CASE BASED REASONING FOR ELICITING KNOWLEDGE FOR THE IMPLEMENTATION OF PROJECT MANAGEMENT PLAN OF SUCCESSFUL BUILDING PROJECTS IN BEIJING, CHINA

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SUMMARY

China's construction industry size is huge and rapidly increasing. Numerous successful projects are emerging. Construction Ministry of China promulgated annual prestigious construction project awards, Luban and Great Wall Prizes. The aim of this study is to examine the project success from the Luban and Great Wall prizes' projects. In order to achieve the research aim, two research objectives are established. The first research objective is to adopt the completed project data to build the model, which has been given the name as CASE_PMP. In the existing literature, project success has a set of quantitative indicators, namely, project success Key Performance Indicators (KPI), and correspondingly the determinants, namely, Critical Success Factors (CSF). And the second objective is to use CASE_PMP to estimate the project time and cost to prepare the tender document. In order to accomplish the research objectives, a three-step research method is formulated. The first step is to establish the sampling method for data collection. The second step is to build the CBR model. One hundred and four Luban and Great Wall prize projects' data have been collected in Beijing China to build the CBR model. The model is tested by the average error rate and the average deviation, 4.35% and 3.00% respectively. After verification and validation, the weights of CSFs generated from the model are analysed as the preliminary results. The third step is to conduct a semi-structured interview to expand the discussion of the results. The interview is conducted to ask practitioners on their opinions of the most important CSFs as selected by the weights which have been ranked top five and to discuss the usage, advantage, disadvantage of CASE_PMP. Some significant CSFs identified, such as the system to ensure achievement of quality objective, planning (schedule effectiveness), and project contract, are in compliance with the interviews results. Four out of five respondents asserted that CASE_PMP is useful to estimate the project time and cost for tendering purpose by automating the traditional estimation method, i.e. project manager and marketing department do the manual estimation.

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Chapter 1 Introduction

1.1 Background

China's construction industry has been rapidly growing in recent decades. China is the third largest construction market in the world after the USA and Japan. At a value of US$ 165 billion in 2007 the sector contributes 5.6% to GDP (Solidiance, 2009). Its spending increased 165% in the last four years, from 2004 to 2008, according to the National Bureau of Statistics of China; it is still expanding at 25% annually (U.S. Commercial Service, 2009). The average annual output growth of building construction was 11.64% in 1998-2001, and more than the average annual GDP growth of 6.98 % (National Statistics of P. R. China, 2003). Numerous successful projects have emerged in recent decades. It provides a research opportunity to examine the successful project experience and apply it to new projects.

This study intends to examine successful projects. The Construction Ministry of China has promulgated annual prestigious construction project awards, namely Luban Prize, which is the national level prize. Thirty one regions (province, municipal city and autonomous region) in China have their own construction prizes. For example, the municipal level prize in Beijing is named the Great Wall prize. The author decided to focus on cities that have high GDP and a rapidly growing construction industry. Amongst these thirty one regions, Beijing was chosen because it is one of China's most economically developed areas and has a rapidly growing construction industry. The detailed explanation for selecting Beijing will be given in Chapter Five. The projects which won the Luban and Great Wall prizes in Beijing were chosen as the data source as those projects provided an arena to explore project success. This study proposes to utilise Case Based Reasoning (CBR) to model the relationship of project success and its determinants. It is advanced because recent research demonstrated the potential benefits of CBR in construction management and economics and, in one study, its superior performance over other

Artificial Intelligence (Yau and Yang 1998) and traditional prediction techniques, such as regression (Leake, 1996) was highlighted. Yau and Yang did an evaluation of CBR and other AI technologies, particularly rule based expert systems (ESs) and neural networks (NNs) and concluded that CBR is more tolerant of incomplete information (Yau and Yang 1998). CBR has the ability to harness limited data set to do self training and establish the weights of independent variables with higher accuracy compared with the other traditional model techniques such as regression (Leake, 1996). The details of how CBR is superior will be discussed in section 3.4.1. In addition, Chapter 3 will address CBR concept and applications. The most important Critical Success Factors (CSFs) which are independent variable, as selected by the top five ranked weights are discussed in Chapter 7 and the in-depth interview for the importance order of CSFs is addressed in Chapter 8.

1.2 Purpose of the research

In the existing literature, project success has a set of quantitative indicators, namely project success Key Performance Indicators (KPIs) (KPI Working Group, 2000). Correspondingly, the determinants, CSFs, are well established in the construction industry (Chan and Chan, 2004).

The aim of this study is to elicit the project success experience from the projects that have been awarded the Luban and Great Wall prizes. In order to achieve the research aim, two research objectives are established. The first objective of this study is to collect completed project CSFs and KPIs from Luban and Great Wall projects in Beijing to model their relationship. This study adopts a different approach to identify CSFs. Previous studies identified the significant factors that contributed to the successful performance of projects using respondents' subjective opinions. However, it has been well established that human judgments (i.e. predictions or evaluations based on incomplete or uncertain information) generally is subject to systematic error, or bias, as well as unsystematic error, or variance (Bowman, 1963). Instead of using respondent's subjective judgments for the significance of factors to project success, this research attempts to use objective data of the completed projects, which have won the construction awards, to build the quantitative model, which is given the name CASE_PMP, and derive the importance of the significant factors for project success.

The second objective of this study is to estimate the project KPIs based on the model CASE_PMP for project tender document preparation. The most commonly used method in Beijing, China is based on company's previous project record and project manager's experience to estimate the project time and cost. The estimated project time and cost will be included in the tender document. This is the traditional method. Using CASE_PMP can be a complementary approach to the traditional methods. CASE_PMP may be helpful for supporting project managers' estimating and in checking manual estimation because human judgment generally is subject to systematic error, or bias, as well as unsystematic error, or variance. It may help the inexperienced project manager to improve the effectiveness of estimation and increase the reliability and fairness of the traditional approach.

1.3 Statement of the problem

Having more than twenty years' history, Luban prize and Great Wall prize are the most prestigious construction awards in China. It is a government award and represents the highest level of successful projects in China. In order to examine what are the most important CSFs from these projects, this study proposes to utilise CASE_PMP to modelling the dependent variables, KPIs, and the independent variables, CSFs. This study identifies the most important CSFs based on a selection by the top five ranked weights which are generated from CASE_PMP.

This study uses the project CSFs during construction stage's to estimate project time and cost for tender document preparation. This is because the project time and cost in the tender document are estimated based on previous completed project experience, i.e. CSFs incurred during the construction stage.

In order to achieve the above stated two research objectives, a concise and manageable research problem was formulated: what is the relationship between the KPIs and CSFs during construction stage for the Luban and Great Wall prizes projects in Beijing, China? It attempts to organise and provide the linkage of the research elements, the dependent variables, KPIs, and the independent variables, CSFs. It also delimits the research scope.

1.4 Research hypothesis

Through literature review which leads to the development of the hypothesis, the research adopted a quantitative approach with the objective of examining the relationship between a series of predictors(X), namely, Critical Successful Factors (CSFs) and criterion variables (Y) representing success of a project, namely, Key Performance Indicators (KPIs). This study is to study how these factors affect project success separately and collectively, so it is hypothesised that Project success (KPIs) is a function of CSFs.

The mathematical statement of the hypothesis is:

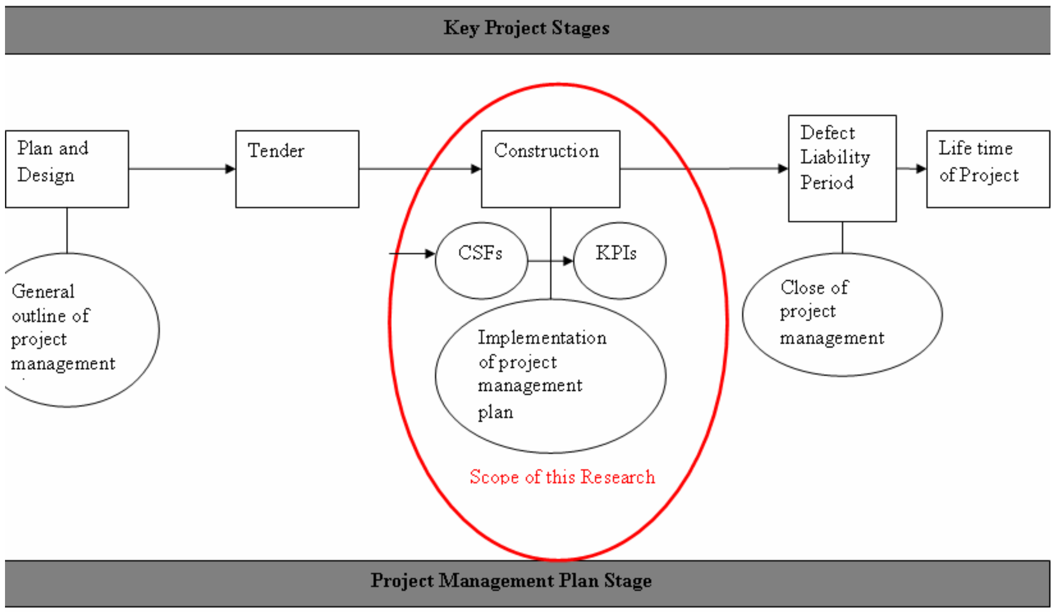
$$KPI_n = f(CSF_1 + CSF_2 + ...CSF_m)$$
$$n = 1,2.....6$$
$$m = 1,2,.....25$$

Here n is the number of the KPIs and m is the number of the CSFs. The details of all indicators for KPIs and CSFs will be elaborated in Chapter Two.

1.5 Research scope

Section 1.3 explained this study attempts to model the Luban and Great Wall projects' KPIs and CSFs during construction stage. As depicted in Figure 1.1., the research scope was delimited to the project construction stage. The purpose of research is based on CSFs during the construction stage to estimate the project KPIs for tender document preparation. Case-based reasoning (CBR) has the ability to utilize existing cases as data (Hammond, 1986). It is a method of solving a current problem by analogising the solutions to previous similar problems and has emerged as a popular method in the construction management and economics area. The CSFs and KPIs of the projects that have been awarded the Luban and Great Wall prizes during the construction stage are used to build the model and estimate time and cost of new projects.

Fig 1.1 Research Scope



Source: author

1.6 Research Method

The research method includes three steps. The first step is to formulate the sampling method for data collection. After the data are collected, the project data will be processed to satisfy the dataset requirement to build the CBR model. That includes establishing the CSFs and KPIs as the input and output and treatment for missing data. The second step is to build the CBR model and there are several steps to build the model. The detailed steps will be explained in Chapter 6. Test cases are used to assess the model performance and examined that the weights are optimum in terms of the average error rate for all KPIs and project types and the average deviation. Verification and validation are conducted thereafter. The CSFs are discussed based on the top five derived weights of Project Management and Non-Project Management group CSFs as the preliminary results. In order to expand discussion of analysis results and explore model CASE_PMP's practicality, its advantages and disadvantages, a semi-structured interview is conducted as the third step. The interview is addressed in Chapter 8.

1.7 Outline of the structure of the thesis

This chapter briefly discusses a general introduction to the background, motivation, research questions, objectives, hypothesis, research scope and research method.

Chapter 2, consisting of two parts, presents a holistic and critical review of the project success and the project success determinants. The first part describes the literature evolution of project success. The second part reviews previous research work in project success determinants.

The research methodology of the present study is given in the Chapter 3 and Chapter 4. Chapter 3 reviews the concepts and the applications of case based reasoning in the literature. CBR used in this study is introduced. Chapter 4 explains the research method and strategy used in this study. The justification for the chosen research methods is discussed and a research strategy is formulated.

The detailed data collection and analysis are addressed in Chapters 5 and 6. Chapter 5 focuses on the detailed data collection method, introduction of Luban and Great Wall prizes and the techniques to deal with the missing data. Chapter 6 introduces the data analysis and modelling.

The concluding portion of the thesis, Chapter 7, Chapter 8 and Chapter 9, summarizes the major findings of the study and provides recommendations that future study should take into consideration. Chapter 7 presents the preliminary results discussion. Chapter 8 expands the results analysis by qualitative interview, and Chapter 9 summarizes the research findings and possibility to extend the findings and recommendations for future study.

Chapter 2 Measurement and Determinants of Project Success

2.1 Introduction

This chapter discusses the measurement of project success in terms of Key Performance Indicator (KPI) for project success and the determinants of project success which are the Critical Success Factors (CSF). This chapter reviews CSFs definition and classifies CSFs into two groups, non-project management and project management groups.

2.2 Project Success

2.2.1 Measurement of Project Success-Literature

Numerous researchers have investigated the measurement of project success since 1960's, and especially so during last two decades. In the literature, project success was considered to be tied to performance measurement. Kumaraswamy and Thorpe (1996) included a variety of criteria in their study of project evaluation. These included meeting budget, schedule, and quality of workmanship, client and project manager's satisfaction, transfer of technology, friendliness of environment, health and safety. The word "performance" involved all aspects of the construction process. Performance as applied to on site activities was a broad, inclusive term, encompassing four main elements, namely, productivity, safety, timeliness, and quality (Oglesby, et al., 1989). Alarcon & Ashley (1992) have characterized performance, in a broad definition, as seven criteria or elements on which management should focus its effort: effectiveness, efficiency, quality, productivity, quality of work life, profitability, innovation. The performance criteria of Construction Best Practice Panel (CBPP) for benchmarking are (Thirty, 1997):

- Construction cost
- Construction time
- Predicted design cost
- Predicted design time
- Defects
- Client satisfaction product
- Client satisfaction service
- Profitability
- Productivity
- Safety

Cooke-Davies (2002) noted that the distinction between project success – which cannot be measured until after the project is completed, and project performance– which can be measured during the life of the project is also important. This study attempted to examine the project success after project completion.

The measurement of the project success had no universal agreement. The indicators/criteria of project success varied from project to project, from industry to industry and from people to people. The indicators/criteria of project success for ‘mega project’ and ‘micro project’ were different in the literature (Sohail and Baldwin, 2004; Long et al., 2004). Oya and Walter (2001) discussed that the choice of performance measures, however, was influenced by project type and industry classification. Cox et al., (2003) presented that the construction executive and project manager displayed a substantial difference between their respective Key Performance Indicators (KPI). In addition, the authors asserted that perceived KPIs vary depending on the number of years of experience of the respondents and suggested that there existed a set of common KPIs for all construction regardless of divisions. This study examines project success in the construction industry.

In Kerzner's work, the author presented that in the 1960s, project success was measured entirely in technical terms: either the product worked or it did not. In the 1980s, the following definition for project success was offered. Project success was stated in terms of meeting three objectives:

(1) Completed on time.

(2) Completed within budget.

(3) Completed at the desired level of quality. The quality of a project was commonly defined as meeting technical specifications (Kerzner, 1998).

Chan and Chan conducted a comprehensive literature review of the measurement of construction project success from 1980s to 1990s, "Key Performance Indicators for Measuring Construction Success" (Chan and Chan, 2004). In the early 1990s, at the project level, success was measured by the project duration, monetary cost and project success (Navarre and Schaan, 1990). Time, cost and quality were the basic criteria to project success, namely the "iron triangle" and they were identified and discussed in almost every article on project success, such as that of Belassi and Tukel (1996), Hatush and Skitmore (1997), Walker (1995, 1996) and Atkinson (1999).

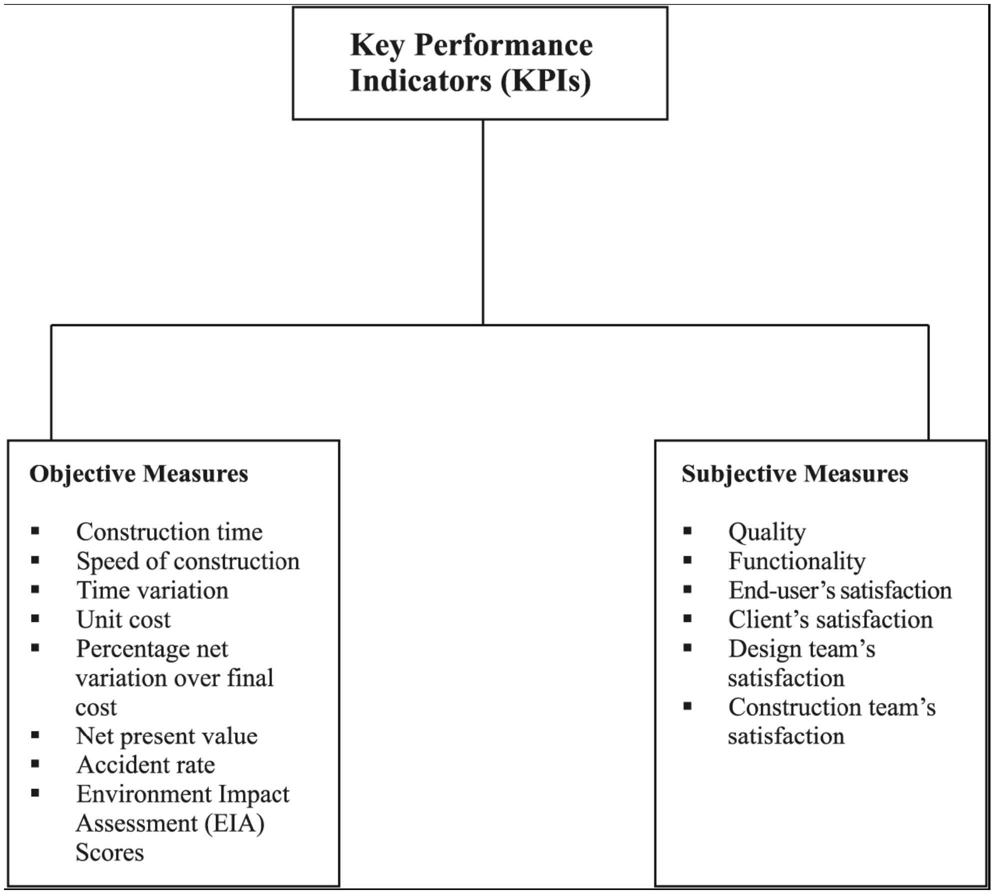
In addition to these basic criteria, Pinto and Pinto (1991) advocated that measures for project success should also include project psychosocial outcomes that refer to the satisfaction of interpersonal relations with project team members. In the late 1980s, after the introduction of TQM (Total Quality Management), a project was considered to be a success by not only meeting the internal performance measures of time, cost and technical specifications but also making sure that the project is accepted by the customer and resulted in customers allowing the contractor to use them as a reference (Kerzner, 1998). Subjective measures such as participants' satisfaction level are known as "soft" measures. Wuellner (1990) suggested the inclusion of satisfaction as a success measure. Pocock et al. (1996) further suggested including the absence of legal claims as an indicator of project success. This then calls for including "safety" as a success indicator as well, since it is reasonable to expect that if accidents occur, both contractors and clients may be subject to legal claims, as well as financial loss and contract delay in the construction project.

Kometa et al. (1995) used a comprehensive approach to assess project success. Their criteria include: safety, economy (construction cost), running/maintenance cost, time and flexibility to users. When applied in more general definition to on site and off site activities project success involved additional aspects. Songer and Molenaar (1997) considered a project as successful if it is completed on budget, on schedule, conforms to user's expectations, meets specifications, attains quality workmanship and minimizes construction aggravation.

Shenhar et al. (1997) proposed that project success was divided into four dimensions based on different project stages. The first dimension was the period during project execution and right after project completion. The second dimension can be assessed shortly afterwards, when the project has been delivered to the customer. The third dimension can be assessed after a significant level of sales has been achieved (1-2 years). Finally, the fourth dimension can only be assessed 3-5 years after project completion. Atkinson (1999) similarly divided project success into three stages: the first stage was "the delivery stage: the process: doing it right"; the second is "post delivery stage: the system: getting it right" and the last stage is "the post delivery stage: the benefits: getting them right". Lim and Mohamed (1999) believed that project success should be viewed from different perspectives of the individual owner, developer, contractor, user, and the public and so on. The authors proposed to evaluate project success from both the macro and micro viewpoints. Sadeh et al. (2000) divided project success into four dimensions. The first dimension was meeting design goals, which applies to contract that is signed by the customer. The second dimension was the benefit to the end user, which refers to the benefit to the customers from the end products. The third dimension was benefit to the developing organization, which refers to the benefit gained by the developing organization as a result of executing the project. The last dimension was the benefit to the technological infrastructure of the country and of firms involved in the development process. The combination of all these dimensions gave the overall assessment of project success.

In 2000, Key Performance Indicators (KPIs) working group of the Department of the Environment, Transport and the Regions presented a KPI report to UK's Minister for Construction. The purpose of the KPIs was to enable measurement of project and organizational performance throughout the construction industry (KPI Working Group, 2000). They proposed that while individual organizations have been measuring their performance for many years, there has been little consistency in the data, and the way it has been published. The report was another step in rectifying this deficiency, which built on the foundation of Construction Industry KPIs by detailing a comprehensive framework for measurement. The calculation methods of the proposed KPIs were divided into two groups. The first group used mathematical formulae to calculate the respective values, such as time, cost, value, safety and environmental performance. The other group used subjective opinions and personal judgments of the stakeholders. This group included the quality, functionality of building and the satisfaction level of various stakeholders. A seven-point scale scoring system was adopted to measure these KPIs. Figure 2.1 showed a graphical representation of the KPIs.

Figure 2.1 KPIs for project success



Source: KPI Working Group, 2000

The above literature was reviewed concept by concept; the following Table 2.1 was the chronological evolution of the measure of the project success. It presented the evolution of project success measurement in the literature. After reviewed all these measurements, this study adopted the most comprehensive and latest measurement, KPIs framework as the base to come out the measurement of project success in this study.

Table 2.1 Chronological evolution of the measure of the project success

Year	Name of the researcher	Conclusions drawn from the study
1960s	Kerzner (1998) reviewed the 1960's	❖ Project success was measured entirely in technical terms: either the product worked or it did

	study	not.
1980s,	Kerzner (1998) reviewed the 1960's study	❖ After the introduction of TQM, a project was considered to be a success meeting the internal performance measures and external performance
	A. De Wit (1988)	❖ Distinguished project success (measured against the overall objectives of the project) with project management success
	Oglesby, Parker, and Howell (1989)	❖ The word "performance" involves all aspects of the construction process.
	Kerzner (1998) reviewed 1980's study	❖ Project success is stated in terms of meeting three objectives: Completed on time, within budget and at the desired level of quality.
Early 1990s,	Navarre and Schaan (1990)	❖ Success was measured by the project duration, monetary cost and project success
	Maloney (1990)	❖ The need for including each of the performance aspects discussed above in the evaluation of construction performance has discussed by Maloney
	Wuellner (1990)	❖ Inclusion of satisfaction as a success measure.
	Alarcon and Ashley (1992)	❖ Seven criteria or elements: effectiveness, efficiency quality productivity, quality of work life, profitability, innovation.
	Pinto and Pinto (1991)	❖ Measures for project success should also include project psychosocial outcomes which refer to the satisfaction of interpersonal relations with project team members.
Late 1990s	Munns and Bjeirmi (1996),	❖ The distinctions between project success and project management success
	Belassi et.al (1996), Hatush et.al (1997) and Walker (1995, 1996).	❖ Time, cost and quality are the basic criteria of project success, and they are identified and discussed in almost every article on project success, such as that of Belassi and Tukel (1996), Hatush and Skitmore (1997) and Walker (1995, 1996).

	Atkinson (1999)	❖ Atkinson (1999) called time, cost and quality as the "iron triangle".
	Baccarini (1999)	❖ Project success is measured both in terms of product (including facilities) success and project management success.
	Pocock et al. (1996)	❖ Including the absence of legal claims as an indicator of project success.
	Kometa et al. (1995)	❖ A comprehensive approach to assess project success. Their criteria include: safety, economy (construction cost), running/maintenance cost, time and flexibility to users.
	Songer and Molenaar (1997)	❖ A project is successful if it is completed on budget, on schedule, conforms to user's expectations, meets specifications, attains quality workmanship and minimises construction aggravation.
	Kumaraswamy and Thorpe (1996)	❖ Included a variety of criteria in their study of project evaluation. These include meeting budget, schedule, and quality of workmanship, client and project manager's satisfaction, transfer of technology, friendliness of environment, health and safety.
	Thirty (1997)	❖ The Construction Best Practice Panel (CBPP) performance criteria for benchmarking.
	Shenhar et al. (1997)	❖ Project success is divided into four dimensions.
	Atkinson (1999)	❖ Divided project success into three stages
	Lim and Mohamed (1999)	❖ Project success should be viewed from different perspectives
In the 2000s	Sadeh et al. (2000)	❖ Divided project success into four dimensions.
	The KPI Working Group (2000)	❖ KPIs are divided into two groups.

Oya and Walter (2001)	❖ The choice of performance measures, however, is influenced by project type and industry classification.
Cooke (2002)	❖ The distinction between Project success measured until after the project is completed, be measured during the life of the project is also important.
Cox et al (2003)	❖ The indicators/criteria of project success for mega project and 'micro project' are different in the literature
Sohail et al. (2004)	❖ The construction executive and project manager displayed a substantial difference between their respective Key Performance Indicators (KPI). And perceived KPIs vary depending on the number of years of experience of the respondents and suggested that there existed a set of common KPIs for all construction regardless of divisions.

Source: author

2.2.2 Construction Prize Criteria of Project Success-Practice

International benchmark measurement for project success (KPIs) cannot be rigidly applied to China's construction industry because of the absence of unanimous KPIs in existing literature. In order to identify the KPIs measurement in China's context, the Luban and Great Wall prizes' criteria are reviewed as the practical measurement to project success because Luban and Great Wall prizes are the most prestigious awards in China. Promulgated by Ministry of Construction of China, the sole government authority that oversees the construction industry in China, the Luban and Great Wall prizes are government award presented to successful project winners.

Luban Prize and Great Wall prize provided a set of criteria for measurement of successful project (China Luban Prize Committee, 2000):

- Project design is advanced and feasible, and conforms to the relevant national and industry design standard. If project is at urban area, it conforms to the urban planning.
- Project Construction conforms to national and industry construction standards, quality level is good, achieving the domestic advanced level for similar projects.
- The client has checked and accepted the completed project.
- The project has no defects and potential quality problem within one year after the project completion.
- Construction site death accident rate is zero.
- Apart from the above five criteria, industrial and transportation project's technical and economic indicators should accomplish the domestic advanced level in this specialty. Residential building and all facilities as a whole conform to the urban planning and environmental protection etc., standards and regulation. All facilities are complete. All sub-projects' quality is good. The occupant rate is up to 40%.

2.2.3 Project Success Measurement of This Study

Table 2.2 presents the comparison of the project success definition of international literature and China's practical measurement, Luban and Great Wall prizes. It depicts summary of project success measurement in literature review and China project success measurement in the context of practice. The purpose is to select KPIs of this study.

In practice, a product success project can have poor project management performance. For instance, the North Sea Oil development projects in the 1970s suffered substantial cost and time overrun (Baccarini, 1999) but were considered the product success. This study incorporated the time and cost as the indispensable indicators of the Key Performance Indicators. In addition, the common criteria, international literature criteria and China's criteria will be selected as the measurement of the project success of this study. These common indicators are quality, client satisfaction, health and safety.

Table 2.2 The comparison of the project success definition of international benchmark and China's Luban and Great Wall prizes

Project success criteria	Literature	Luban and Great Wall prizes Of China	This study
Time	√		√
Cost	√		√
Quality	√	√	√
Client Satisfaction	√	√	√
According to national design and construction standard		√	
Special requirement for industrial and residential project		√	
Client Changes	√		
Business Performance	√		
Health and Safety	√	√	√

Source: author

According to Chan and Kumaraswamy (1997) and Naoum (1994), speed of construction is defined as the measurement of construction time. Speed of construction (K1) is a relative time, which is defined as gross floor area divided by the construction time.

Cost is not only confined to the tender sum, it is the overall cost that a project incurs from inception to completion, which included any cost arising from variations, modification during construction period and the cost arising from the legal claims, such as litigation and arbitration and administrative fee (Sohail and Baldwin 2004, KPI Working Group 2000, Thirty 1997). Unit cost (K2) is a measure of relative cost and is defined as the final construction cost divided by the gross floor area. Cost Variation (K3) is a ratio of final construction cost minus contract sum divided by final construction cost.

Quality score (K4) is another criterion that was repeatedly cited by previous researchers (Sohail and Baldwin 2004, KPI Working Group 2000, Songer and Molenaar 1997). Luban and Great Wall prizes' evaluation committee has published a guideline on how to evaluate the quality score, which is the average score of the structure, the architecture work, the decoration work and other components, such as M&E works (Beijing Construction Quality Management Society, 2004).

In addition, health and safety in terms of construction site death accident rate (K5) and client satisfaction (K6) are another two KPIs of this study. Client satisfaction is measured on the Likert scale from 1 to 5, meaning client is either very unsatisfied to very satisfied. However, as all the Luban and Great Wall project have zero death accident rate so K5 will not be studied in this study. Only five KPIs are investigated.

2.3 The determinants of project success

2.3.1 Project Success and Project Management Success

Section 2.2 discussed the project success measurements, which are dependent variables and Section 2.3 examined the determinants of project success, which are independent variables. In the literature, the project success measurement evolved from traditional iron triangle to multiple dimension, three stages, micro, macro point of view, and subjective and objective measurement. Munns and Bjeirmi (1996) used the concept project management success and identified the distinctions between project success and project management success. Their study examined how the objectives of project and project management were different, and how the emphasis of project management was towards achieving specific, and short-term targets compared to the wider aims of a project, and also highlighted the overlap that exists between project and project management, and the confusion that can arise from the common use of these terms. Baccarini (1999) insisted that project success is measured both in terms of product (including facilities) success and project management success. Product success deals with the project's product and project management success deals with the project process.

Another criterion is based on time dimension. Project management success would include the obvious indicators of completion to budget, satisfying the project schedule, adequate quality standards, and meeting the project goal (Munns and Bjeirmi (1996), Baccarini (1999)). Project management success is short term while project success is long term and often commented on at the end of the project management phase. Project management ends when project delivery is finished and handed over to client.

The objectives of project success and project management success were often intertwined. For example 'completion to budget' might be placed alongside 'profitability' as objectives. Project management success measurements were common across all projects and are easy to measure quantitatively. Many of the project objectives will tend to be either qualitative or not easily measured (Munns and Bjeirmi 1996). Wit (1988) distinguished project success (measured against the overall objectives of the project) with project management success (measured against the widespread and traditional measures of performance against cost, time and quality). The former is success criterion and the later is one of the success factors. Project management is purely a subset of the project as a whole.

The techniques of project management may help to ensure a successful implementation of the project. The project management could not have prevented the failure of the project. Many factors out of control of the project management scope might contribute to the failure of the project. Project management is the application of knowledge, skills, tools and techniques to project activities to meet project requirement (Project Management Institute Inc (PMI), 2004). Project management is “soft” and intangible assets. Therefore, within project stakeholders including client and project team (PMI, 2004) projects are also being considered as an arena for learning; the uniqueness of projects makes each rich in opportunities for personal and organizational learning (Ays,1996; Keegan and Turner, 2001; Lundin and Midler, 1998).

In the literature, the critical success factors for achieving a fully developed project management system were grouped by the stages of the project life cycle (Kerzner, 1998). Chan (Chan and Chan, 2004) conducted a thorough literature review for seven major journals in construction field for determinants of construction project success, Critical Success Factors (CSFs). Five major groups of independent variables, namely project-related factors, project procedures, project management actions, human related factors, and external environment were identified as crucial to project success. Belassi classified the factors into four areas, they are factors related to the project, factors related to the project manager and the team members, factors related to the organization, and factors related to the external environment. The framework suggested not only brings advantages by grouping critical factors, but also helps project managers understand the intra-relationships between the factors in different groups (Belassi & Tukel, 1996). A hierarchical model for construction project success was presented, where success was determined by a variety of factors pertaining to four main project aspects, namely, project characteristics, contractual arrangements, project participants, and interactive processes in study (Chua et. al, 1999). The CSFs of similar nature in terms of the contributions to different project objectives (cost, schedule, quality performance) were logically grouped into one cluster to facilitate pairwise comparisons during the survey.

There are various grouping methods for CSFs depending on the research objectives. This study classified the determinants of Project Success into two groups, project management (PM) characteristics and non-project management (non PM) characteristics. This is because project management arena is rich for learning and research. Non project management characteristics are those factors which do not subject to project delivery team's control and are determined before the construction process, for example the project type and size, the selected project team's characteristics like their experience. Project management characteristics are those factors which could be under the control of the project management team during the construction process. Classifying CSFs into PM and non PM group will be helpful for future studies in developing project management strategy decision system.

In order to identify the CSFs in China's project context, the purpose here is not to come up with all possible critical factors that might affect project success, which would be very difficult, if not impossible, but to focus on the research scope: i.e. during construction stage. Focused on the project construction stage, the purpose of research is based on the CSFs to estimate the project KPIs. Only relevant CSFs were investigated in this study. It is also the intention of this study to clarify what should be considered as critical factors, and their effects which lead to project success or failure. For the non-project management group, it is divided into six sub-groups (F1-F6) and the project management CSFs (F7). The following part examines the relevant literature of CSF and the measurement.

2.3.2 Determinants of Project Success in This Study -Non-Project Management Factors

The client related factors are: 1) type and experience, 2) knowledge of construction project organization, 3) project finance, 4) client confidence in the construction team, 5) owner's construction sophistication, 6) well-defined scope, 7) owner's risk aversion, 8) client project management (Chan and Chan 2004; Chan and Kumaraswamy 1997; Songer and Molenaar 1997; Dissanayaka and Kumaraswamy 1999; Belassi and Tukel 1996; Naoum, 1994; Rowlinson 1988). This study measures the client relevant factors in nominal or ordinal scale. Table 2.3 presents the client related CSFs.

Table 2.3 Coding system for client related CSFs

Client characteristics (F1)	
CSFs	Measurement of this study
Client types (C1)	The funding source of project is public (1) or private (2) or mix source (3).
Client experience (C2)	The number of similar buildings they had commissioned in the past. Those with no previous experience are given a low score of L (or rank 3). Those with some previous experience involved with one or two buildings are given M (or rank 2), and those have considerable experience (involved more than 2) are given H score (or rank 1).
Client's contribution to construction process (C3)	Client unsupportive is cored L (or rank 3), medium is given M (or rank 2), and highly supportive is given H score (or rank 1). During the course of data collection, the respondents who are project managers of Luban and Great Wall prizes gave their subjective judgment for client contribution.
Client criteria (C4)	Client prioritises the three criteria: time, cost and quality. Low construction cost (1); quick construction (2); high construction quality (3); two of these criteria (4), all criteria (5).

Source: author

The designer related factors include the designer's experience and variation frequency (Kelly, et al. 2003; Chan and Kumaraswamy 1997; Naoum, 1994). Table 2.4 presents the designer related CSFs of this study.

Table 2.4 Coding system for designer related CSFs

Designer characteristics (F2)	
CSFs	Measurement of this study
In house/outside designers (C5)	In-house is (1), outside is (2).
Designers experience (C6)	In the same way as the experience of clients.
Designer's times of and significant change orders variations (C7)	The designer's times of significant change orders variations, more than two times scored H (Rank 1), two times scored M (Rank 2), less than two time scored L (Rank 3).

Source: author

Contractors related variables contain contractors' experience and their performances (Kelly, et al. 2003; Dissanayaka and Kumaraswamy 1999; Chan and Kumaraswamy 1997; Naoum, 1994). Table 2.5 presents the contractor related CSFs of this study.

Table 2.5 Coding system for contractor related CSFs

Contractor characteristics (F3)	
CSFs	Measurement of this study
Contractors experience (C8)	In the same way as the experience of clients.

Source: author

Project related factors were identified by a number of researchers (Walker, 1995; Songer and Molenaar 1997; Belout 1998; Chua et.al. 1999; Dissanayaka and Kumaraswamy 1999; Naoum, 1994; James and Wong 2005). Table 2.6 presents the project related CSFs of this study.

Table 2.6 Coding system for project related CSFs

Project characteristics (F4)	
CSFs	Measurement of this study
Building work types (C9)	New (1) or refurbishment (2).
Project size: was defined by building cost (C10) and gross floor area in square meter.	Those less than RMB 3.6 million and 3000 sqm are regarded as small project (rank 3) RMB $8.4 million and 7000 sqm are regarded as normal size projects (rank 2) and those larger than the boundary as the large project (rank 1).
The attributes used to measure this factor were listed as following: Project complexity (C11)	Project manager subjective judgment using the Likert scare from 1 to 5, very complex (5), very incomplex (1).

Source: author

Naoum, (1994) presented that contract relevant factors are important to project success. A number of studies identified the importance of procurement factors (Pocock et al., 1996, 1997; Walker, 1996; Dissanayaka and Kumaraswamy, 1999 Walker and Vines, 2000). Table 2.7 presents the procurement and contract related CSFs of this study.

Table 2.7 Coding system for procurement and contract related CSFs

Procurement and Contract Characteristics (F5)	
CSFs	Measurement of this study
Contract procedure (C12)	Open tendering (1), competitive selected tendering (2), and negotiated contracts (3).
Procurement method (C13)	Traditional approach (1), Design and Build approach (2), management approach (3).

Source: author

Various study supported economical, political social environment as factors affecting project success (Walker and Vines 2000; Chua et.al. 1999; Songer and Molenaar 1997; Naoum, 1994) further described "environment" as all external influences on the construction process, including social, political, and technical systems. The attributes used to measure this factor are economic environment, social environment, political environment, physical environment, industrial relation environment, and level of technology advanced. However, this study examines the projects in Beijing, China. Therefore, except the climate and the underground utilities, other factors like the social, political, economical factors are same for all projects and hence not being discussed in this study. Table 2.8 presents other CSFs of this study.

Table 2.8 Coding system for other CSFs

Other factors (F6)	
CSFs	Measurement of this study
Obstruction due to underground utilities and or inclement weather (act of god) (C14)	L (rank 3) M (rank 2) and H (rank 1). The measurement is to ask the respondent's subjective opinion on climate and underground situation.

Source: author

2.3.3 Determinants of Project Success in This Study -Project Management Factors

Project management action is a key for project success. Many factors related to the skills and characteristics of project managers and team members were proposed for the successful completion of projects (Hubbard, 1990; Belassi and Tukel, 1996). Then, the variables in project management included adequate communication, control mechanisms, feedback capabilities, troubleshooting, coordination effectiveness, decision making effectiveness, monitoring, project organization structure, plan and schedule followed, and related previous management experience (Belout ,1998; Chua et. al, 1999; Walker and Vines, 2000). In their recent study, Pinto and Slevin demonstrated the importance of selecting project managers who possess the necessary technical and administrative skills for successful project (Pinto and Slevin, 1989). Chan presented that project management (Chan and Chan, 2004) includes communication system, control mechanism, feedback capabilities, planning effort, organization structure, safety and quality assurance program, control of subcontractors' works, and finally the overall managerial actions.

