusions can be drawn:

- The curve shows that the probabilistic distribution of duration risk is consistent with the trend in construction practice, i.e. the probability of duration risk will decrease with the increase of duration delay.
• The duration risk of the project is very low, and the largest probability over the planned duration for a 3-day delay is only 12.5%. The reason for the low risk is the risk consequences (delay in days) and their probabilities (Table 7.1) are low.

• The duration risk may be neglected for a delay of more than 10 days due to the very low risk probability (less than 0.5%).

• According to the analysis, the strategies dealing with the duration risk may be established. For example, the contractor could agree that, if duration delay was more than 10 days, the penalty could double the standard rate.

7.2.3 Computer program based on the approach of this model

The model has been implemented to examine and ensure its correctness and consistency in Visual C++. The computer program consists of the following steps, which are depicted in the flowchart in Figure 7.3:

1) Accept user’s inputs of consequences and their probabilities of n risk factors.
2) Calculate the consequences and probabilities for all combinations of risk factors according to formula 7.2.5 and 7.2.6. A function is defined using a recursive algorithm to get m combinations of n risk consequences.
3) Sum the probabilities for the same risk consequence, and arrange the risk consequences in the ascending order using a bubble sort algorithm.
4) Calculate the probability distribution according to formula 7.2.7 to 7.2.9.
5) Draw the graphic diagram of probability against consequence.
Using recursive algorithm to calculate the consequence and probability results for combinations of \( \binom{m}{n} \).

Save the results into vectors:
- \( m\_CResult \)
- \( m\_PResult \)

Sum probabilities for each different consequence.

Start

Accept user input

Input is valid?
  - Yes
    - \( m = 1 \)
  - No
    - \( m > n \)?
      - Yes
        - Calculate for all combinations
      - No
        - \( m = m + 1 \)

\( i = 0 \)

\( Count = N \)

\( i < Count? \)
  - Yes
    - Save result into vectors:
      - \( Consequence.push\_back(m\_CResult[i]) \)
      - \( Probability.push\_back(Psum) \)
    - \( i = i + 1 \)
    - \( j = i + 1 \)
    - \( PSum = m\_PResult[i] \)
  - No
    - \( j < Count? \)
      - Yes
        - \( Psum = Psum + m\_PResult[j] \)
        - \( m\_CResult[j] = m\_CResult[j] \)
        - \( m\_PResult[j] = m\_PResult[j] \)
        - \( k = j \)
        - \( k < Count - 1? \)
          - Yes
            - \( j = j + 1 \)
          - No
          - \( Count = Count - 1 \)
        - \( j = j + 1 \)
      - No
        - \( m\_CResult[i] = m\_CResult[i] \)
        - \( m\_PResult[i] = m\_PResult[i] \)

To next page
Figure 7.3  Flow chart for the computer program

For the same example in this Chapter, the data in Table 7.1 are employed again, and a graphic curve of project duration risk (Figure 7.4) produced by the computer program shows full consistency with that produced by manual calculations using this model.
7.3 ANALYSIS AND DISCUSSION

The application of the model shows how contractual risk (duration risk) can be modelled, calculated and analysed to provide information to assist managers in decision making. As stated in Section 7.2.2, the outcome of the probabilistic analysis model of contract risks is consistent with the trend in the construction practice, i.e. the probability of duration risk will decrease with the increase of duration delay, or increase with the decrease of duration delay. It is easy to understand that the duration risk for short time delay is larger than that for long time delay according to experience. However, the relationship between the duration risk and its probability is non-linear, and the model can provide a good indication of the ranges that must be considered carefully. As shown in the example, the probability is 12.5% for a duration delay of 3 days, about 5-10% for a duration delay of 4-8 days, and 0.5% (very small and can be neglected) for a
duration delay of 10 days. In order to demonstrate the practicability, effectiveness and characteristics of the model, it is necessary to provide a comparison between this model and other models.

- The Monte Carlo method is a simulation technique, and the technique has been used for the simulation of random process, for example, the simulation of duration and cash flow of construction projects. In other words, a computer program forecasts the entire range of results possible for a given situation through Monte Carlo simulation. The probabilistic analysis model provides a computational procedure of contractual risks. Therefore, the two techniques are aimed at different tasks. However, the Monte Carlo technique can be employed to improve the data required as input of the proposed method. The experts provide a range of values for the risk factors and their probabilities rather than just a single value as shown in Table 7.1. Therefore, a triangular distribution of the optimistic, normal and pessimistic values can be employed to simulate the outcomes of risk and their corresponding probability. This will be a future research effort that requires the development of a computer program and determination of data from construction projects and experts involved.

- Fuzzy logic method is very theoretical and needs a lot of complicated computation. Moreover, it has a tendency to produce average results from individual risk factors. Therefore, it cannot be implemented in real-life situations for risk analysis of construction projects. The model developed in this chapter is more straightforward and simpler than the fuzzy logic method for quantitative risk analysis in practical construction projects.

- The ANN method is usually employed for problems that cannot be solved directly by mathematical modelling. Generally speaking, calculations for mathematical modelling are easier than those for non mathematical modelling. Furthermore, the ANN method for quantitative risk analysis requires a large number of samples for training and calculations to be carried out. It usually takes a lot of time, and unfortunately, sometimes the training process does not converge.
The Critical Path Method (CPM) of networks is a simple and widely used method for modelling the execution of a project, such as the schedule risk analysis model of network planning (Xu and Feng, 1998). It is therefore appropriate to make a direct comparison between the probabilistic analysis model of contractual risks and the CPM. The model developed in this research is distinct from the schedule risk analysis model of network planning in the following ways:

- The calculation procedure of this model is simpler than that of the schedule risk analysis model of network planning. For network planning of construction projects, information about time, labour and material is needed for each activity in the construction process. In the schedule risk analysis model of network planning, the project is broken down into activities or packages, and the probabilistic distribution for each activity at risk must be selected. Then, the probabilistic curve of project completion can be drawn based on a statistical analysis. If the probability of project completion is \( P \), the probability of duration risk is \( (1-P) \). So, the schedule risk analysis model of network planning requires a large amount of technical preparation to be carried out, such as construction organisation design and the selection of probabilistic distribution for each activity. However, the model developed in this chapter is straightforward because it does not depend on network planning but on the probabilistic analysis of contractual risk factors.

- The proposed model can be modified easily to test the changes in basic estimates and assumptions about risk ranges. However, once the network plan changes (which is inevitable), it is hard for the model of network planning to follow the change.

- The proposed model can be applied to determine the likely range of project outcomes including time, quality, cost and safety. However, it is hard to apply the schedule risk analysis model of network planning to determine the probabilistic distribution of quality and safety, and it can be used for the probabilistic analysis of time and cost only when the estimate of these parameters can be broken down into activities or packages as a schedule.
However, some parameters cannot be broken into activities or packages, such as quality and safety (Yan, 2005a).

7.4 CONCLUSIONS

With the intention of utilising rigorous treatment of statistical theory applied to uncertainties, a precise mathematical description for the application is necessary. However, the quantitative analysis of project risks is too complicated due to the non-linearity and randomness of risk factors, and it is nearly impossible to develop a precise mathematical model. Any mathematical model has its advantages and disadvantages including assumptions and constraints. The major assumption for the probabilistic analysis model is that the risk factors are independent so that a simple additive model can be employed. The application of the model has shown how contractual risk can be modelled, calculated and analysed for a construction project, and indicates that the assumption is practically acceptable for mathematical modelling. As seen in the comparative analysis, the major advantage of the model is its simplicity and practicability for different project environments. However, more risk factors may need to be considered, e.g. for international projects, special risk factors must be considered, including inflation, policy of tax change, rate of currency exchange and climate conditions besides direct project risks. The effectiveness and reliability of a mathematical model depends on two aspects, the data required and the model itself. Like any mathematical model, it is important to consult trustworthy professional experts and obtain reliable data in order to apply the proposed model (Yan, 2005a).

In the construction industry, both qualitative analysis and quantitative analysis are useful for project decision making. In order to support project decision making by mathematical methods, generally it is necessary to employ historical data as input. However, in the Chinese construction industry (CCI), the lack of historical data is a major difficulty for quantitative risk analysis. The effective method to overcome the difficulty is to build databases from future projects, containing system information, historical data such as probability of winning a bid, etc. At the present time, if historical data are not available and no experiment can provide the
data, it will be necessary to use a qualitative technique. Different from other industries in which the production process repeats again and again, construction projects are often unique. Therefore, the decision making in the construction industry may depend on subjective judgments based on past experience and information obtained through the Delphi method or a group of suitable qualified people for a brainstorming exercise. It is necessary to analyse, prioritise and calculate important quantifiable risks based on the project environment, project characteristics and bidding documents. For the analysis of quantifiable contractual risks, the effective information entropy model and probabilistic analysis model are presented and discussed with example applications to demonstrate their validity and effectiveness. The research aims to identify and adopt the best practice of project risk management (PRM), and provide practical guidelines of PRM strategies for the CCl, which will be detailed in the next chapter.
CHAPTER 8 STRATEGIES AND RECOMMENDATIONS FOR PRM IN CCI

The Chinese construction law and practice are still very different from the international norm. If foreign participants are to make a success out of doing business in China, they must understand the Chinese way of life. Particularly, they must be prepared to adapt to an environment where new rules are created as circumstances and situations change (Lam and Chen, 2004). Currently the annual output of the construction industry is approximately US$ 93 billion which accounts for more than 6% of the Gross Domestic Product (GDP) and has been growing at an average annual rate of about 10% since 1980s (2000, 2001, SSBC - State Statistical Bureau of China). Before the 1980s, the Chinese construction industry (CCI) was only a subordinate activity of the state's capital investment plans instead of independent industry. Since the Chinese economic reform, the CCI has been recognised as an important independent and profitable sector of the national economy. However, planned economics still influence the practice of the reform and development in China. It will take a long time to realise that construction is not just the labourers who are on the job site performing the actual construction, but that it also includes many professionals who focus on research and development to improve the processes and methods of construction.