Project management CSFs are those CSFs occurs during construction stage because the research scope of this study was delimited to construction stage. Project management is the application of knowledge, skills, tools and techniques to project activities to meet project requirements. The project management process is the plan-do-act-check cycle. This cycle is linked by the results from one stage of the cycle as the input of another stage. E.g. ‘plan stage’ is linked to the input of ‘do’ stage. And it becomes a closed loop cycle (Project Management Institute (PMI), 2004).

In construction industry, it is encouraged to conduct project scope management at the very early stage of the project. Previous research has shown that increased levels of scope definition during the early planning, or pre-project planning phase of a project can greatly improve the accuracy of cost and schedule estimates as well as the probability of meeting or exceeding project objectives (Griffith and Gibson 1995, Hackney 1992; Hamilton and Gibson 1996; Merrow 1988; Merrow et. al.1981). In China, the Code of Construction Project Management (GB/T 50326-2005) issued by Ministry of Construction included complete project management standards which cover all aspects of construction project management (Ministry of Construction, 2005).

The Code of Construction Project Management provided a reference for this study to examine the project management CSFs in China’s context. This code included sixteen aspects of project management: project scope management; project management planning; project management organization; project manager responsible system; project contract management; project purchasing management; project schedule management; project quality management; Occupational Health and Safety Assessment Series management; project environment management; project cost management; project resource management; project information management; project risk management; project communication management; project completion management.

According to the literature (Belout 1998; Chua et al. 1999; Walker and Vines 2000; Sidney, 2002; Chan and Chan, 2004) and the Code of Construction Project Management, project management planning comprises two major components: one is general outline of the project management plan; another is the implementation of the project management plan. The general outline of the project management plan is worked out at very early stage of the project. After preparing bidding and the construction contracting, the employer proceeds to select the construction project manager. The nominated project manager accepts the employer's appointment and organizes the project management team. The project management team is responsible to work out the implementation of the project management plan. The construction project management will be executed based on the implementation of the project management plan during the construction process.

This in-depth description of construction project management practice provided specific set of project management knowledge in China's construction industry. Construction project management involved many aspects. Investigating every aspect of project management, if it is not impossible, will be very difficult. Therefore, this study will focus on the investigation of the implementation of project management planning during the construction stage.

This study will examine the implementation of project management plan as the scope. Six aspects of the implementation of the project management plan were explored: construction deployment, construction plan, construction schedule plan, resource supply plan, construction preparation plan, technology management plan. Table 2.9 depicts the project management CSFs of this study.

Construction deployment contains five parts: project quality, schedule, cost and safety objective; the input human resource, the maximum and average people number; sub-contracting plan, labour using plan, material supply plan, equipment and plan supply plan; construction procedure; project management general arrangement.

Construction plan includes five components: construction consequence and flow; construction phase setting off; construction methods and plant selection; safety construction design; environment protection content and methods.

Construction scheduling plan comprises the general construction schedule plan and unit project scheduling plan. Resource demand plan was constitutive of five different resource demand plans: labour, primary material and turn over material, plant, prefabricated articles, large-size equipments and facilities.

Construction preparation plan consists of six aspects preparation: the construction preparation organization and schedule; technology preparation and quality plan; construction site plan; construction team and management team; material; finance.

Technology management plan is the technology, organization, finance and contract ways to ensure the achievement of project management objective from the technology aspects. It ensures the achievement of the schedule, quality, safety, cost, quarter construction, and environment and civilization construction objectives. The following parts elaborate how the project management CSFs are measured in this study.

Table 2.9 Coding system for Project Management CSFs

Project management planning (F7)	
CSFs	Measurement of this study
Project management team organization (C15)	Organized in the streamline structure; the major project construction function team is under the direct level of the project manager, yes (2) no (1). The major project construction function is the quality team, material team and finance team etc.
Project management team works out the schedule plan (C16)	On the daily based (3), weekly based (2), and monthly based (1).
The main contractor and subcontractor's communication (C17)	The subcontractor's meeting is daily based (2) or fix period meeting not daily based (1).
The effectiveness of the construction scheduling (C18)	structure and installation part work is consequential but if the scheduling of these two parts has the overlap, it is effective. Alternative measurement is the application of the CPM to shorten the construction duration: yes (2) no (1).
The labour (skilful worker) input man (19)	day per square meter (divided by the Gross Floor Area (GFA))
The major material (Steel) consumer (C20)	kg /per square meter (divided by the GFA).
The construction preparation (C21)	the administration work preparation (the construction work permission); the technology work preparation (construction drawing familiar, preparation of the standard, preparation for the measurement and experiment etc.); the site preparation (Construction Equipment, Temporary Works, water/electricity preparation); the supply of the plant, materials and goods preparation. The number of all the above preparations: all (3), any three (2), any two or one (1).
The technology management (C22)	The measurement; experiment; documentation; development technology management objective; the technical methods to save cost; promotion of the new technology; quantify management and other technology management. The measurement scale of this indicator is ordinal. There are 8 aspects of this variable. Hence achieving all aspects will be given the highest ranking (1), and correspondingly achieving any six or five aspects will be given the second rank (2), and achieving four or less aspects will be given the third rank (3).
The system to ensure achievement of quality objective (C23)	Have the organization guaranty system for example, the ISO 9002 or any other third party certificate system for quality guaranty Yes (2), No(1).
The quality management (C24)	The quality objective is high standard or not. The planning the quality score is 95% or above (3), medium level is 80% or above (2), low level is less than 80% (1).
Building types (C25)	Public –used buildings complex (1), industrial (2), commercial (3), residential (4).

Source: author

2.4 Chapter summary

This chapter addressed the research framework, i.e. dependent and independent variables of this study: KPIs and CSFs. It reviewed the literature and measurement in the practice and hence selected the KPIs and CSFs of this study. In the literature, the project success measurement evolved from traditional iron triangle to subjective and objective measurement. This study used KPIs to measure the project success with the consideration of international literature and China's practical measurement to project success, i.e. Luban Prize and Great wall prize criteria. Chan conducted a thorough literature review for seven major journals in construction field for determinants of construction project success and presented the term Critical Project Success Factor (CSFs) with respect to project success in the context of construction project (Chan and Chan, 2004). The determinants of project success were classified into two groups and seven sub groups. They were the non project management characteristics group and project management characteristics group.

Chapter 3 A Review of Case-Based Reasoning

3.1 Introduction

This chapter addresses the concept and application of Case-Based Reasoning (CBR). Reviewing the origin and the development of CBR as a branch of the Artificial Intelligence (AI) is for the purpose of introducing the concept of CBR with other AI techniques. The application of CBR is presented in two parts. First part is its general application and second part is its application in construction management and economics. The proposed CASE_PMP and all its components are discussed in the last section. The concept and application of CBR utilized by CASE_PMP is addressed and justification is provided.

3.2 Case-Based Reasoning concept

3.2.1 Artificial Intelligence and Case Based Reasoning

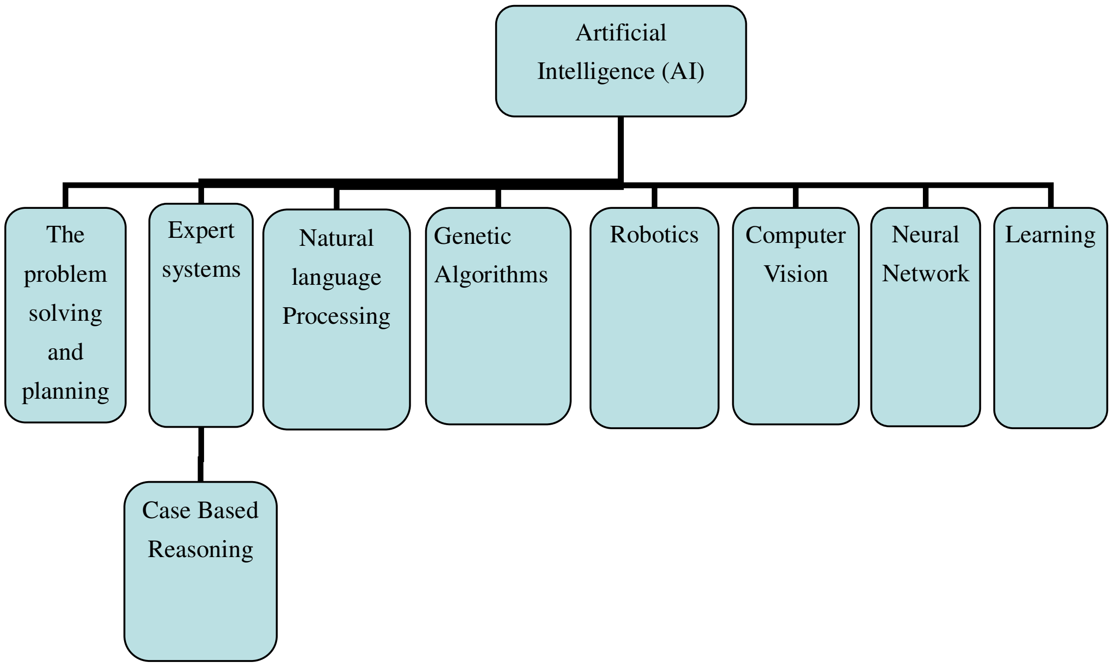
Artificial Intelligence (AI) is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable (McCarthy, 2004). The development that took place in the field of AI and related topics can be classified into eight specialized branches: the Problem Solving and Planning, Expert Systems, Natural Language Processing, Robotics, Computer Vision, Learning, Genetic Algorithms, Neural Network (Krishnamoorthy, 1996). Another description of the main topic of AI was that it includes knowledge representation, formalization of general reasoning machineries, diagnosis, planning, learning, search, vision and natural language system (Henri, 1998). In the early 1950s, Herbert Simon, Allen Newell and Cliff Shaw conducted experiments resulted in a program called Logic Theorist, which consisted of rules of already proved axioms in writing programs to imitate human thought processes. This was a major step in the development of AI. Newell, Shaw and Herbert developed a program called General

Problem Solver (GPS) in 1959 that could solve many types of problems. It was able to prove theorems, play chess and solve complex puzzles (Newell, et al., 1960, Newell et al.1963). Indeed, much research has been done in cognitive psychology to try to report the rules that human beings, especially experts, follow as a model of their thinking in various domains (Newell et al., 1958, Newell et al., 1972).

Some different views exist in the knowledge acquisition of AI field. Instead of developing the program using the rules, the earlier AI techniques, namely Rule-Based models, solve the problems not by generalizing rules but by a memory of stored cases recoding specific prior episode (Leake, 1996). New solutions are generated not by chaining of the rational rules, but by retrieving the most relevant cases from the memory and adapting them to fit the new situation. This idea is motivated by the cognitive science. There are five ways of knowledge acquisition, namely rational, emotional, subconscious, physical, and non conscious. No system consisting of simple rules will work in modelling the mind. A system of rules could be developed to model the conscious mind; modelling non conscious mind presents other problems (Schank, 1999). The basic unit of knowledge here was not rule but case (Slade, 1991). Case-based reasoning (CBR) viewed intelligence as depending upon knowledge that is not rationally known to the problem solver. CBR is not necessarily a conscious process. Since CBR depended on reminding, it has the same properties as the reminding process. Sometimes we are vividly reminded and other times we don't sense that we are reminded at all. (Schank, 1999).

CBR is now a mature sub field of artificial intelligence (Leake, 1996). The fundamental principles of CBR have been established and numerous applications have demonstrated its role as a useful technology. Recent progress has also revealed new opportunities and challenges for the field. Figure 3.1 shows the branches of the AI and the relationship of CBR with these branches.

Figure 3.1 Relationship of Branches of AI and CBR



Source: Krishnamoorthy, 1996

3.2.2 Case Based Reasoning Concept

The CBR works by recalling what has happened in the past in the similar situations rather than by projecting what would work in the future (Hammond, 1986). CBR provided many advantages to problem solving in a knowledge-based environment (Kolodner, 1993). It was a major paradigm in automated reasoning and machine learning. In CBR, a reasoner solves a new problem by noticing its similarity with one or several previously solved problems and by adapting their known solutions instead of working out a solution from scratch. In many aspects, CBR is a problem solving method different from other AI approaches. In particular, in addition to using general domain dependent heuristic knowledge like in the case of expert systems, it is able to use the specific knowledge, previously experienced, problem situations. Another important characteristic is that CBR implies incremental learning since a new experience is memorized and available for future problem solving each time a problem is solved.

CBR is a powerful and frequently used way of human problem solving. Results from cognitive psychology have shown its psychological plausibility (Ramon, 2001).

Aamodt and Plaz described a Case-Based Reasoning as a cyclic process comprising "the 4R's": Retrieve, Reuse, Revise and Retain (Aamodt and Plaza, 1994), that is:

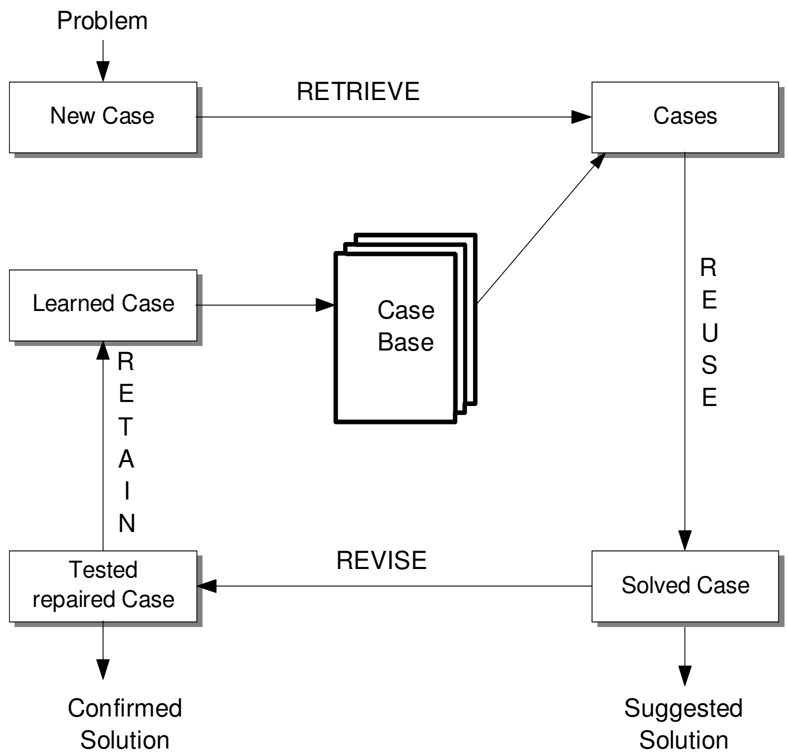
1. RETRIEVE the most similar previously experienced case or cases
2. REUSE the information and knowledge in the retrieved case(s) to solve the new problem
3. REVISE the solution
4. RETAIN the parts of this experience that are likely to be useful in the future by incorporating it into the case base.

More specifically, Ramon presented that the case based reasoning include four components (Ramon, 2001). They were index and retrieval system, memory organization, adaptation and evaluation, forget, integration with other techniques, and uncertainty, imprecision and incompleteness. The most basic problems in CBR are the retrieval and selection of cases since the remaining operations of adaptation and evaluation will succeed only if the past cases are the relevant ones. Another basic problem is that of memory organization. Good indexing is not enough when the case memory is large. Good organization of the memory is necessary because a simple linear organization, like a list, is very inefficient for retrieval purposes (Watson and Perera, 1997). The basic idea is to organize specific cases which share similar properties under a more general structure called 'generalized episode' (GE). A GE contained norms, cases and indices. Norms are features common to all cases, indexed under a GE, and indices are features which discriminate between cases of a GE.

A good adaptation of old cases to fit the new case can reduce significantly the amount of work needed to solve it (Hammond, 1986, Sycara, 1987). Even assuming that the basic problems of retrieval and indexing have been solved there is still an additional, somehow unexpected, problem resulting from an uncontrolled growth of the case memory which may result in the degradation of the performance of the system, as a direct consequence of the increased cost in accessing memory. Existing approaches to this problem included: storing new cases selectively (for example only when the existing cases in memory lead to a classification error) and deleting cases occasionally (Kibler and Aha, 1988), and incorporating a restricted expressiveness policy into the indexing scheme, by placing an upper bound on the size of a case that can be matched (Francis and Ram, 1993). In some application domains there is a need to combine CBR with other reasoning techniques such as model-based or rule-based reasoning. Some examples are: JULIA (Hinrichs, 1988), integrating CBR and constraints for design tasks; Karacapilidis et al integrated CBR and argumentation-based reasoning to address group decision making processes (Karacapilidis et al., 1997). Uncertainty, imprecision and incompleteness are problems that pervade the CBR reasoning process. Uncertainty and imprecision are presented in the semantics of abstract features used to index the cases, in the evaluation of the similarity measures computed across these features, in the determination of relevancy and saliency of similar cases, and in the modification rules used in the solution adaptation phase. Incompleteness is also presented in the partial domain theory used in indexing and retrieval, in the (usually) sparse coverage of the problem space by the existing cases, and in the description of the problem.

In Faltings's work (Faltings, 1997), the author used probability theory to model the uncertainty associated with the main assumption of CBR to similar problems corresponding similar solutions. He showed that even if that assumption was not met for particular instances, it was correct on the average. In Rodriguez's work (Rodriguez et al., 1997), the authors proposed a Bayesian network modelling for CBR. Their model uses two networks, one for ranking categories, and another for identifying exemplars within categories. This view leads to the notion of modelling similarities by conditional probabilities. Therefore it computed the probability of an exemplar given the features to classify a new case. Probability theory cannot however model imprecision easily. Fuzzy logic provides better techniques to deal with imprecision. Figure 3.2 depicts the process cycle of CBR from a well known authority and one of the founders of CBR technique (Aamodt and Plaza, 1994).

Figure 3.2 Process cycle of CBR



Source: Aamodt and Plaza , 1994

3.3 Case based reasoning applications

3.3.1 CBR General Applications

CBR has been applied to three aspects, problem-solving tasks; interpretive tasks; and as a retrieval tool to augment people's memories, aid in decision making, and teaching (Leake, 1996).

CBR has been applied to a wide variety of problem solving tasks, including planning, diagnosis, and design. In each of these tasks, cases are useful in both suggesting solutions and in warning of possible problems that might arise. In design, problems are defined as a set of constraints, and the problem solver is required to provide a concrete artifact that solved the constraint problem. Several problem solvers have been built to do case based design. CYCLOPS (Navinchandra, 1988) use case based reasoning for landscape design. KRITIK and KRITIK2 (Goel 1989, Goel and Chandrasekaran 1989; Stroulia et al. 1992) combined case based with model based reasoning for design of small mechanical and electrical devices. CBR can address many of these planning issues. PLEXUS (Alterman 1986, 1988) program that adapted knowledge about riding a subway to other tasks was able to do execution-time repairs by adapting and substituting semantically-similar steps for those that have failed. CHEF addressed the problem of anticipating difficulties before execution time by learning from the problematic experiences. TUCKER (Marks, Hammond, and Converse 1989) was an errand running program that keeps track of its pending goals and was able to take advantage of opportunities that arise that allow it to achieve goals earlier than expected. In diagnosis, a problem solver was given a set of symptoms and asked to explain them. PROTOS (Bareiss 1989a), which diagnosed hearing disorders, was designed to ensure that this happens in an efficient way. In PROTOS' domain, many of diagnoses manifested themselves in similar ways, and only subtle differences differentiate them. A novice was not aware of the subtle differences; experts were. PROTOS began as a novice, and when it made mistakes, a 'teacher' explained its mistake to it. As a result, PROTOS learned these subtle differences. As it does, it left difference pointers in its memory that allowed it to move easily from the obvious candidate diagnosis to the correct one.

Interpretive case based reasoning was used for tasks such as classifying a new situation in context, showing cause or demonstration of rightness of an argument, position, or solution, or predicting the effects of a solution. PROTOS provided an example. Rather than classifying new hearing disorders using necessary and sufficient conditions, PROTOS did classification by trying to find the closest matching case in its case base. Adversarial reasoning means making persuasive arguments to convince others that our positions are right. A program called HYPO (Ashley and Rissland 1987b, Ashley 1990) modelled the argumentation lawyers do.

HYPO not only determined which cases are most similar to its new situation, but it also used its cases to create cogent and coherent arguments in support of some position or other. HYPO's method for creating an argument in support of some position had several steps. The new situation was first analysed for relevant factors. Based on these factors, similar cases were retrieved. They were positioned with respect to the new situation. Some supported the situation and some went against it. Projection, the process of predicting the effects of a decision or plan, was an important part of the evaluative component of any planning or decision making scheme. For example, SCIED (Chandler 1994, Chandler and Kolodner 1993) used similar methods to help teachers make science activities work for their classrooms. SCIED is an application of projection.

Psychologists have found that people are comfortable using cases to make decisions (Ross 1989a, 1989b, Klein and Calderwood 1988, Read and Cesa 1991) but do not always remember the right ones. The computer was used as a retrieval tool to augment people' memories and to alleviate this problem. Teaching strategies and build teaching tools that teach based on good examples were also the applications of the CBR (Kolodner et al. 1996). If people were comfortable using examples to solve problems and knew how to do it well, then one of responsibilities as teachers might be to teach them the right example and effective ways to index them. The teaching methodology called problem based learning held much in common with CBR and is based on this notion. These above applications of the CBR embodied the extensive usage of this technique in various fields and industries and the latter part of this chapter will investigate the application of CBR in construction management and economics area.

3.3.2 CBR Applications in Construction Management and Economics Area

Recent research demonstrated the potential benefits of CBR in construction management and economics and its superior performance over other AI and traditional prediction techniques.

Further exploring CBR's capability in the construction management and economics domain was a worthwhile task because CBR applications are becoming popular in the fields of construction management and economics and civil engineering (Tah et, al., 1999). In Yau's study, the application of CBR in construction management area has been extensively reviewed and summarized. The author presented the various applications of the CBR in the life cycle of the construction project. For example, the risk analysis in the feasibility study, project design, cost and duration estimation in the conceptual planning stage, and selection the contractor's and bid price prediction and prepare the bidding document at the procurement and contracting stage, site layout, schedule generation and control, time and cost control, quality control, safety inspection, resource management, operation management, dismantle and rebuild management (Yau and Yang, 1998). This study presented the CBR application in construction management and economics in terms of the function of the CBR.

In the area of design there have been a number of CBR models developed, including: CASETOOL, a system for bridge design (Kumar and Krishnamoorthy, 1995) and BRIDGER, a system to aid the conceptual design of cable-stayed bridges (Reich and Fenves, 1995). Faltings et al. (Fatlings, 1997) and Shih (Shih, 1991) applied CBR to architectural design, and Flemming (Flemming, 1997) and Rivard et al.(Rivard et al., 1988) addressed building design issues.

In the area of planning, Tah et al. created CBRidge Planner to aid the planning of highway bridge projects (Tah et al., 1999). Another planning model, CasePlan was developed for scheduling and planning boiler erection by Dzeng and Tommelein (Dzeng and Tommelein, 1997). All of these CBR models and systems design or plan but do not predict. In the more recent past, CBR has been used successfully in prediction and estimation problems (Morcous, 1999).

Some examples of the few applications of CBR to prediction and estimation are Arditi and

Tokdemir to predict the outcome of construction litigation; Yau and Yang developed a model to estimate construction duration and costs of building construction projects (Arditi and Tokdemir 1999a,b; Yau and Yang 1998). Yau and Yang also proposed a CBR's application in the time and cost estimation of the construction project (Yau and Yang, 1998).

In the decision making area, Chua presented a case based reasoning approach in bid decision making (Chua et al., 2001). The objective of this system was to propose a bid markup level to the decision maker on the basis of past experience. Past bid cases were stored in the case base or case library. Factors that the decision maker considered to be significant determinants of the bid markup are built into the system as the domain knowledge. Another piece of work of Chua was a decision support system prototype for contract strategy formulation using the case-based reasoning approach. The prototype was called CB-Contract (Chua and Loh 2006). Beliz (Beliz, et al., 2006) proposed a case-based reasoning decision support tool which is constructed to demonstrate how experiences of competitors in international markets may be used by contractors, to support international market selection decisions. Two hundred and fifteen cases from the Turkish construction industry have been used to build the model, namely CBR-INT. The above four function areas in the construction management and economics signified the emerging use of CBR and the next section will introduce the CBR approach used in this study.

3.4 Proposed CASE_PMP system

3.4.1 Why CBR

Having reviewed the CBR concept and its applications in various areas especially in construction management and economics field, this study adopts CBR to establish the link between KPIs and CSFs. There are three reasons. Firstly, CBR is an advanced AI branch for quantitative model. Recent research demonstrated the potential benefits of CBR in construction management and economics and, in one study, its superior performance over other AI and traditional prediction techniques. Yau and Yang did an evaluation of CBR and other AI technologies, particularly rule based expert systems (ESs) and neural networks (NNs). ESs can be applied in experience-orientated and knowledge-intensive domains. ESs cannot learn and have extremely limited tolerance of incomplete input information when default values in the system are inadequate for the new problem. NNs are particularly appropriate for pattern-recognition problems but they are based on numerical computations designed to adjust neuron weights in the net, thereby limiting the input and output to purely numerical figures. In NNs, the knowledge base in a trained net is deemed a “black box,” since it is represented in a series of numerical vectors that can not be understood by human. Furthermore, NNs must have a large body of data sets for training, and their problem-solving structure is normally defined by varying the number of layers and number of layers and the number of neurons in each layer. In CBR, the knowledge base is represented by previous cases. Notably, if new cases are incorporated, the case base can be easily updated. CBR retrieve cases and ranks them on the basis of the user-defined similarity function. As long as the input information generally fits into the similarity function, CBR does it retrieval. Therefore CBR is more tolerant of incomplete information (Yau and Yang 1998). Arditi and Tokdemir developed a CBR model and neural networks for same problem solving and found that CBR model predicted the outcome of construction litigation more accurate than neural networks (Arditi and Tokdemir 1999b). In addition, CBR has the ability to harness limited data set to do self training and establish the weights of independent variables with higher accuracy compared with the other traditional model techniques such as regression (Leake, 1996).

Secondly, CBR has the ability to utilize existing data as cases (Hammond, 1986). It is a method of solving a current problem by analogising the solutions to previous similar problems. CBR can deal new projects to achieve success by analysing the Luban and Greatwall prize successful projects.

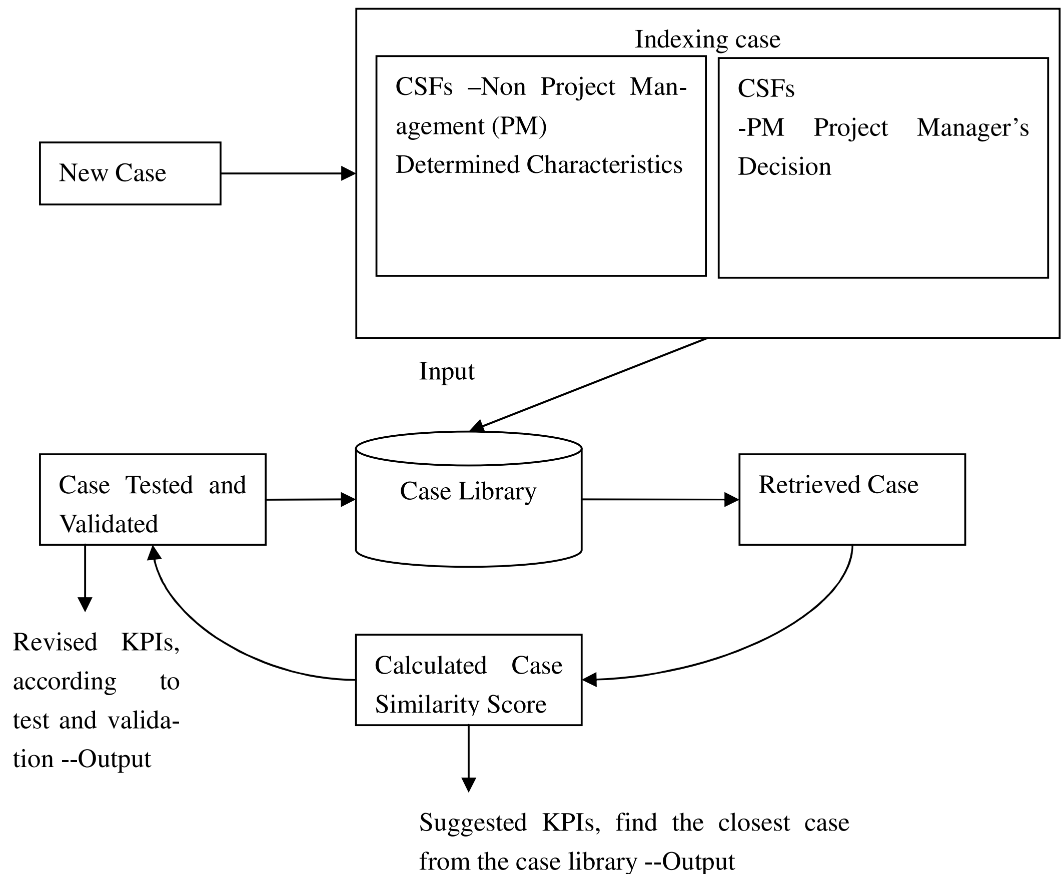
Thirdly, CBR has emerged as a popular method in the construction management and economics area. Applications of CBR to prediction and estimation are a model to estimate construction duration and costs of building construction projects (Arditi and Tokdemir 1999a,b; Yau and Yang 1998). It was proven in the literature for the feasibility to estimate and predict the project time and cost.

3.4.2 Framework of CASE_PMP

These past successful projects can bring successful project management experience into new projects. A case provides a way of projecting effects based on what has been true in the past. Cases with similar plans that were failures can point to potential plan problems. Cases with similar plans that were successful give credence to the current plan (Kolodner and Leake, 1993). The framework of the proposed system CASE_PMP is depicted in Figure 3.3. CASE_PMP principally derives the weights of the attributes (CSFs) and can serve the purpose of predicting the project success value based on the generated weights of CSFs. Adopting the method of CBR projecting effects, which is the process of predicting the effects of a decision or plan, is an important part of any planning or decision making scheme. When everything about a situation is known, projection is merely a process of running known inferences forward from a solution to see where they lead (Kolodner and Leake, 1993).

CASE_PMP builds the case base with those prestigious projects which have won Luban and Great Wall awards. As the interpretive CBR, CASE_PMP delivers its role to form the judgment about a new situation by comparing and contrasting it with cases that have already been classified (Ashley and Rissland, 1987a). The workflow of the CASE_PMP is to determine the attributes weights based on the case base, and retrieve the closest projects in the case base. With the adaptation module to the new case, CASE_PMP can estimate the project success values with the derived attribute weights of CSFs.

Figure 3.3 Framework of CASE_PMP



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3.4.3 Case Indexing

A case can be defined as a conceptualised piece of knowledge representing an experience that teaches a lesson fundamental to achieving the goals of the reasoner (Kolodner 1993). Case library is comprised by previous cases. One of the main concerns of CBR is index problem which ensure that the right cases can be recalled at the right time. Indexing problem has two aspects: one is the vocabulary problem that requires appropriate labels be assigned to the case so that it can be easily referenced in the case library during retrieval. The other problem is that of organizing the cases so that searching through the case library can be efficient and accurate

(Chua et al 2001).

3.4.3.1 Case attributes- index vocabulary

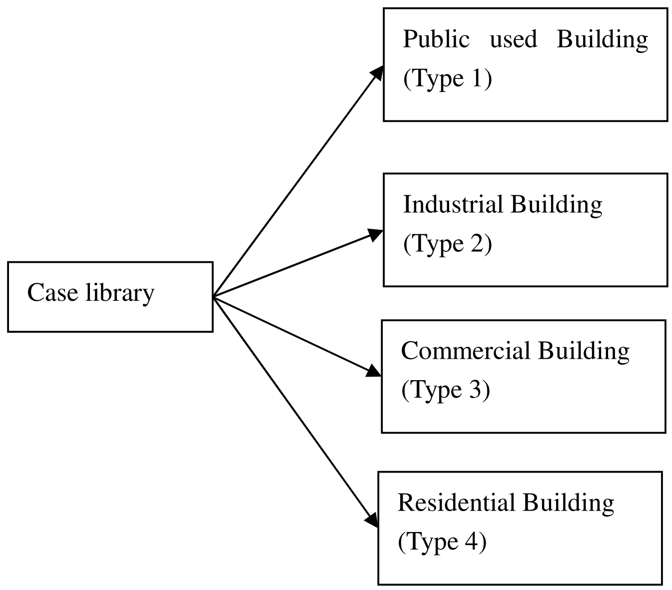
In order to recall the right case effectively, the index will comprise only the key determining factors. Too many indices, however, can impair the efficiency of the case-based reasoner. Any case vocabulary must be able to represent the specific and relevant features of a case. Twenty five key determinants of the project success factors (CSFs) and six significant indicators for the project success (KPIs) are the vocabularies of the case attributes. The accurate and valid definition of each attribute value will firstly recall the case precisely and secondly enhance effectiveness of the retrieval process. Complex value definition will aggravate the searching workload unnecessarily. Two scales of attribute are non-metric and metric measurement. For example, Client experience (C2), was measured as the number of similar building they had commissioned in the past. Those with no previous experience were given a low score. Those with some previous experience involved with one or two buildings were given a medium score, and those have considerable experience were given a high score. The literature definition of this attribute is valid but not complex.

3.4.3.2 Memory organization

In order to recall the right case efficiently, the organization of the cases is very important. There are actually two sets of attributes of the cases. In this study, cases are organized by the fundamental classification of the output of CBR:, i.e. KPIs. An indexing tree has been incorporated in the case structure to enhance the search in the case base.

The indexing tree corresponded to the most discriminating attribute with regard to the sub goal: project type. Cases deposited under each of the lower level represented very dissimilar situations from the other nodes at the same level. When a new situation was presented, the similarity search was confined only to each project type of the new case, instead of the entire case base. Effectively, the project type other than the new case was pruned away. Indexing tree can block the effect of project type which might reduce the similarity of cases significantly. In the present study, all cases were deposited under different project types.

Figure 3.4 Index tree on project types



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3.4.4 Case Retrieval

Case retrieval uses the process of calculating attribute and case similarity and to determine the weights of the attributes. Similar cases are retrieved from the case base on the basis of similarity value. The similarity value ranges from 0 to 1; a similarity value of 1 means exact matching and 0 means totally different. Case similarity value is the sum of the product of the attribute similarity value and weight of the entire attribute. There are three main approaches in indexing cases, namely nearest neighbour, inductive reasoning, and knowledge-guided indexing (Barletta 1991). Optimisation technique such as Generalized Reduced Gradient (GRG2) non-linear optimisation is used to find the weights of each input feature. The detailed calculation methods are given in Chapter Six.

3.4.5 Adaptation

When the case retrieval cannot find the closest case under certain accuracy requirement, the adaptation part of CBR will be the next step. The similarities and differences between new and prior cases are used to determine how the solution of the previous case can be adapted to fit the new situation. After determine the attribute weights, with the right way of describing a problem, similar problems have solutions that are usefully similar, easy to adapt to the new situation. In this study, when a new case comes in, it will go through a retrieval process to find the closest possible case. The retrieved case will be tested and validated by the author. And then it will be revised. The revised case will then be a new case to be adapted and incorporated into project library (case base).

3.5 Chapter Summary

This chapter addressed case based reasoning, its concepts and applications. The brief description of the Artificial Intelligence (AI) area was discussed. And as one of main topics of AI, principle definition of CBR, classification, reasoning and process were presented. The applications of CBR were generally presented as problem-solving tasks, interpretive tasks, and as a retrieval tool to augment people's memories, aid in decision making, and teaching. The application in the construction management and economics area were highlighted, the four applications, namely design, planning, prediction and estimation and decision making support. The latter part of this chapter presented the approach of CBR intended to be utilized in this study. The proposed system CASE_PMP was using one of branch of CBR, i.e. the interpretive CBR, and the projection effects of CBR. The framework of the CASE_PMP and the primary components of the CBR were discussed, such as case indexing, case retrieval and adaptation.

Chapter 4 Research Methodology

4.1 Introduction

This chapter describes the research method adopted in this study. The sampling relevant method is chosen and applied in this study. The sampling design and data collection are addressed. A research strategy is finally formulated, highlighting the different stages of research and the techniques to be applied in each stage.