Construction projects may not have the same risk level for different countries, and it is significant to identify and adopt the best practice in project risk management (PRM) to develop the CCI. The research illustrates that in the CCI, the concept, principle and procedure of risk management are more important than specific techniques for qualitative risk analysis. Quantifiable analysis of contract risks is a part of contract risk management. Based on non-quantifiable contractual risks in the framework of contractual risk management, the research has studied the concept, classification, identification and management of contractual risks, contract strategies associated with the project procurement route (PPR), and the assessment, selection and application of the PPR. This provides a solid foundation
to develop PRM strategies for the CCI. PRM in China is in an early stage and needs industry support, powerful law environments and a mature construction market. Several important challenges to the CCI must be overcome to gain the full benefits of PRM, such as the development of the engineering consulting industry and the restructuring of Chinese construction firms. These challenges not only formulate the framework of PRM strategies in China, but also motivate the reform of the Chinese construction market to harmonise with the construction administration system, legislation environment and management mechanisms.

8.1 INTRODUCTION AND APPLICATION OF INNOVATIVE PPRs

At present, the Chinese construction legislation is in advance of the correlative construction administration system and management mechanisms. This has resulted in the administration system and management mechanisms causing delays in the process of the reform of the Chinese construction market. In order to change the situation, several important challenges to the Chinese construction industry (CCI) must be overcome. For these challenges, the introduction and application of innovative PPRs will play a key role in the promotion process.

This study suggests that potentially large improvements to PRM and reform of the Chinese construction market could result from the introduction and application of innovative PPRs. According to international practices of project management, clients have the power to choose the PPR in light of project characteristics, time, finance and market conditions. In the international construction market, besides the Traditional PPR, there are various other approaches as described in Chapter 5. The emergence of Design/Build (D/B) as a popular PPR (alternative delivery system) is perhaps the most significant trend within the construction industry for the past 40 years. Currently, the D/B approach covers a very broad variety of applications, e.g. high-tech buildings, highways, bridges, airports and transportation projects. In order to introduce innovative PPRs to the CCI, this research puts forward practicable strategies as follows:
Based on the analysis in Chapter 5, it is impossible to introduce all PPRs at the same time. At the project level, the choice of PPR depends on the characteristics and attributes of the project and its environment. Different PPRs are suitable for different projects. However, the cases in this research illustrate that at present the General Engineering Packaging (GEP) PPRs are more appropriate to the CCI, especially for large and complicated construction projects. Therefore, at the industry level, first, the D/B PPR should be applied in the CCI. Secondly, based on the D/B model, the Turnkey, EPC and BOT PPRs can be employed in practice. Through the restructuring of construction enterprises, large Chinese construction groups and companies will have the capability to package construction projects with D/B, turnkey and EPC PPRs.

For the Traditional PPR, the principle, mechanism and programme of the New Engineering Contract (NEC) should be considered and utilised in the CCI. The structure of the NEC is suitable for the CCI (Appendix D provides details), and the NEC stimulates good management, lays a great emphasis on communications, co-operation and win-win arrangements, and the need for clear definitions at the outset of various types of information.

Although people are studying for the application of the Construction Management (CM) model in the CCI (Wang, 2002), the CM model does not suit the current situation in the CCI. There are two major reasons. First, Chinese construction regulations require that all design documents have to be completed before construction that means it is illegal to construct a project while designing. Second, there is no specialist profession to provide CM managers in the CCI. In the view of the author, it will take a considerable period of time to implement the CM model in China, and the application of the CM model depends on the development of the Chinese construction market and improvement of the Chinese construction regulations.

At present, the Management Contracting (MC) method is quite suited for the CCI, and is an effective approach based on engineering consultants to manage the construction project, instead of organising a project management team by the client, specially, for public works in China. However, the MC model needs the engineering consulting industry to provide professional services, i.e.
qualified engineers for the clients. For this purpose, the vital issue is to develop the Chinese engineering consulting industry. The development will deal with the reform of the construction market, the innovation of administrative system and the development of construction regulations in the CCI. During the process of developing the Chinese engineering consulting industry, the government may play a crucial role, such as providing relative policies and regulations.

- For the construction of infrastructure or public works (public sector projects), it used to be unclear about who should manage the project development phase. The regulations on Implementing Project Owner Responsibility System were introduced in 1996 by the Ministry of Construction (MoC). However, so far there has been no proven approach to manage this type of project. It is probably the most important and difficult task to implement the project owner responsibility system. If owners are in charge of project planning, financing, construction and operation, they have to learn and understand:

  - how to operate a project according to market mechanisms, instead of a bureaucratic method that exists under the planned economy system.
  - how to manage the construction project according to contract conditions, instead of the client's arbitrary decision.
  - the dependence on engineering consultants to manage the construction project, instead of organising a project management team by the client.

8.2 RESTRUCTURING OF CONSTRUCTION ENTERPRISES

With the introduction of innovative PPRs, three fundamental issues must be considered. Firstly, the restructuring of construction enterprises; secondly, the issue of China’s own comprehensive standard contract conditions in parallel to those by the major professional bodies in the world, e.g. the American Institute of Architects (AIA) and the Institution of Civil Engineers, UK (ICE); and thirdly, the development of the Chinese engineering consulting industry.
The structure of construction enterprises in China has been formed under a centrally planned economy. For the application of innovative PPRs, it is an important factor and basic condition to restructure the Chinese construction enterprises. The structure of the construction enterprises refers to the relationship of the companies in terms of size, capacity and market share that can then affect or decide their competitive manner in the market. To provide an example of comparison with a market economy, data have been drawn from the United Kingdom. The UK construction industry is well established and recognised internationally as a mature construction market. The structure of construction enterprises in the UK has been formed under a market economy and continues to be adjusted by the need of the construction market. Therefore, in the UK, the construction industry is operated under an optimum enterprise structure and market conditions. Table 8.1 shows the composition of China’s construction companies (Chinese Construction Statistics, 1998). Table 8.2 shows the composition of UK construction companies (DETR, 2000).