4.2 Sampling method

4.2.1 Sampling Design

The Luban prize has been in existence for 20 years with hundred over projects in Beijing have won the award, and Great Wall prize has ten years history and over 3000 projects. It would be appropriate to merge the two prizes' projects as the population because they are similar accolades in regional level and national level. The total project number is 3998. According to statistical data sampling principles, the required minimized sample size is 94 projects with 95% confidence level and 10% limit of error and 50% response distribution rate. The formula is presented below (Hamburg, 1985).

$$x = Z(^{c}/_{100})^{2} r(100\text{-}r)$$
$$n = {}^{N\,x}/_{((N\text{-}1)E^{2} + x)}$$

N is the population size, r is the fraction of responses that the author is interested in, and Z(c/100) is the critical value for the confidence level c. For this study, Z(c/100) is 1.96. r is 50% so:

x =3.84×0.5×0.5=0.96

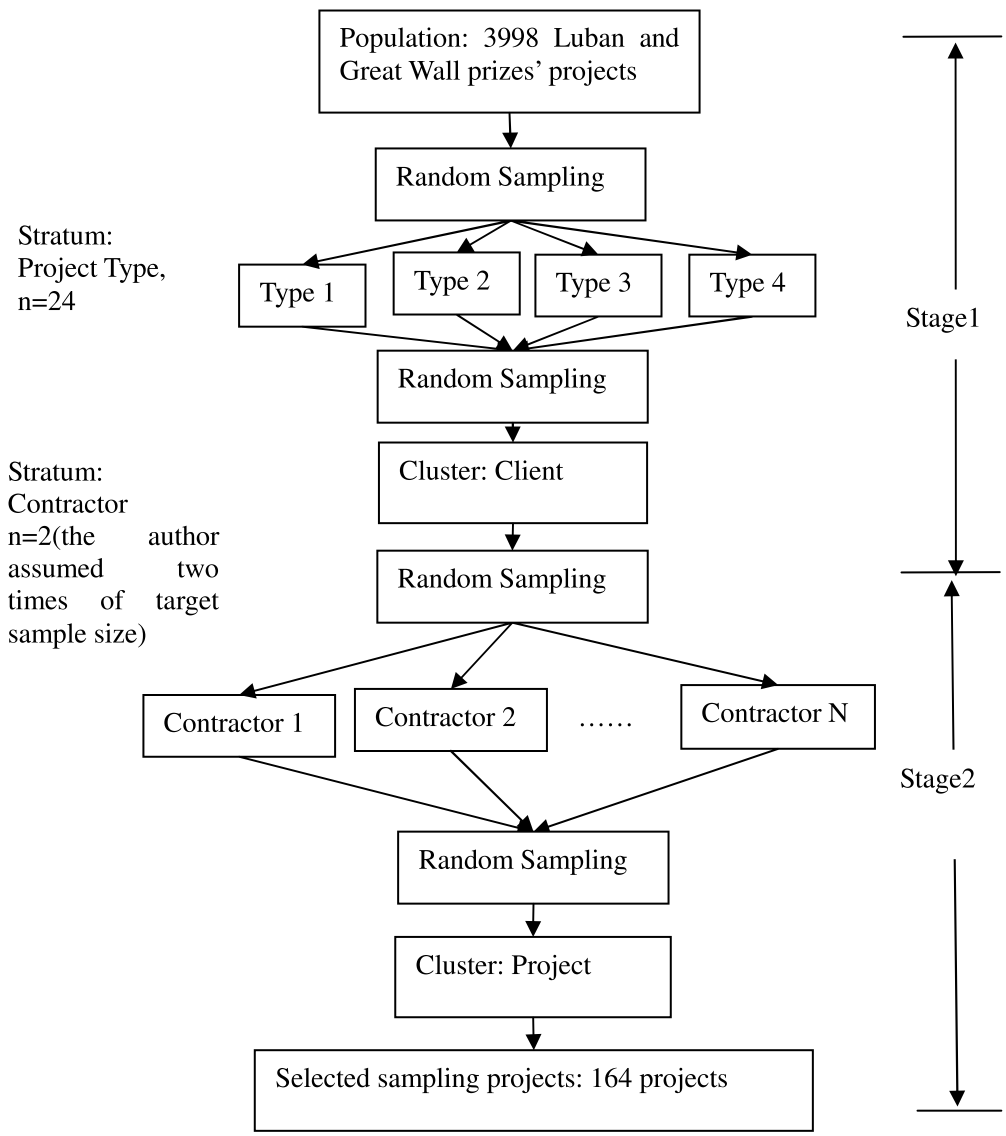
E is margin of error and is 10% here. So:

n=3998×0.96/(3997×0.01+0.96)=94

Four project types and 24 projects for each type are involved in this study. In consideration of some project data unavailability and non-response from some respondents, it is recommended to draw the sampling with more projects. Approximately two times of the minimized sample projects have been drawn.

With the well-defined target population, the list of projects can be downloaded from the website of Ministry of Construction (http://www.mohurd.gov.cn/zh/bzjl/lbj/) and Beijing Construction Quality Management Society (http://www.bjgczl.com.cn/linian.asp). The projects are listed by project name, project type, project participants (i.e. client, designer and contractors), and project year. The project list was presented in Microsoft Excel.

Figure 4.1 Sampling design diagram



Source: author

Two stages of sampling were adopted as shown in Figure 4.1. First stage was stratified by project type to ensure that each project type has sufficient number of projects and clustered by client and second stage was stratified by contractor and clustered by project name randomly. Clustering the project by client and project was because a finite population is cheap and convenient to draw a cluster sample. This study needs to approach the client and contractor for data collection because it is necessary to involve the relevant parties as not a single project participant would have all of the types of data the author intended to collect (i.e. 25 CSFs and 5 KPIs). A cluster sample of projects with client within the four project types involved considerably less effort to contact different clients, as opposed to a simple random sample of the same number of projects spread over many more clients.

Statistical software SPSS (Statistical Package for the Social Sciences) was used to assist in executing the two stage sampling design. Figure 4.2 demonstrates how the "Complex Samples" module of SPSS selected sample according to the designed two stage sampling plan. The relevant sampling elements were coded for the ease of using SPSS software to select samples. The project name was coded by Project ID (Proj_ID), project type (Proj_Type), main contractor (Con_ID) and client (Client_ID) Project is Luban or Great-Wall Prize (Proj_Prize). Project year (Proj_Year).

At the first stage, the sample was stratified by project type (Proj_Type) to ensure each project type has sufficient number of projects, 24 projects for each stratum (Proj_Type) and clustered by client (Client_ID) because this study needs to approach client as the start of data collection. After the author obtains the approval from the client, the author will proceed to collect data from the corresponding contractor of this project. The second stage was stratified by contractor (Con_ID) to ensure each contractor is approached with sufficient number of projects which get approval from the client. And the sample is clustered by Project ID (Proj_ID) because project is coded by completion year. In other words, for a contractor, a cluster sample of projects with project completion year involved considerably less effort, as opposed to a simple random sample of the same contractor's projects, which spread over twenty years of projects. As well known, project data may be out of date if it was completed 20 years ago. The drawn sampling projects must encompass more than 94 projects in consideration of the rejection of the respondents and/or unavailability of project data. So in the second stage, the unit applied to each stratum was two because the author assumes two times of 94 projects were selected. Totally 188 projects were listed to ensure 94 projects to be collected in the event of only half response rate. Figure 4.3 is the example of how the SPSS executed the designed sampling plan.

Figure 4.2 Complex Samples Module of SPSS

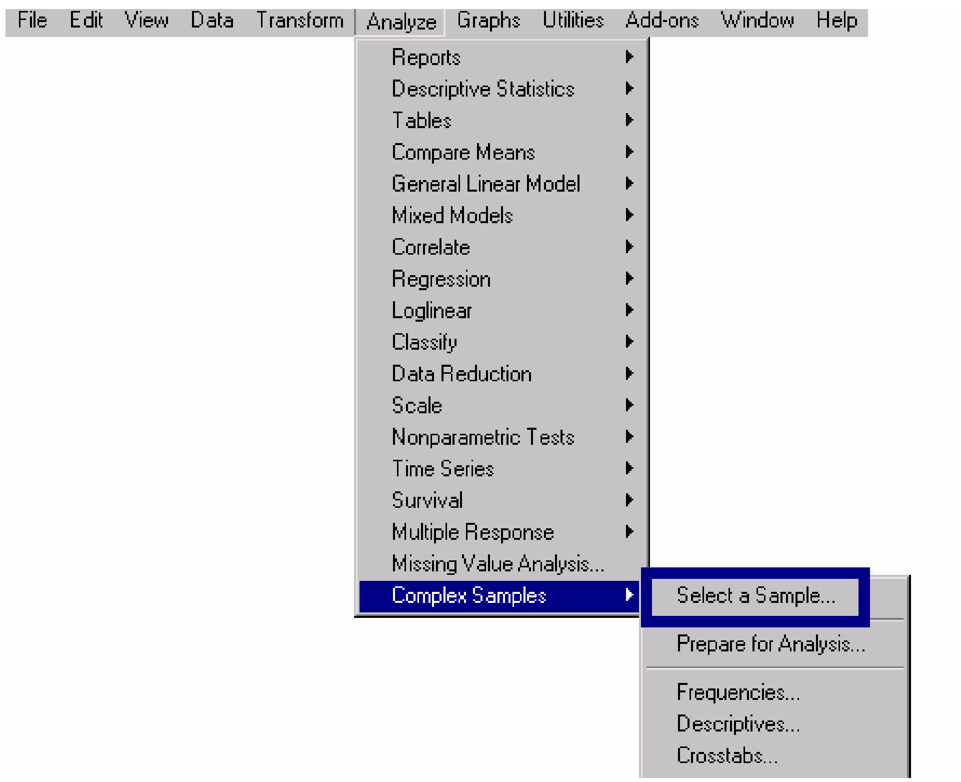


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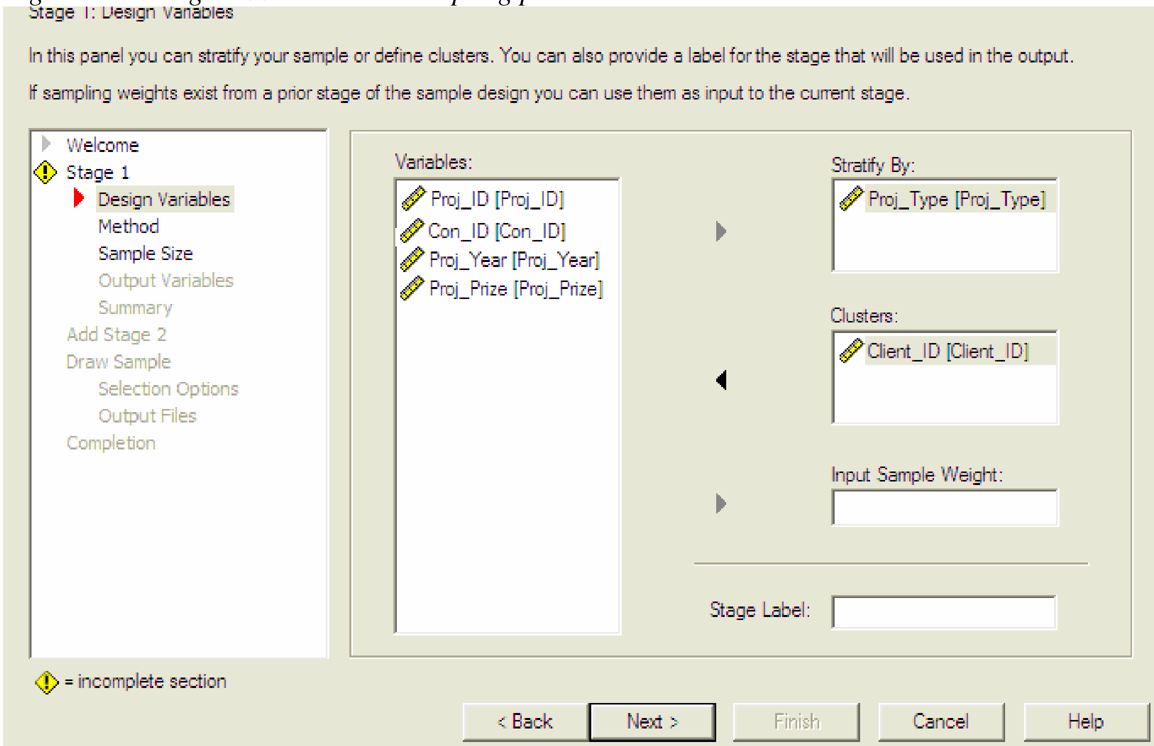
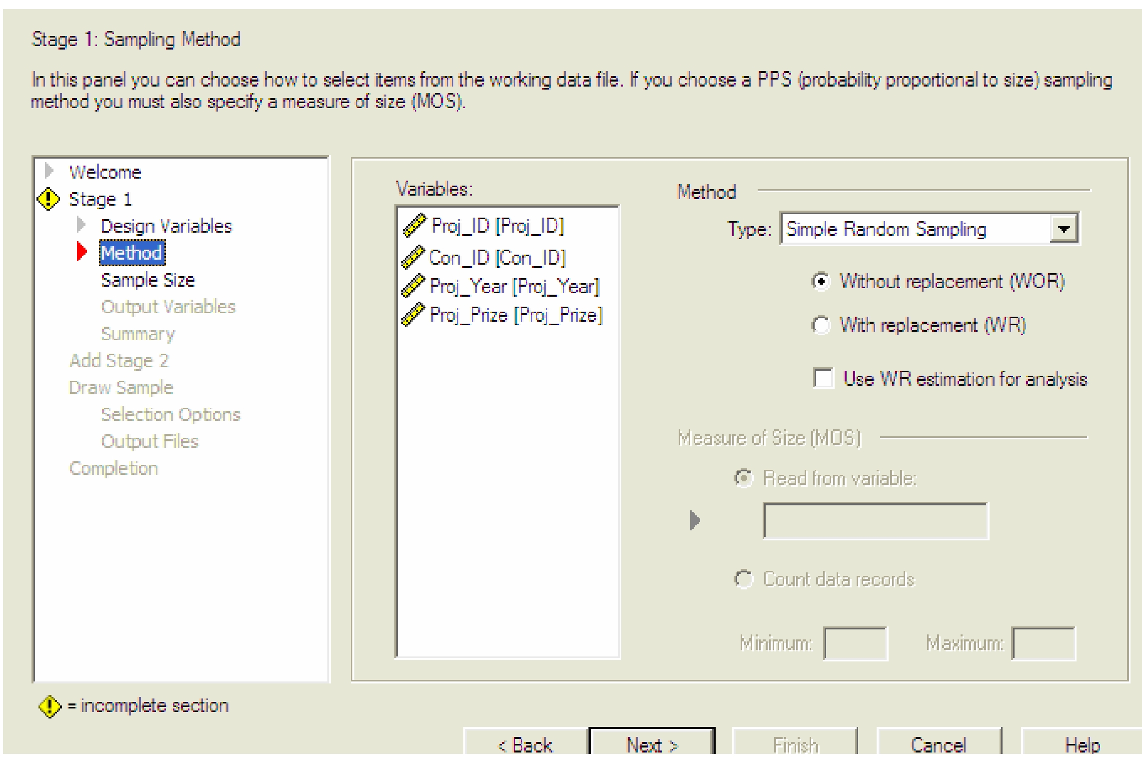
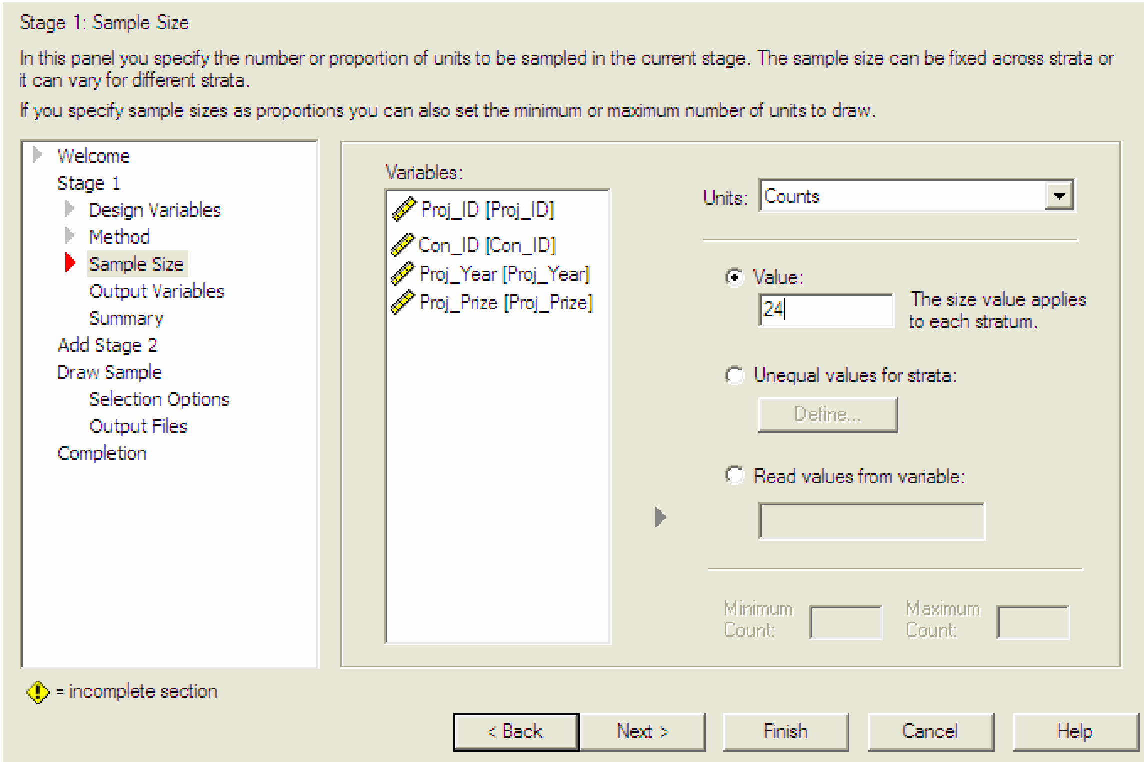
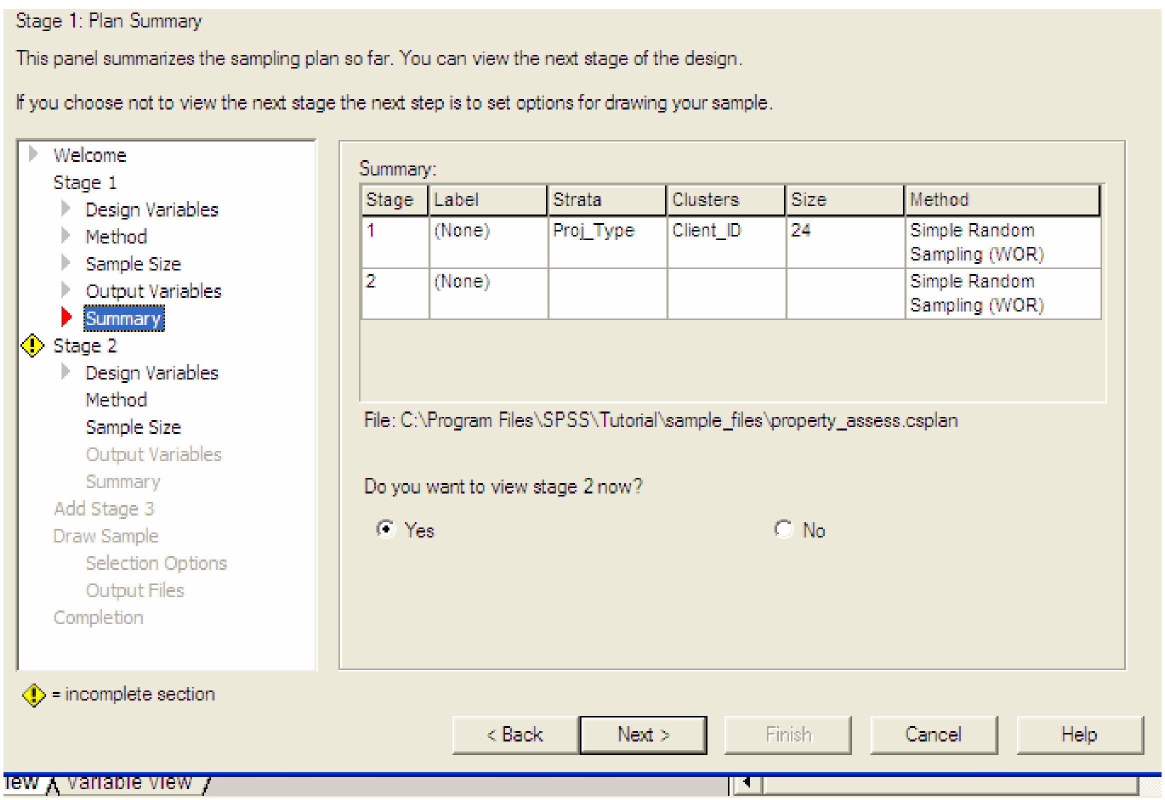
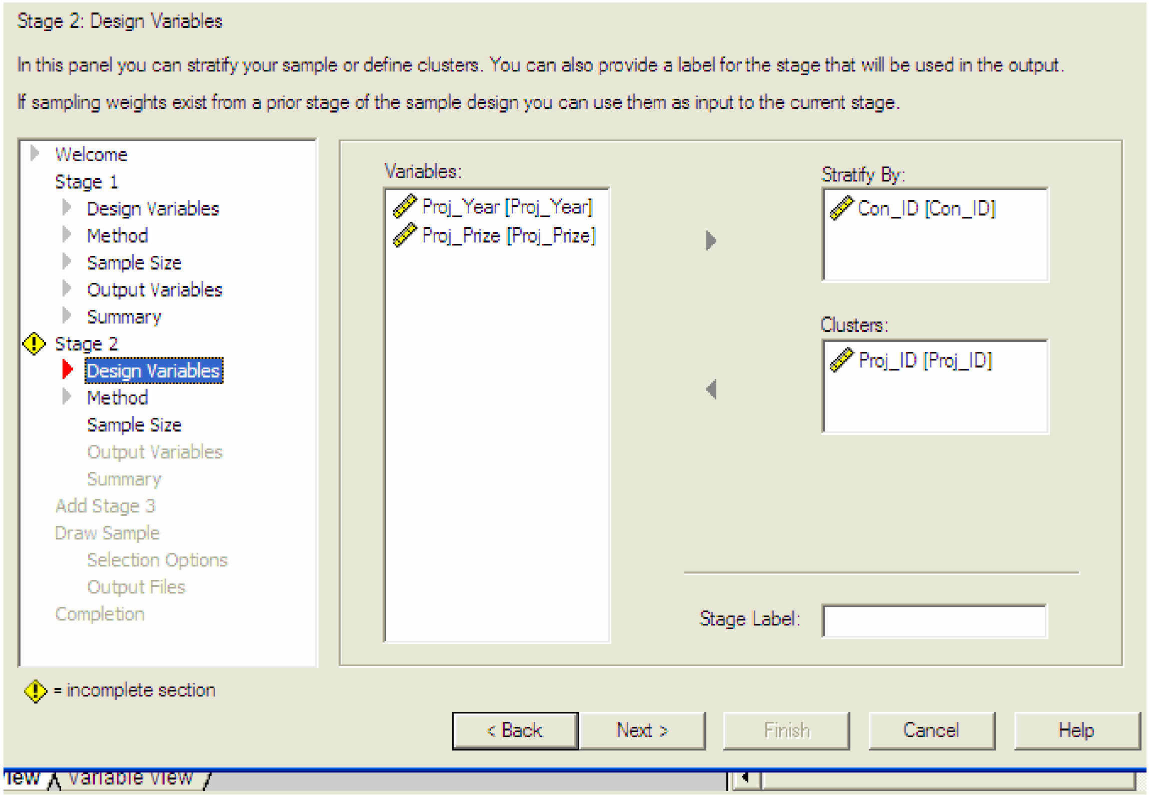
Figure 4.3 Using SPSS to execute sampling plan

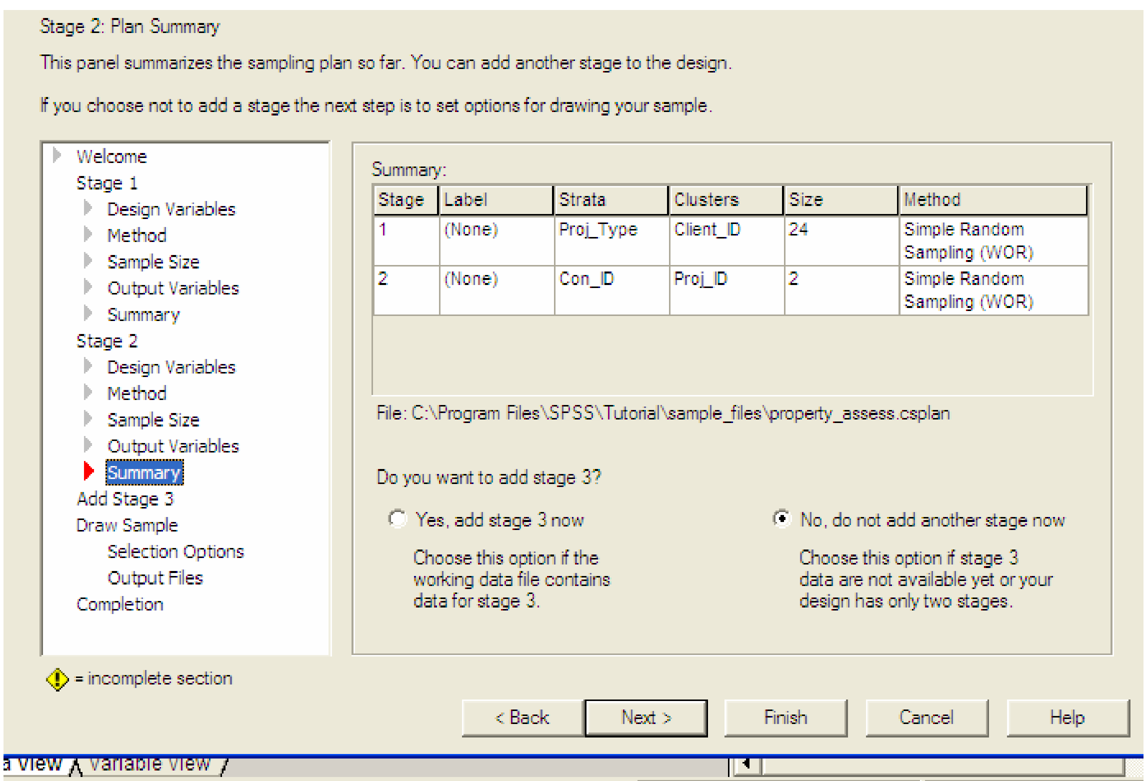





Stage 1: Sample Size
In this panel you specify the number or proportion of units to be sampled in the current stage. The sample size can be fixed across strata or it can vary for different strata.
If you specify sample sizes as proportions you can also set the minimum or maximum number of units to draw.
Welcome
Stage 1
Design Variables
Method
Sample Size
Output Variables
Summary
Add Stage 2
Draw Sample
Selection Options
Output Files
Completion
Variables:
Proj_ID [Proj_ID]
Con_ID [Con_ID]
Proj_Year [Proj_Year]
Proj_Prize [Proj_Prize]
Units:
Counts
Value:
24
The size value applies to each stratum.
Unequal values for strata:
Define...
Read values from variable:
Minimum Count:
Maximum Count:
= incomplete section
< Back
Next >
Finish
Cancel
Help


Stage 1: Plan Summary
This panel summarizes the sampling plan so far. You can view the next stage of the design.
If you choose not to view the next stage the next step is to set options for drawing your sample.
Welcome
Stage 1
Design Variables
Method
Sample Size
Output Variables
Summary
Stage 2
Design Variables
Method
Sample Size
Output Variables
Summary
Add Stage 3
Draw Sample
Selection Options
Output Files
Completion
Summary:
Stage | Label | Strata | Clusters | Size | Method
1 | (None) | Proj_Type | Client_ID | 24 | Simple Random Sampling (WOR)
2 | (None) | | | | Simple Random Sampling (WOR)
File: C:\Program Files\SPSS\Tutorial\sample_files\property_assess.csplan
Do you want to view stage 2 now?
Yes
No
= incomplete section
< Back
Next >
Finish
Cancel
Help
Variable View





Source: author

Figure 4.4 the selected sampling project lists

	Proj_ID	Con_ID	Client_ID	Year	Proj_Type	Award	InclusionProbability_1_	SampleWeightCumulative_1_	InclusionProbability_2_	SampleWeightCumulative_2_	SampleWeight_Final_
1	2697	24	512	2006	1	2	.	.	.	.	.
2	181	25	1162	1999	1	2	.	.	.	.	.
3	290	25	930	2001	1	2	.	.	.	.	.
4	2022	25	1166	2004	1	2	.	.	.	.	.
5	3080	25	1166	2006	1	2	.	.	.	.	.
6	3579	25	930	2007	1	2	.	.	.	.	.
7	3720	26	0	1997	1	1	.	.	.	.	.
8	2126	27	109	2004	1	2	.	.	.	.	.
9	2791	27	109	2006	1	2	.	.	.	.	.
0	3658	27	109	2007	1	2	.	.	.	.	.
1	798	32	175	2002	1	2	.	.	.	.	.
2	1144	35	1468	2003	1	2	.	.	.	.	.
3	2222	35	1666	2005	1	2	.	.	.	.	.
4	2291	35	1146	2005	1	2	.	.	.	.	.
5	2486	35	1866	2005	1	2	.	.	.	.	.
6	2754	35	926	2006	1	2	.	.	.	.	.
7	2756	35	308	2006	1	2	.	.	.	.	.
8	2759	35	171	2006	1	2	.	.	.	.	.
9	3026	35	172	2006	1	2	.03	30.54	1.00	30.54	30.54

Source: author

Table 4.1 The summary of the SPSS sampling output

			Stage 1	Stage 2
Design Variables	Stratification	1	Proj_Type	Con_ID
	Cluster	1	Client_ID	Proj_ID
Sample Information	Selection Method		Simple random sampling without replacement	Simple random sampling without replacement
	Number of Units Sampled		24	2
	Variables Created or Modified	Stagewise Inclusion (Selection) Probability	InclusionProbability_1_	InclusionProbability_2_
		Stagewise Cumulative Sample Weight	SampleWeightCumulative_1_	SampleWeightCumulative_2_
Analysis Information	Estimator Assumption		Equal probability sampling without replacement	Equal probability sampling without replacement
	Inclusion Probability		Obtained from variable InclusionProbability_1_	Obtained from variable InclusionProbability_2_

Source: author

The selected projects were marked in the project population list by adding “InclusionProbability_1”, “SampleWeightCumulative_1_”, “InclusionProbability_2”, “SampleWeightCumulative_2_” and “SampleWeight_Final_” in the row (like Proj_ID 3026) demonstrated in the Figure 4.4. Output was the summary of the sampling selection (i.e. how many projects were selected for each project type and proportion of the unit sampled etc). Figure 4.4 is the SPSS output for the selected projects. Table 4.1 is the summary of the SPSS sampling output.

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4.2.2 Data Collection Method

After the sampling project is selected, this study introduces the data collection method and develops the spreadsheet based CBR with the datasets. The model name is given as CASE_PMP.

The research utilizes the completed objective project data to identify the most important CSFs , as opposed to unstructured, semi-structured and structured interview and survey to identify the CSFs from the project participants or expert's subjective opinion. This study uses the derived weights of CSFs to identify the importance of CSFs by weights' ranking, as opposed to the subjective opinion to identify the importance of CSFs by mathematical or statistical model to conduct analysis and conclusion.

The uniqueness of construction projects makes each rich in opportunities for personnel and organizational learning (Ays, 1996; Keegan and Turner, 2001; Lundin and Midler, 1998). Generating the knowledge from previous projects will help personnel or organization to prevent similar mistakes and achieve project success (Tidd, et.al,1997). A valuable way to capture knowledge generated during the course of a project is to hold a post project review (PPR). This is a formal review of the project which examines the lessons learnt, and the review will be used to benefit future projects' (Lane, 2000). PPRs are also called post-mortems (Collier, et al.1996, Elhami, et al. 2000). Previous researchers adopted various methodologies to conduct PPR, ranging from retrieve the previous project record (i.e. the Microsoft project record and documentation) to unstructured, semi-structured and structured interview and survey (Elhami, et al. 2000, Andrew, 2005).

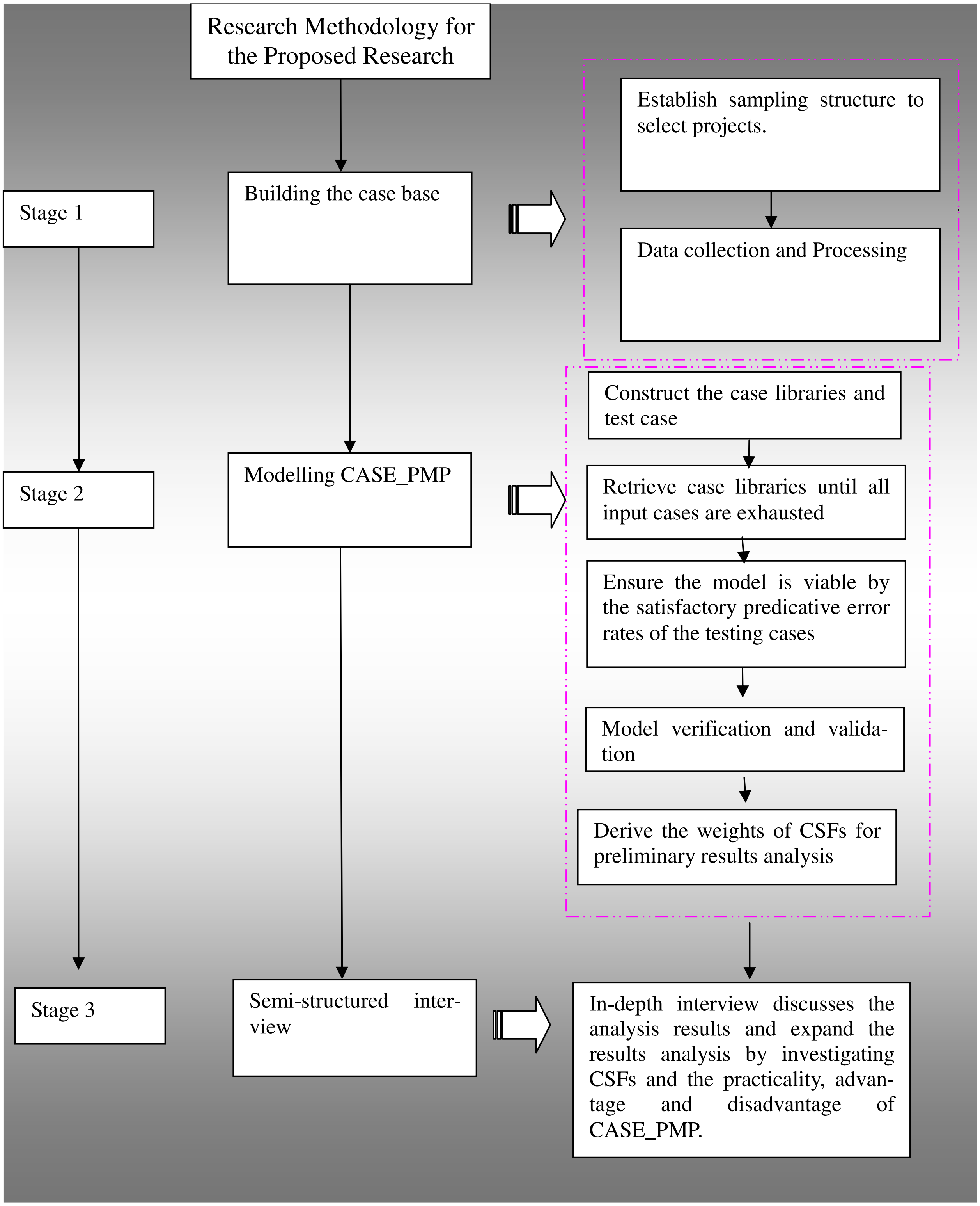
The sample of projects provided a robust and valid basis for testing the research hypothesis. Previous researchers' experience has indicated that it is extremely difficult to do questionnaire survey by mail in China (Liu et al. 2004). Therefore, the author conducted a field study and physically went to the project contractors and clients, and liaised with Beijing Construction Quality Management Society to obtain the project data. The details of data collection will be elaborated in the next chapter.

The data collection vehicle is the questionnaire. An example of the questionnaire which was completed by a respondent is appended in the Appendices (Appendix 3). The questionnaire contained the measurement and determinants of project success, namely KPIs and CSFs which has been discussed in Chapter 2. The questionnaire includes: 1. Introduction: encompassing the aims of the study, Luban/Great Wall Project name and year; 2. Client characteristics; 3. Designer characteristics; 4. Contractor characteristics; 5. Project characteristics; 6. Contract characteristics; 7. Others; 8. Project management CSFs; and 9. KPIs. The Chinese questionnaire (Appendix 4 is an example of a completed Chinese Questionnaire) is the translated version of English one and it was used to collect date in Beijing. The English version of the questionnaire is appended in Appendix 1.

4.3 Research Strategy

To accomplish the efficiency, i.e. completing research without wasting efforts, and to achieve effectiveness, i.e. achieving research purposes throughout the research process, a quantitative approach to answering the research questions is adopted. To achieve the overall objective, three separate, but sequentially related, stages of analysis are carried out as depicted in the following diagram (Figure 4.5). The first step is to establish the sampling method for data collection. The sampling projects data are collected. After the data collection, the project data is processed to satisfy the dataset requirement to build the CBR model. The second step is to build the CBR model and there are several steps to build the model. After the model is built, the model is tested by the test cases quantitatively. After verification and validation are conducted, the generated weights of the attributes are analysed as the preliminary discussion of results. In order to expand discussion of analysis results and explore CASE_PMP practicality, advantages and disadvantages, a semi-structured interview is done.

Fig 4.5 Flowchart showing the various stages in the proposed research design



Source: author

4.4 Chapter summary

In this chapter, the research methodology was discussed. Two stage statistical sampling was adopted. At the first stage, the sample was stratified by project type to ensure each project type has sufficient number of projects and clustered by client. The second stage was stratified by contractor and clustered by Project. In order to achieve research purpose, three stage research strategy was used. The first stage was to build the case library. The second stage was to build CASE_PMP model. This study adopted Case Based Reasoning (CBR) research as the quantitative analysis tool. Five steps were used to build CASE_PMP. And the third stage was to conduct the semi-structured interview for expanding the results analysis.

Chapter 5 Data Sources and Data Collection

5.1 Introduction

This chapter gives a brief introduction for the project data source, projects of China's construction industry's prize, Luban and Great Wall prizes. The projects from two prizes are selected as the data source and justifications are described by introducing the origin of the prizes, the organisation which establishes and awards these prizes, the winning criteria of these two prizes. A research decision is made to select Beijing. The detailed data collection process is described and the methods to deal with the missing data are presented.

5.2 Projects of Luban and Great Wall prizes as the data source

Two prizes' projects are chosen for this study, namely Luban prize and Great Wall prize. The prize origin, the organisation that set up the prize and the winning criteria are discussed to explain why this study selects projects of the two prizes as the data source.

5.2.1 Origin of prizes and awarding organisations

Luban Prize for Construction Project was established by the Construction Industry United Association of China in 1987. The main purpose of setting this prize is to encourage contractors in the industry to enhance the management of delivering the construction projects. And also encourage contractors to enhance the construction projects' quality and strive for the excellence for the completed construction projects. The ultimate objective is to promote project quality's improvement in China. It is a prestigious award in the industry. Initially non-government award, approximately twenty projects won this prize annually in China. The application for this prize should follow the well established and transparent procedure. The evaluation method is very rigorous and of high standards. The evaluation committee is organized to execute the evaluation with rigorous discipline. The committee is composed of distinguished officials and experts who are nominated by State Council of People's Republic of China and municipal authorities, such as the former Minister of Ministry of Construction, Tan Qinlian, the former Minister of Ministry of Transportation, Hu Xijie etc. The list of the expert's name can be found in website of Luban Prize introduction (http://www.gzpmc.org/modules/news/article.php?storyid=433). The vote of the experts for evaluation is anonymous. The committee is independent to the organisation which is responsible for the applications, the preliminary evaluations and post awarding checks. The involvement of two independent organisations ensures the reliability, credibility and fairness of this prize.

Because of the prestige of this prize and its substantial influence in the industry, Ministry of Construction of China, the sole government authority to oversee the construction industry in China, decided to present this prize as the government award. Ministry of Construction names the "Luban Prize for Construction Project" or "Luban prize" in short. The name contains two levels of honours, nationally high standard quality projects and high standard quality management projects. Luban prize is an annual award.