Table 8.1 Composition of Chinese construction companies (Chinese Construction Statistics, 1998)

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<tr>
<td>Number of employees (×1000)</td>
<td>11580</td>
<td>13440</td>
<td>14460</td>
<td>14980</td>
<td>21220</td>
<td>21020</td>
</tr>
<tr>
<td>Number of companies</td>
<td>14536</td>
<td>20998</td>
<td>23315</td>
<td>34133</td>
<td>41364</td>
<td>44017</td>
</tr>
<tr>
<td>Average number of employees</td>
<td>797</td>
<td>640</td>
<td>620</td>
<td>621</td>
<td>513</td>
<td>477</td>
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Table 8.2 Composition of UK construction companies (DETR, 2000)

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<tbody>
<tr>
<td>Number of employees (×1000)</td>
<td>842.2</td>
<td>753.2</td>
<td>753.3</td>
<td>750.9</td>
<td>707.1</td>
<td>778.5</td>
</tr>
<tr>
<td>Number of companies (×1000)</td>
<td>205.7</td>
<td>195.1</td>
<td>194.7</td>
<td>194.1</td>
<td>163.3</td>
<td>160.1</td>
</tr>
<tr>
<td>Average number of employees</td>
<td>4.09</td>
<td>3.86</td>
<td>3.87</td>
<td>3.87</td>
<td>4.33</td>
<td>4.86</td>
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Table 8.1 demonstrates the numbers of both employees and construction companies in the CCI increased by 82% and 203% respectively, and the average
number of employees by the construction company decreased by 40% in the five-year period. The change is good for restructuring the Chinese construction enterprises but further effort is needed. Table 8.2 shows the number of both employees and construction companies in the UK construction industry decreased by 7.6% and 22% respectively, and the average number of employees by the construction company increased by 19% in the period. Despite the changes in both China and the UK, in 1997, the average number of employees employed by the construction companies in China was 477 that is 98 times higher than that of the UK (4.86). The big difference in construction enterprise size between China and the UK indicates that the size of Chinese construction enterprises is generally too large and the inappropriate structure cannot meet the need of the construction market under market economy.

According to the State Statistical Bureau of China (1999), the number of companies employing less than 100 employees is only 0.29%; the number of companies employing 100-299 is 2.27%; and the number of companies employing more 300 or more is 97.44%. In fact, most Chinese construction companies employ more than 2000 employees. The existing structure allows all construction companies to enter the construction market at the same time and play the same role. The negative effect is the increased intensive competition that causes construction market disorder, waste of valuable resources, and reduced profit levels and corruption within the industry. This structure has been shaped under a centrally planned economy and it does not satisfy the needs of the construction market operating in a market economy. According to experience in the international construction market, in order to meet its needs and improve the market competitive ability, construction enterprises must possess a flexible production force. The construction industry must also possess an optimum enterprise structure consisting of a small number of general contracting corporations, about ten times as many medium construction companies and a much larger number of small construction firms. For the CCI, it is a tough task to restructure the industry due to the influence of centrally planned economics, and so far, the situation has not been changed significantly. In order to achieve the
optimum enterprise structure and promote the development of the Chinese construction market, the restructuring of China's construction enterprises is necessary.

Through the restructuring, the largest construction groups or corporations will act as general contractors and they may develop cross-national business links. The major functions of the largest construction corporations are project planning, environmental assessment, project financing, tendering and bidding, design and management besides the General Engineering Packaging (GEP). These companies can contract (package), operate and manage large-scale construction projects under the D/B, EPC, Turnkey or BOT models, such as airports, harbours and industrial plants. They should have sufficient human resources and advanced expertise of managing construction projects for merging technology, economics, management and regulations. They should possess a flexible production force and a staff size of several thousands or more so that they are able to contract several large construction projects at the same time.

Medium sized construction companies should be restructured to operate as specialist contractors under the new model and market conditions, with a staff size in the order of several hundreds or more including project managers, engineers and labour. They can provide construction services in individual regions, and have the expertise to construct medium-scale projects, such as residential and civil buildings, schools, bridges and highways. Conversely, small construction companies account for the majority of the organisation by the ratio being in excess of 98%. Small companies operating as subcontractors usually provide labour services, such as construction site work, repairs and maintenance and decorative work. Considering the rich labour resources in China and the current situation of the Chinese construction enterprises, the size of small companies should not copy absolutely that of a developed country such as the UK, but the number of employees can be reduced gradually. The target of the size of small companies should be between several and one hundred employees. The purpose in so doing is to achieve a better structure of construction enterprises and achieve an efficient construction market. The novel structure of construction enterprises can
provides a mechanism and condition for the introduction and application of innovative PPRs, and speed up the reform of the Chinese construction market.