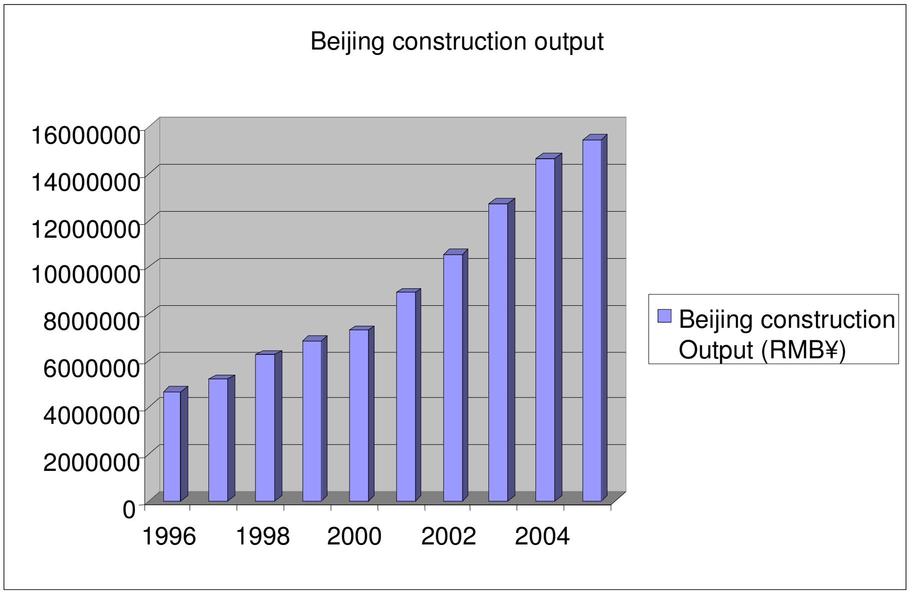
Great Wall prize is the municipal level award, equivalent to Luban Prize, in Beijing. Using the name Great Wall is of Beijing's city level. The same purpose as the Luban prize, Great Wall prize was awarded for the high quality and high standard management projects. Beijing Construction Quality Management Society and Beijing Construction Authority are responsible for the evaluation and awarding of this prize. These two organisations are the subsidiary and the corresponding organisation for Luban prize awarding organisations, Ministry of Construction of China and China Construction Industry Association. The successful projects which won Luban and Great Wall prizes are suitable project data for the study.

5.3 Selection of projects in Beijing

As explained in the earlier section of this chapter, Luban prize promulgated by Ministry of Construction of China represented the highest level construction projects awards in China. Thirty one regions have their own construction prize. Province, municipal city and autonomy region are China's political administration area. For example, Beijing, Shanghai, Tianjin and Chongqing are municipal city. Qinhai and Tibet are autonomy regions in China. And each region has municipal level prize. For example, the municipal level prize in Beijing is named Great Wall prize. A research decision was made to focus on cities that have high GDP and a rapidly growing construction industry. Among these cities which have the prestigious construction award, Beijing was chosen because: Firstly, it is China's economically developed area. Geographically, there are six regions in China, named North China (Hua Bei), Eastern North China (Dong Bei), East China (Hua Dong), South China (Hua Nan), Southern East (Xi Nan), Western North (Xi Bei). Among these regions, there are three economically developed regions, North China (Hua Bei), East China (Hua Dong), and South China (Hua Nan). The GDP of these three regions contributed to 76.0% GDP of whole country in 1997 and keeps increasing over the years. In 2005, reaches 78.4 %(Source: National Statistical Bureau, 2008). This study focuses on the urban cities of these regions because China is a developing country where most areas of this country are rural places. The illiteracy rate of these rural areas is relatively high where most construction works lack governmental supervision. Choosing these rural places to conduct research is very difficult due to the scarcity of official and credible data source. Therefore, the research delimits the scope to the cities in these three economically developed regions. There are five major cities in these areas, namely, Beijing, Tianjin, Shanghai, Guangzhou, Shenzhen. And amongst them, Beijing was chosen because she is the capital of China which has a population of more than 8 million. It is the political centre of China where the government control is highly effective.

Secondly, Beijing has a rapidly growing construction industry, from 1996 to 2005, Beijing's construction industry's output increased almost 4 times over 10 years (National statistical Bureau, 2008). Figure 5.1 depicts the Beijing's construction output over the years.

Figure 5.1 Beijing's construction output over the years



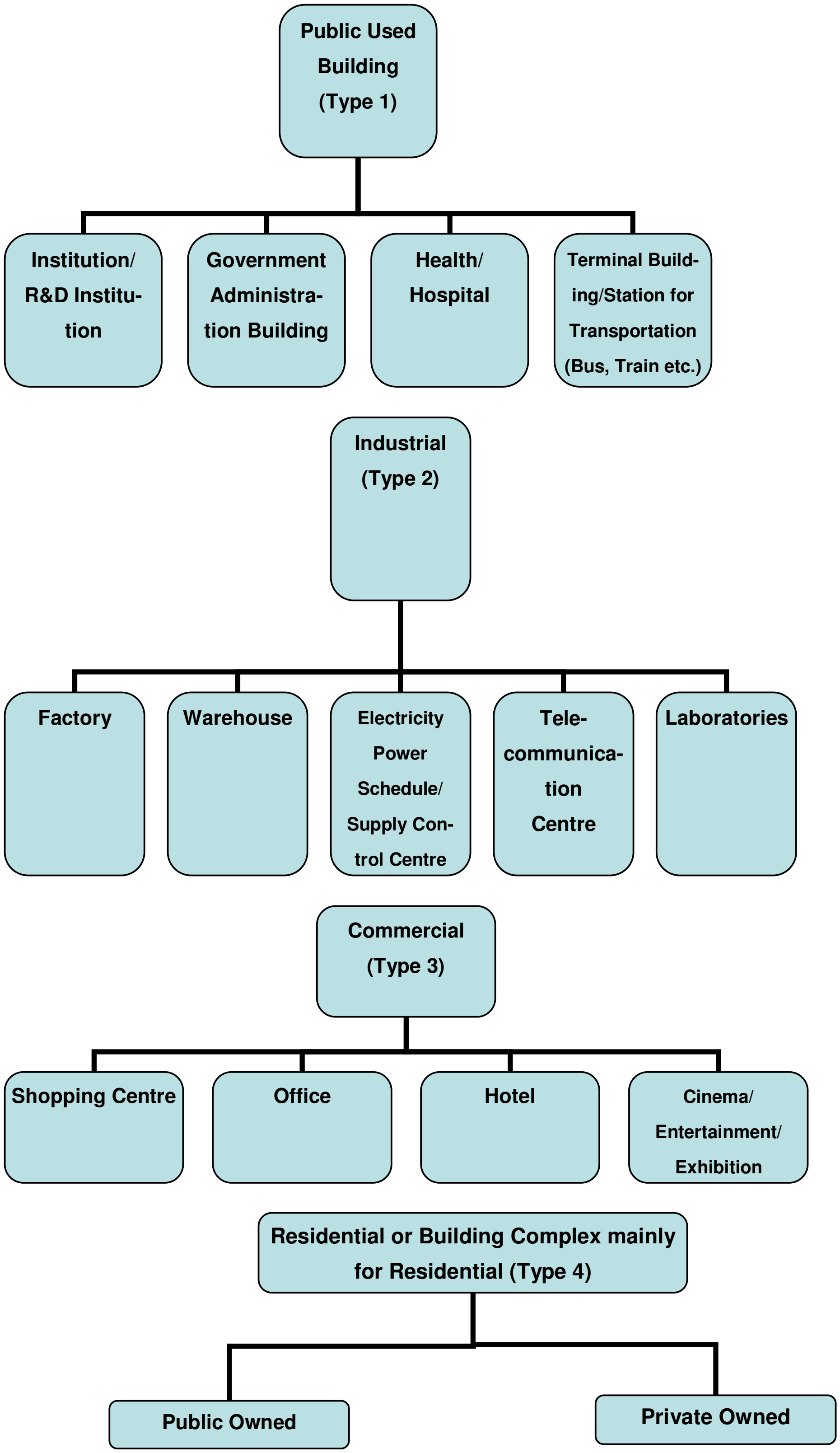
Source: National Statistical Bureau China

Thirdly, the construction projects in Beijing are the better representation of the high quality level of construction works in China than other regions. In 1996, Beijing had won Luban award with 11 projects out of 101 projects of China. The percentage of Beijing won projects in whole China varied from 1996 to 2006, the highest percentage was 13% in 2001, and the lowest percentage was 6% in 2004. However geographical area of Beijing only contributed to 0.10% of whole China but it has contributed 6% to 13% of prize award in China. There were sufficient projects in Beijing to be used for this study.

Therefore, this study selects projects that have been awarded the Luban prize and Great Wall prize. The project type for these awards is industrial, commercial, transportation, hydropower, public urban facility and landscape, residential project (Appendix 2 is project type classification of Luban and Great Wall prizes).

Building projects normally contribute to half of the total projects. This study focused on the building projects. According to a grouping of building projects by need or use, this study re-classified the building type as shown in the Figure 5.2. Four types of projects include public used building (Type 1), industrial (Type 2), commercial (Type 3), and residential (Type 4).

Figure 5.2 Building classification (project type)



Source: author

5.4 Data Collection

When forming a case base for the CBR approach, accumulating actual project is the most difficult task. In order to find a robust and valid basis for testing the research hypothesis, this study selected the sample of projects which won Luban and Great Wall prizes. The author physically went to the project contractors and clients, also liaised with Beijing Construction Quality Management Society to obtain the project data.

Based on the selected sampling projects discussed in Chapter 4, the relevant parties, i.e. client and contractor have been approached for the project data (i.e. 25 CSFs and 6 KPIs). The project lists of the selected projects whereby their data have been collected are highlighted in the cell) (Appendix 3). This study has received 64% response rate out of 188 projects. Hundred and four projects data have been collected. (27 projects of Type 1, 24 projects for Type 2, 24 projects for Type 3, 29 projects for Type 4).

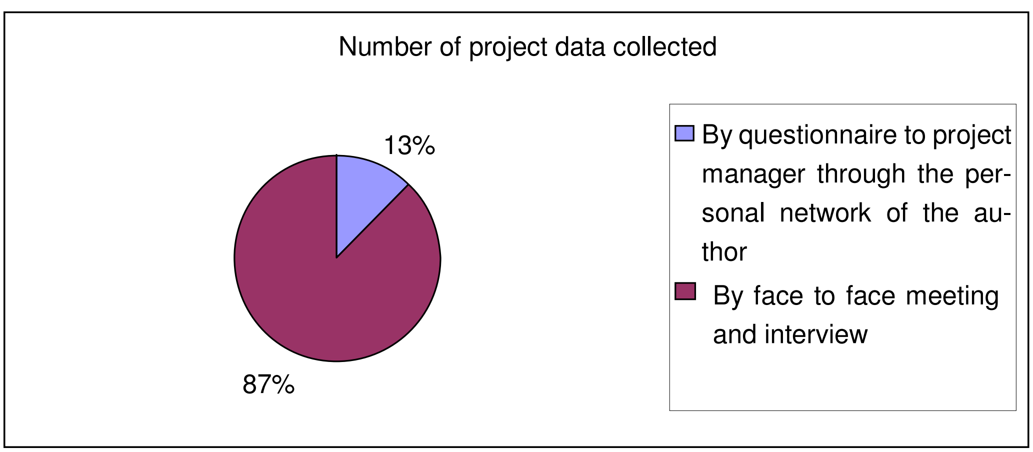
In order to achieve a positive response, two parallel data collection approaches are employed. The first one is to do survey using the questionnaire (Appendix 1) through the personal networking. The author has obtained the contact information of the project managers which have been awarded the MPM (Master of Project Manager) in the tertiary institution where the author studied undergraduate degree. The questionnaires were distributed to those project managers of the sampling selected projects to fill in the questionnaires. (Appendix 4 is an example of a completed survey questionnaire). Thirteen projects response were collected through email.

Another approach is to get the contact information of the contractors in Beijing Yellow Page (Directory of Beijing Companies). Phone call and face to face meeting have been arranged to collect the project data. The author has approached Quality Departments in these contractors who are responsible for applying for the Luban and Great Wall prizes. The Quality Departments have provided the application form (Appendix 5 is an example of the Luban and Great Wall application form) to the author. The application form contains information such as project participant introduction, project introduction, construction time, cost information and quality score. The questionnaire items: non project management CSFs (C1-C6) and some KPIs (K1-K5) were extracted from the application form.

The remaining information collected by the author during follow-up interviews with the project manager of these projects was for the project management CSFs (C7). And the client satisfaction information can be found in the project survey form to client, which is standard documentation for Luban and Great Wall projects. Few projects lacking of client satisfaction information, Client satisfaction (K6) are collected from the clients directly.

In addition, the author had been to Beijing Construction Quality Management Society to explain the research aims and obtained their support to recommend to clients and contractors who have initially refused to response. And finally the author has obtained a satisfactory response rate for this study. Majority project data (91 projects) were collected by the second method. Figure 5.3 shows the percentage of project data collected by two methods.

Figure 5.3 The number of the project data collected by the two approaches



Source: author

5.5 Dealing with Missing Data

Missing data arise because of the unavailable data. There are various ways to deal with missing data. The missing value can be input with the sample mean, however, if the data range is vast and data is scattered; it may decrease the data quality very much (Tan, 2004). There are some other ways, for example based on the previous knowledge (Tan, 2004).

Two projects' unit cost KPI (K2) was missing. The solution is to find the data from the previous knowledge. Many published cost information can be used to input the missing value. Utilizing the historical cost data published by cost information provide, this study attempted to maximize the accuracy of the data. Rider Levett Bucknall (RLB), which is a global professional cost information provider operating from countries across Americas, Asia, Oceania, Europe, Middle East and Africa in the property and construction industry, is selected to input the miss cost value.

Two projects' labour and the material input values (C19-20) have missing value. The data range is not so vast therefore the missing value can be input with the sample mean.

Table 5.1 shows the missing data treatment strategy. Table 5.2 is an example of the cost information provided by RLB in the fourth quarter (Q1) of the year 2001 in Beijing, China (http://www.asia.rlb.com/hongkong/cost_data.html). For example, for one project (Project ID is 3516), the miss cost value uses office Q4 2001 RBL data (mid value of office with high quality) because it is a high end office project.

Table 5.1 Missing data treatment strategy

Missing data type	Project No.	Strategy to deal with missing data
Missing data range is vast: i.e. project cost (K2)	Proj.3516; 3256	Replace with the previous knowledge, which is published historical project cost benchmark of similar projects
Missing data range is not vast: i.e. labour input(C19),material input(C20)	Proj.2013, 2747	Replace with the same project type sample mean

Source: author

Table 5.2: An example of the cost information in 4^{st} Quarter in 2001 in Beijing, China

Type of Building	Hong Kong HK$	Macau MOP	Beijing RMB	Chengdu RMB
Office				
High Quality	12,500 - 16,700	12,000 - 16,500	6,000 - 8,800	5,100 - 7,500
Medium Quality	10,800 - 12,600	10,100 - 12,300	4,500 - 6,200	3,850 - 5,300
Ordinary Quality	9,300 - 11,300	8,100 - 10,500	3,300 - 4,400	2,800 - 3,750
Shopping Centre				
High Quality	17,100 - 20,300	16,500 - 20,800	6,700 - 10,100	5,700 - 8,600
Medium Quality	13,300 - 15,800	N/A	5,200 - 6,600	4,450 - 5,600
Residential				
High Rise; High Quality	11,000 - 13,700	8,400 - 13,300	3,300 - 4,500	2,800 - 3,850
High Rise; Better Quality	9,400 - 11,200	6,800 - 9,100	2,800 - 3,300	2,400 - 2,800
High Rise; Ordinary Quality	8,000 - 9,500	5,800 - 7,100	1,600 - 2,400	1,350 - 2,050
House; High Quality	18,200 - 21,400	N/A	3,800 - 5,100	3,250 - 4,350
House; Medium Quality	13,500 - 17,000	N/A	2,400 - 3,100	2,050 - 2,650
Hotel (including FF&E)				
5-Star	19,100 - 23,200	19,100 - 23,400	10,000 - 12,800	8,500 - 10,900
3-Star	15,500 - 17,900	15,300 - 18,200	7,300 - 9,200	6,200 - 7,800
Industrial				
Landlord; High Rise	5,700 - 6,600	N/A	1,900 - 2,700	1,600 - 2,300

Source: RLB website

5.6 Chapter summary

This chapter discussed the origin of the Luban and Great Wall prizes, the organisation which established and awarded these prizes, the winning criteria of these two prizes. As the capital of China, Beijing was chosen as the research domain and the projects which won Luban prize and Great Wall prize were utilized in this research to investigate the relationship of the critical project success factors (CSFs) and project success indicator (KPIs). Then this chapter addressed the detailed data collection and processing for missing data. Next chapter will focus on the modelling and data analysis.

Chapter 6 Data Analysis and Modelling

6.1 Introduction

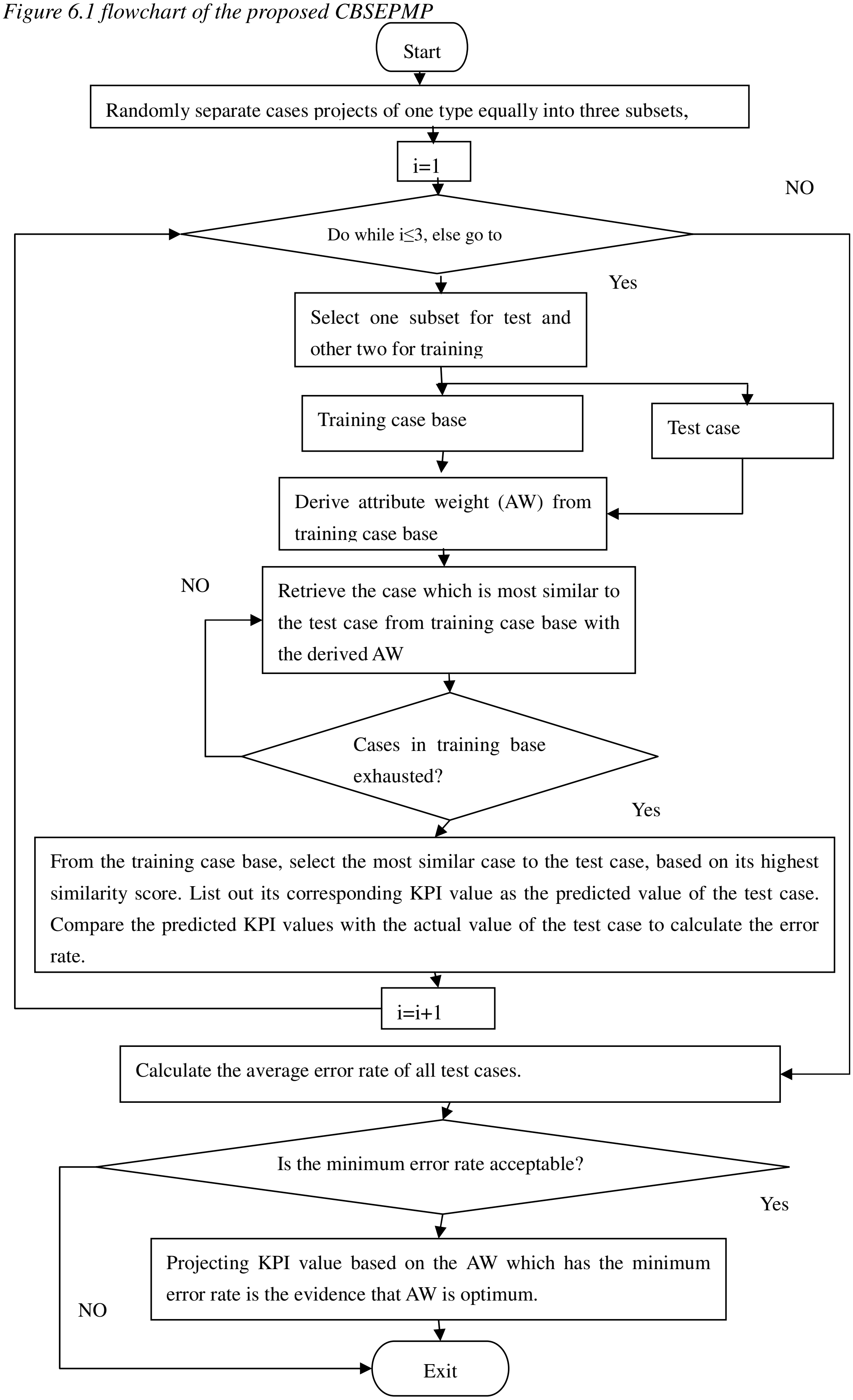
This chapter describes the procedures on how to build the spreadsheet-based CBR model in Microsoft Excel by using the collected project data pertaining to the four types of buildings. Four types of projects are modelled separately. Generalized Reduced Gradient (GRG2) non-linear optimisation is used in generating the attribute weights. The model performance is assessed in terms of predictive accuracy. That is, the predicted values are compared with the actual observed values to verify the predictive efficacy of the model.

6.2 Modelling flowchart of model CASE_PMP

Four types of projects are modelled separately. For example, 27 projects of Type 1 are randomly and equally divided into three subsets, two of which are used for training and the other one is used for testing. The algorithm repeats three times until every project has gone through the training and testing. The use of the three-way cross-validation with three randomly selected groups containing equal number of projects is suggested to test weights for internal validity.

The following diagram portrays the modelling flowchart of the proposed CASE_PMP.

Figure 6.1 flowchart of the proposed CBSEPMP



Source: author

6.3 Format the data structure

The data were organized in the form of two matrices such as those presented in Figure 6.2, one for the test cases and one for the input cases (training cases). Organizing the 27 projects for Type one in the case libraries, they were divided equally into three subsets. 18 projects were arranged as the input cases and 9 projects can be designated as test cases. The input and test cases were represented in rows and the input attributes (CSFs) were represented in columns. The attributes were the 25 CSFs as input and 6 KPIs as the output in the spreadsheet format. The output value (KPIs) was placed in a column next to the input attributes. The values of the attributes for each test and input case were represented, respectively, by I_{ik} and I'_{jk} (where I_{ik} represented the value of the attribute (CSFs) k (k=1,2, . . . , p, P=25 here) for test case i (i=1,2, . . . ,m, m=9 here), and I'_{jk} represented the same type of information for input cases j (j=1,2, . . . ,n, n=18 here). The weights of the attributes W_k (k=1, 2, . . . , p p=25 here) were located at the top of the matrix in a row that corresponded to individual attributes. The value of output was represented by O_{is} and O'_{js} (s=1, 2, . . . , q q=6 here). After formatting, semantic information was added to the data in the form of numerical and textual attribute values.

Figure 6.2 Formatting data to a case spreadsheet

1	A	B	C	D	...	X	Y		AE
2	Weights	w_1	w_2	w_3	...	w_p	0		0
3	Case No.	TEST CASEBASE Attributes					Output Attribute		
4		1	2	3	...	p			
5	Case 1	I_{11}	I_{12}	I_{13}	...	I_{1p}	O_{11}	...	O_{1q}
6	Case 2	I_{21}	I_{22}	I_{23}	...	⋮	O_{21}		O_{2q}
7	⋮	⋮					⋮	⋮	⋮
8	Case m	I_{m1}	I_{m2}	I_{m3}	...	I_{mp}	O_{m1}		O_{mq}
9								...	
10	Case No.	INPUT CASEBASE Attributes					Output Attribute		
11		1	2	3	...	p			
12	Case 1	I'_{11}	I'_{12}	I'_{13}	...	I'_{1p}	O'_{11}	...	O'_{1q}
13	Case 2	I'_{21}	I'_{22}	I'_{23}	...	⋮	O'_{21}		O_{2q}
14	⋮	⋮					⋮	⋮	⋮
15									
16	Case n	I'_{n1}	I'_{n2}	I'_{n3}	...	I'_{np}	O'_{n1}	...	O'_{nq}
17									

Source: author

6.4 Calculating Attribute Similarities

Attribute similarity functions were used to define how similar the attribute values were to each other. Attribute similarities were computed with respect to each test case versus every case retrieved from the input case base. Examples of textual and numerical similarity calculations were presented as follows.

Attribute similarity was denoted by S_{ijk} where i=test case (i=1,2, . . . ,m), j=input case (j=1,2, . . . ,n), and k=attribute (k=1,2, . . . , p). Assuming that the value of the first attribute for the first test case I_{11} was textual, its similarity with the attribute value I'_{11} was established as follows:

If text in I_{11} appears to be exactly the same as text in I'_{11}, then similarity S_{111} = 1, or else similarity = 0.

Assuming that the value of the third attribute for the first test case was numerical, its similarity for attribute value was established as follows:

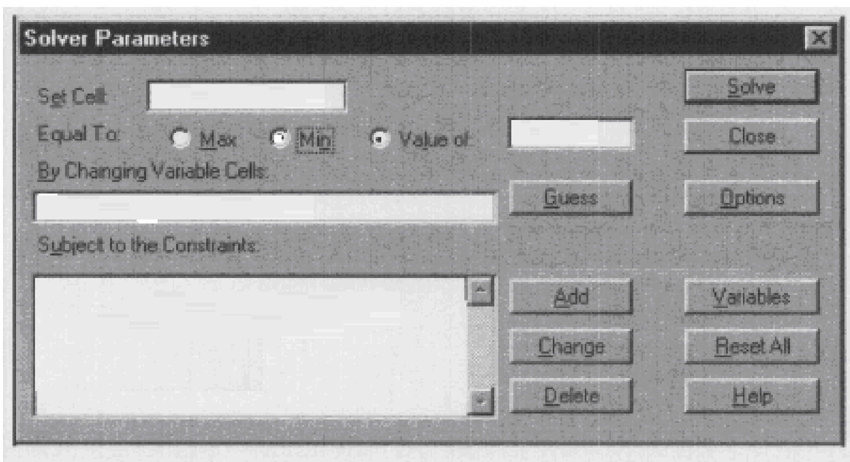
$$S_{113} = \frac{\min(|I_{13}|,|I'_{13}|)}{\max(|I_{13}|,|I'_{13}|)}.$$

6.5 Establishing attribute weights

After all the attribute similarity values were calculated in ($n \times p$) matrices, once for each test case, the next step was to construct the weight vector that will be used in computing case similarities. Weights assign a value of importance to each attribute. In general, retrieval of the most relevant case was determined by the presence of a greater number of higher priority (more important) attributes matching between the test case and the retrieved case.

This study employed the "Generalized Reduced Gradient (GRG2) non-linear optimisation" to calculate the weights of the attribute. GRG 2 was developed by Leon Lasdon, University of Texas at Austin, and Allan Waren, Cleveland State University. In order to use GRG2 to generate weights, one of the cases in the input case base was removed and called an "evaluation case." The similarities between the attributes of the evaluation case and the corresponding attributes of the remaining cases were calculated. Given the start-up assumption that attributes have equal importance, case similarities (CS) were derived between the evaluation cases versus the remaining input cases by taking the average of all attribute similarities. The relationship that governed the similarity of the input case that has an output that is closest to the output of the evaluation case was plugged into the GRG2 algorithm "Solver" for maximization (for taking it closer to 1). The Solver optimisation screen was shown in Figure 6.3 with the adjustable cells containing the optimisation variables. In this study, the range of the attribute weights was set between 0 and 1, the iteration was set to 100. The precision was set to 10^{-6}. The tolerance was 5%, the convergence was 10^{-4} and Solver was run 100 times to find the optimum attribute weights that generated the maximum case similarity CS (closest to 1). This process was repeated as many times as the number of cases in the input case base by taking a different case out as the evaluation case at each cycle. The averages of the weights produced by GRG2 at each cycle were used to run CBR in next part.

Figure 6.3 Solver optimisation screen



Source: author

6.6 Calculating weighted case similarities

Case similarities were computed for each test case with respect to each input case by using the attribute similarities calculated in part 3 and the attribute weights generated in part 4. For positive weights and normalized similarities, the weighted case similarities were always between 0 and 1, with a score of 1 indicating the case most similar to the test case and 0 the least. Weighted case similarities were computed according to the following formula:

$$\mathrm{CS}_{ij} = \frac{\sum_{k=1}^{p} S_{ijk} w_k}{\sum_{k=1}^{p} |w_k|}$$

for test case i=(1,2, . . . ,m) and input case j=(1,2, . . . ,n) for all attributes k=(1,2, . . . , p), where CS_{ij} =weighted case similarity between test case i and input case j over all the attributes k; S_{ijk} =similarity between test case i and input case j for attribute k; and W_k =weight of attribute k.

6.7 Using test case to calculate the error rate

The highest weighted case similarity for a test case i indicated the closest matching input case j in the case base. This operation was conducted for each test case.

Max CS_{ij} $= \max(CS_{i1}\ CS_{i2}, ,\ldots\ldots.\ CS_{ij})$ for each $i(i = 1,2,\ldots.n)$

Once the highest weighted case similarities were identified for respective test cases, the corresponding case numbers and outputs were also listed. The random selection of the test set may affect the accuracy of testing. In other words, the test results were likely to change when different testing sets are selected. It is common practice to repeat the random project selection, training, and testing process several times and to pick the best results. The resulting outputs generated in the preceding step were compared with the respective actual outputs. The differences constitute the errors. The average of the error values of all test cases was the overall error of the CBR process.

Each type of project data were equally divided into three subsets, two of which are used for training and the other one is used for testing. One issue in achieving high-quality CBR design was construct validity and internal validity (Easton, 1995). Internal validity refers to the reliability of a study (Dane, 1990). The use of three-way cross-validation with three randomly selected groups containing equal number of projects was suggested for this study. The CBR process of random selection of project test set, training and testing was repeated 3 times for different test sets until all the cases are being selected as test case and training case. The internal validity has also been tested for case redundancy, that is no all cases should have the same project KPI values when all the project CSFs were different, and for case consistence, no all cases should have the same project CFS values when all the project KPIs were different. However, the safety KPI (K5) is not applicable because all Luban and Great Wall prizes' projects were zero death accident and thus only five KPIs model performance were discussed in this study. Table 6.1 summarized the overall error rates (average and average deviation of overall error rates). The detail results table was appended in appendix 6.

The weights were optimum as the average error rate for all KPIs and project types was 4.35% and the average deviation was 3.00%. For KPIs, construction speed (KPI 1) has the highest average error rate across project type of 10.19%. That is probably because the overall error rate depends on the KPIs value variations. That is, for construction speed (KPI 1), the value varied a wide range from 11.82 m2/day to 909.13 m2/day. The project with the lowest construction speed among the 104 project library is one residential project, the data were collected through the questionnaire and the project manager has indicated that the project is very complex among the residential projects and probably it is the reason of the lowest construction speed. The project with the highest construction speed is an industrial project with a simple design and low complexity. It can be observed that industrial project (Type 2) have the highest error rate for KPI 1. Some industrial projects have high construction speed owing to simple design and low complexity. However several projects of this type have low construction speed because of reasons like inclement weather etc. Construction speed (KPI 1) value of industrial projects varied vastly from high to low. Generally the project KPI whose value varies greatly has relatively higher error rate and lower predictive accuracy.

Unit cost (KPI2) value varied and the average error rate was the second high. From cost variation (K3) and quality score (K4), it was observed that the value variation was positively associated with average error rates across project types. For client satisfaction (KPI 6) using the Likert scale from 1 to 5, the KPI value is either 4 or 5. This meant that client is either satisfied or very satisfied and the model can predict with an average error rate of 0.21%. KPI value did not vary significantly hence can obtain more accurate predictive value through CBR model.

Across all project types, average error rates did not vary as significantly as the average error rates across KPIs. The average error rates across KPIs varied from 0.21% to 10.19% while the average error rates across various project types changed from 3.37% to 5.15%. This is to say that the model performance does not depend on the project type but depend on project KPIs because KPIs value variation was high. All building projects used to predict the KPI value have similar model performance in terms of error rate. In other words, CASE_PMP is not biased against any project type.

Table 6.1 Summary of overall error rates for the various outputs and project types

Overall error rates	Type 1	Type 2	Type 3	Type 4	Average error rate for different outputs	Average Deviation
KPI 1	8.90%	14.54%	8.81%	8.49%	10.19%	2.91%
KPI 2	8.33%	2.93%	8.25%	5.29%	6.20%	2.60%
KPI 3	4.75%	6.25%	4.03%	2.09%	4.28%	1.73%
KPI 4	0.98%	1.21%	0.11%	0.98%	0.82%	0.49%
KPI 6	0.00%	0.83%	0.00%	0.00%	0.21%	0.42%
Average error rate for different project types	4.59%	5.15%	4.24%	3.37%	Average error rate for all outputs and project types=4.35%	Average error rate deviation for all outputs and project types=3.00%
Standard Deviation	4.08%	5.67%	4.24%	3.49%		

Note: KPI 5 (safety) has not be studied because all Luban and Great Wall prizes' projects are zero death accident so all the value are the same.
Source: author

6.8 Chapter summary

This chapter presented the Spreadsheet CBR model development steps. Firstly, the data was organized and format in spreadsheet into two matrices, tests case and input cases. The input attributes and output value of each case was in column and cases were in raw. The rules to calculate the attribute similarities were defined. The attribute weights were established by GRG2 and the case similarities was calculated. The generated weights and using test case to calculate the error rate were discussed. The model performance by various project types and KPIs was addressed. It was found that the weights were optimum as the average error rate for all KPIs and project types was 4.35% and the average deviation was 3.00%. In addition, across all project types, average error rates did not vary as significantly as the average error rates across KPIs. It was found that CASE_PMP is not biased against any project type.

Chapter 7 Verification and Validation of Model and Discussion of Results

7.1 Introduction

This chapter establishes the verification and validation of CASE_PMP. The verification consists of correctness checking, internal consistency checking and completeness checking. CASE_PMP is validated qualitatively. The validation results are satisfactory. And then the preliminary discussion of the results is presented. The analysis results are discussed using the most critical CSFs and findings are compared with the previous research.

7.2 Verification and Validation of CASE_PMP

The attribute weights were determined by using GRG2. The CBR Excel model was run and the performance of the model was evaluated in Chapter 6. Verification and validation are adopted to evaluate the performance of the proposed CASE_PMP.

7.2.1 Verification of CASE_PMP

Several guidelines on verification of CBR systems have been proposed by several CBR research (Francisco, 2001, Ng and Smith, 1998, Kolodner, 1993). The verification and validation (V&V) of the system consisted of two main objective: one is to assess the utility and the viability of the system's framework and the other is to assess the overall effectiveness the system, as a whole and by its sub-components, in addressing the predictive ability of the project success.

There were three aspects for verification of the model (Ng and Smith, 1998): correctness checking, internal consistency checking and completeness checking. The case correctness was checked during the data collection stage when the official documents were provided by the contractors to ensure accuracy of the data. And data collected through the questionnaire has been random checked by the author for accuracy.

The internal consistency checking of the case library is to detect redundancy or contradiction of cases. A case is redundant if it is succeeded in the same situation and has the same conclusions as another case. Although redundancy does not necessarily cause logical problems, it might affect the efficiency of the system. Two cases are contradictory if they succeed in the same situation but with conflicting conclusions reported (Suwa et al. 1984). A case consistency test is conducted to verify the existence of redundant or contradictory cases. The concepts of the test are that, for case redundancy, no two cases should have the same project KPI values when all the project CSFs are same, and for case consistency, no two cases should have the same project KPI values when all the project CSFs are different. However, the safety KPI (K5) was not applicable because all Luban and Great Wall prizes' projects had zero death accident and thus only five of the six KPIs were discussed in this study. The cases were checked and there were no redundancy and no contradiction of cases.

Regarding completeness checking of the case library, the likelihood of seeing stronger similarities would be higher when the number of cases could be increased to 23 cases as recommended by Ng and Smith (Ng and Smith, 1998). As the four types of project cases in the case library exceeded 23 the completeness criterion has been satisfied. However, the fully ideal coverage of the cases library is not viable in practice; therefore this study clarified the coverage scope of the cases of CASE_PMP in the following table.

Table 7.1 Case library coverage range

CSF attribute Number	CSF attribute	Range
1	Project Size GFA	7,000 m2- 154,160.24 m2
2	Project Type	Building project
KPI attribute Number	KPI attribute	
1	Construction Speed	11.82 m2/day-909.13 m2/day
2	Construction Unit Cost	RMB ¥830-10757.51
3	Cost Saving	0.80%-10%
4	Construction Quality Score	80-100
5	Client satisfaction (Likert scale, 1-5,5 is very satisfactory 1 is very dissatisfactory)	4-5

Source: author

7.2.2 Validation of CASE_PMP

In essence, verification determines if the system is built right and validation determines if the right system is built (Ng and Smith, 1998). There are three limitations for validation (Ng and Smith, 1998). The first limitation is that CBR system may not always achieve exact match, it is often of the type that do not have simple right or wrong answers. The aim of validation is not to determine whether the CBR system gives correct answers but rather whether its answers are valid. Second limitation is associated with the potential for human bias. A final limitation is concerned with the level of performance expected to the model. Adequate performance level is a difficult value to quantify (Ng and Smith, 1998; Spring, 1993). A set of four hypothetical case studies, one of each project type are used to validate the model. The author made phone call interview to raters, and asked for their qualitative assessments for the output of CASE_PMP according to a specified rating scheme. The raters were asked to assign grade from 5 (very satisfactory) to 1(very unsatisfactory) to represent the degree of reasonability of the output.

Bareiss (1989b) has asserts that the accuracy of a CBR system can be assessed subjectively by experts and semi experts of the domain. In the literature, few experts are invited to do the validation for CBR model (Bareiss 1989b; Ng and Smith, 1998; Spring, 1993). The random sampling is applied to draw minimum size of sample. The same formula used in Chapter 4 (Section 4.2.1) is employed to draw 16 respondents from the population, i.e. 96 winners of Beijing Outstanding Project Management Award from 2001-2008. Phone calls were made to do the validation as project managers usually are occupied by project-related work. Unlike the routine office work, they need to spend time on site, and other project participants' office. Therefore, telephone interview is effective to solicit their comments because it will not prolong the interview time too long and can reach different project manager in relatively short time period. Face to face interviews are luxury as the author will need to arrange another field trip and input vast resource which may not be necessary. Chapter 8 discusses the in-depth telephone interview and the details regarding the advantages and disadvantages of telephone interview versus telephone interview. Questionnaire was attached in the appendix 7.

Based on the statistical inference theory, Friedman test is performed to examine the null hypothesis: the response is not reliable (i.e. the column data is same) if the critical value is statistically significant (Tan, 2004). Table 7.2 shows the example of the sample of response.