In 2000, the Ministry of Construction (MoC) of China suggested to form 40-50 general contracting corporations at the state level, 450 medium construction companies, and the remainder as small firms (the Guideline for the Reform of the Chinese Construction Markets, MoC, China). The numbers are only a guideline and it is a tough task to implement the optimum enterprise structure because so many companies want to be in the general contracting group, and the relocation of construction company staff must be considered and solved. It is important to realise that the restructuring of the construction enterprises cannot depend on centrally planed methods but a market economy, i.e. through market competition in the construction industry. Different construction companies have to take their own market positions (roles) at different levels. The government should provide policies and regulations support, such as improving the bidding environment, developing different levels of construction markets in order to speed up the process of enterprise restructuring.

8.3 ISSUE OF NEW STANDARD CONDITIONS OF CONSTRUCTION CONTRACT

There are several standard contract conditions for the D/B PPR, e.g. the ICE Conditions of Contract for Design and Construction (1995) and the FIDIC Orange Book. With the development of the CCI, other PPRs should be explored and applied in China. The Ministry of Construction (MoC) of China has issued the New Construction Contract Conditions (NCCC, 1999, 3rd Edition), which are the only contract conditions for construction projects in China. Although the document has adopted the principal clauses of the FIDIC Red Book, the problem is that the Red Book belongs to the unit price or re-measure contract but the NCCC operates with the Lump Sum Contract. As discussed before, the Lump Sum Contract of the Traditional PPR is efficient for small and simple construction projects and is therefore limited in its use. The CCI has become familiar with
Lump Sum Contracts and this inhibits Chinese project participants from adopting other PPRs where the design and construction phases are not separated.

With the reform of the organisation model of construction projects and the development of the GEP, China will issue its own comprehensive standard contract conditions in parallel to those by major professional bodies in the world, such as the AIA, USA and the ICE, UK. These standard contract conditions may adopt the principal clauses of the ICE Conditions of Contract for Design and Construction, FIDIC Silver Book, i.e. FIDIC Conditions of Contract for EPC/Turnkey projects, etc. Meanwhile, it is necessary to improve the NCCC. The NEC provides benefits for the improvement and development of the NCCC due to its flexibility, clarity and simplicity. The NEC avoids discipline specific terminology, legalistic complex language and cross-references, and references to the practices of construction industry. The responsibility of the NEC for design is not fixed with either the client or the contractor but can be set at any amount from nil to the full total with any party. The NEC encourages good management, lays a great emphasis on communications, co-operation and programming and the need for clear definitions at the outset of various types of information. Also, the NEC may be facilitated in different ways, and the NEC aims to be an all-purpose contract for all construction and engineering disciplines. Depending on the need of the client and the characteristics of the project, the client can make its own contract choice, such as the certainty of price is the dominant aspiration and then, given a few restrictive circumstances and particular preferences, the obvious strategic choice will be a Lump Sum Contract. Therefore, the NEC suits the current practice of the CCI (Yan, 2002).

8.4 DEVELOPMENT OF ENGINEERING CONSULTING INDUSTRY

The gap between the Chinese construction industry (CCI) and the Western construction industry is largely due to the lack of a consulting sector. The development of Western engineering consulting was initiated under market economics, and has been developing with the progress of market economics for about two hundred years. However, the Chinese consulting industry is the
outcome produced under the translation from planned centre economics to market economics, and is in its infancy. For example, the processes of design and construction have been separated for a long time. At present, the design firms number more than 10,000 of which Category A (top level) design firms account for about 1000. Although some design firms have carried out certain consulting work, they are not regarded as consultants according to the standards of international engineering. The technical qualifications of Chinese engineers are good but their education and training is often limited to a specific sector. So far, the organisation system of the design firms does not meet the need of the market economy and therefore does not assist in the adoption of international practices for the construction industry. The development of the engineering consulting industry will support the business and management activities within the CCI, provide the foundation and conditions for the introduction and application of innovative PPRs, and enhance China's international practice and standards. Development of an effective consulting sector in the construction industry is necessary to improve PRM and to develop the industry. In order to advance the Chinese consulting industry, the following aspects should be considered:

- Change is needed to translate the function of the design firms, specifically those advanced design firms. The transition of the design firms to progressive consultants will require practitioners to engage in the design work and various management activities, including project planning, choice of PPRs, project assessment, contractual management, engineering supervision, etc. Meanwhile, other approaches can also be used for the transition, such as rebuilding or reorganisation of large national construction companies.

- The development of a professional construction body is a motivation to develop the CCI. The key questions of the Chinese professional body are its role and function in the construction industry, and relationship with the government. In order to develop the Chinese professional construction body, it is valuable to adopt the experiences of major professional bodies in the world, such the AIA, the ICE and the CIOB. The objective of the Chinese professional construction body is to act as an independent industry
organisation, and the major function is professional training, registration management of professional engineers, editing and writing up contractual and project management documents. Research on the construction industry is increasing throughout the world and topics are changing as current needs change. However, there is a need to increase research collaboration between industry and academia, government and academia, and industry and government to advance the construction industry (Masce et al., 2004).

However, these issues could not be resolved on a one by one basis because they deal with the administration system and regulation environment of the construction industry as a whole. Since the construction industry interacts with various sectors, the market reform should be harmonised with the construction administration system, legislation environment and management mechanisms. The ultimate target is to establish new management models in order to enable the industry to function in the competing environment of globalisation. The basic characteristics of the new model should be a flexible production force, a reasonable organisation structure for the companies within the industry, and a defined regulatory system that promotes a healthy business environment and assists the administration of the industry.

The most significant event in recent years has been China's entry to the World Trade Organization (WTO). Consequently, China's construction market will open to foreign contractors and engineering consultants in 2006. As for other industries, WTO has made up trade regulations of the construction industry for its members, and the CCI must follow the regulations. To this end, a comprehensive regulatory framework with realistic implementation measures is identified as necessary. At the central planning level, the government introduced examples of regulations that constituted 'best practice' from other economic systems to form the basic template. Nevertheless, the progress of implementation of the policies and regulations has been very slow, and the major reason is that the administration system under the centrally planned economy still largely affects the current construction practice. Law and regulations account for one aspect while providing conditions for innovation within the industry is another task. This research develops PRM
strategies to provide the conditions to suit the current practice in the CCI. For example, different innovative PPRs should be introduced and applied in the CCI at different development phases of the construction market; the CM model does not suit the current situation in the CCI; the restructuring of Chinese construction enterprises depends on the development of the construction market instead of traditional planning.

In September of 2004, the Chinese government issued the Decision for the Reform of National Investment System. The decision emphasises that all public projects invested by the government must implement a substitute construction system, i.e. a project management company in charge of project building and control is chosen through unlimited bidding, instead of organising a project management team by the client. This provides great market opportunities to develop the Chinese consulting industry. Nevertheless, the substitute construction system is new to the CCI, and the system deals with the restructuring of the Chinese construction enterprises, PPR and Chinese consulting industry. The studies in this research not only answer these issues, but also provide guidelines and technical support to implement the system, e.g. the change of client’s role, the selection, assessment and organisation of various PPRs, contract strategies and contract interface management. Further case studies of construction projects and investigation can be carried out in contractual risk management in conjunction with the PPR. However, the major difficulty is how to obtain the information and data for further case studies. At the present time, Chinese clients and contractors are reluctant to provide project information and data. The research has employed indirect information and data except for the case study of the new campus project of Shenyang Jianzhu University.
CHAPTER 9  CONCLUSIONS AND FUTURE WORK

This thesis has aimed to present strategies and suggest recommendations for project risk management (PRM) in the Chinese construction industry (CCI), by identifying and adopting the best practice appropriate for the conditions operating in China. This has been achieved by realising the specific objectives set for the research through a number of activities which are summarised below.

1) A comprehensive literature review has led to a good understanding of the risk characteristics and PRM in the construction industry in general, while a survey of the CCI has provided a clear statement of the current practice and attitude of the Chinese project participants towards PRM in particular.

2) The analysis of the survey results and case studies has been conducted to determine possible ways in which the current PRM methods and techniques could be adopted in the CCI. This has been realised through the development of a framework for contractual risk management, and an investigation of the selection and applications of the project procurement route (PPR) and contractual risks associated with the PPR.

3) A probabilistic analysis model and an effective information entropy model for key contractual risks (e.g. optimum tendering prices) have been proposed for quantitative analysis. The validity and applicability of the models have been demonstrated with sample data for the CCI.

4) The CCI has been looked into as a particular case for PRM, taking into account China’s unique situation, which has been undergoing a remarkable transition period from a centrally planned economy to a market economy, especially in recent years since China’s entry into the WTO. In response to this dynamic scenario, practical guidelines have been recommended for strategies for PRM in the CCI.

The major findings and conclusions are summarised, and avenues for future research identified below.
9.1 MAJOR FINDINGS

The major findings of the research include:

1) Project participants in the Chinese construction industry (CCI) have little knowledge and understanding of project risks and project risk management (PRM), and most companies have not utilised PRM. For Chinese contractors, the major risks typically come from their clients. Chinese clients have traditionally managed construction projects themselves, but their ability in project management is much weaker than that of professional engineers (consultants or architects) and contractors.

2) The project management model adopted in the CCI is a kind of Design/Bid/Build (D/B/B), with the client directly subcontracting but without the assessment and selection of the project procurement route (PPR), which is popular.

3) The concept and principles of the PPR are new to the CCI. There is only one standard set of construction contractual conditions, and Chinese project participants have become familiar with the Lump sum contract based on the traditional PPR.

4) The major gap in the construction industry between China and the developed world is the issue of management, followed by technology and economics.

5) Modelling and analysis techniques are generally task-specific and require historical data as input.

9.2 CONCLUSIONS

Based on the findings from the research, the following conclusions are drawn:

1) Through the analysis of qualitative contractual risks and contract strategies, the research has established PRM strategies for identifying and adopting the best practice to provide practical guidelines for the CCI. The strategies emphasise that contractual risk management (CRM) of construction projects
should be considered critical, and the application of innovative PPRs is a breakthrough to improve CRM and speed up the development of the CCI.

2) The Chinese construction market is not yet suitable for development under market economics. Restructuring is needed before there can be significant reform of the Chinese construction market. Meanwhile, the development of the engineering consulting industry for the application of the general engineering packaging (GEP) and other innovative PPRs will be an internal stimulus to the CCI.