Table 7.2 The example of the sample of response

	KPIs				
Respondent Comments	K1	K2	K3	K4	K6
1	3	3	3	4	3
…	…	…	…	…	…
…	…	…	…	…	…
16	3	5	4	5	5
Total	R1=72	R2=62	R3=65	R4=70	R6=68

Note: KPI 5 (safety) has not been studied because all Luban and Great Wall prizes' projects are zero death accident so all the value are the same

Source: author

The test statistic is given by:

$$F_r = \frac{12}{nk(k+1)} \sum_{j=1}^{k} R_j^2 - 3n(k+1)$$

$$n = 16\, respondent\ s$$

$$k = 5\, KPIs$$

So applied the formula to calculate the statistic value:

$$F_r = \frac{12}{16 \times 5 \times 6}(72^2 + 62^2 + ... + 68^2) - 3 \times 16 \times 6 = 281$$

The critical value for $\alpha = 0.05$ is 5.99 and the null hypothesis of not reliable response can be rejected.

An additional benefit offered by this approach is that multiple experts are involved in all assessments, thus avoiding insular judgments regarding what constitutes adequate performance. As shown in the Table 7.3, sixteen respondents have showed their comments to 5 KPIs. Totally eighty feedbacks for various KPIs are received. In general, none of assessors expressed unreasonable to all the output of CASE_PMP. Feedback from thirty-eight responses expressed “very reasonable” to the output of CASE_PMP. Feedback from twenty-one responses commented “reasonable” and feedback from twenty one responses showed “moderately reasonable”.

Table 7.3 Validation Results

Project types	KPIs	Project Manager Comments("5" denotes "very resonable","1" denotes "very unreasonable")				
		5	4	3	2	1
Type 1	K1	2	1	1		
	K2	1	1	2		
	K3	2	1	1		
	K4	2	2			
	K6	2	1	1		
Type 2	K1	2	2			
	K2	2		2		
	K3	1	2	1		
	K4	3		1		
	K5	2	2			
Type 3	K1	4				
	K2	1	2	1		
	K3	2	1	1		
	K4	2		2		
	K5	1	1	2		
Type 4	K1	2	1	1		
	K2	1	1	2		
	K3		3	1		
	K4	3		1		
	K5	3		1		
Sum of Frequency Account		38	21	21	0	0

Source: author

7.3 Analysis Results Discussion

The identification of key factors for construction project success enables appropriate allocation of limited resources. In reality, the various factors contribute differently to different project KPIs (Jaselskis and Ashley 1991). The present study attempted to distinguish these factors according to different project KPIs. Focusing at the project execution stage; the success-related factors were organized in various project types for various project success KPIs in the present study. In this way, meaningful comparisons can be made among the factors at various project type levels with the tangible value with respect to the various project success KPIs. The four groups of weights for various project types were presented in the Table 7.4.

Table 7.4 The CSFs attributes weights of CASE_PMP

CSFs Weights for Cons. Time (K1)	C1	C2	C3	C4	C5	C6	C7	C8	C9
Type 1	0.65495	0.32017	0.68574	0.60466	0.53095	0.68574	0.68574	0.68574	0.50584
Type 2	0.2971	0.12491	0.43091	0.42	0.30789	0.43132	0.43132	0.39397	0.41966
Type 3	0.20929	0.23229	0.41068	0.47899	0.47576	0.59369	0.62986	0.62986	0.61473
Type 4	0.3876	0.23754	0.49739	0.40222	0.3629	0.47657	0.50509	0.50509	0.45318

	C10	C11	C12	C13	C14	C15	C16	C17	C18
Type 1	0.46812	0.4927	0.68574	0.68574	0.6119	0.39	0.68574	0.28016	0.68574
Type 2	0.30147	0.38951	0.43132	0.43132	0.43132	0.26019	0.43132	0.21782	0.43132
Type 3	0.44652	0.33685	0.62986	0.62986	0.48241	0.41367	0.46657	0.30713	0.5755
Type 4	0.33479	0.39315	0.44782	0.50509	0.44965	0.30556	0.40794	0.2577	0.50509

	C19	C20	C21	C22	C23	C24	C25
Type 1	0.49585	0.50303	0.53505	0.46969	0.68316	0.4696	0.68574
Type 2	0.72625	0.48848	0.33571	0.3381	0.42386	0.41091	0.43132
Type 3	0.40901	0.39336	0.54708	0.42285	0.62986	0.43117	0.62986
Type 4	0.44793	0.38072	0.44367	0.3292	0.50509	0.29003	0.51452

CSFs Weights for Cons. Cost (K2)	C1	C2	C3	C4	C5	C6	C7	C8	C9
Type 1	0.60893	0.2783	0.70778	0.53378	0.56409	0.70767	0.70767	0.70791	0.54658
Type 2	0.27418	0.20643	0.66842	0.46436	0.55034	0.66883	0.66883	0.34781	0.66277
Type 3	0.2059	0.26802	0.36842	0.31377	0.41735	0.52954	0.61901	0.61901	0.60387
Type 4	0.31675	0.39137	0.57374	0.44375	0.44979	0.55335	0.59038	0.59038	0.54828

	C10	C11	C12	C13	C14	C15	C16	C17	C18
Type 1	0.34114	0.4504	0.70767	0.70767	0.62682	0.41841	0.70767	0.26643	0.70767
Type 2	0.51495	0.43902	0.66883	0.66883	0.66883	0.27312	0.66883	0.38743	0.66883
Type 3	0.43961	0.32714	0.61901	0.61901	0.49173	0.44802	0.47465	0.22863	0.52406
Type 4	0.39064	0.34997	0.59403	0.59038	0.57624	0.35279	0.46778	0.38632	0.59038

	C19	C20	C21	C22	C23	C24	C25
Type 1	0.30083	0.34605	0.55266	0.5063	0.7045	0.44197	0.70693
Type 2	0.10417	0.26351	0.58738	0.3145	0.66883	0.47701	0.66457
Type 3	0.24646	0.25468	0.57499	0.46782	0.61901	0.40719	0.61901
Type 4	0.11023	0.35767	0.53088	0.45375	0.59038	0.40378	0.59981

CSFs Weights for Cons. cost variance(Cost Saving) (K3)	C1	C2	C3	C4	C5	C6	C7	C8	C9
Type 1	0.63426	0.33246	0.73678	0.39154	0.60171	0.73668	0.73668	0.73692	0.42392
Type 2	0.1917	0.14067	0.72483	0.30816	0.62069	0.72524	0.72524	0.49629	0.71919
Type 3	0.12029	0.13366	0.54198	0.3106	0.56563	0.6795	0.71241	0.71241	0.69727
Type 4	0.16602	0.38505	0.57792	0.27633	0.53675	0.63514	0.64833	0.64833	0.6065

	C10	C11	C12	C13	C14	C15	C16	C17	C18
Type 1	0.12226	0.4323	0.73668	0.73668	0.71441	0.49525	0.73668	0.2767	0.73668
Type 2	0.26726	0.29868	0.72524	0.72524	0.72524	0.29547	0.72524	0.34735	0.72524
Type 3	0.58076	0.25854	0.71241	0.71241	0.59951	0.37535	0.58823	0.3044	0.64678
Type 4	0.40104	0.36498	0.54828	0.64833	0.57451	0.48216	0.41529	0.44095	0.64833

	C19	C20	C21	C22	C23	C24	C25
Type 1	0.11111	0.14148	0.61907	0.39419	0.73351	0.47537	0.73593
Type 2	0.04287	0.1736	0.66658	0.46299	0.72524	0.45299	0.72099
Type 3	0.06312	0.06591	0.66227	0.55412	0.71241	0.51691	0.70815
Type 4	0.08903	0.26763	0.59331	0.45278	0.64833	0.24493	0.65776

CSFs Weights for Cons.Quality score(K4)	C1	C2	C3	C4	C5	C6	C7	C8	C9
Type 1	0.68202	0.28144	0.78365	0.35928	0.6446	0.78355	0.78355	0.78379	0.37425
Type 2	0.1831	0.19179	0.78028	0.33815	0.67613	0.78069	0.78069	0.49266	0.77464
Type 3	0.16431	0.19044	0.41304	0.23788	0.48932	0.5972	0.70823	0.70823	0.69309
Type 4	0.17294	0.386	0.61749	0.29381	0.55852	0.65671	0.68562	0.68562	0.64378
	C10	C11	C12	C13	C14	C15	C16	C17	C18
Type 1	0.13377	0.40946	0.78355	0.78355	0.70809	0.49652	0.78355	0.28112	0.78355
Type 2	0.24785	0.3393	0.78069	0.78069	0.78069	0.21201	0.78069	0.27736	0.78069
Type 3	0.43285	0.22502	0.70823	0.70823	0.55885	0.4881	0.48096	0.16984	0.59487
Type 4	0.42424	0.31941	0.55471	0.68562	0.59517	0.38397	0.41015	0.31254	0.68562
	C19	C20	C21	C22	C23	C24	C25		
Type 1	0	0.08474	0.56815	0.37478	0.78038	0.44127	0.7828		
Type 2	0	0.22185	0.72433	0.43877	0.78069	0.38049	0.77643		
Type 3	0.01632	0.02854	0.66488	0.45084	0.70823	0.42744	0.70823		
Type 4	0.01101	0.22036	0.63077	0.46474	0.68562	0.20781	0.69504		

CSFs Weights for client satisfaction (K6)	C1	C2	C3	C4	C5	C6	C7	C8	C9
Type 1	0.71375	0.22643	0.81617	0.36346	0.68281	0.81607	0.81607	0.81631	0.2131
Type 2	0.21693	0.18949	0.78518	0.36309	0.68103	0.78559	0.78559	0.52649	0.77954
Type 3	0.12247	0.17837	0.41065	0.22797	0.4702	0.57688	0.70899	0.70899	0.69385
Type 4	0.29383	0.34496	0.71988	0.10521	0.56779	0.68354	0.75316	0.75316	0.49848
	C10	C11	C12	C13	C14	C15	C16	C17	C18
Type 1	0.10411	0.42765	0.81607	0.81607	0.68446	0.45032	0.8148	0.17372	0.81607
Type 2	0.27942	0.3442	0.78559	0.78559	0.78559	0.15703	0.78559	0.25015	0.78559
Type 3	0.41202	0.22027	0.70899	0.70899	0.56451	0.49495	0.48637	0.16567	0.59096
Type 4	0.2911	0.32356	0.67312	0.75316	0.67294	0.3401	0.60648	0.18869	0.75316
	C19	C20	C21	C22	C23	C24	C25		
Type 1	0	0.09597	0.53617	0.21674	0.81289	0.41061	0.81532		
Type 2	0.04167	0.2301	0.72923	0.49318	0.78559	0.32349	0.78133		
Type 3	0	0.0242	0.6705	0.44714	0.70899	0.42061	0.70899		
Type 4	0	0.02172	0.57046	0.33732	0.75257	0.23366	0.75869		

Source: author

7.3.1 Discussion of results by project type

Top five ranking of CSFs is adopted to identify the significance of the CSFs. (Chan and Kumaraswamy (1997)). The ranking of the top five project management and non project management CSFs for each project KPIs of various project types is presented in Table 7.5. If the value of the attribute weights is same for different CSFs, for instance, they are same as the rank one, these factors juxtapose as the rank one. Evidently, each set of CSFs differs depending on the type of the project and the project KPIs. Nonetheless, top four most frequently ranked top five CSFs are identified in non-PM group across the project type and various KPIs from the non project management group: (1) Designer's times of and significant change orders variations (C7), average ranking is 1.7; (2) Procurement method (C13), average ranking is 1.7; (3) Project type (C25), average ranking is 2.05; (4) Designers experience (C6), average ranking is 2.53. For the project management group, top four CSFs are identified regardless of project KPIs and project type: (1) the system to ensure achievement of quality objective (C23), the average ranking is 1.5; (2) the effectiveness of the construction scheduling (C18), the average ranking is 1.6; (3) the construction preparation (C21), the average ranking is 2.58; (4) project management team work out the schedule plan (C16), the average ranking is 2.63.

The comparison of the weights of top five non-project management and project management group can indicate their degree of the contribution to project success as presented in Table 7.6.

Table 7.5: The ranking of the top five non-project management and project management for each project KPIs of various project types "1" denotes Ranking No.1; "2" denotes Ranking No.2; "3" denotes Ranking No.3; "4" denotes Ranking No.4; "5" denotes Ranking No.5. (Part 1)

	K1				K2				K3				K4				K5				No. of Times the criterion has been ranked top five	Average Ranking
Non-PM	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4		
C1	2																5				2	3.5
C2																					0	0
C3	1	2		3	2	2		5	2	2		5	2	2		5	2	2		3	15	2.67
C4	4	3	5																		3	4
C5	5					5				5				5	5			5	5		7	5
C6	1	1	3	4	3	1	3		3	1	4	3	3	1	3	3	3	1	3	4	19	2.53
C7	1	1	1	2	3	1	1	3	3	1	1	2	3	1	1	2	3	1	1	2	20	1.7
C8	1	5	1	2	1		1	3	1		1	2	1		1	2	1		1	2	0	0
C9		4	2	5		4	2			4	3	4		4	2	4		4	2		13	3.38
C10							5														1	5
C11																					0	0
C12	1	1	1		3	1	1	2	3	1	1		3	1	1		3	1	1	5	17	1.76
C13	1	1	1	2	3	1	1	3	3	1	1	2	3	1	1	2	3	1	1	2	20	1.7
C14	3	1	4		5	1	4	4	5	1	5		5		4			1	4		14	3.36
C25	1	1	1	1	4	3	1	1	4	3	2	1	4	3	1	1	4	3	1	1	20	2.05

Table 7.5: The ranking of the top five non-project management and project management for each project KPIs of various project types "1" denotes Ranking No.1; "2" denotes Ranking No.2; "3" denotes Ranking No.3; "4" denotes Ranking No.4; "5" denotes Ranking No.5. (Part 2)

	K1				K2				K3				K4				K5				No. of Times the criterion has been ranked top five	Average Ranking
PM	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4		
C15									4			3	4		4	5	5		4	5	8	4.25
C16	1	3	4	4	1	2	4	3	1	1	4		1	1	5	4	2	1	5	3	19	2.63
C17						5				5		5		5				5			5	5
C18	1	3	2	1	1	2	3	1	1	1	3	1	1	1	3	1	1	1	3	1	20	1.6
C19	5	1		2																	3	2.67
C20	4	2		5																	3	3.67
C21	3		3	3	3	3	2	2	3	2	2	2	3	2	2	2	4	2	2	4	19	2.58
C22					4		5	4		3	5	4		3		3		3			9	3.78
C23	2	4	1	1	2	1	1	1	2	1	1	1	2	1	1	1	3	1	1	2	20	1.5
C24		5	5		5	4		5	5	4			5	4				4			10	4.6

Source: author

Table 7.6: The weights value of the top five non-project management and project management CSFs for each project KPIs of various project types

	Schedule performance				Unit Cost				Cost variance			
Non-PM	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4
1	0.685741	0.4313248	0.6298646	0.5145164	0.7079136	0.6688278	0.6190121	0.5998093	0.7369196	0.7252437	0.7124081	0.6577555
2	0.6549497	0.4309137	0.6147251	0.505092	0.707776	0.6684166	0.6038727	0.5940314	0.736782	0.7248326	0.7081503	0.6483311
3	0.6118962	0.4200012	0.5936854	0.4973882	0.7076721	0.6645699	0.5295367	0.5903849	0.7366781	0.7209859	0.6972687	0.6351387
4	0.6046598	0.4196567	0.482405	0.4765691	0.7069252	0.6627744	0.4917344	0.5762441	0.7359311	0.7191904	0.6795018	0.6064959
5	0.5309528	0.3939693	0.4789859	0.4531801	0.6268188	0.5503397	0.4396051	0.573736	0.7144051	0.6206868	0.5995119	0.5779165
PM	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4
1	0.685741	0.7262462	0.6298646	0.505092	0.7076721	0.6688278	0.6190121	0.5903849	0.7366781	0.7252437	0.7124081	0.6483311
2	0.6831565	0.4884777	0.5754989	0.4479293	0.7044994	0.6688277	0.5749857	0.530879	0.7335054	0.6665775	0.6622686	0.5933117
3	0.5350473	0.4313248	0.5470765	0.4436656	0.5526594	0.5873832	0.5240589	0.467783	0.6190659	0.4629852	0.6467802	0.4821575
4	0.50303	0.4238618	0.4665671	0.4079429	0.506296	0.477005	0.4746541	0.4537462	0.4952543	0.4529906	0.5882267	0.452783
5	0.4958451	0.4109121	0.4311722	0.3807193	0.4419703	0.3874305	0.4678166	0.4037834	0.4753705	0.3473525	0.5541201	0.4409504

	Quality				Client Satisfaction			
Non PM	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4
1	0.7837917	0.7806892	0.7082307	0.6950394	0.816308	0.7855916	0.7089943	0.7586908
2	0.7836541	0.780278	0.6930912	0.685615	0.8161703	0.7851805	0.6938549	0.7531612
3	0.7835502	0.7764313	0.5972034	0.6567059	0.8160664	0.7813337	0.5768761	0.7198795
4	0.7828032	0.7746358	0.5588459	0.6437798	0.8153195	0.7795382	0.5645083	0.6835404
5	0.7080927	0.6761322	0.4893169	0.6174855	0.7137487	0.6810347	0.470196	0.6731219
PM	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4
1	0.7835502	0.7806892	0.7082307	0.685615	0.8160664	0.7855916	0.7089943	0.7531612
2	0.7803775	0.7243306	0.6648826	0.63077	0.8148014	0.7292331	0.670495	0.752573
3	0.5681484	0.4387696	0.5948712	0.4647358	0.8128937	0.4931811	0.5909643	0.606479
4	0.4965228	0.3804928	0.4880976	0.4101523	0.5361652	0.3234889	0.4949518	0.5704611
5	0.4412664	0.2773615	0.4809611	0.3839691	0.4503222	0.2501534	0.486366	0.3401014

Source: author

7.3.2 Comparison with the previous study

The importance of the CSFs is derived from the objective project data. The identified top five CSFs are compared with the previous studies with respect to the significance of the CSFs in the literature.

For the CSFs of construction project success in China, some studies confined to international architectural engineering and constructing (AEC) companies for critical success factors of project success to venture to China market (Ling et. al., 2006). Different with this study's objective, the group of studies focuses on the CSFs for the interests of the international AEC firms. All the projects in this study are mainly undertaken by the domestic AEC firms. In fact, the construction market in China is dominated by the domestic AEC firms.

Lacking of research for the CSFs for projects undertaken by domestic AEC firms in China in the international literature arena leads to the comparison of the finding of this study with the CSFs of international domain. Chan et al. (2002) has done a thorough literature review for the CSFs. Table 7.7 presents the comparison of findings of this study with the international literature. A review of the literature suggests the absence of the consensus in the literature for the importance of CSFs. Various countries have different CSFs. In this study, the applicable CSFs for China's project are identified based on the top five derived weights of PM and non-PM group. There are some CSFs which have not been identified in the previous research. They are Procurement method (C13) and Project type (C25) in non PM group. In PM group it is the system to ensure achievement of quality objective (C23).

The absence of the consensus in the literature for the importance of CSFs and the difference of identified CSFs in this study signifies that it is necessary to extend the discussion of analysis results by in-depth interview. In the next chapter the author will explore the interview for the purpose of the in-depth discussion of analysis results.

Table 7.7 the comparison of findings of present study with the literature

The comparison of finding of the present study with the previous research	Baldwin, et. al., (1972)	NEDO, (1983)	Chalabi, et. al., (1984)	Arditi, et. al., (1985)	NEDO , (1986)	Okpala et. al., (1988)	Naoum et. al., (1991)	Mansfield et. al., (1994)	Assaf, et. al., (1995)	Chan, et. al., (1997)	Kaming, et. al., (1997)	This study
Non PM												
CSFs in the literature												
Inclement Weather and underground(C14)	√	√			√					√		
Contractor (C8)	√	√			√				√			
Design Variation(C7)		√		√	√				√	√	√	√
Contract Type(C12)					√		√					
Designer experience(C6)							√	√				√
CSFs for this study												
Project Type (C25)												√
Procurement procedure (C13)												√
PM												
CSFs in the literature												
Labour supply (C19)	√			√	√				√		√	
Material supply (C20)		√		√	√	√		√	√		√	
Construction Planning(C16)			√	√							√	√
Construction preparation(C21)					√	√		√	√			√
Communication(C17)					√					√		
Planning (Schedule effectiveness)(C18)									√		√	√
CSFs for this study												
The system to ensure achievement of quality objective (C23)												√

Source: author

7.4 Chapter Summary

Firstly the verification and validation of CASE_PMP was discussed. The results of the preliminary data analysis for the derived weights of the CBR model were discussed. Four sets of weights for CSFs were derived for five KPIs of various types of projects. The results were discussed on project type, ranking of the top five non-project management and top five project management CSFs for each project KPIs. Comparing the findings with the literature revealed that there was no general agreement for the CSFs of different countries. In the next chapter the author will conduct the in-depth interview to expand the discussion of the analysis results.

Chapter 8 In-depth Interview for Results Discussion

8.1 Introduction

This chapter addresses the in-depth interview to project managers who were the winners of Outstanding Project Manager Award, China 2008. In Chapter 7, the author discussed the preliminary analysis results and further discussion of analysis results is expanded in this chapter. Objective of the interview is to solicit project manager's point of view on the analysis results and practicality, advantages and disadvantages of model CASE_PMP. The interview nature is semi-structured. The information collected from these interviews is then analysed qualitatively.

8.2 Purpose and method of in-depth interview

CASE_PMP was verified and validated and importance of CSFs was discussed in Chapter 7. However, the lack of consensus for the importance of CSFs of this study and literature triggers the in-depth analysis. And the verification and validation of model did not discuss the practicality, viability of CASE_PMP. The objectives of in depth interview are:

i. To examine with practitioners what are the most important CSFs.
ii. To discuss with practitioners for the usage, advantage, disadvantage of CASE_PMP.

In-depth interviews were conducted with experienced project managers. The advantages and disadvantages of telephone interview and face to face interview are presented in Table 8.1. Telephone interview was employed as project managers usually are occupied by project-related work. Unlike the routine office work, they need to spend time on site, and other project participants' office. Therefore, telephone interview is effective to solicit their comments because it will not prolong the interview time too long and can reach different project manager in relatively short time period. Face to face interviews are luxury as the author will need to arrange another trip and input vast resource which may not be necessary. In addition, project managers usually are too busy to arrange the face to face interview.

Table 8.1 The advantages and disadvantages of telephone versus face to face interview

	Telephone Interview	Face to Face Interview
Advantages	1) the number of different people can be reached in a relatively short period of time. 2) From the respondents standpoint it would eliminate any discomfort that some of them would feel less uncomfortable disclosing personal information over the phone than face to face. 3) not to prolong the interview time too long.	1) the researcher can adapt the questions as necessary, clarify doubt and ensure that the responses are properly understood, by repeating or rephrasing the questions. The researcher can also pick up nonverbal cues from the respondent.
Disadvantages	1) the respondent could unilaterally terminate the interview without warning or explanation 2) the researcher will not be able to see the respondent to read the non-verbal communication	1) the geographically limitations they may impose on the surveys and the vast resources needed. 2) respondents might feel uneasy about the anonymity of their responses when they interact face to face interviews. 3) prolonged process

Source: http://www.blurtit.com/q734868.html and http://www.blurtit.com/q949775.html

The interviews are semi-structured in nature because a set of questions was developed as a guide of framework to be explored for the interviewer and yet open end for each question for respondents to reply. The questions list was appended in the Appendix 8. During the course of the interviews, the interviewees were introduced to research scope, results and CASE_PMP model. The most critical CSFs identified in this study were explained in details and ask their comments. The usage, advantage and disadvantage were asked. The interview record is attached in the Appendix 9.

8.3 Respondents Profile

A group of five project managers who were the winners of 2008 China Outstanding Project Manager Award in Beijing have participated the semi-structured interview. The Outstanding Project Manager Award is the highest honour promulgated by China Construction Association to project managers.

The respondents typically hold a project managerial post in their organization and are very experienced. Two respondents have promoted to higher management position due to their outstanding project management performance. In general, the experience of the respondents ranges from 10 to 20 years. They all have track records for Luban and Great Wall prizes' projects. One of the compulsory requirements of this award is extensive project management experience including being project manager at least three years consecutively for projects which won national level awards. In addition, it is compulsory that project manager join the training organized by China Construction Association continuously for two years. As such, the respondents are experienced and knowledgeable so that a reasonable level of confidence and coherence in their responses is assured.

8.4 Discussions about CSFs

The respondents were asked to rank the Critical Success Factors in order of importance. Except for the lists of CSFs identified in this study, respondents have pointed out other CSFs. Human judgments generally are subject to systematic error, or bias, as well as unsystematic error, or variance, especially expose to massive information, like the entire lists of 25 numbers of CSFs. In view of the above mentioned respondents were introduced the CSFs by the grouping in Chapter Two to minimise the human bias and make them answer interview questions effectively with the grouping CSFs.

8.4.1 Quality Assurance System

Almost all respondents have indicated clearly that the quality assurance system presides over other factors as the top critical CSFs. It was consistent with the findings: the system to ensure achievement of quality objective (C23) is one of the most important CSFs. Some opinions expressed by respondents are listed as follows:

The technology is very important to quality management through the quality assurance system. In other words, technology can facilitate the optimisation of construction implementation plan. During the process of working out the construction implementation plan, project manager needs to discuss with technical staff to ensure the construction implementation plan, cost and detailed construction methods. For instance, the excavation work for one sports stadium project, the project team adopted the technology innovation by using the excavated soil to back-fill the foundation of piling system. It saved the process of transporting soil out of the site. This technology saved construction time during the raining season.

During the construction process, the quality assurance system is critically important. Usually, self-checking is the most effective way. For example, the structural work is essential to project. The concrete work usually is done by the specialist. Project manager must record properly, be clear about the details like which part was done by which person. For example, in one project, project manager found the overall total deviation of the verticality of the main structure exceeded the allowable plane bending norms by more than two millimetres. Despite the minor error, they still requested the specialist to rework the concrete work. It ensured the project quality and made the structural work specialists realized that quality is their survival skill. Some project team formulated hundred over rules and regulations which were exhaustive and detailed to guarantee the project quality.

8.4.2 Scheduling Technology: CPM and PERT

Among the CSFs posed to the respondents, it was generally found that utilization of scheduling technology, i.e. Critical Path Management (CPM) and Program (or Project) Evaluation Review Technique (PERT) is ranked as important CSFs. These observations follow closely the findings of this study: Planning (Schedule effectiveness) (C18) is one of the most important CSFs. Whilst four respondents rated scheduling technology as the important CSFS, it was noted that one respondent claimed that scheduling technology was only fairly important. According to their experience, project manager usually worked from PERT network to identify critical path based on key points and technical difficulty of projects. The non-critical path was inserted into critical path. The labour, materials and equipment were allocated to the nodes of network. Project resource was planned and schedule was controlled by working out detailed network. For instance, in every work flow section, project manager estimates quantities of steel, formwork and concrete, and then calculate the resource demand in terms of labour, material and equipment based on their experience and quantities quota which was published by official government sources. All these were marked in the network and briefed to relevant project participants, such as subcontractors, plumbing and sanitary services, air-conditioning and mechanical ventilation services, fire protection systems, and electrical systems etc. The detailed PERT network could present the project time and resource allocation unambiguously to all the project participants, especially to the site personnel. The project schedule and resource allocation were clearly understood by the respective parties. It is beneficial to utilise project resource effectively, and ensure project is delivered on time and within budget.

8.4.3 Contract Issue

All the respondents, with the exception of one, had confirmed construction contract was critical CSF. This is in alignment with the findings of this research. Project contract (C13) is one of the important CSFs. Most respondents recognised that contract, especially contract clause, was an important contribution to project success. Contractors have to be very serious about the contract clause after they are awarded the tender. Sometimes the dispute arises from the unfavourable contract to them. They have to pursue legal claim for the settlement. However, it is noted that if contractors and clients are subject to legal claims, it will cause the financial loss and contract delay in the construction project and constitutes obstacle project success.

Further investigation by asking the respondents revealed that most respondents emphasized that the contract with client serves more as a tool for contractual agreement and reference to work out the construction implementation plan but the contracts with subcontractors and other specialists are important tool for contractor to achieve the project objective determined in the contract with client. For example, the contract between client and contractor will stipulate the project time, cost details etc. The contractor will sub-contract the scope of work to sub-contractor to delivery the project. It is critical to ensure the entire project can be completed by organising and coordinate various subcontractors' work.

8.4.4 Construction Technology

The interview revealed a mixed response from the interviewees. Three respondents emphasized that technology management is to guarantee that the project can complete on time, with the customer satisfied quality standard, and saving cost. For example, one project was constructed during the raining season; the earthwork was difficult as the soil contained sand and was soft. According to the normal construction procedure, the retaining wall needs to be built before the foundation sheets. However, it will destroy the soil because of the soil was too soft. The project manager readjusted the construction procedure by casting the concrete work of the foundation sheets firstly and secondly is the retaining wall. As such, this project was completed during the raining season. The excavated sands were used to refill the foundation and saved cost including buying sand cost and sand transportation cost, as well as the labour and equipment costs.

On the other hand, two respondents claimed that technology is not the most important CSFs. Project team can delivery the project successfully, technology can not play its part without a functional team. In this research, technology is not one of most critical CSFs. It is in compliance with the statement of these two respondents.

8.4.5 Project management organization

Two respondents asserted project management organization is one of the most important CSFs although this research did not find project management organization (C15) was important CSF. They claimed that project manger is the top authority for the project. Project manager has the decision rights to construction implement plans, project team personnel appointment, key technology decision, purchasing for construction equipment, resource allocation, project scheduling, construct issue, design changes, and contractual claim etc.

Other than construction technology and project management organization, four other critical CSFs, Construction Preparation (C21), Design Variation(C7), Designer Experience(C6), Project Type (C25), are most critical CSFs identified by this study but respondents did not express their agreements. They claimed that by their experience, these CSFs were not so important to project success.

8.4.6 Other CSFs suggested by respondents

One respondent suggested some other CSFs. They are:-

Project manager is encouraged to discuss with subcontractors, outsourcing specialists on the construction implementation plan in order for them to optimise the construction implementation plan.

It has been proven that a long term cooperation relationship with subcontractors and outsourcing specialists is helpful to delivery project successfully because they will understand your requirement. Calling open tender for subcontractor and outsourcing specialists may not be the most effective way to select appropriate partners. The good relationship is beneficial for project delivery.

Safety management is very important CSFs and prevention is primary. In the daily safety management, strict self-checking system is important to project quality system. In addition, the subcontractor and outsourcing specialist are briefed on the safety management system, the rules and regulations. The safety responsibility agreement is signed with them. The safety details are executed in the project team. Every safety management step must have person-in-charge. Project manager and subcontractor need interactions.

Team work is one of the most critical CSFs. Project team must have team spirit. A strong team is the most important CSF for project success. To create a happy and positive atmosphere in the project team is to cultivate the team culture and team spirit. The team culture emphasizes on cooperation, and project management needs the cooperation of various parties.

8.5 Discussions of CASE_PMP

CASE_PMP was briefed to the respondents in detail, including background, the system architecture, input and output, modelling methods. The background introduction describes the research objective, i.e. to build CASE_PMP model with the input which are independent variables, CSFs, and output which are dependent variables, KPIs. Luban and Great Wall prizes' projects were collected as data to build the CASE_PMP model. The indexing case module, retrieval cases module, calculated cases module, test and validation module were explained to respondents. CBR in terms of concept and method were briefed to respondents as well. The second objective of research is briefed to respondents as well, i.e. using CASE_PMP to estimate the KPIs, e.g. project time and cost information.

8.5.1 Model Practicality

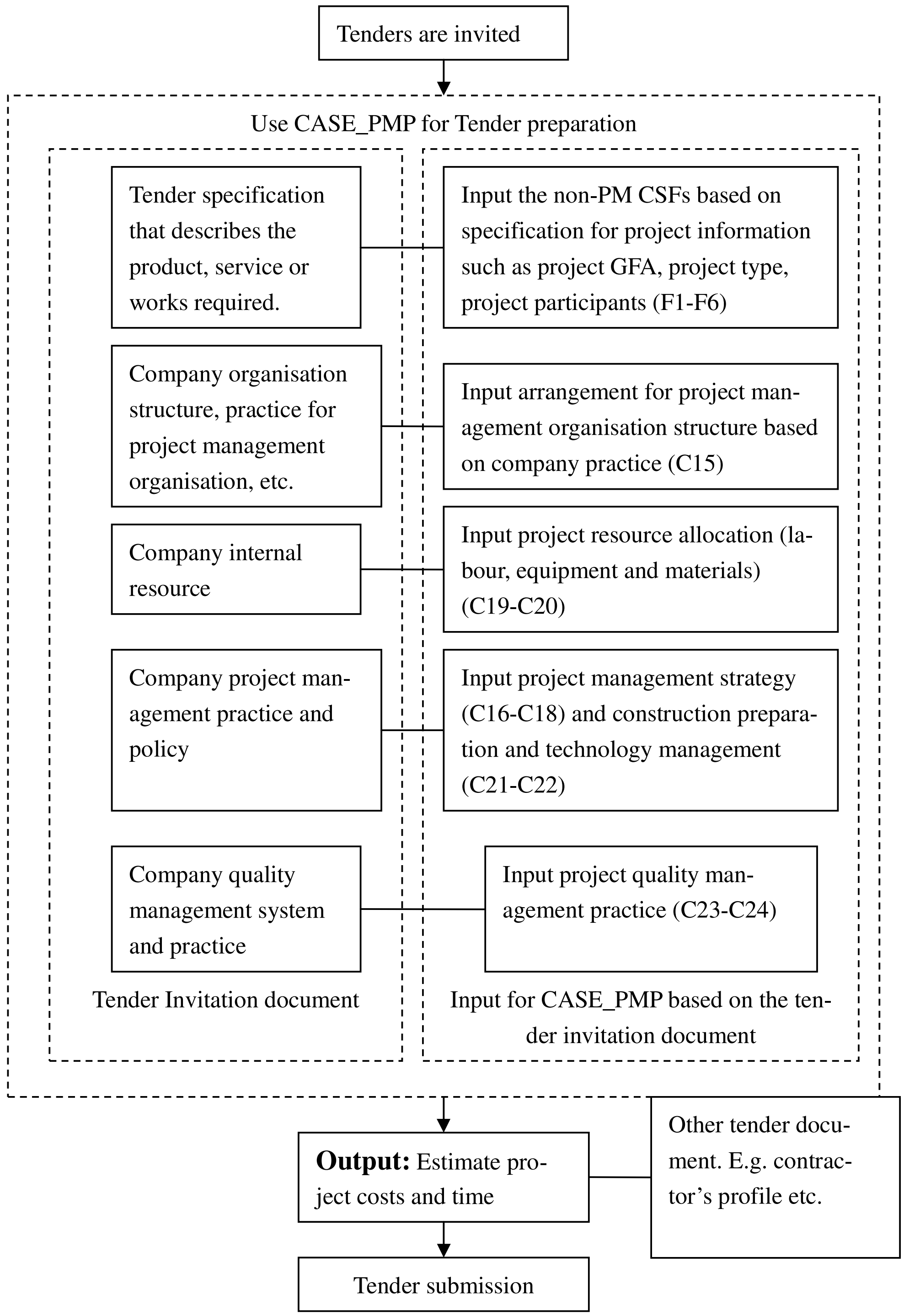
The respondents were requested to comment on the practical usage of CASE_PMP. Four respondents asserted that CASE_PMP was useful to estimate the project cost and time for the purpose of preparing tender document. Currently, the most commonly used method is based on company's previous project record and project manager's experience to estimate the project time, cost and incorporate them into the tender document. Contractor receives the tender invitation from client, which includes Conditions of tender; an explanation of the evaluation criteria to be used to evaluate the bids; a specification describing the product, service or works required; Conditions of Contract and Forms to be completed etc. For instance, if it is a high end residential project with GFA 100,000 m2, the project site is located at the centre of Beijing city. The in-house marketing department will estimate the project time and cost based on company's previous projects record. Let's say this company has undertaken one similar high end residential projects previously, but the project site is not located at the centre of city but close to the suburb. To estimate the project time and cost for tender document preparation, the market department will estimate for example the project cost with the consideration of cost fluctuation, project location etc. Project manager will comment the estimation results and finalize it for tender document submission. This is called manual estimation process.

Using CASE_PMP could be a complementary approach to the traditional methods to estimate project time and cost for tender document preparation. It has been well established that human judgments (i.e. predictions or evaluations based on incomplete or uncertain information) generally is subject to systematic error, or bias, as well as unsystematic error, or variance (Bowman, 1963). Project time and cost estimated by the in house market department or project manager would be subject to errors and bias. CASE_PMP may be helpful for supporting project managers' estimating and check manual estimation. It may help the inexperienced project manager to improve the effectiveness of estimation and increase the reliability and fairness of the manual estimation. However, one limitation of CASE_PMP is lacking of consideration with the factors for cost fluctuation and project site location variation.

As claimed by one respondent, CASE_PMP can be only used to support to do estimating. Case library have hundred over projects for four types of building projects. It is necessary to investigate if the case library exposes a gap in the case coverage. As we all known, an incomplete case library will not be capable to respond to all possible project scenario that may arise in the reality. Increasing more projects in the case library can improve CASE_PMP competency. Usually marketing department has more than 50 projects in the database to help them do the estimation. So it is not advisable to use CASE_PMP to the actual estimation.

The detailed process on how model can be used to prepare tender document is depicted in Figure 8.1.

Figure 8.1 Use CASE_PMP for Tender preparation



Source: author

As shown, CASE_PMP can be used in the tender process for tender document preparation. Non-PM CSFs can be input based on specification, company organisation structure. As for PM

CSFs, project manager could input various scenarios according to: 1) practice for project management organisation, 2) company internal resource, 3) company practice for project management, 4) company quality management system, 5) company information and the resource allocated to project. Project time and cost are estimated as output. In addition, the model could be used after the tender stage to estimate KPIs with the updated status of projects CSFs, such as PM CSFs.

8.5.2 CASE_PMP merits and demerits

The respondents commented on the merits and demerits of CASE_PMP. The respondents affirmed that the model design and logic is viable. All respondents expressed that the model concept is easy to understand and viable and they showed their strong interests for the model. Future research will look at developing the user interface and the complete software.