3) It is important to select the most appropriate PPR for the project under consideration. At the moment, the General Engineering Packaging (GEP) is most appropriate to the CCI, especially for large and complicated construction projects. First the Design/Build (D/B) PPR should be applied. Subsequently, the Turnkey PPR, Engineering Procurement Construction (EPC) PPR and Build-Operate-Transfer (BOT) PPR can become practicable.

4) For the purpose of innovating in the Chinese construction market, Chinese clients must learn and understand the dependence on engineering consultants to manage the construction project, instead of organising a project management team by themselves.

5) For the quantifiable analysis of key contractual risks, the two mathematical models proposed provide new approaches to the analysis and prediction of project risks by utilising expert experience as well as historical data. Other techniques can be used as complementary to the proposed methods in order to produce more reliable results.

9.3 FUTURE RESEARCH

Future effort for this research will be in two major areas.

9.3.1 Strategies for Project Risk Management

Further investigation could be carried out in contractual risk management (CRM) in conjunction with the project procurement route (PPR). This could include further case studies of construction projects and investigation into special contract
conditions, and consequently making more detailed recommendations on PRM strategies.

The implementation of the strategies requires a powerful legal environment and a mature construction market. How to provide these conditions is another topic for further research. This involves the construction administration system, legislation environment and management mechanisms. It is important to build connections with relative government departments (e.g. the Ministry of Construction - MoC) to ensure a regulatory framework with enforcement to support the implementation process.

It is also important to establish effective education and training environments through continued professional development to gain sufficient attentions and attitude from the industry on all key issues about PRM. Further research is required into effective ways to encourage investigation of the roles of education, financial supports and a regulation framework that facilitates changes. More effort is also necessary to identify efficient mechanism for monitoring progress and how this is reflected in outcomes.

9.3.2 Mathematical Modelling and Analysis

The effectiveness and reliability of a mathematical model depends on the model itself and the data required. For the application of the probabilistic analysis model, the major difficulty is to obtain reliable information as input data. The data currently used is in the form of a single value taken from experts for the risk factors and their probability. An alternative method is to employ the Monte Carlo simulation technique to obtain more reliable data with a range of values for each risk factor and its probability as the input for the simulation.

For the effective information entropy model, the major difficulty is to establish the effective information distribution for individual construction projects, which is based on expert experience, accumulated factual data and the characteristics of the project. Future research effort is required to explore effective way to build
databases from future projects, containing system information, historical data such as probability of winning a bid, and effective information distribution of various projects provided by experts, in order to apply the model and provide support to participants.
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APPENDIX A. ACRONYMS

AIA: American Institute of Architects
ANN: Artificial neural networks
BOT: Build-Operate-Transfer
CCI: Chinese construction industry
CIOB: Chartered Institute of Building, UK
CM: Construction management
CPM: Critical path method
CRM: Contractual risk management
D/B: Design/Build
D/B/B: Design/Bid/Build
ECL: Economical Contract Law
EPC: Engineering procurement construction
FIDIC: International Federation of Consulting Engineers
GDP: Gross domestic product
GEP: General Engineering Packaging
ICE: Institution of Civil Engineers, UK
JCT: Joint Contracts Tribunal Ltd, London
MC: Management contracting
MOC: Ministry of Construction of China
NCCC: New Construction Contract Conditions
NEC: New Engineering Contract
NPP: National People’s Parliament
PFI: Private Finance Initiative
PRM: Project risk management
PPR: Project procurement route
RMP: Risk management process
SACU: Shenyang Jianzhu University (Formally Shenyang Architectural and Civil Engineering Institute)
SSBC: State Statistical Bureau of China
WTO: World Trade Organisation
APPENDIX B. GLOSSARY

Contract risk: The risks arise from the legal relationship between the project participants, and from the contract interfaces between different contracts (Section 4.4).

Contract form: General Contractual Conditions.

Engineer: A special term in the construction industry that represents architect or consultant, such as used in the contract conditions of International Federation of Consulting Engineers (FIDIC) and Institution of Civil Engineers, (ICE, UK) contract conditions.

General Contractual Conditions: Standard contractual form, such as FIDIC red book, Standard Form of Contract for D/B published by the Joint Contracts Tribunal (JCT) in 1981.

Project company: the company takes all reliabilities for the financing, Build, Operation and Transfer of BOT project.

Risk factor: Risk is caused by risk factors, and therefore, risk factor that could result in risks occurring do not affect project activities directly but do so through risks. For example, risk of duration overrun could be caused by many risk factors such as weather, site condition, force majeure and unforeseen problems.

Special Contractual Conditions: Concrete contractual conditions for a factual construction project formed through the amendment and supplement to General Contractual Conditions.

Traditional PPR: The Design/Bid/Build (D/B/B) model called as traditional construction mode, has lasted for about two hundred years. Since the PPR was employed in the 1970s, the D/B/B model has been viewed as the Traditional PPR in the construction industry.
APPENDIX C. QUESTIONNAIRE

1. General questions about risk and attitude towards risk management

1) What is risk according to your understanding?
2) Is risk different from uncertainty? If yes, what is the difference?
3) Is the distinction between risk and uncertainty vague in the construction field? If so, is it necessary to identify the distinction?
4) Do you think it is necessary to identify project risks at the project planning phase?
5) Someone said that 'risk management is important only for special projects such as international projects'. Do you agree and why?
6) Would you like to attend training on risk management?