8.5.2.1 Case library representativeness

The respondents were asked if case library is representative for reasoning. CASE_PMP builds the case library with those prestigious projects which have won Luban and Great wall awards. The case library represented the high level project success. The project cost and time estimated by CASE_PMP may be a very competitive bid. In this sense, CASE_PMP is useful for tender document preparation. Nevertheless, contractors should be cautious to the outcome of CASE_PMP because there is the possibility for CASE_PMP to produce an unachievable project cost and time for contractor. Contractor may keep the awareness for their capability to deliver the project. One respondent asserted that it is necessary to increase the project number in the case library to improve the representativeness. Another respondent also claimed that CASE_PMP is not developed for one contractor only. The incompatibility of information from one contractor to another will cause the difficulty to input CSFs and become an obstacle for the representativeness of case library.

8.5.2.2 CBR appropriateness as the quantitative model for CASE_PMP

CBR is to solve new problem by adapting solutions that were used to solve old problems. This approach offers a paradigm that is close to the way project manager estimate project time and cost. Project manager estimate time and cost based on the most similar old projects. The model design and logic is viable and concept is easy to understand. Three respondents agreed with the indices used in CASE_PMP. The retrieval case module, calculated module, test and validation module are appropriate to for the task to find out the most similar old project and the corresponding similarity score. The test and validation module is viable. It is exactly same as the process project manager adopts in the estimation results to suit the particular circumstances of the current project. CBR is a suitable tool to establish CASE_PMP. The whole design and modules of CASE_PMP are viable and suitable. CASE_PMP is a feasible model. The modules are logically viable. The selection of indices, i.e. CSFs, is accurate as project manager would use the same CSFs to estimate project time and cost. The accurate indices could affect the accuracy of retrieval. The calculated module for similarity score is feasible and the test and validation module is also viable.

8.5.2.3 Potential benefits of CASE_PMP

CASE_PMP would have advantageous effects for more objective estimation. It is well known that the current approach to estimate project time and cost to prepare tender is based on subjective estimation and the current approach is still at primitive stage. There is a need for more advanced and more objective estimation. CASE_PMP can be used as an innovative technology for future tender document preparation provided it has improved its cases coverage. CASE_PMP can increase consistency for tender document preparation if the author can develop it to be compatible to all contractors. In other words, CASE_PMP can be developed with consideration of different contractors' individual conditions. E.g. some small contractor may not have a company internal resource management system like those reputable contractors and hence they will face difficulties to input project resource allocation. So a compatible CASE_PMP would be able to advise project resource allocation input regardless of if contractor have existing internal resource management system or not. Using CASE_PMP can generate greater efficiency to do estimation as the current approach requires inter-departmental cooperation and spend more time. Using IT tool is helpful to reduce human power investment and thus reduce cost.

8.5.2.4 Weakness of CASE_PMP

One respondent stated that CASE_PMP was an academic model as there are some CSFs were excluded from the model. CSFs that are excluded are: project manager is encouraged to discuss with subcontractors, outsourcing specialists on the construction implementation plan, a long term cooperation relationship with subcontractors and outsourcing specialists, safety management and team coherence. As explained in Chapter 2 and Chapter 7, there is the absence of the consensus of CSFs in the literature because various countries have different CSFs. The respondent affirmed that the four CSFs identified by this respondent were his individual opinion and were mainly from the project management experience in Beijing. The collective and unanimous characteristics of this respondent's opinion are lacking. It is recommended that for future study, the author will be conducting in-depth case study for specific CSFs applicable to projects in Beijing.

The respondent insisted on that the traditional method is still their priority as the respondent claimed that his personal reluctance to try out CASE_PMP. It is understood that the reluctance was associated with the human's bias again computer. Experts may be biased against introducing computer systems into their domain to replace their knowledgeable judgment. The respondent is a senior staff with more than twenty years experience. He is not familiar with those IT technologies and hence not keen to introduce new IT stuff in his practice career.

One respondent claimed that CASE_PMP did not incorporate cost fluctuation and project site variation into model. The case library represented the high level project success. The project cost and time estimated by CASE_PMP may be estimated as a very competitive bid. Nevertheless, contractors should be cautious about the outcome of CASE_PMP because there is the possibility for CASE_PMP to produce an unachievable project cost and time for the contractor.

One respondent explained that it is necessary to investigate if the case library exposes a gap in the case coverage. It is well known that an incomplete case library will not be capable to respond to all possible project scenarios that may arise in the reality.

One respondent stated that it is not developed for one contractor only. The incompatibility of information from one contractor to another will cause the difficulty to input CSFs and become an obstacle for the representativeness of the case library.

8.6 Chapter Summary

This chapter presented the in-depth interview conducted for purpose of expanding analysis results discussion. The objective and method of interview were introduced. The objective was to examine with practitioners what are the most important CSFs and to discuss with practitioners for the usage, advantage, disadvantage of CASE_PMP. The interview nature was semi-structured and conducted by telephone because using the telephone is the most effective way. The telephone call will not prolong the interview as the project managers are very busy. Face to face interview will require travelling which is not necessary and involved vast resource. Project managers have busy schedule and their work nature is not routine office work. Therefore questionnaire or face to face interview is difficult to arrange. The respondents were winners of Outstanding Project Manager Award, and their profiles were briefly introduced. Lastly, the information collected from these interviews was analysed qualitatively. The most important CSFs expressed by the respondents were discussed and their compliance and non-compliance with this research were presented by different CSFs. Furthermore, the respondents' point of view on the CASE_PMP model for its usage, appropriateness, case library representativeness, potential benefits and weakness were addressed.

Chapter 9 Conclusions and Recommendation for Future Study

9.1 Introduction

This chapter firstly addresses the review of the research purpose, research questions. Summary of the research findings is discussed in terms of predictive accuracy rate, the importance of the CSFs and interview conducted to examine importance of CSFs and some characteristics CASE_PMP, such as practicality, merits and demerits etc. The verification and validity of the hypothesis is addressed by quantitative and qualitative validation. The conclusion and discussion are examined. The contributions to knowledge and practice are presented. Limitation of the current study and recommendation for future studies are finally discussed.

9.2 Review of Research Purpose

The first research objective is to build the CBR model. The second is to use the model to estimate the KPIs to provide information for tender document preparation. Both research objectives were achieved. The detailed steps were addressed as follows.

This research adopted the data of the completed projects which won the construction awards in China to build a quantitative model and derive the importance of the significant factors for project success from the derived model. The importance was optimum as the average error rate for all KPIs and project types was 4.35% and the average deviation was 3.00%. Verification and validation of CASE_PMP were conducted. The completeness, consistency and correctness were verified. Qualitative validation was conducted by telephone interview and validation results were satisfactory. More than half of preliminary analysis results are in compliance with interviews results.

The usage, merits and demerits of CASE_PMP were explored by semi-structure interview. A set of questions was developed as a guide of themes framework to be explored for the interviewer. The information collected from these interviews was then analysed qualitatively. The most important CSFs expressed by the respondents were discussed and their compliance and non-compliance with this research was addressed. Furthermore, the respondents' point of view on the CASE_PMP model was discussed regarding model practicality, merits and demerits, case library representativeness, CBR appropriateness as the quantitative model for Case_PMP, potential benefits and weakness of Case_PMP.

9.3 Summary of the Research Findings

Summary of the research finding are discussed in the following three aspects. The model performance was tested by the predictive accuracy rate and strengthened by qualitative validation. The importance of the CSFs was identified and discussed. Qualitative interviews to project managers who were the winner of Outstanding Project Manager Awards Beijing, China 2008 were used to expand the discussion on the most critical CSFs and model CASE_PMP usage, merits and demerits.

The model performance is assessed and the weights are optimum as the average error rate for all KPIs and project types is 4.35% and the average deviation is 3.00%. For KPIs, construction speed (KPI 1) has the highest average error rate of 10.19%. For client satisfaction (KPI 6) using the Likert scale from 1 to 5, the KPI value is either 4 or 5. This meant that client is either satisfied or very satisfied and the model can predict with only an average error rate of 0.21%. Across all project types, all error rates for various project types do not vary as significantly as the KPIs. It shows that the model performance does not depend on the project type. All building projects can be used to predict the KPI value by using this model and it is not biased against any project type.

The absence of the consensus in the literature for the importance of CSFs signifies that various countries have different CSFs. In this study, the applicable CSFs for China's project are identified based on the top five derived weights of PM and non-PM group. There are some CSFs which have not been identified in the previous research. They are Procurement method (C13) and Project type (C25) in non PM group. In PM group it is the system to ensure achievement of quality objective (C23).

Some results of the current study are in compliance with interviews results. They are: the system to ensure achievement of quality objective (C23), Planning (Schedule effectiveness) (C18), Project contract (C13). Technology management (C22) and project management organization (C15) received mix comments by respondents, some expressed that they are critical, some indicated that they are not critical. In addition, four other critical CSFs, construction preparation (C21), Design Variation (C7), Designer Experience (C6), Project Type (C25), are the most critical CSFs identified by this study but respondents did not express their agreement. One respondent suggested some other CSFs which did not include in this study. Such as project manager is encouraged to discuss with subcontractors, outsourcing specialists on the construction implementation plan, a long term cooperation relationship with subcontractors and outsourcing specialists, safety management and team coherence.

Four respondents asserted that CASE_PMP was useful to estimate the project cost and time for the purpose of preparing tender document. Using CASE_PMP could be a complementary approach to the traditional methods to estimate project time and cost for tender document preparation. The respondents affirmed that the model design and logic was viable and expressed their understanding for the models' details such as the system architecture, input and output, modelling methods-CBR etc. However, one respondent stated that CASE_PMP was an academic model and claimed that the traditional method is still their priority.

9.4 Verification and Validation of CASE_PMP

There are three aspects of verification if the performance of the model: correctness checking, internal consistency checking and completeness checking. The case correctness was checked during the data collection stage when the official documents were provided by the contractors to ensure accuracy of the data. And data collected through the questionnaire has been randomly checked by the researcher for the accuracy. The internal consistency checking of the case library was to detect redundancy or contradiction of cases. The safety KPI (K5) was not applicable because all Luban and Great Wall Prize projects had zero death accident and thus only five of the six KPIs were discussed in this study. Regarding completeness checking of the case library, the likelihood of seeing stronger similarities would be higher when the number of cases could be increased to 23 cases as recommended by Ng and Smith (Ng and Smith, 1998). As the four types of project cases in the case library exceeded 23 the completeness criterion has been satisfied.

In addition, the model was quantitatively and qualitatively validated. Quantitatively, the predictive accuracy showed an acceptable average error rate for all KPIs and project types as 4.35% and the average deviation is 3.00%. Qualitatively, the results of the current study were validated. A set of four hypothetical case studies, one of each project type were used to validate the model. The author made phone call interview to raters, and asked for their subjective assessments for the output of CASE_PMP according to a specified rating scheme. Eighty responses were received for five KPIs. In general, none of raters expressed unreasonable to all the output of CASE_PMP. Feedback from thirty-eight responses expressed “very reasonable” to the output of CASE_PMP. Feedback from twenty-one responses commented “reasonable” and feedback from twenty one responses showed “moderately reasonable”.

9.5 Conclusion and discussion

The results have shown that the prediction error rate of model CASE_PMP is acceptable. The average error rate for all KPIs and project types is 4.35% and the average deviation is 3.00% so CBR is a feasible model to establish the links of CSFs and KPIs. In addition, verification and validation of model were investigated and model has satisfactory performance. Hence CBR can be a useful technique in modelling the CSFs and KPIs relationships. The research objective one, i.e. to build the CBR model CASE_PMP has been accomplished. Further in-depth interview was conducted to discuss the importance of CSFs and usage, advantage and disadvantages of CASE_PMP. The results can be used to estimate the KPIs for the preparation of tender document. Therefore the research objective two, to estimate the project KPIs based on the model for project tender document preparation, has been achieved.

9.6 Contributions

The contribution of this study to knowledge is that CASE_PMP can provide the preliminary mechanism for modelling the relationships of CSFs and KPIs by applying completed project data to fill the knowledge gap. The importance of CSFs is determined by the derived attribute weights of CSFs. Previous studies identified the significant factors that contributed to the successful performance of projects using respondents' subjective opinions (Pinto and Slevin, 1987, Belassi and Tukel, 1996).In addition, the study has provided a demonstration of a new application of an Artificial Intelligence tool to the construction management area.

Potential contribution to practice is that CASE_PMP can be used to estimate the project time and cost for the preparation of tender document. Case-based reasoning (CBR) has the ability to utilize existing data as cases (Hammond, 1986). It is a method of solving a current problem by analogising the solutions to previous similar problems. Using the successful projects, CASE_PMP estimate the project time and cost based on the most similar projects in the case library. This approach offers a paradigm that is close to the way project manager estimate project time and cost.

9.7 Limitations of the research

It was observed that industrial project (Type 2) had the highest error rate for KPI 1 (construction speed) which was 14.54%. To improve, CASE_PMP can be used to predict the KPIs more accurately with a larger library of real cases.

The input of CBR is numbers which sometimes is hard to memorize by users. For example, user needs to input exact project information like labour input and material input. It is expected to develop more user friendly interface by using other advanced technology like fuzzy logic and hence improve the model usage. Project manager can input the input by "small", "medium" or "high" accordingly, which is easily input by human and hence make the input less difficult. In addition, this study only used one optimisation technique, namely the Generalized Reduced Gradient (GRG2) non-linear optimisation to calculate the weights of the attribute. It would be recommended to employ more optimisation techniques to calculate the attribute weights, for example, feature counting, gradient descent, and genetic algorithms. Different approaches will experiment regarding which optimisation technology can have less error rate and hence select it to improve prediction accuracy. E.g., in Sevgi's study, it was found that genetic algorithms (GA)-augmented optimisation technology yielded an average error of 16.23% whereas feature counting and gradient descent had average errors of 17.63 and 21.20%, respectively. And the optimisation technology which has the lower error rate is used to improve the model accuracy.

Some limitations of CASE_PMP are commented by the respondents during the in-depth interview. One respondent claimed that CASE_PMP was too academic orientated as there are some CSFs were not included in the model, e.g., cost fluctuation and project site variation. The respondent still preferred the traditional method, i.e. based on previous project experience and project manger to estimate the project time and cost, for preparing the tender document but has no intention to try CASE_PMP because this respondent is a senior staff who is not familiar with those IT technologies and hence not keen to learn the new technologies. In addition, the case library was comprised of the Lu ban and Great Wall Prize, which is high level construction award in the industry, so contractors should be cautious about the outcome of CASE_PMP because there is the possibility for CASE_PMP to estimate an unachievable project cost and time based on the prize awarded project library. Lastly, one respondent explained that studies is needed to investigate if the case library exposes a gap in the case coverage.

9.8 Recommendations for future research

The results obtained can help the practitioner to identify the significance of the CSFs for new projects, and accordingly advises the construction professionals on the suitable project management strategy (project management CSFs) with respect to different project scenarios. The different project scenarios are reflected by different non-project management CSFs to achieve project success. The project data are from Beijing, China, the project management knowledge generated can be tested to generalize to other relevant parts of China because it is in compliance with four relevant aspects of PMBOK, i.e. the project management organization (C16), the main contractor and subcontractor's communication (C18), the construction technology (C21), and the system to ensure achievement of quality objective (23).

It is recommended for further study to examine how to improve the accuracy rate of the CBR model. It is worth experimenting with different weight optimisation techniques. The investigation on the impact of external factors of the project domain, for example, different countries' culture and political influence on the project management strategies because they have different CSFs. A decision support model can be developed. If the CASE_PMP can be put into practical use and with the accumulated real case and the improved accuracy rate, it can more rigorously generate knowledge. The hybrid model combining the CASE_PMP and a decision support technique such as decision tree can be proposed to predict the project success KPIs value based on different scenarios of the selected project management method. It can be the scope for future work.

All respondents during the in-depth interview expressed that the model concept is easy to understand and viable and they showed their strong interests for the model. The potential research will develop the user interface and the complete software. Some other CSFs which are not included in this study were identified in the in-depth interview. It is recommended that for future study, the author will be conducting in-depth case study for specific CSFs applicable to projects in Beijing.

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Appendix 1: Questionnaire for Survey for Luban and Greatwall Projects in Beijing, China

Dear Respondent,

This study attempts investigate the Luban and Greatwall prize projects in China. This research establishes the Case Based Reasoning Model CASEPMP by collection of Beijing Luban and Great Wall Prize project. CASEPMP is used to model the project success indicator (Key Performance Indicators (KPIs)) and the dependents of project success indicator (Critical Success Factors (CSFs). The purpose of this questionnaire is to gather your company's Luban and Greatwall project information.

We hope that you can contribute to this study. Your responses will be treated as confidential.

Thank you for your kind assistance.

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1. Project Name

2. Which year's Luban/Greatwall Projects

Client Related CSFs (F1)

3. The funding source of project is
[ ] Private (1)
[ ] Public (2)
[ ] Others (3)

4. Client experience (C2) The number of similar buildings they had commissioned in the past.
[ ] Those with no previous experience are given a low score of L (or rank 3).
[ ] Those with some previous experience involved with one or two buildings are given M (or rank 2),
[ ] Those have considerable experience (involved more than 2) are given H score (or rank 1).

5. Client's contribution to construction process (C3)

[ ] Client unsupportive is cored L (or rank 3),
[ ] medium is given M (or rank 2),
[ ] highly supportive is given H score (or rank 1).

6. Client criteria (C4) Client prioritizes the three criteria: time, cost and quality

[ ] Low construction cost (1);
[ ] quick construction (2);
[ ] high construction quality (3);
[ ] two of these criteria (4),
[ ] all criteria (5).

Designer characteristics (F2)

7. In house/outside designers (C5):

[ ]In-house is (1),
[ ]outside is (2).

8. Designers experience (C6)
[ ] Those with no previous experience are given a low score of L (or rank 3).
[ ] Those with some previous experience involved with one or two buildings are given M (or rank 2),
[ ] Those have considerable experience (involved more than 2) are given H score (or rank 1).

9. Designer's times of and significant change orders variations (C7)
[ ] The designer's times of significant change orders variations, more than two times scored H (Rank 1),
[ ] two times scored M (Rank 2),
[ ] less than two time scored L (Rank 3

Contractor characteristics (F3)

10. Contractors experience (C8)

[ ] Those with no previous experience are given a low score of L (or rank 3).
[ ] Those with some previous experience involved with one or two buildings are given M (or rank 2),
[ ] Those have considerable experience (involved more than 2) are given H score (or rank 1).

Project characteristics (F4)

11. Building work types (C9)

[ ] New (1)

[ ] refurbishment (2).

12. Project size: was defined by building cost (C10) and gross floor area in square meter.

[ ] Those less than RMB 3.6 million and 3000 sqm are regarded as small project (rank 3)

[ ] RMB $8.4 million and 7000 sqm are regarded as normal size projects (rank 2)

[ ] and those larger than the boundary as the large project (rank 1).

13. The attributes used to measure this factor were listed as following: Project complexity (C11)

[ ] very complex (5),

[ ] complex (4),

[ ] medium (3),

[ ] in complex(2),

[ ] very incomplex (1).

Procurement and Contract Characteristics (F5)

14. Contract procedure (C12)

[ ] Open tendering (1),

[ ] competitive selected tendering (2),

[ ] and negotiated contracts (3).

15. Procurement method (C13)

[ ] Traditional approach (1),

[ ] esign and Build approach (2),

[ ] management approach (3).

Other factors (F6)

16. Obstruction due to underground utilities and or inclement weather (act of god) (C14)

[ ] L (rank 3)

[ ] M (rank 2)

[ ] and H (rank 1).

Project management planning (F7)

17. Project management team organization (C15) Organized in the streamline structure; the major project construction function team is under the direct level of the project manager,

[ ] yes (2)

[ ] no (1).

18. Project management team works out the schedule plan (C16)
[ ] On the daily based (3),
[ ] weekly based (2),
[ ] and monthly based (1).

19. The main contractor and subcontractor's communication (C17)
[ ] The subcontractor's meeting is daily based (2)
[ ] or fix period meeting not daily based (1).

20. The effectiveness of the construction scheduling (C18) structure and installation part work is consequential but if the scheduling of these two parts has the overlap, it is effective. Alternative measurement is the application of the CPM to shorten the construction duration:
[ ] yes (2)
[ ] no (1).

21. The labor (skilful worker) input man (19)
day per square meter (divided by the GFA).

22. The major material (Steel) consumer (C20)
kg /per square meter (divided by the GFA).

23. The construction preparation (C21) the administration work preparation (the construction work permission); the technology work preparation (construction drawing familiar, preparation of the standard, preparation for the measurement and experiment etc.); the site preparation (Construction Equipment, Temporary Works, water/electricity preparation); the supply of the plant, materials and goods preparation. The number of all the above preparations:

[ ] all (3),
[ ] any three (2),
[ ] any two or one (1).

24. The technology management (C22) The measurement; experiment; documentation; development technology management objective; the technical methods to save cost; promotion of the new technology; quantify management and other technology management. The measurement scale of this indicator is ordinal. There are 8 aspects of this variable. Hence

[ ] achieving all aspects will be given the highest ranking (1),
[ ] and correspondingly achieving any six or five aspects will be given the second rank (2),
[ ] and achieving four or less aspects will be given the third rank (3).

25. The system to ensure achievement of quality objective (C23)Have the organization guaranty system for example, the ISO 9002 or any other third party certificate system for quality guaranty [ ] Yes (2),

[ ] No(1).

26. The quality management (C24) The quality objective is high standard or not.
[ ] The planning the quality score is 95% or above (3),
[ ] medium level is 80% or above (2),
[ ] low level is less than 80% (1).

27. Building types (C25)
[ ] Public –used buildings complex (1),
[ ] industrial (2),
[ ] commercial (3),
[ ] residential (4).

Key performance Indicator:

Speed of construction (K1): is a relative time, which is defined as gross floor area divided by the construction time.

Unit cost (K2): is a measure of relative cost and is defined as the final construction cost divided by the gross floor area.

Cost Variation (K3): is a ratio of final construction cost minus contract sum divided by final construction cost.

Quality score (K4):

Health and safety in terms of construction site death accident rate (K5):

Client satisfaction (K6):

---END-------------

Appendix 2: Luban and Great wall prize project classification

附件 1

鲁班奖工程类别划分

1．公共建筑工程。包括：办公楼、教学楼、科研楼、实验楼、影剧院、体育馆、体育场、游泳馆、训练馆、娱乐场、宾馆、饭店、商业楼、医院、邮电通讯楼、电力调度楼、火车站、汽车站、铁路站房、机场候机楼、会堂、仓库等。

2．工业、交通、水利工程。

工业建设项目。包括附件 2 所列各类工业。

交通工程。包括公路、铁路、大桥、机场、码头、港口、隧道、船闸等。

水利工程。包括水库、农田灌溉工程和生活、生产引水工程等。

3．市政、园林工程。包括城市道路、立交桥、高架桥、地铁、轻轨、独立水厂、公园、动物园、植物园等。

4．住宅工程。包括住宅小区、高层住宅、公寓和以住宅为主的综合楼等。

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Appendix 3: The selected sampling project list and projects data which have been collected

	项目名称	总包	编号	地址和联系电话	业主单位	编号
	莲花小区群体住宅楼（9 栋）	1.中国建筑第一工程局第二建筑公司（二组团 1# 2#楼，2#地下车库，2.北京市第一房屋修建工程公司（二组团 3# 4# 5#楼，3.北京市第三住宅建筑工程公司（一组团 1# 2# 3#楼）4.北京市第六住宅建筑工程公司（一组团 4# 5#楼，1#地下车库）	6		北京天鸿集团华宝公司	813
	万国公寓	中国国际建设公司	31	010-85276677 北京市朝阳区麦子店街 37 号 北京盛福大厦 12 层 邮编：100026 电话：86-10-85276677/89498866-5285	北京汉斯京盛房地产开发有限公司	1336
1	北京市公安局朝阳分局治安拘留所综合楼.	中国建筑一局(集团)有限公司	35	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	北京市公安局朝阳分局	926
2	中国音乐学院排演厅及综合教学楼工程	中国建筑一局(集团)有限公司	36	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	中国音乐学院	308
3	中国地质大学(北京)科研综合楼	中国建筑一局(集团)有限公司	37	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	中国地质大学北京	171
4	奥林匹克公园网球中心工程.	中国建筑一局(集团)有限公司	38	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	北京鹏森工程项目管理有限责任公司	1654

5	北京首都国际机场 3 号航站楼旅客过夜用房西楼工程	中国建筑一局(集团)有限公司	39	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	北京首都机场扩建工程指挥部	1635
6	中国地质调查科研业务用房工程	中国建筑一局(集团)有限公司	35	地址：北京市丰台区西四环南路 52 号邮编：100073 83982057(档案部）83982366 （办公室）83982475 党委工作部 （李部长）	中国地质调查科研业务用房项目领导小组办公室	172
7	东方艺术大厦 C 楼改造工程	中国建筑一局(集团)有限公司	36	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	东方艺术大厦有限公司	12
8	国家游泳中心	中国建筑一局(集团)有限公司	37	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	北京市国有资产经营有限责任公司	953
9	沈阳奥林匹克体育中心体育场工程	中国建筑一局(集团)有限公司	38	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	北京鹏森工程项目管理有限责任公司	1654
10	北京市人民检察院新建办公业务用房	中国建筑一局(集团)有限公司	39	地址：北京市丰台区西四环南路 52 号 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （李部长）	北京市人民检察院	909
	京师园住宅小区 4#楼工程	中国建筑一局(集团)有限公司	35	地址：北京市丰台区西四环南路 52 号 （丰台体育中心） 邮编：100073 83982057(档案部） 83982366 （办公室）83982475 党委工作部 （25 打电话给） 83982708(董经理） /dongqc@cscec1b.net	北京师范大学房地产开发有限责任公司	1185
	国家地震紧急救援训练基地	中国建筑工程总公司	46	三里河路 15 号中建大厦 电话:086-010-88082888 （办公室 88082991）市场管理部 （88082956 邹经理 zouji@cscec.com.cn）(打通了，邹经理帮我转）人力部 （88082774）	中国地震局综合观测中心	173

	中直机关复兴路 4 号院职工住宅Ⅱ标段 13#～16#楼	中国建筑工程总公司	46	三里河路 15 号中建大厦 电话:086-010-88082888 （办公室 88082991）市场管理部（88082956 邹经理 zouji@cscec.com.cn）人力部（88082774）880839129 （综合管理部）	中直机关住房服务中心	334
11	金宝街 6 号地(金宝汇)工程	中国建筑第一工程局第三建筑公司	54	地址：北京市西四环南路 52 号中建一局大厦 邮编：100073 电话：86-10-83982229 83982240（质量部）	北京华富金宝房地产开发有限公司	638
12	北京香港马会会所	中国建筑第一工程局第三建筑公司	54	地址：北京市西四环南路 52 号中建一局大厦 邮编：100073 电话：86-10-83982229 83982240（质量部）	北京华富金宝房地产开发有限公司	638
	索龙电子(北京)有限公司厂房工程	中国建筑第一工程局第三建筑公司	54	地址：北京市西四环南路 52 号中建一局大厦 邮编：100073 电话：86-10-83982229 83982230	索龙电子(北京)有限公司	1885
13	大红门住宅区 A-01 地块商业、公寓及地下车库工程,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2212	北京银帆基业房地产开发有限公司	1575
14	北京市计算机工业学校第二教学楼.	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2213	北京市计算机工业学校	1136
15	国典大厦,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2214	北京国电房地产开发有限公司	725
16	总参军训和兵种部 9088 工程,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2215	中国人民解放军总参谋部军训和兵种部营建办公室	84
17	地质科研楼工程,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2216	北京矿产地质研究院有色金属矿产地质调查中心	1423
18	体彩北京生产基地 1#综合厂房工程	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2217	北京中体彩印务技术有限公司	455
19	外经贸专用网主中心,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2218	中国国际电子商务中心工程部	167
20	北京（国家）蛋白质组研究中心实验及办公楼	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2219	北京正旦国际科技有限责任公司	1322
21	海淀区魏公大厦 A 座,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2220	北京国华时代房地产开发有限公司	719
22	客隆酒仙桥商场,	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/67215544-2221	北京京客隆超市连锁集团有限公司	526
23	中京艺苑(含中国京剧大剧院)	中国建筑第一工程局第二建筑公	55	北京市永外海户屯 165 号/67215544-2212	北京中京艺苑房地产开	454

		司			发有限责任公司	
	星海乐器园一总装分厂、音源分厂	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/010-67215544（无人接听）	北京星海乐器有限责任公司	1292
	国药物流有限责任公司物流中心工程	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/010-67215544	国药物流有限责任公司	1748
	联想电脑生产厂房	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/010-67215544	联想电脑集团控股公司	1890
24	北京同仁医院经济技术开发区院区门诊医技病房楼	中国建筑第一工程局第二建筑公司	55	北京市永外海户屯 165 号/010-67215544	首都医科大学附属北京同仁医院	1927
	中直机关马连道经济适用房住宅小区 11#楼、17#楼	中国建筑第一工程局第五建筑公司	56	010-65762471/65737626 （党务部齐部长）/北京朝阳区定福庄北里 1 号鲁班大厦 65737675(质量部）（魏先生）项目管理部（65762472）庞经理 2 点 （）	中直机关住房服务中心	334
25	万通发展大厦（A 、C 座）	中国建筑第一工程局第五建筑公司	56	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	北京经济发展投资公司万通发展大厦	1453
26	北京生命科学研究所实验及办公大楼	中国建筑第一工程局第五建筑公司	57	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	中关村生命科学园发展有限责任公司	23
27	北京新城国际公寓(一期)工程	中国建筑第一工程局第五建筑公司	58	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	北京万置房地产开发有限公司	410
28	仁达科教中心	中国建筑第一工程局第五建筑公司	59	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	中国人民大学校园建设管理处	42
29	中国通用技术大厦工程	中国建筑第一工程局第五建筑公司	60	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	中国通用技术（集团）控股有限责任公司通用技术大厦基建处	301
30	北京利达永信电子有限公司二期工程	中国建筑第一工程局第五建筑公司	61	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	北京利达永信电子有限公司	610
31	全国海关信息中心备份中心工程	中国建筑第一工程局第五建筑公司	62	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	中华人民共和国海关总署基建办公室	33
32	金融街 G4D 写字楼工程	中国建筑第一工程局第五建筑公司	63	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	北京市电信房地产开发有限责任公司	1101
33	北京建外 SOHO 七期工程	中国建筑第一工程局第五建筑公司	64	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	北京红石建外房地产开发有限公司	1451
34	训练局综合训练馆（举重、篮球）工程	中国建筑第一工程局第五建筑公司	65	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	国家体育总局训练局	1712

	北京市三露厂生产、科研、培训综合楼	中国建筑第一工程局第五建筑公司	56	010-65762471 北京朝阳区定福庄北里 1 号鲁班大厦	北京市三露厂	878
	朝阳望京新城 B 区 6-10 号地 A 区二期 A-3 综合楼	中国新兴保信建设总公司	78	010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）	北京方恒房地产开发有限公司	1278
35	总参防化指挥工程学院学员食堂及锅炉房工程	中国新兴保信建设总公司	78	010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）	中国人民解放军防化指挥工程学院院务部	142
36	江西大厦(一期)	中国新兴保信建设总公司	78	010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）(	江西省人民政府驻北京办事处	1852
37	北京联兴盛业印刷有限公司大兴新厂址建设工程厂房 2 及办公楼	中国新兴保信建设总公司	78	010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）(	北京联兴盛业印刷有限公司	1462
38	华汽综合楼工程	中国新兴保信建设总公司	78	李强项目经理 010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）	北京汽车工业集团总公司	1339
39	建设工业仪器生产厂房(附属办公室等 6 项)	中国新兴保信建设总公司	79	李强项目经理 010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）	北京博飞仪器股份有限公司	678
40	广益大厦	中国新兴保信建设总公司	78	李强项目经理 010-67667271/6456（党务部）2：00（中国北京市丰台区永定门外东铁营顺八条 9 号，张部长）	北京宸京房地产开发有限公司	849
	北京工商大学良乡新校区图书馆	中国新兴建设开发总公司	81	中国北京西三环中路 17 号 100036 电话:8610-68227396	北京工商大学新校区建设指挥部	876
41	安德大厦	中国新兴建设开发总公司	82	中国北京西三环中路 17 号 100036 电话:8610-68227397	北京安德置业有限公司	824
42	北京华贸中心酒店,	中国新兴建设开发总公司	83	中国北京西三环中路 17 号 100036 电话:8610-68227398	北京华贸素拉潘酒店发展有限公司	660
43	北京嘉捷产业园 CEV 厂房	中国新兴建设开发总公司	84	中国北京西三环中路 17 号 100036 电话:8610-68227399	北京嘉捷美锦科技发展有限公司	708
44	先进钛合金精密成型件产业化等 5 项	中国新兴建设开发总公司	85	中国北京西三环中路 17 号 100036 电话:8610-68227400	北京百慕航材高科技股份有限公司	1411
45	生产试验用房	中国新兴建设开发总公司	86	中国北京西三环中路 17 号 100036 电话:8610-68227401	京卫医药科技集团有限公司	366
46	样品车间及综合楼等四项工程	中国新兴建设开发总公司	87	中国北京西三环中路 17 号 100036 电话:8610-68227402	北京京珠盛世服饰有限公司	532
	军品生产厂房及科研楼	中国新兴建设开发总公司	88	中国北京西三环中路 17 号 100036 电话:8610-68227403	国营北京曙光电机厂	1752
	北京仪器厂 1# 2#生产厂房	中国第二十二冶金建设公司	89	021-56600506	北京市仪器厂仪表建设工程承发包公司	911

	上地北区 2 号地块科技厂房 E 号楼及 E 号集中制冷站	中国航空港建设总公司	91	北京市海淀区北四环西路 87 号 电话：（010）88852857 工程部 88853379	北京实创科技园开发建设股份有限公司	844
	东方华府北区中学	中天建设集团有限公司第四建设公司	97	0571-28861666	北京在义北方置业有限公司	734
	北苑住宅区 A 西区(上元雅苑)（群 10 栋）	中建一局建设发展公司	103	010-64726243（需要找人）	北京新凯房地产开发有限公司	1255
	北京检验检疫局综合实验楼	中建保华建筑有限责任公司	112	010-52072881	中华人民共和国北京出入境检验检疫局大楼基建办	28
47	北京通信公司综合业务楼	中铁建设集团有限公司	137	010--68687619（经理办)/51885010(办）/51885857（fanghongwei)(质量部）	中国网通集团北京市通信公司	265
48	北京昌平区综合体育馆	中铁建设集团有限公司	138	010--68687619（经理办)/51885010(办）/51885857（fanghongwei)(质量部）	北京市昌平区体育局	1049
49	中国铁道建筑总公司西十住宅楼即地下车库	中铁建设集团有限公司	139	010--68687619（经理办)/51885010(办）/51885857（fanghongwei)(质量部）	中国铁道建筑总公司机关基建办公室	303
	轻汽西厂区改造项目(公建区)	中铁建设集团有限公司	136	010--68687619（经理办)/51885010(办）/51885857（fanghongwei)(质量部）	北京瑞景清源房地产开发有限公司	1398
	上元雅苑(上元住宅区 A 西区)B 区工程	中集建设集团有限公司	139	010-63318851	北京新凯房地产开发有限公司	1255
	北京联合大学应用文理学院实验楼	北京万兴建筑集团公司	147	北京市大兴区黄村镇龙河路 18 号 电话：010-69241750 69252832(工程部）69247457（李总）	北京联合大学应用文理学院基建办公室	1463
50	纽朗(北京)医药包装设备生产基地	北京万兴建筑集团有限公司	147	北京市大兴区黄村镇龙河路 18 号 电话：010-69241750 69252832(工程部）69247457（李总）	纽朗包装机械(北京)有限公司	1886
51	北京稻香村北七家食品加工厂	北京东兴建设有限责任公司	156	北京市东城区礼士胡同 75 号 86 010 64156699 64176573(技术质量部）王先生	北京稻香村北七家食品加工厂	1439
	桃园 A 地块住宅工程	北京中创世纪建筑工程有限公司	164		北京天鸿集团公司	813
	青年路 C 区住宅小区 9#楼	北京中谷成开发建设有限公司	170	Tel:010-64213231 至 3235 中国北京市朝阳区北三环东路 12 号	北京润丰房地产开发有限公司	1370
	上地北区 2 号地块科技厂房 C 座	北京中铁大都工程有限公司	171	01060243205,北京市大兴区欣荣大街	北京华控技术有限责任公司	641
	永兴嘉轩居住楼 3#、4#楼	北京京西建筑集团有限责任公司	178	69836278 门头沟区新桥大街 44 号 69862888	北京永兴嘉业房地产开发有限公司	1327

52	中国银行信息中心办公楼及综合服务楼工程、生产机房楼	北京住总集团有限责任公司	188	北京市海淀区阜城路 5 号北京市住总集团第三分公司	北京中银大厦有限公司	496
53	中国牧工商(集团)总公司农优产品仓储配送项目工程	北京住总第三开发建设有限公司	184	北京市海淀区阜城路 5 号北京市住总集团第三分公司	世纪润通国际贸易有限公司	9
54	樊家村危改(万年花城)5#地块 5-6#楼-5-2.5#楼,	北京住总第三开发建设有限公司	184	北京市海淀区阜城路 5 号北京市住总集团第三分公司	北京万年花城房地产开发有限责任公司	402
55	回龙观居住区后期 G06 区 01 号楼等十项	北京住总第三开发建设有限公司	185	北京市海淀区阜城路 5 号北京市住总集团第三分公司	北京天鸿嘉诚房地产开发有限公司	810
56	翠成馨园 B-C16(小学)	北京住总第三开发建设有限公司	186	北京市海淀区阜城路 5 号北京市住总集团第三分公司	北京住总房地产开发有限责任公司	555
	常营居住区一期工程 231#楼	北京住总第六开发建设有限公司	186	010-67019997	北京天鸿置地土地开发有限责任公司	813
	嘉轩城市花园 8#楼	北京住总集团有限责任公司住三分部	190	68355348 88371468（质量部）	北京嘉轩房地产开发有限公司	711
	还建北京第二实验小学工程	北京住总集团有限责任公司工程总承包部	192	82847983　朝阳区华严北里 51 号楼	北京城市开发集团有限责任公司	742
	新康家园二期住宅 4#、5#楼	北京城乡建设集团有限责任公司建兴建筑工程分公司	220	北京市宣武区鸭子桥路 6 号（万隆酒店 526 室） +86 10-87772316(not reachable)	北京新康房地产发展有限公司	1267
57	239 厂科研试验综合楼	北京城乡欣瑞建设有限公司	227	北京市工程建设质量管理协会	北京航星机器制造公司	1477
58	主工房(含办公楼)	北京城建北方建设有限责任公司	250	北京市工程建设质量管理协会	中钞信用卡产业发展有限公司基建筹建处	346
	东风小区 E2 区 14#、16#住宅工程	北京城建一建设工程有限公司	231	北京市海淀区北太平庄路 18 号城建大厦 A 座 1305 - +86 10-62091305	北京天鸿房地产开发有限责任公司	813
	大运村公寓 11#办公楼	北京城建七建设工程有限公司	233	62011844/82023475/82022885(技术部梁部长） 丁副部长 （北京市朝阳区德胜门外祁家豁子 2 号/	北京天鸿集团公司北京天鸿集团公司	813
59	北京卷烟厂联合工房工程	北京城建三建设发展有限公司	235	北京市昌平区太海路 81756655/81756408（技术质量部）	北京卷烟厂	683
	通州富河园二期工程 4#楼	北京城建三建设工程有限公司	235	北京市昌平区太海路 81756655/81756408（技术质量部）	北京市开原房地产开发有限责任公司	1015
	北京昌平东小口陈营商业中心工程	北京城建九建设工程有限公司	236	68186719 （114）/ 010-68215588- 质量部	北京市裕友房地产开发集团	1128