2. Major risk events in the Chinese construction industry

1) Give at least five major risks in construction projects in China.
2) Give the probability (very low, low, large, or very large) and consequences (very low, low, large, or very large) of the risks mentioned above.
3) As a contractor, which risk is the most serious and must be considered first in China?
4) Give one or more examples of a risk event in the construction process in your company.
5) Give the reason for the risk event and risk consequences.
6) Give one or more examples to illustrate risk (e.g. duration delay) consequences in your company.

3. The relationship of project management and project risk management

1) What is your understanding of project management?
2) What is the major model of project management in the Chinese construction industry?
3) What is your understanding of project risk management?
4) Is risk management necessary in project management for a successful project?
5) Are the major contents of project risk management the same as those of project management?
6) Are the objectives of project risk management the same as those of project management?
7) Someone said that ‘the purpose for project risk management is to reduce project uncertainties’. Do you agree and why?

4. General practice and strategies of risk management, and major difficulties for applying risk management

1) Has project risk management been employed in your company? If yes, give as many examples as possible.
2) Have you experienced risk losses in your work due to the neglect of project risk management?
3) Give as many methods as possible for risk management, such as experience, mathematical model and insurance.
4) Do you think it is difficult to understand risk and risk management?
5) Do you think it is difficult to implement project risk management in your company? If yes, give reasons, unavailability of time or finance or lack of expertise.

5. The project procurement route (PPR) and contract management

1) Do you know what PPR is?
2) If yes, explain the concept of PPR and provide types of PPR.
3) Which type of contract is most often employed in your company, Lump sum contract, unit price contract or other contracts?
4) What is the major approach of project contracting (packaging) in your company?
5) What is General Engineering Packaging?
6) What are the major difficulties for the implementation of General Engineering Packaging in China?
7) Do you know the Construction Management approach or Management Contracting model?

6. The development tendency of risk management after China’s entry into the World Trade Organisation (WTO)

1) Are you satisfied with the service and conditions of the Chinese construction market, such as bidding conditions?

2) After China’s entry into the WTO, is the pressure on the Chinese construction enterprises mainly from inside, outside, homeland or international construction market?

3) Should there be an emphasis on project risk management China’s entry into the WTO?

4) Do you think project risk management will be more important China’s entry into the WTO?

5) As a decision maker, do you think it is crucial to manage project risks China’s entry into the WTO?
APPENDIX D. STRUCTURE OF NEC

The New Engineering Contract (NEC) system is a family of contract documents. Here, the word ‘new’ means a challenge to traditional contracts. Different from traditional contracts, the structure of the NEC (as of January 1996) comprises four types of contract, six kinds of payment mechanism, nine groups of core clauses and 14 sorts of general clauses.

1) the engineering and construction contract
2) the engineering and construction subcontract
3) the professional service contract
4) the adjudicators contract

The significant characteristics of the NEC are the options for the payment method. Clients may make a selection from the follow six main options in order to select a special payment mechanism.

A: priced contract with activity schedule
B: priced contract with bill quantities
C: target contract with activity schedule
D: target contract with bill quantities
E: cost reimbursable contract
F: management contract

In these main options, management contract dose not comprise the construction management (CM) model, a priced contract dose not comprise the design/building (D/B) and Turnkey model. These options provide, in descending order, a broad scale of distribution of risks in price with Option A providing maximum certainty of price for the client and Option F provide the least. The client may make an option from the six payment mechanisms, which forms the basis to make up a construction contract.
The core clauses of the NEC are grouped into nine sections, numbered as follows:

1) General
2) The contractor’s main responsibilities
3) Time
4) Testing and defects
5) Payment
6) Compensation events
7) Title
8) Risks and insurance
9) Disputes and termination

The secondary options of the NEC includes 14 clauses labelled G to Z:

G: performance bond
H: parent company guarantee
J: advance payment
K: multiple currencies (for use with Options A and B)
L: sectional completion
M: limitation of design liability
N: fluctuations (for use only with Options A, B, C and D)
P: retention (for use only with Operation A, B, C, D and E)
Q: bonus for early completion
R: delay damages (liquidated)
S: low performance damages
T: changes in the law
U: special conditions
V: trust fund
Z: additional conditions

The client may make a selection from the six main options as to which type of pricing mechanism is to apply. For any one of the main options, the contract should include the nine core clauses, and some secondary options as the client
thinks fit that allow the client to build up the provisions in the contract to suit its individual policies. Somehow, the NEC may be viewed as buffet contracts. The client can choose and make up a contract depending on its own purpose and project characteristics.

In contract provision, the NEC is expressed more simply and clearly than existing forms of contract. The NEC avoids discipline-specific terminology, legalistic language and cross-references, and references to the practices of construction industry. The responsibility for design is not fixed with either the client or the contractor but can be set at any amount from nil to total with any party. The NEC stimulus to good management lays a great emphasis on communications, cooperation and programming and the need for clear definitions at the outset of various types of information.

Under the NEC, the relationships between the participants have changed and the organisation structure of the NEC is different from that of the traditional building model.