60	国际服装英超研发设计(中国)产业园	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京英超工贸有限公司	1480
61	永定路商业住宅楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京邦泰置业有限公司	1525
62	北京财源国际中心—东塔楼工程,	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京建机天润房地产开发有限公司	1208
63	鼎固科贸综合楼二期工程,	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京鼎固房地产开发有限公司	1655
64	天都嘉园 3#住宅楼,	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京罗兰德房地产开发有限公司	1456
65	解放军总医院沙窝居住区(颐晟小区)2#、3#楼工程	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民解放军总医院院务部	77
66	三里河二区 3 号地 1#楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中央国家机关三里河联建办公室	315
67	军博莲花小区经济适用房	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民革命军事博物馆	145
68	北京安慧北里(4307)住宅 9#楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民解放军总装备部后勤部	110
69	公安部物证鉴定中心住宅楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	公安部物证鉴定中心	390
70	红居危改小区南区住宅楼工程	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京裕泰达房地产开发有限公司	1495
71	西北旺镇区二期工程(3标段)	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京德成兴业房地产开发有限公司	1218

72	远洋山水西区一期工程Ⅱ标段(3#、4#)	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中远房地产开发有限公司	345
73	太阳星城 F 区二期 11#、15#、16#、18#楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京太阳宫房地产开发有限公司	816
74	总政机关四道口经济适用住宅小区 1、2 号楼工程	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民解放军总政治部机关营建办公室	105
75	总装备部离休干部住宅(南)楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民解放军总装备部后勤部基建办公室	110
76	77#工业产业配套单身公寓工程III标段	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京经济技术投资开发总公司	1454
77	东湖湾名苑 301#住宅、302#住宅	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京市东湖房地产公司	888
78	总政机关莲花池小区住宅 16 号楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民解放军总政治部机关离休干部住房修建办公室	104
79	万泉寺住宅小区 A 区 5#、6#住宅楼	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	中国人民解放军装甲兵工程学院	140
80	永丰嘉园(三组团)	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588-质量部 （二公司和九公司同一个号码）	北京德成兴业房地产开发有限公司	1218
	海淀看守所二标段	北京城建二建设工程有限公司	237	010-68215588- 质量部 北京市海淀区复兴路 81 号 010-68215588- 质量部 （二公司和九公司同一个号码）	北京德成置地房地产开发有限公司	1220
81	石榴庄住宅小区 C 区 1#-8#楼工程(群体)	北京城建五建设工程有限公司	240	市场营销部： 电话：+86-10-64895535/64895700（办公司）/技术部（64895721/2021）64895857（质量部）	北京银科房地产开发有限公司	1579
	北京工商大学良乡新校区工科教学楼及实习楼	北京城建五建设工程有限公司	240	市场营销部： 电话：+86-10-64895535/64895700（办公司）/技术部（64895721/2021）64895857（质量部）	北京工商大学	876

	姚家园住宅小区 2#楼、4#楼	北京城建五建设工程有限公司	240	市场营销部： 电话：+86-10-64895538 党委工作部宣传： 电话：+86-10-64895850/53	北京银科房地产开发有限公司	1579
	西客站南广场综合服务楼	北京市第五城市建设工程公司	409		北京市公共交通总公司基建处	918
82	中关村西区 25＃地工程	北京城建七建设工程有限公司	232	62011844/82023475/82022885(技术部梁部长） 丁副部长 （北京市朝阳区德胜门外祁家豁子 2 号/（see data)	北京科技园置业股份有限公司	1432
83	总参作战部测绘局工程西 2 楼(8551)	北京城建七建设工程有限公司	232	62011844/82023475/82022885(技术部梁部长） 丁副部长 （北京市朝阳区德胜门外祁家豁子 2 号/（see data)	中国人民解放军总参谋部作战部测绘局管理处	82
84	大运村公寓 11#办公楼	北京城建七建设工程有限公司	232	62011844/82023475/82022885(技术部梁部长） 丁副部长 （北京市朝阳区德胜门外祁家豁子 2 号/（see data)	北京天鸿集团公司北京天鸿集团公司	813
85	大运村公寓 12#楼	北京城建七建设工程有限公司	232	62011844/82023475/82022885(技术部梁部长） 丁副部长 （北京市朝阳区德胜门外祁家豁子 2 号/（see data)	北京天鸿集团公司北京天鸿集团公司	813
86	常营居住区一期工程 4#标段工程 224#、225#楼	北京城建七建设工程有限公司	232	62011844/82023475/82022885(技术部梁部长） 丁副部长 （北京市朝阳区德胜门外祁家豁子 2 号/（see data)	北京天鸿房地产开发有限责任公司	813
87	秘书局办公楼改扩建工程	北京城建亚泰建设工程有限公司	244	公司地址：中国北京市朝阳区东土城路 9 号 公司电话：(010)64215588-6610（技术部）/6670(质量部）	国务院办公厅行政司房管处	1698
88	北京会议中心 9 号楼	北京城建亚泰建设工程有限公司	245	公司地址：中国北京市朝阳区东土城路 9 号 公司电话：(010)64215588-6610（技术部）/6670(质量部）	北京京会花园置业有限公司	521
	永泰大酒店 A、B 座及冷热源机房	北京城建北方建设有限责任公司	250	地址：北京市朝阳区北土城西路 11 号城建开发大厦东座 邮编：100029 电话：82080429	北京永泰酒店管理有限公司	1330
	东陶机器（北京）二期厂房工程	北京城建四建设工程有限公司	254	北京海淀区王庄路 27 号 ADD:NO.27,电话/Tel：010-62315599/	东陶机器（北京）有限公司	13
	开阳里三 区 1#非配套公建工程	北京天恒建设工程有限公司	282	地 址：北京市大兴区黄村镇市场路东巷 5 号 邮政编码：102600 联系电话：010-69242348/69258027(技术质量部）-8024（王工）（	北京城市开发集团有限责任公司城区分公司	742
	国家计生委住宅楼	北京天桥建筑有限责任公司第十分公司	284	北京市宣武区先农坛街 18 号 +86 10-63516728 北京天桥建筑有限责任公司物资分公司（还没查到技术质量部的电话）	国家计生委住宅楼基建办公室	1740
	雅昌彩印天竺厂房	北京天源建筑工程有限责任公司	287	北京市顺义区空港工业区 B 区裕民大街 9 号 80495323.	北京雅昌彩色印刷有限公司	1603
	地坛体育中心东看台工程	北京市东城区第二建筑工程公司	293	北京市东城区北京市东城区春松胡同 1 号 10-65241474	北京市东城区体育运动	883

					委员会	
	东风小区 E2 区 17-19#住宅及地下车库	北京市朝阳田华建筑集团第五分公司	374		北京天鸿房地产开发有限责任公司	813
	中直机关马连道经济适用房住宅小区 1#楼	北京市第二建筑工程有限责任公司	405	8610-81960470/68352861-技术质量部 68332211-8205	中直机关住房服务中心	334
89	北京长城华冠汽车设计研发中心项目工程	北京市第二建筑工程有限责任公司	406	8610-81960470/68352861-技术质量部 68332211-8206	北京长城华冠汽车技术开发有限公司	1586
	广电总局招待所改建工程	北京市第二建筑工程有限责任公司	405	8610-81960470	国家广播电影电视总局行政管理局	1720
	病房楼、门诊医技楼等 2 项工程(北京右安医院一期改扩建工程)	北京市第五建筑工程有限公司	410	北京市朝阳区安苑东安里三区 10 号系电话：010-64914477	首都医科大学附属北京佑安医院	1927
90	金宝街 5#地综合楼工程	北京市第六建筑工程公司	414	北京市海淀区太平路 32 号联系电话：01068210010（办公室）-68214477（转技术质量部）	北京华海金宝房地产开发有限公司	647
91	金融街 F10（3）金殿大厦	北京市第六建筑工程公司	414	北京市海淀区太平路 32 号联系电话：01068210010（办公室）-68214477（转技术质量部）	中国大唐集团公司	174
92	金运大厦	北京市第六建筑工程公司	414	北京市海淀区太平路 32 号联系电话：01068210010（办公室）-68214477（转技术质量部）		
	中国地质调查科研业务用房工程	中国建筑一局(集团)有限公司	35	中国地质调查科研业务用房项目领导小组办公室		172
93	北京现代汽车 2 工厂涂装车间、总装车间	北京建工集团有限责任公司第二直属工程经理部	442	010-63524831（总机）-技术质量部	北京现代汽车有限公司	1394
94	A380 机库工程	北京建工集团有限责任公司	438	010-63524831（总机）-技术质量部	北京飞机维修工程有限公司	1625
95	北京世纪华侨城旅游主题社区商业中心	北京建工集团有限责任公司总承包二部	439	010-63524831（总机）-技术质量部	北京世纪华侨城实业有限公司	427
96	国家粮食局科学研究院科研楼	北京建工集团有限责任公司总承包二部	439	010-63524831（总机）-技术质量部	国家粮食局科学研究院	1734
97	北京农业生态工程试验基地"配套工程"	北京建工博海建设有限公司	431	北京市西城区三里河北街甲一号，北京建工博海建设有限公司 100045	北京农业生态工程试验基地	594
98	望都家园 25#～31#工程	北京建工集团有限责任公司总承包二部	439	010-63524831（总机）-技术质量部	北京世桥房地产开发有限公司	423
99	花家地西里五组团 A、B、C 座及车库	北京建工集团有限责任公司总承包二部	439	010-63524831（总机）-技术质量部	北京金隅嘉业房地产开发公司	1557
100	当代万国城北区 1#、2#、3#、5#、10#住宅楼及地下车库工程	北京建工博海建设有限公司	431	北京市西城区三里河北街甲一号，北京建工博海建设有限公司 100045	北京当代鸿运房地产经营开发有限公司	1217
	中直联建关厢小区 B 区住宅楼及地下车库	北京建工一建工程建设有限公司	429	010-63524831（总机）-技术质量部	中直机关住房服务中心	334

	朝阳广场	北京建工四建工程建设有限公司	417	北京市崇文区永定门外大街160号北 - +86 10-67232175/67222404（114电话）-技术质量部 67225651/FAX 68523014	联合置地房地产开发有限公司	1889
	中直联建关厢小区C区C1# 、C2#楼	北京房修一建筑工程有限公司	449	中国·北京市西城区太平湖东里甲5号 电话：86-010-66077200	中直机关住房服务中心	334
	常营居住区一期205#楼	北京正荣建设工程有限责任公司	464	北京市朝阳区西大望路24号（52012810）	北京天鸿房地产开发有限责任公司	813
	红螺寺中学学生公寓	北京金桥建筑工程有限公司	502	北京市怀柔县迎宾北路北大街12号（89691233）	北京金港物业管理有限公司	1552
	北京友谊医院门诊急诊教学综合楼	北京长城贝尔芬格伯格建筑工程有限公司	509	北京市朝阳区西坝河南路1号金泰大厦16层 - +86 10-64402721	首都医科大学附属北京友谊医院	1927
	魏公村危改小区1#、4#、5#住宅楼	北京陶然建筑有限公司	513	北京市宣武区广外天宁寺前街2号/ 63263618/63263613	北京魏公元鼎房地产开发有限责任公司	1646
	北京工商大学教学实验楼	北京韩建集团有限公司	514	北京 北京市 海淀区西四环北路117号 +86 10-88493043	北京工商大学规划建设处	876
	常营居住区一期415-418#住宅楼	北京鼎华建筑工程有限公司	526	北京市丰台区西四环南路52号 - +86 10-83982211	北京天鸿房地产开发有限责任公司	813
	绿城·百合公寓住宅小区62#、63#、66#楼	北京龙建集团有限公司	527	北京市房山区良乡月华大街3号 邮编：102488 电话：89369810（准备开会）	北京阳光绿城房地产开发有限公司	1592
101	华电(北京)热电有限公司郑常庄燃气热电工程	天津电力建设公司	555	北京市工程建设质量管理协会	华电(北京)热电有限公司	1684
102	新华联光机电一体化产业基地1#楼	湖南新华联建设工程有限公司	625	北京市工程建设质量管理协会	北京新华联置业有限公司	1259
103	三院159厂81#建筑物	中航天建设工程公司	123	北京市工程建设质量管理协会	国营第一五九厂	1754
104	北汽福田汽车股份有限公司研发楼(一期)	北京怀建集团有限公司	445	北京市工程建设质量管理协会	北京福田汽车股份有限公司	1428

Appendix 4: an example of a completed survey questionnaire (mandarin)

北京市鲁班奖长城杯建筑项目成功经验研究 (附件一)

1. 说明

尊敬的北京市建设单位的项目经理/负责人：

悉闻贵单位荣获历年的北京市鲁班奖/长城奖。为促进高质量项目成功经验的交流和推广， 本问卷列出了项目成功的相关因素以及项目的技术及经济指标，真诚地希望您能帮助完成本调查问卷，非常感谢您的合作。 最后请放心，本调查只做学术目的，您所提供的信息将完全保密。

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Research Student
Department of Building
4 Architecture Drive 117566
National University of Singapore
Tel: 65 6516-3513 Fax: 65 6775-5502
e-mail: g0403444@nus.edu.sg

1. 项目的名字：

回龙观文化居住区后期G06区（经济适用房）

2. 获得那一年的鲁班奖或者长城奖

2007年度结构长城杯.

3. 项目资金来自 (C1)

[ ] 公共 (1)

[ ] 私人 (2)

[√] 其他 (3)

一. 业主性质(F1)

4. 业主经验 (C2), 以业主以往有过类似项目经验为参照

[ ] 没有以往经验为 L (rank 3)

[ ] 有一些经验(参与过一或两个项目) 为 M (or rank 2)

1

[✓] 有丰富经验(参与两个或以上项目 2) 为 H (or rank 1)

5. 业主贡献(C3), 业主对项目成功的贡献：

[ ] 业主对项目的建设不很支持 (or rank 3),

[✓] 业主对项目的建设支持中等 (or rank 2),

[ ] 业主对项目的建设支持度高(or rank 1).

6. 业主标准(C4), 对时间，成本和质量的要求.

[ ] 业主强调低成本(1),

[ ] 业主强调项目短时间建设(2),

[ ] 业主强调高质量(3),

[✓] 业主强调项目时间成本和质量中的任两个(4),

[ ] 业主强调项目的时间,成本和质量(5).

二. 咨询设计企业性质(F2)

7. 咨询设计企业是内部/ 外部(C5),

[✓] 内部 (1),

[ ] 外部 (2).

8. 咨询设计企业经验(C6), 以咨询设计企业以往有过类似项目经验为参照.

[ ] 没有以往经验为 L (rank 3)

[✓] 有一些经验(参与过一或两个项目) 为 M (or rank 2)

[ ] 有丰富经验(参与两个或以上项目 2) 为 H (or rank 1).

9. 咨询设计企业重大变更情况(C7), 咨询设计企业重大变更次数,

[ ] 多于两次 H (Rank 1),

[ ] 两次 M (Rank 2),

[✓] 少于两次 L (Rank 3).

三. **建筑承包企业性质(F3)**

10. 企业经验(C8), 以建筑承包企业以往有过类似项目经验为参照.

[ ] 没有以往经验为 L (rank 3)

[✓] 有一些经验(参与过一或两个项目) 为 M (or rank 2)

[ ] 有丰富经验(参与两个或以上项目 2) 为 H (or rank 1).

四. **项目情况(F4)**

11. 项目情况(C9):

[✓] 新建 (1)

[ ] 翻新 (2)

12. 项目的建筑面积是(C10):

[✓] 大于 20000 平方米（1）

[ ] 10000-20000 平方米（2）

[ ] 小与 10000 平方米 （3）

13. 项目复杂度 (C11): 项目经理主观评断项目的复杂度， 从 1 到 5,

[ ] 5 非常复杂

[ ] 4 复杂

[√] 3 中等

[ ] 2 不非常复杂

[ ] 1 非常不复杂

五. 合同性质(F5)

14. 工程采购方式(C12)：

[√] 公开招标(1),

[ ] 邀请招标(2),

[ ] 议标(3)

15. 工程建设方式(C13)：

[√] 传统(1)

[ ] D& B (2),

[ ] 其它(3)

六. 其他因素(F6)

16. 遇到地面以下不测情况或者恶劣气候对项目的影响(C14)：

[ ] 低 L (rank 3)

[ ] 中 M (rank 2)

[√] 高 H (rank 1)

七． 实现项目管理计划(F7)

17. 项目管理队伍的组织结构(C15)是扁平结构，施工组织直接在项目经理的领导下:

[✓] 是(2)

[ ] 否(1)

18. 项目施工管理队伍的进度计划是 (C16):

[ ] 以每天为单位计划 (3),

[✓] 以每周为单位计划 (2),

[ ] 以每月为单位计划(1).

19. 总包和分包的会议周期是 (C17):

[ ] 每天例会(2)

[✓] 定期例会但不是每天(1).

20. 施工进度计划是否有效：(C18) 结构和安装工程有无重叠进度或者应用关键路径（CPM）等技术来缩短项目工期:

[ ] 是 (2)

[✓] 否 (1).

21. 技术工人（如木工，钢筋工等）的劳动力计划，进场人数，时间除以建筑面积（人/天/建筑面积）(C19):

22. 主要材料（钢材/钢筋）的需用量 kg /平方米（建筑面积）(C20)

约 30kg/m²

23. 建筑施工的准备工作(C21): 施工行政许可准备工作， 技术准备工作（熟悉施工图建立健全现场测量和试验系统机制， 施工现场的准备（四通一平），施工设备，材料的准备. 以上各项准备，有明确的计划和准备的数目。

[✓] 所有 (3),

[ ] 任意三个 (2),

[ ] 任意一个或两个 (1).

24. 施工技术管理(C22):测量，试验，文档管理，设立技术管理目标，采用先进施工技术节约成本，推广新技术，量化管理或者其他方法。以上七各方面，实际施工中有涉及到几个：

[✓] 全部 (3),

[ ] 五六个(2),

[ ] 三四个或者更少(1).

25. 工程质量保证体系(C23)如有 ISO 9000 或其他质量认证系统(GB):

[✓] 是 (2),

[ ] 否(1).

26. 计划的项目优良率（C24）:

[ ] 大与或等于 95% (3),

[✓] 大与或等于 80% (2),

[ ] 小于 80% (1).

七. 项目成功因素

27. 建筑速度(K1) 建筑面积除以建筑工期(竣工时间减去开工时间)

165 m^2/天

28. 单位成本(K2) 建筑成本除以建筑面积

约 1000元/m^2.

29. 降低成本率为(K3)

6%

30. 分部工程质量优良率(K4)

100%

31. 分项工程质量优良率(K4)

100%

32. 安全指标 (K5)，工伤事故率为 0%

33. 从 1 到 5 业主对项目的满意度是（1 是最不满意，5 是最满意）(K5)

[ ] 5

[√] 4

[ ] 3

[ ] 2

[ ] 1

---END---

Appendix 5: a sample of the Luban and Greatwall application form

P.S. The official form for applying Luban and Great Wall Prize (in Chinese)

经典

北京市建筑结构长城杯工程申报表

工程项目 东方艺术大厦C楼改造工程

申报单位 中国建筑一局（集团）有限公司

申报时间 2007年03月25日

北京市工程建设质量管理协会监制

10000

表（一）

工程名称	东方艺术大厦 C 楼改造工程	建筑面积	21382 m²
工程地址	朝阳区东三环北路东方路 1 号	施工许可证（开工证）编号	[2006]施（朝）建字 0081 号
建设单位	东方艺术大厦有限公司	结构类型（层数）	框架-抗震墙 地上 9 层，地下 2 层
设计单位	北京城建设计研究总院有限责任公司	建设监理单位	北京国金管理咨询公司
总承包单位	中国建筑一局（集团）有限公司	质量监督单位	北京市朝阳区质量监督站
项目负责人	刘　泽	项目技术负责人	李光凯
开工时间	2006 年 09 月 11 日	计划竣工时间	2008 年 02 月 29 日

工程结构简况介绍：

本工程结构安全等级为二级，设计使用年限 50 年。本建筑为丙类建筑，抗震设防烈度八度；一类高层建筑，一级旅馆。结构抗震等级：剪力墙为一级，框架为二级。基础类型为桩筏基础，基底标高-8.57m、-8.67m、-9.77m。结构形式为全现浇钢筋砼框架-抗震墙结构。砼标号主要为：筏基底板及地梁、地下室外墙、水箱、水池 C35S8；顶部为室外的顶板及顶梁 C40S8；-2～2 层框架柱及剪力墙 C50；3 层及以上框架柱、剪力墙、框架梁、次梁、楼板 C40；楼梯、坡道 C30；构造柱、圈梁 C20；垫层 C15。钢筋类别有：HPB235、HRB335、HRB400、ϕ^{s}5.20mm 钢绞线(有粘结后张法)。钢筋连接方式：直径 18 以上的直螺纹连接、其余的为搭接。

所属区、县、市集团总公司、创优片组评审机构推荐意见：

同意申报

推荐单位章

2007 年 4 月 3 日

建设单位推荐意见：

建设单位章

2007 年 4 月 6 日

监理单位推荐意见：

同意申报

监理单位章

2007 年 4 月 3 日

申报联系人	刘　泽、李光凯	电　　话	13321156301 13321156361

表（二）

建筑结构长城杯初评小组推荐意见: 初评组长:　　　　　　年　月　日
建筑长城杯工程评委会评审意见: 评委会章 年　月　日

2224

表（一）

工程名称	北京利达永信电子有限公司二期工程		建筑面积	10969.98 m²
工程地址	北京市经济技术开发区 31#街区		总造价	1829 万元
结构类型	框架结构	层数	地上四层，局部五层	
结构质量评价等级	北京市结构长城杯金质奖	结构质量评价单位	北京市优质工程评审委员会	
开工时间	2005 年 4 月 24 日	竣工验收日期	2006 年 3 月 14 日	
备案日期	2006 年 3 月 21 日	备案证明文件编号	20060111	
建设单位	北京利达永信电子有限公司		施工许可证编号	施 1920050015（建）
设计单位	中国中轻国际工程有限公司			
监理单位	北京远东工程项目管理有限公司			
总承包单位	单位名称：中国建筑第一工程局第五建筑公司			
	项目负责人	李克成	技术负责人	汤德芸
	质量负责人	郭凤华	竣工验收质量评价	合格
主分包设备安装单位	中建润通机电安装有限公司			
主分包装修、装饰单位	北京鸿恒基幕墙工程有限公司			

申报理由：

该工程是兼具生产和办公两大功能的现代化综合性建筑。

工程开工伊始，项目部就认真进行了创优策划，明确了“确保北京市建筑长城杯”的创优目标。目标确定后，严抓施工组织设计、施工方案的编制和落实及现场的施工管理。通过清水混凝土结构、抗静电环氧自流平地面、异型玻璃幕墙、钢网架阳光板采光屋面、3 厚“贴必定”BAC 自粘卷材+1.5 厚丙稀酸涂料防水屋面施工等多种新工艺、新技术的应用和贯彻 ISO9001 质量运行体系，确保了过程精品。

工程于 2006 年 3 月 14 日竣工交验一次通过，工程质量受到建设、监理、质量监督部门的一致好评。9 个分部工程，全部合格，观感质量综合评价为“好”。

工程交竣使用后，工程中各项设备、设施运转使用正常，功能完备，屋面、厕浴间无渗漏，工程质量受到建设单位的好评。获 2006 年度中建一局集团“精品杯”工程。

经企业自检，本工程符合申报北京市建筑长城杯工程申报条件，特此申报，请予以检查验收。

申报单位章

2007 年 1 月 22 日

申报联系人	李建宁	电　话	13701276260

表（三）

所属区、县、市集团总公司、创优片组评审机构推荐意见：   推荐单位章　　　年　　月　　日
建设单位推荐意见： 我单位对此项工程施工质量满意，工程各项功能完备，满足使用要求，同意申报。 联系人：[illegible] 联系电话：67862161　建设单位章 2007 年 1 月 22 日
监理单位推荐意见： 施工单位严格按照设计文件施工，工程质量符合法律、法规和工程建设强制性标准，我单位对工程验收评为优，同意申报 联系人：[illegible] 联系电话：13701218295　监理单位章 2007 年 1 月 22 日
建设、设计、监理、施工等单位竣工验收质量评价结论： 本工程在施工中大量应用了"四新技术"，各分部分项工程质量满足设计要求和施工质量验收规范规定。工程技术资料齐全完整、真实有效。工程观感质量评价"好"。 申报单位章 2007 年 1 月 22 日

表（二）

工程简介：（结构、装修、电气及设备安装主要做法和特点） 本工程东西长 67m，南北宽 54m，总建筑面积为 10969.98 m^2，是兼具生产和办公两大功能的综合性建筑。地上 4 层，局部 5 层。建筑物檐高 26.55m，地上部分首层层高为 4.5m，标准层层高为 4.2。±0.00 绝对标高 29.35m，室内外高差 0.45m ，最大基底标高-6m。防火等级为二级。 本工程基础结构形式为独立柱基，主体结构形式为框架结构，抗震设防烈度为八度。混凝土强度等级：基础垫层 C10，地下独立柱基 C30，楼梯 C30，柱、梁、板一、二层采用 C35，三层以上为 C30，构造柱、圈过梁为 C20。本工程结构施工所有混凝土均采用商品混凝土。本工程所采用的钢筋有 HPB235 和 HRB335 两种强度等级。采用现场加工， 直径≥18mm 的钢筋采用直螺纹连接接头。直径＜18mm 的钢筋采用绑扎搭接接头。梁板式楼梯，楼板厚度 120mm。梁的截面几何尺寸（宽 mm ×高 mm）主要有：200×500、250×500、250×400、350×600、600×1050 等，柱（mm × mm）的截面几何尺寸主要有：500×600、600×600、650×650、700×700、850×850、Φ450；柱：采用 18 厚双面覆膜多层板。梁板、楼梯：采用 15 厚双面覆膜多层板。 本工程为精装修工程，建筑外檐和屋面造型独特，采用铝塑复合板和玻璃幕墙与采光钢结构圆形亮顶相结合，立面风格简洁明快，注重细部处理，突出现代艺术风格。室内装修做法：顶棚为乳胶漆涂料、铝合金吊顶、石膏板吊顶、矿棉吸音板吊顶等；楼地面工程为水泥楼地面、抗静电环氧自流平、现浇水磨石楼地面、通体砖楼地面、塑胶楼面，内墙为乳胶漆墙面、釉面砖墙、吸音墙面；门窗有：钢质防火门、实木门、电子感应弧形门、铝合金中空玻璃窗、卷帘门；屋面分为不上人屋面、钢网架阳光板采光屋面。 本工程给水采用支管 PP-R 干管钢塑管，水源来自院内自来水管网。下水屋顶花园排水、空调、排风机房冷凝水自成系统排入室外雨水井废水，采用 UPVC 管进行污废分流。屋面雨水采用 87 型雨水斗，卫生间污水经立管汇集后排至室外化粪池处理后接至厂区内污水管网。消防系统：厂区内室外消防给水由市政给水管网供给；室内消火栓给水由一期厂房供给。通风空调系统：空调系统为闭式二管制；通风系统采用热回收式新风换气机；卫生间由排气扇通过金属软管排入独立排风竖井。 本工程电气照明采用单电源配电，每层照明箱配管引出至灯具、插座；应急照明自带镉镍电池，使用时间不少于 60min。消防系统利用一期消防控制室，主要包括：火灾自动报警系统、消防联动控制系统、紧急广播系统、消防直接对讲通话系统。本建筑为三级防雷；本工程的避雷、接地线须与一期工程做良好连接，女儿墙上设避雷带作接闪器，避雷带选用Φ10 圆钢，高处屋顶所有金属构筑物均应与接闪器作可靠焊接；利用结构柱主钢筋（至少两根>16）作引下线，因下显出女儿墙 200mm 与屋顶避雷带可靠焊接。

主要分包单位、分包项目及工程量：

中建润通机电安装有限公司承担机电安装工程，工程造价 260 万元，项目经理李贵云，联系电话 13911507563；

北京鸿恒基幕墙工程有限公司承担外幕墙工程，工程量 5120㎡，工程造价 420 万元，项目经理高大军，联系电话 13311318458；

表（一）

工程名称	北京石榴庄住宅小区（C区）	建筑面积	97126.78m^2
工程地址	丰台区石榴庄	总造价	17672万元
结构类型	住宅楼为剪力墙、车库为框架结构	层　数	地上6~15层、地下2层
结构质量评价（等级）	优良	结构质量评价单位	北京市工程建设质量管理协会
开工时间	2007年3月1日	竣工验收日期	2008年12月8日
备案日期		备案证明文件编号	
建设单位	北京城建投资发展股份有限责任公司	施工许可证（开工证）编号	2006规(丰)建字0237号
设计单位	北京建筑设计研究院		
监理单位	北京新恒元工程监理咨询有限公司		
总承包单位	单位名称：北京城建五建设工程有限公司		
	项目负责人：钱益平	技术负责人	彭华
	质量负责人：王习勤	竣工验收质量评价	合格
主分包设备安装单位	北京城建五机电安装分公司		
主分包装修、装饰单位	安徽巢湖华胜建筑劳务有限公司、河南省新蒲建筑工程承包有限公司、安徽铜陵京安建筑劳务有限公司		

申报理由：

中报集团优质工程

北京城建五建设工程有限公司

申报单位章

年　月　日

申报联系人	周文	电　话	13801231435

不拍了

表（二）

工程简介：（结构、装修、电气及设备安装主要做法和特点）：

一、结构：工程基础形式为墙下条形基础、局部筏板基础，地下车库为独立柱基，主体结构形式除地下车库为框架结构外，其余均为全现浇钢筋混凝土剪力墙结构。

二、装修：户内为初装修，内墙及顶棚为耐水腻子，地面为 60mm 厚 CL7.5 陶粒混凝土，卫生间防水为 1.5mm 厚单组分聚氨酯防水涂料；地下室和楼梯间墙面为耐水腻子，地面为水泥砂浆面层；首层入口及首层电梯前厅为大理石地面，二层以上电梯前室为玻化砖；楼梯间及电梯前室部分墙面为耐擦洗内墙涂料；外墙外保温，95mm 厚聚苯保温板大模内置，饰面层为陶瓷面砖。楼内户门为三防门，公共部分为钢制防火门，外窗为中空玻璃断桥铝合金窗。楼内每单元设一部电梯，小区共设二十三部电梯。

三、电气：现场主要工程有动力、照明系统结构预埋、穿线、安装调试；火灾自动报警及联动系统、通信系统、综合布线系统、有线电视系统、安全防范系统等弱电系统的配管。

照明配电采用分层树干式配电，动力配电以电缆放射式为主，局部采用链式配电。本工程所有管线全部采用焊接钢管敷设。

四、设备安装：

1、给水系统：

本小区上水管来自于小区南侧道路上的市政管网，管径 DN150,形成环网供给小区。生活给水泵房设置在地下一层，市政供水引入生活水箱，经变频水泵加压后供给各楼。加压后由泵房引出在本小区形成环网。给水系统分二个区，地下一层至地上六层由市政自来水直供，供水压力为 0.3MPa；七层以上为加压供水，供水压力为 0.60MPa。

2、采暖系统

热源由城市热力管网提供一次热水，一次水温为 130/80℃。经设在地下的热力站进行热交换，换热后供给 85/60℃的热水用作采暖系统用热水。系统工作压力为 0.8MPa。地下一层的卫生间、水泵房、库房等，系统采用双管上行下给，干管设于地下夹层中，采用分户计量采暖，主立管均采用下行上给双管异程式。

3、排水系统

地下部分：地下一层人防厕所排水经污水池集水后由污水泵排出室外；地下一层车库雨污水集水后，经室内沉沙隔油池由污水泵提升后再排入市政雨水管道。地上部分：卫生间或厨房污水分别汇合后排至室外，经室外化粪池处理后排入市政污水管道。地上首层单排，二层至顶层一起排，设伸顶透气立管。室内排水管采用 A 型机制柔性接口排水铸铁管，法兰连接；室内雨水管及压力排水管均采用热镀锌钢管，法兰连接。

4、中水系统

中水系统分两个区，其中地下一层至地上二层由市政中水直供，供水压力为 0.12MPa；二层以上为加压供水，供水压力为 0.6MPa。

5、热水系统

本楼热水供应由热力站供应。各住户卫生间设电热水器，厨房间设燃气热水器。系统压力设计待定。热水立干管采用内衬塑钢管，快装连接件连接。进户管道设于地下夹层。

Appendix 6: The detail table of predictive value and actual value for various output and project type

Type 1 – KPI 1

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
12	2754	0.99481127	45	3794	113.64	106.76	0.06444
21	1690	0.967984309	19	2747	86.92	96.41	0.09843
24	3672	0.991037929	14	2759	79.82	79.59	0.00289
25	780	0.986717153	16	3269	84.17	69	0.21986
29	2540	0.98395755	14	2759	79.82	81.13	0.01615
36	2758	0.963452565	40	2595	61.26	61.31	0.00082
41	1925	0.974217491	44	3159	56.96	56.95	0.00018
44	3159	0.900042484	18	3516	55.54	56.96	0.02493
45	3794	0.96343142	19	2747	86.92	113.64	0.23513
1	2060	0.898020509	41	1925	56.95	51	0.11667
9	2707	0.963779153	5	407	59.46	59.95	0.00817
11	3488	0.959566983	5	407	59.46	58.83	0.01071
15	3026	0.996235313	1	2060	51	49.3	0.03448
16	3269	0.993364053	14	2759	79.82	84.17	0.05168
17	3274	0.993497563	20	3711	302.3	212.74	0.42098
18	3516	0.971160371	41	1925	56.95	55.54	0.02539
33	3654	0.981293482	21	1690	96.41	96.85	0.00454
35	2757	0.982940183	25	780	69	72.73	0.05129
3	2242	0.936236597	16	3269	84.17	85.44	0.01486
5	407	0.968883517	9	2707	59.95	59.46	0.00824
13	2756	0.991166405	15	3026	49.3	42.78	0.15241
14	2759	0.994553395	16	3269	84.17	79.82	0.0545
19	2747	0.981957887	3	2242	85.44	86.92	0.01703
20	3711	0.9641227	17	3274	212.74	302.3	0.29626
27	2749	0.983583836	13	2756	42.78	33.74	0.26793
40	2595	0.965531661	36	2758	61.31	61.26	0.00082
43	2115	0.985630438	45	3794	113.64	142.89	0.2047
						Average Error Rate	0.08902

Type 1 – KPI 2

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
12	2754	0.997585726	21	1690	3603.24	3500	0.0295
21	1690	0.978848101	12	2754	3500	3603.24	0.02865
24	3672	0.995830021	36	2758	2500	2564.1	0.025
25	780	0.989081348	11	3488	2000	2015.11	0.0075
29	2540	0.992535577	20	3711	8654.51	10757.51	0.19549
36	2758	0.963668016	9	2707	2500	2500	0
41	1925	0.988003606	33	3654	2500	2500	0
44	3159	0.925578648	18	3516	3850	4500	0.14444
45	3794	0.979194334	17	3274	5000	6500	0.23077
1	2060	0.898354298	21	1690	3603.24	4000	0.09919
9	2707	0.973144594	15	3026	2500	2500	0
11	3488	0.95799774	25	780	2015.11	2000	0.00755
15	3026	0.997418692	9	2707	2500	2500	0
16	3269	0.994516034	1	2060	4000	3724.163333	0.07407
17	3274	0.995541517	3	2242	4681	5000	0.0638
18	3516	0.974146566	1	2060	4000	3850	0.03896
33	3654	0.987173624	41	1925	2500	2500	0
35	2757	0.988302707	43	2115	3040.6	2500	0.21624
3	2242	0.928345929	44	3159	4500	4681	0.03867
5	407	0.975401874	11	3488	2000	1700	0.17647
13	2756	0.992390972	15	3026	2500	2500	0
14	2759	0.995121811	16	3269	3040.6	2500	0.21624
19	2747	0.980826597	16	3269	3793.06958	3793.069583	0
20	3711	0.968444713	45	3794	6500	8654.51	0.24895
27	2749	0.983583836	12	2754	3500	4436	0.211
40	2595	0.971646862	1	2060	4000	4081.6	0.01999
43	2115	0.988662311	35	2757	2500	3040.6	0.17779
						Average Error Rate	0.08334

Type 1 – KPI 3

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
12	2754	1	43	2115	0.04	0.04	0
21	1690	0.987066048	44	3159	0.01	0.008	0.25
24	3672	1	5	407	0.04	0.04	0
25	780	1	5	407	0.04	0.04	0
29	2540	1	33	3654	0.04	0.04	0
36	2758	0.965663153	33	3654	0.04	0.04	0
41	1925	1	33	3654	0.04	0.04	0
44	3159	0.943201854	21	1690	0.008	0.01	0.2
45	3794	0.995219045	5	407	0.04	0.03	0.33333
1	2060	0.900509229	9	2707	0.05	0.1	0.5
9	2707	0.989679563	16	3269	0.05	0.05	0
11	3488	0.95481922	5	407	0.04	0.04	0
15	3026	0.998569159	17	3274	0.05	0.05	0
16	3269	0.997483745	14	2759	0.05	0.05	0
17	3274	0.997528625	15	3026	0.05	0.05	0
18	3516	0.974275831	15	3026	0.05	0.05	0
33	3654	0.99289023	41	1925	0.04	0.04	0
35	2757	0.99351609	43	2115	0.04	0.04	0
3	2242	0.92557882	5	407	0.04	0.04	0
5	407	0.98750018	29	2540	0.04	0.04	0
13	2756	0.996202085	15	3026	0.05	0.05	0
14	2759	0.99774737	16	3269	0.05	0.05	0
19	2747	0.983657805	9	2707	0.05	0.05	0
20	3711	0.98488591	9	2707	0.05	0.05	0
27	2749	0.986157995	25	780	0.04	0.04	0
40	2595	0.97939297	33	3654	0.04	0.04	0
43	2115	0.99344401	35	2757	0.04	0.04	0
						Average Error Rate	0.04753

Type 1 – KPI 4

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
12	2754	1	15	3026	0.8	0.85	0.05882
21	1690	0.988109282	12	2754	0.85	0.85	0
24	3672	1	44	3159	1	1	0
25	780	1	43	2115	1	1	0
29	2540	1	1	2060	0.95	0.95	0
36	2758	0.963724806	33	3654	0.85	0.85	0
41	1925	1	15	3026	0.8	0.8	0
44	3159	0.94751121	20	3711	0.95	1	0.05
45	3794	0.997571697	20	3711	0.95	1	0.05
1	2060	0.907407296	19	2747	0.95	0.95	0
9	2707	0.99776774	5	407	0.85	0.85	0
11	3488	0.960886831	21	1690	0.85	0.85	0
15	3026	1	18	3516	0.8	0.8	0
16	3269	0.999065101	14	2759	0.85	0.85	0
17	3274	1	35	2757	0.85	0.85	0
18	3516	0.979687486	40	2595	0.8	0.8	0
33	3654	1	13	2756	0.85	0.85	0
35	2757	1	5	407	0.85	0.85	0
3	2242	0.929071335	45	3794	1	0.95	0.05263
5	407	0.994004027	9	2707	0.85	0.85	0
13	2756	0.999320708	14	2759	0.85	0.85	0
14	2759	1	27	2749	0.85	0.85	0
19	2747	0.991936491	45	3794	1	0.95	0.05263
20	3711	0.996331822	29	2540	0.95	0.95	0
27	2749	0.993324735	17	3274	0.85	0.85	0
40	2595	0.983219221	41	1925	0.8	0.8	0
43	2115	1	24	3672	1	1	0
						Average Error Rate	0.00978

Type 1 – KPI 6

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
12	2754	1	15	3026	4	4	0
21	1690	0.988076305	14	2759	4	4	0
24	3672	1	17	3274	4	4	0
25	780	1	17	3274	4	4	0
29	2540	1	14	2759	4	4	0
36	2758	0.964158848	33	3654	4	4	0
41	1925	1	33	3654	4	4	0
44	3159	0.952282256	20	3711	5	5	0
45	3794	0.997117934	20	3711	5	5	0
1	2060	0.907295143	19	2747	5	5	0
9	2707	0.997450489	44	3159	5	5	0
11	3488	0.964997319	43	2115	4	4	0
15	3026	1	12	2754	4	4	0
16	3269	0.999050093	29	2540	4	4	0
17	3274	1	24	3672	4	4	0
18	3516	0.984568794	29	2540	4	4	0
33	3654	1	41	1925	4	4	0
35	2757	1	43	2115	4	4	0
3	2242	0.936327628	45	3794	5	5	0
5	407	0.994651399	35	2757	4	4	0
13	2756	0.999103769	15	3026	4	4	0
14	2759	1	29	2540	4	4	0
19	2747	0.991400352	45	3794	5	5	0
20	3711	0.995160352	45	3794	5	5	0
27	2749	0.993755168	17	3274	4	4	0
40	2595	0.982971137	33	3654	4	4	0
43	2115	1	35	2757	4	4	0
						Average Error Rate	0

Type 2- KPI 1

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
4	2013	0.905627872	100	3544	155.26	166.1513043	0.06555
26	2224	0.94164959	87	3546	43.44	47.28	0.08122
39	2541	0.958542383	52	3020	79.22	74	0.07054
52	3020	0.908832029	39	2541	74	79.22	0.06589
53	3512	0.929623586	54	3653	61.56	68.9	0.10653
54	3653	0.910751387	53	3512	68.9	61.56	0.11923
55	3510	0.931153279	91	2724	145.8	109.31	0.33382
56	2479	0.954631667	86	3251	251.01	436.59	0.42507
85	3228	0.977906926	4	2013	166.151304	172.81	0.03853
86	3251	0.961671226	90	2722	195.11	251.01	0.2227
87	3546	0.986496624	26	2224	47.28	43.44	0.0884
88	2689	0.953449167	56	2479	436.59	909.13	0.51977
89	2717	0.997803003	26	2224	47.28	53.91	0.12298
90	2722	0.989356937	94	3068	145.35	195.11	0.25504
91	2724	0.97428403	97	3013	157.75	145.8	0.08196
92	2789	1	100	3544	155.26	183.57	0.15422
93	2812	0.96527197	55	3510	109.31	104.07	0.05035
94	3068	0.989666831	91	2724	145.8	145.35	0.0031
95	3054	0.995189278	93	2812	104.07	91.55	0.13676
96	3036	0.96527197	99	3076	111.23	110.7	0.00479
97	3013	0.96849482	91	2724	145.8	157.75	0.07575
98	2989	0.964874762	91	2724	145.8	113.93	0.27973
99	3076	0.96527197	96	3036	110.7	111.23	0.00476
100	3544	1	92	2789	183.57	155.26	0.18234
						Average Error Rate	0.14538

Type 2 – KPI 2

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
4	2013	0.898469588	90	2722	1500	1500	0
26	2224	0.963929813	94	3068	1800	1667.28	0.0796
39	2541	0.966002046	94	3068	1800	3989	0.54876
52	3020	0.923272327	85	3228	1500	1500	0
53	3512	0.943813466	85	3228	1500	1500	0
54	3653	0.923272327	86	3251	1500	1500	0
55	3510	0.943813466	85	3228	1500	1500	0
56	2479	0.970380899	86	3251	1500	1500	0
85	3228	0.992891173	54	3653	1500	1500	0
86	3251	0.983482812	54	3653	1500	1500	0
87	3546	0.986496624	93	2812	1200	1200	0
88	2689	0.980045398	53	3512	1500	1500	0
89	2717	0.997803003	93	2812	1200	1200	0
90	2722	0.995210895	86	3251	1500	1500	0
91	2724	0.985009478	86	3251	1500	1500	0
92	2789	1	87	3546	1200	1200	0
93	2812	0.997920555	89	2717	1200	1200	0
94	3068	0.989666831	26	2224	1667.28	1800	0.07373
95	3054	0.995189278	87	3546	1200	1200	0
96	3036	0.96527197	89	2717	1200	1200	0
97	3013	0.96849482	91	2724	1500	1500	0
98	2989	0.964874762	87	3546	1200	1200	0
99	3076	0.96527197	89	2717	1200	1200	0
100	3544	1	86	3251	1500	1500	0
						Average Error Rate	0.02925

Type 2 – KPI 3

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
4	2013	0.902761556	92	2789	0.05	0.1	0.5
26	2224	0.966071065	85	3228	0.04	0.04	0
39	2541	0.968206517	85	3228	0.04	0.04	0
52	3020	0.923748093	85	3228	0.04	0.05	0.2
53	3512	0.946386183	85	3228	0.04	0.05	0.2
54	3653	0.923748093	86	3251	0.04	0.05	0.2
55	3510	0.946386183	85	3228	0.04	0.05	0.2
56	2479	0.973420672	86	3251	0.04	0.04	0
85	3228	0.99833497	87	3546	0.04	0.04	0
86	3251	0.989765321	87	3546	0.04	0.04	0
87	3546	0.995637815	100	3544	0.04	0.04	0
88	2689	0.995326231	98	2989	0.04	0.05	0.2
89	2717	0.997803003	95	3054	0.05	0.05	0
90	2722	0.995712842	87	3546	0.04	0.04	0
91	2724	0.990616615	95	3054	0.05	0.05	0
92	2789	1	94	3068	0.05	0.05	0
93	2812	0.997815273	87	3546	0.04	0.04	0
94	3068	0.996439364	53	3512	0.05	0.05	0
95	3054	0.995189278	94	3068	0.05	0.05	0
96	3036	0.997815273	87	3546	0.04	0.04	0
97	3013	0.992434031	87	3546	0.04	0.04	0
98	2989	0.995448485	87	3546	0.04	0.04	0
99	3076	0.997815273	87	3546	0.04	0.04	0
100	3544	1	87	3546	0.04	0.04	0
						Average Error Rate	0.0625

Type 2 – KPI 4

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
4	2013	0.902594062	85	3228	0.85	0.9	0.05556
26	2224	0.965986778	86	3251	0.85	0.85	0
39	2541	0.96812766	85	3228	0.85	0.85	0
52	3020	0.924669852	94	3068	0.8	0.8	0
53	3512	0.947394029	94	3068	0.8	0.8	0
54	3653	0.924669852	98	2989	0.8	0.8	0
55	3510	0.947394029	85	3228	0.85	0.85	0
56	2479	0.973372969	98	2989	0.8	0.8	0
85	3228	1	95	3054	0.8	0.85	0.05882
86	3251	0.991600397	94	3068	0.8	0.85	0.05882
87	3546	1	100	3544	0.8	0.8	0
88	2689	1	98	2989	0.8	0.85	0.05882
89	2717	1	96	3036	0.8	0.85	0.05882
90	2722	0.994973132	86	3251	0.85	0.85	0
91	2724	1	86	3251	0.85	0.85	0
92	2789	1	86	3251	0.85	0.85	0
93	2812	1	89	2717	0.85	0.85	0
94	3068	0.995365063	100	3544	0.8	0.8	0
95	3054	0.995189278	100	3544	0.8	0.8	0
96	3036	1	100	3544	0.8	0.8	0
97	3013	0.995365063	100	3544	0.8	0.8	0
98	2989	1	96	3036	0.8	0.8	0
99	3076	1	100	3544	0.8	0.8	0
100	3544	1	87	3546	0.8	0.8	0
						Average Error Rate	0.01212

Type 2 – KPI 6

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
4	2013	0.902594062	87	3546	4	4	0
26	2224	0.965986778	85	3228	4	4	0
39	2541	0.96812766	85	3228	4	4	0
52	3020	0.924669852	85	3228	4	4	0
53	3512	0.947394029	85	3228	4	4	0
54	3653	0.924669852	85	3228	4	4	0
55	3510	0.947394029	85	3228	4	4	0
56	2479	0.973372969	85	3228	4	4	0
85	3228	0.998463973	95	3054	4	5	0.2
86	3251	0.988061848	95	3054	4	4	0
87	3546	0.995975789	100	3544	4	4	0
88	2689	0.995688346	98	2989	4	4	0
89	2717	0.997930406	99	3076	4	4	0
90	2722	0.994897875	94	3068	4	4	0
91	2724	0.988847186	98	2989	4	4	0
92	2789	1	100	3544	4	4	0
93	2812	0.998131425	89	2717	4	4	0
94	3068	0.995189278	85	3228	4	4	0
95	3054	0.995189278	85	3228	4	4	0
96	3036	0.998131425	89	2717	4	4	0
97	3013	0.991807884	88	2689	4	4	0
98	2989	0.996107134	88	2689	4	4	0
99	3076	0.998131425	89	2717	4	4	0
100	3544	1	92	2789	4	4	0
						Average Error Rate	0.00833

Type 3 – KPI 1

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
2	3543	0.950273126	77	2674	115	114.51	0.00428
8	1678	0.931316627	58	2711	195.95	197.64	0.00855
10	3610	0.934583776	37	2225	246.7	215.89	0.14271
22	2761	0.93471501	79	3604	40	38	0.05263
28	840	0.94314391	31	30.55	30.55	30.48	0.0023
30	3025	0.97367434	83	3275	150.21	137.52	0.09228
31	2118	0.966741085	28	840	30.48	30.55	0.00229
32	3517	0.987073363	42	2050	58.24	63.4	0.08139
34	2748	0.983710556	83	3275	150.21	150.75	0.00358
37	2225	0.959421021	102	2684	241.32	246.7	0.02181
38	2226	0.990876697	102	2684	241.32	193.92	0.24443
42	2050	0.991595696	32	3517	63.4	58.24	0.0886
50	2545	0.928648397	103	2532	112.9	103.78	0.08788
51	3619	0.938174834	102	2684	241.32	207.59	0.16248
58	2711	0.967482668	8	1678	197.64	195.95	0.00862
59	3239	0.976295261	37	2225	246.7	280.67	0.12103
77	2674	0.93043768	34	2748	150.75	115	0.31087
78	2289	0.86612313	32	3517	63.4	74.6	0.15013
79	3604	0.938554409	22	38	38	40	0.05
83	3275	0.952797316	34	2748	150.75	150.21	0.00359
84	3024	0.956995919	34	2748	150.75	173.43	0.13077
102	2684	0.991595696	37	2225	246.7	241.32	0.02229
103	2532	0.979949089	2	3543	114.51	112.9	0.01426
104	3712	0.988243	32	3517	63.4	91.53	0.30733
						Average Error Rate	0.08809

Type 3 – KPI 2

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
2	3543	0.961950874	58	2711	2000	2000	0
8	1678	0.936350192	32	3517	3500	3500	0
10	3610	0.95076022	37	2225	5000	4744.86	0.05377
22	2761	0.937130853	103	2532	6000	7325	0.18089
28	840	0.944661676	77	2674	2437	2380.95	0.02354
30	3025	0.976277804	77	2674	2437	2920.19	0.16547
31	2118	0.968113688	2	3543	2000	936.06	1.13662
32	3517	0.991174612	8	1678	3500	3500	0
34	2748	0.988583916	102	2684	5000	5000	0
37	2225	0.971217797	59	3239	5000	5000	0
38	2226	0.992219996	102	2684	5000	5000	0
42	2050	0.995308062	102	2684	5000	5661.12	0.11678
50	2545	0.936953691	102	2684	5000	5070.43	0.01389
51	3619	0.941037913	83	3275	3500	3837.88	0.08804
58	2711	0.974590412	2	3543	2000	2000	0
59	3239	0.982859821	34	2748	5000	5000	0
77	2674	0.93144052	28	840	2380.95	2437	0.023
78	2289	0.86612313	34	2748	5000	5000	0
79	3604	0.93239439	22	2761	7325	7000	0.04643
83	3275	0.952515576	32	3517	3500	3500	0
84	3024	0.956995919	8	1678	3500	3500	0
102	2684	0.993111674	42	2050	5661.12	5000	0.13222
103	2532	0.981779763	104	3712	6000	6000	0
104	3712	0.988921621	103	2532	6000	6000	0
						Average Error Rate	0.08253

Type 3 – KPI 3

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
2	3543	0.965896932	102	2684	0.04	0.038217391	0.04664
8	1678	0.936350192	102	2684	0.04	0.04	0
10	3610	0.95076022	37	2225	0.04	0.04	0
22	2761	0.937130853	2	3543	0.03821739	0.03	0.27391
28	840	0.944661676	37	2225	0.04	0.04	0
30	3025	0.976277804	32	3517	0.04	0.04	0
31	2118	0.968113688	38	2226	0.04	0.04	0
32	3517	0.991174612	42	2050	0.04	0.04	0
34	2748	0.992766268	102	2684	0.04	0.04	0
37	2225	0.97486791	31	2118	0.04	0.04	0
38	2226	0.995220435	102	2684	0.04	0.04	0
42	2050	0.996897178	102	2684	0.04	0.04	0
50	2545	0.935894559	102	2684	0.04	0.04	0
51	3619	0.94107123	59	3239	0.05	0.05	0
58	2711	0.975853589	59	3239	0.05	0.05	0
59	3239	0.982924727	58	2711	0.05	0.05	0
77	2674	0.931380313	42	2050	0.04	0.04	0
78	2289	0.890145168	79	3604	0.008	0.011	0.27273
79	3604	0.959872163	78	2289	0.011	0.008	0.375
83	3275	0.966304057	32	3517	0.04	0.04	0
84	3024	0.966119848	38	2226	0.04	0.04	0
102	2684	0.999603722	38	2226	0.04	0.04	0
103	2532	0.992596691	30	3025	0.04	0.04	0
104	3712	0.992705261	30	3025	0.04	0.04	0
						Average Error Rate	0.04035

Type 3 – KPI 4

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
2	3543	0.972431344	104	3712	0.95	0.95	0
8	1678	0.964599301	37	2225	0.85	0.85	0
10	3610	0.974816606	37	2225	0.85	0.85	0
22	2761	0.95435625	102	2684	0.85	0.85	0
28	840	0.952916094	31	2118	1	1	0
30	3025	0.985183179	84	3024	0.8	0.8	0
31	2118	0.980366656	28	840	1	1	0
32	3517	0.997899187	59	3239	0.85	0.85	0
34	2748	1	32	3517	0.85	0.85	0
37	2225	0.988773277	59	3239	0.85	0.85	0
38	2226	1	102	2684	0.85	0.85	0
42	2050	1	77	2674	1	1	0
50	2545	0.936418109	102	2684	0.85	0.85	0
51	3619	0.948513379	103	2532	0.85	0.85	0
58	2711	0.98701354	59	3239	0.85	0.85	0
59	3239	0.98701354	58	2711	0.85	0.85	0
77	2674	0.938553646	42	2050	1	1	0
78	2289	0.893712515	79	3604	0.925	0.925	0
79	3604	0.966988217	2	3543	0.95	0.925	0.02703
83	3275	0.970263967	8	1678	0.85	0.85	0
84	3024	0.970263967	30	3025	0.8	0.8	0
102	2684	1	38	2226	0.85	0.85	0
103	2532	0.994383411	58	2711	0.85	0.85	0
104	3712	0.994383411	2	3543	0.95	0.95	0
						Average Error Rate	0.00113

Type 3 – KPI 6

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
2	3543	0.975360124	78	2289	5	5	0
8	1678	0.964599301	37	2225	4	4	0
10	3610	0.974816606	37	2225	4	4	0
22	2761	0.95435625	102	2684	4	4	0
28	840	0.952916094	37	2225	4	4	0
30	3025	0.985183179	59	3239	4	4	0
31	2118	0.980366656	38	2226	4	4	0
32	3517	0.997899187	42	2050	4	4	0
34	2748	1	32	3517	4	4	0
37	2225	0.992122719	31	2118	4	4	0
38	2226	1	32	3517	4	4	0
42	2050	1	32	3517	4	4	0
50	2545	0.934071863	32	3517	4	4	0
51	3619	0.948261426	103	2532	4	4	0
58	2711	0.986562494	103	2532	4	4	0
59	3239	0.986562494	103	2532	4	4	0
77	2674	0.939245459	32	3517	4	4	0
78	2289	0.893415803	2	3543	5	5	0
79	3604	0.96730716	2	3543	5	5	0
83	3275	0.970422285	8	1678	4	4	0
84	3024	0.970422285	8	1678	4	4	0
102	2684	1	32	3517	4	4	0
103	2532	0.994666515	32	3517	4	4	0
104	3712	0.994666515	32	3517	4	4	0
						Average Error Rate	0

Type 4 – KPI 1

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
6	3710	0.94196402	70	2150	117.76	86.49	0.36154
7	1791	0.939855458	60	718	88.29	114.29	0.22749
23	1142	0.979923889	61	1183	343.48	320	0.07338
46	3197	0.969033955	71	2352	57.88	60.61	0.04504
47	3178	0.921600446	6	3710	86.49	83.3	0.0383
101	3366	0.886417157	67	2422	190.31	209.78	0.09281
57	1009	0.978753956	23	1142	320	261.62	0.22315
60	718	0.985022492	6	3710	86.49	88.29	0.02039
61	1183	0.983314927	23	1142	320	343.48	0.06836
62	1203	0.982454207	82	3170	149.09	141.06	0.05693
63	1787	0.970607053	74	3172	60.9	56.07	0.08614
64	1334	0.978588053	65	1054	68.66	66.76	0.02846
65	1054	0.984071898	64	1334	66.76	68.66	0.02767
66	1785	0.996460422	75	3359	114.9	123.46	0.06933
67	2422	0.99681438	69	1799	182.73	190.31	0.03983
68	1634	0.992935419	61	1183	343.48	467.78	0.26572
69	1799	0.987914365	67	2422	190.31	182.73	0.04148
70	2150	0.983314927	75	3359	114.9	117.76	0.02429
71	2352	0.968653051	63	1787	56.07	57.88	0.03127
72	3000	0.981189444	66	1785	123.46	128.3	0.03772
73	2840	0.970426618	80	808	160.71	165.52	0.02906
74	3172	0.983146905	63	1787	56.07	60.9	0.07931
75	3359	0.993481138	66	1785	123.46	114.9	0.0745
76	3371	0.981189444	66	1785	123.46	114.76	0.07581
80	808	0.894978151	73	2840	165.52	160.71	0.02993
81	1060	0.95901994	7	1791	114.29	104.9	0.08951
82	3170	0.951032961	62	1203	141.06	149.09	0.05386
						Average Error Rate	0.08486

Type 4 – KPI 2

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
6	3710	0.949105903	70	2150	2000	1700	0.17647
7	1791	0.939855458	46	3197	1500	1500	0
23	1142	0.984673821	67	2422	2500	2750	0.09091
46	3197	0.974853153	47	3178	1500	1500	0
47	3178	0.921600446	46	3197	1500	1500	0
101	3366	0.955707399	71	2352	2000	1819.48	0.09922
57	1009	0.984374875	76	3371	2000	2000	0
60	718	0.995062482	76	3371	2000	2000	0
61	1183	0.99373315	65	1054	2000	2000	0
62	1203	0.992291604	61	1183	2000	2000	0
63	1787	0.977844128	61	1183	2000	2000	0
64	1334	0.991518375	61	1183	2000	2000	0
65	1054	0.996133853	61	1183	2000	2000	0
66	1785	0.999140856	67	2422	2500	2500	0
67	2422	0.999226771	66	1785	2500	2500	0
68	1634	0.995430918	69	1799	5000	5000	0
69	1799	0.995489496	68	1634	5000	5000	0
70	2150	0.993838063	61	1183	2000	2000	0
71	2352	0.994120253	72	3000	2000	2000	0
72	3000	0.99574849	73	2840	2000	2000	0
73	2840	0.993758422	72	3000	2000	2000	0
74	3172	0.99728627	72	3000	2000	2000	0
75	3359	0.999276339	72	3000	2000	2000	0
76	3371	0.997149213	60	718	2000	2000	0
80	808	0.997149213	7	1791	1500	830	0.80723
81	1060	0.897505777	101	3366	1819.48	1760	0.0338
82	3170	0.964886331	68	1634	5000	4100	0.21951
						Average Error Rate	0.05286

Type 4– KPI 3

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
6	3710	0.951675394	62	1203	0.04	0.04	0
7	1791	0.939855458	61	1183	0.05	0.05	0
23	1142	0.987964747	76	3371	0.04	0.04	0
46	3197	0.978445614	80	808	0.02	0.02	0
47	3178	0.921600446	82	3170	0.075	0.067	0.1194
101	3366	0.955707399	81	1060	0.0203	0.03	0.32333
57	1009	0.988840877	76	3371	0.04	0.04	0
60	718	1	76	3371	0.04	0.04	0
61	1183	1	65	1054	0.05	0.05	0
62	1203	0.995112329	75	3359	0.04	0.04	0
63	1787	0.981379695	61	1183	0.05	0.05	0
64	1334	0.994400464	72	3000	0.04	0.04	0
65	1054	0.996572176	61	1183	0.05	0.05	0
66	1785	0.999238261	61	1183	0.05	0.05	0
67	2422	0.999314435	75	3359	0.04	0.04	0
68	1634	0.995948935	61	1183	0.05	0.05	0
69	1799	0.996000872	74	3172	0.05	0.05	0
70	2150	0.996457158	61	1183	0.05	0.05	0
71	2352	0.987682433	60	718	0.04	0.04	0
72	3000	0.99574849	75	3359	0.04	0.04	0
73	2840	0.993758422	75	3359	0.04	0.04	0
74	3172	0.99728627	66	1785	0.05	0.05	0
75	3359	0.999276339	73	2840	0.04	0.04	0
76	3371	0.997149213	60	718	0.04	0.04	0
80	808	0.897505777	46	3197	0.02	0.02	0
81	1060	0.95901994	46	3197	0.02	0.0203	0.01478
82	3170	0.964886331	82	3170	0.067	0.075	0.10667
						Average Error Rate	0.0209

Type 4– KPI 4

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
6	3710	0.954795209	62	1203	0.8	0.85	0.05882
7	1791	0.939855458	71	2352	0.8	0.85	0.05882
23	1142	0.988138513	76	3371	0.8	0.85	0.05882
46	3197	0.98054908	69	1799	0.85	0.85	0
47	3178	0.921600446	82	3170	0.9825	1	0.0175
101	3366	0.955707399	71	2352	0.8	0.8	0
57	1009	0.989881456	76	3371	0.8	0.8	0
60	718	1	76	3371	0.8	0.8	0
61	1183	1	65	1054	0.85	0.85	0
62	1203	0.998535112	71	2352	0.8	0.8	0
63	1787	0.98460927	61	1183	0.85	0.85	0
64	1334	0.998535112	71	2352	0.8	0.8	0
65	1054	1	61	1183	0.85	0.85	0
66	1785	1	69	1799	0.85	0.85	0
67	2422	1	72	3000	0.8	0.8	0
68	1634	1	69	1799	0.85	0.85	0
69	1799	1	68	1634	0.85	0.85	0
70	2150	0.998535112	61	1183	0.85	0.85	0
71	2352	0.998360452	72	3000	0.8	0.8	0
72	3000	0.998814481	71	2352	0.8	0.8	0
73	2840	0.998259557	75	3359	0.8	0.8	0
74	3172	0.999243286	66	1785	0.85	0.85	0
75	3359	1	73	2840	0.8	0.8	0
76	3371	0.999205068	60	718	0.8	0.8	0
80	808	0.892017067	82	3170	0.9825	0.975	0.00769
81	1060	0.963057647	80	808	0.975	0.925	0.05405
82	3170	0.972903354	80	808	0.975	0.9825	0.00763
						Average Error Rate	0.00975

Type 4– KPI 6

Test Case	Proj_ID	Highest case similarity score	case No.	Proj. No	Output value	Actual output value for test cases	Error
6	3710	0.958113285	62	1203	4	4	0
7	1791	0.939855458	71	2352	4	4	0
23	1142	0.988138513	76	3371	4	4	0
46	3197	0.98054908	81	1060	5	5	0
47	3178	0.921600446	81	1060	5	5	0
101	3366	0.955707399	71	2352	4	4	0
57	1009	0.989881456	76	3371	4	4	0
60	718	1	76	3371	4	4	0
61	1183	1	65	1054	4	4	0
62	1203	1	60	718	4	4	0
63	1787	0.985548108	61	1183	4	4	0
64	1334	1	60	718	4	4	0
65	1054	1	60	718	4	4	0
66	1785	1	60	718	4	4	0
67	2422	1	60	718	4	4	0
68	1634	1	60	718	4	4	0
69	1799	1	60	718	4	4	0
70	2150	1	60	718	4	4	0
71	2352	1	60	718	4	4	0
72	3000	1	60	718	4	4	0
73	2840	1	60	718	4	4	0
74	3172	1	60	718	4	4	0
75	3359	1	60	718	4	4	0
76	3371	1	60	718	4	4	0
80	808	0.901352805	81	1060	5	5	0
81	1060	0.968678537	82	3170	5	5	0
82	3170	0.976071347	81	1060	5	5	0
						Average Error Rate	0

Appendix 7 Validation Questionnaire

Dear construction manager:

This research establishes the Case Based Reasoning Model CASEPMP after collected hundred over of Beijing Luban and Great Wall Prize project. CASEPMP is used to estimate the project success indicator (Key Performance Indicators (KPI)) by retrieving the most similar projects from the CASEPMP database. The purpose of this questionnaire is to gather the feedback and comments for CASEPMP.

A Contractor recently participates to bid for a public used project. A new government office, CFA is 25,000 m2. As a project manger of contractor, you are required to estimate the Key Performance Indicators (KPIs), i.e. project cost, construction speed, project quality and client potential satisfaction to prepare the tender document. The project details are listed below:

The client is public client, with considerable experience involved in more than two similar projects previously. Project objectives are the cheapest cost, shortest time and best quality. Highly support to the project. This project employed the external consultant with considerable experience, involved in more than two similar projects. And designer has less than two times of significant change orders.

Your company has considerable experience involved in more than two similar projects. Project complexity is not complex and this project is traditional procurement project with open tender. Obstruction due to underground utilities and or inclement weather is low

Project management team organization is streamline and schedule plan is daily based. The main con and sub con meeting is fixed period meeting but not daily base. Construction schedule is effective because the structure and installation part work scheduling has the overlap and applied CPM to optimize project schedule. Average skillful worker input is 500 per day and major material steel consumption, is 80KG/m2. Your company has in-house construction equipment for project use. Your company has ISO 9002 system to ensure achievement of quality objective. And the planning the good quality rate is 80%.

Construction preparation is well organized, including the administration work preparation (the construction work permission); the technology work preparation (construction drawing familiar, prep-aration of the standard, preparation for the measurement and experiment etc.); the site preparation (Construction Equipment, Temporary Works, water/electricity preparation); the supply of the plant, materials and goods preparation.

The technology management includes the measurement; experiment; documentation; development technology management objective; the technical methods to save cost; promotion of the new technology; quantify management; other technology method.

As project manager, you are requested to estimate the project success indicator (Key Performance Indicators (KPI)), i.e. constriction time, cost quality and client satisfaction etc. as the reference of tender document preparation.

CASEPMP has estimated these indicators as below; please use your professional knowledge and experience to assess their reasonability.

	Level of satisfaction				
	Most				Least
	5	4	3	2	1
	[ ]	[ ]	[ ]	[ ]	[ ]
• Construction Period is 290-330days，	[ ]	[ ]	[ ]	[ ]	[ ]
• Unit cost is ￥3500-4000/m2	[ ]	[ ]	[ ]	[ ]	[ ]
• Cost Variation 5%	[ ]	[ ]	[ ]	[ ]	[ ]
• Quality score 85%	[ ]	[ ]	[ ]	[ ]	[ ]
• Client satisfaction is 4 Client satisfaction was measured by the Likert scale from 5 to 1, meaning client is either very satisfied to very unsatisfied)	[ ]	[ ]	[ ]	[ ]	[ ]

Appendix 8 Qualitative interview questions list

Questions for winners of 2008 Outstanding Project Manager Group:

1. In your opinion, what is the most critical CSFs for project success

1.1. If the most critical CSFs are associated with the client related factors?
1.2. If the most critical CSFs are associated with the designer related factors?
1.3. If the most critical CSFs are associated with the contractor related factors?
1.4. If the most critical CSFs are associated with the project characteristics related factors?
1.5. If the most critical CSFs are associated with the contract related factors?
1.6. If the most critical CSFs are associated with climate or underground related factors?
1.7. If the most critical CSFs are associated with the project management related factors?
1.8. If the most critical CSFs are associated with other factors not mentioned above. You may illustrate you opinion by project experience.

2. Background

2.1. This study defined and used project cost, construction period, project quality and client satisfaction to measure project success, namely Key Performance Indicators.
2.2. The determinants of project success are called Critical Success Factors (CSFs), this study has defined the CSFs.
2.3. This research establishes the Case Based Reasoning Model CASEPMP after collected hundred over of Beijing Luban and Great Wall Prize project. CASEPMP is used to estimate KPI by retrieving the most similar projects CSFs from the CASEPMP database. The research scope is to investigate the KPIs and CSFs during construction stage.

3. CASEPMP usage, advantages and disadvantages.

3.1. In your opinion, do you think CASEPMP is useful in construction practice? Why? eg. Tender document preparation.
3.2. In what way(s) might CASEPMP be used for? E.g. actual estimating, supporting project managers' estimation, check manual estimation, staff training etc.
3.3. Are case library representative for reasoning?
3.4. What do you think to use CBR as the quantitative model for CASEPMP? Do you think indexing case module, retrieval cases module, calculated cases module, test and validation module are suitable? In your opinion, what are advantages of CASEPMP?What are disadvantages of CASEPMP?

4. Future and Miscellaneous

4.1. What is the potential benefit of CASEPMP? E.g. increase consistency for tender document preparation, more objective estimation, improved accuracy, greater efficiency, cost reduction, better training or rationalize the tender preparation process?
4.2. Any other points you would like to discuss.

Appendix 9 Semi-Structured Interview Record of Winners of Outstanding Project Manager Award 2008

Respondent A:

Q1: In your opinion, what are the most important Critical Success Factors?

R1: Based on my experience, quality assurance system is foremost if the project team has the desire to win the Luban and Greatwall prize. During construction process, the system to ensure achievement of quality objective is the key. Essentially, it is necessary to control quality in the process.

Contract is another critical factor to project success. As contractor, we have to be very serious about the contract clause after we are awarded the tender. Sometimes the dispute arises from the unfavorable contract to us. We have to pursue legal claim for the settlement. However, it is noted that if contractors and clients are subject to legal claims, it will cause the financial loss and contract delay in the construction project and constitutes obstacle project success.

As we all known, to ensure the project complete on time, project team would adopt advanced scheduling technology such as Critical Path Management (CPM) or Program (or Project) Evaluation Review Technique (PERT).

I have graduated 15 years, my major is civil engineering. As my career started as technician, technology management is quite important for me. Technology is to guarantee that the project can complete on time and with the customer satisfied quality standard, at same time saving cost. For example, one project was constructed during the raining season; the earthwork is difficult as the soil contain sand level and is soft. According to the normal construction procedure, the retaining wall needs to be built before the foundation sheet. However, it will destroy the soil. The project manager readjusted the construction procedure by casting the concrete work of the foundation sheet firstly and followed by the retaining wall. As such, this project was completed during the raining season. The excavated sand was used to refill the foundation and that saved construction cost, including cost of purchasing sand and sand transportation, as well as the labor and equipment costs.

Q2:[Introduction of CASEPMP] *CASEPMP was briefed to the respondents in details, including background, the system architecture, input and output, modeling methods. The background introduction descried the research objective, i.e. to build CASEPMP model with the input which are independent variables, CSFs, and output which are dependent variables, KPIs. Luban and Greatwall prize projects are collected as data to build the CASEPMP model. The indexing case module, retrieval cases module,

calculated cases module, test and validation module are explained to respondents. CBR in terms of concept and method are briefed to respondents as well. CASEPMP is capable to estimate the KPIs, e.g. project time and cost information.*
* Note: this part will be omitted in the subsequent record for respondent B to E
Do you think CASEPMP is useful in construction practice? Do you find CASEPMP useful for estimating the project time and cost for the purpose of preparing tender document?

R2: CASEPMP was useful to estimate the project cost and time for the purpose of preparing tender document.

Q3: In what way(s) might CASEPMP be used for? E.g. actual estimating, supporting project managers' estimation, check manual estimation, staff training etc.

R3: Currently, the most commonly used method is based on company's previous project record and project manager's experience to estimate the project time cost and incorporate them into the tender document. Contractor received the tender invitation from client, which includes Conditions of tender; an explanation of the evaluation criteria to be used to evaluate the bids; a specification describing the product, service or works required; Conditions of Contract and Forms to be completed etc. For instance, if it is a high end residential project with GFA 100,000 sqm, the project site is located at the center of Beijing city. The in-house marketing department estimates the project time and cost based on company's previous projects record. Let's say this company has undertaken one similar high end projects previously, but the project site is not located at the center of city but close to the suburb. To estimate the project time and cost for tender document preparation, the market department will estimate for example the project cost with the consideration of cost fluctuation, project location etc. Project manager will comment the estimation results and finalize it for tender document submission.

I think CASEPMP may be helpful for supporting project managers' estimating and check manual estimation of market department and project manager. It may help the inexperienced project manager to improve the effectiveness of estimation and increase the reliability and fairness of the manual estimation.

Q4: Are case library representative for reasoning?

R4: CASEPMP builds the case library with those prestigious projects which have won Luban and Greatwall awards. The case library represented the high level project success. The project cost and time estimated by CASEPMP may be a very competitive bid. In this sense, CASEPMP is useful for tender document preparation. Nevertheless, contractors should be cautious to the outcome of CASEPMP because there is the possibility for CASEPMP to produce an unachievable project cost and time for contractor. Contractor may keep the awareness for their capability to delivery the project.

Q5: What do you think to use CBR as the quantitative model for CASEPMP? Do you think indexing case module, retrieval cases module, calculated cases module, test and validation module are suitable?

R5: I am not familiar with the computer technology so I would rather not contribute to any comments.

Q6: What is the potential benefit of CASEPMP? E.g. increase consistency for tender document preparation, more objective estimation, improved accuracy, greater efficiency, cost reduction, better training or rationalize the tender preparation process?

R6: I think CASEPMP would have advantageous effects for more objective estimation. As we all known, the current approach to estimate project time and cost to prepare tender is based on subjective estimation and still at primitive stage. There is a need for more advanced and more objective estimation.

Respondent B:

Q1: In your opinion, what are the most important Critical Success Factors?

R1: Project management organization is the most important CSFs (i.e. project management organization (C15) in this study). As a project manger, you are the top authority for the project. Project manager has the decision right to construction implement plan, project team personnel appointment, key technology decision, purchasing for construction equipment, resource allocation, project scheduling, construct issue, design changes, and contractual claim etc.

As far as a project manager concern, quality assurance system is critical important for me to achieve Luban or Greatwall Prize. And quality assurance system is the system to ensure achievement of quality objective.

Technology management can facilitate the optimization of construction implementation plan. During the process of working out construction implementation plan, project manager needs to discuss with technical staff to ensure the construction implementation plan, cost and detail construction methods. For instance, the excavation work for one sports stadium project, the project team adopted the technology innovation by using the excavated soil to backfill the foundation of piling system to avoid the soil to be transmitted out of the site. This technology saved construction time.

For me, scheduling technology such as Critical Path Management (CPM) and Program (or Project) Evaluation Review Technique (PERT) is another important CSFs. There is a Chinese old saying, if you do not plan, then you plan to fail. My over twenties years experience has proven, especially for mega size project, scheduling management is indispensable for the project to catch schedule. After the structure work, during the stage of interior decoration, the installation of the M&E work and decoration, there will be many teams in the site and an effective schedule is strongly needed.

For me, technology is not the most important CSFs. Project team can delivery the project successfully, technology can not play its part without a functional team. Team coherence is one of the most critical CSFs. Project team must have team spirits. A strong team is the most important CSFs for project success. To create a happy and positive atmosphere to project team, it is necessary to cultivate the team culture and team spirit. The team culture emphasizes on cooperation, project management needs the cooperation of various parties.

Q2: [Introduction of CASEPMP] Do you find CASEPMP useful for estimating the project time and cost for the purpose of preparing tender document?

R2: CASEPMP is useful to estimate the project cost and time for the purpose of preparing tender document.

Q3: In what way(s) might CASEPMP be used for? E.g. actual estimating, supporting project managers' estimation, check manual estimation, staff training etc.

R3: I think CASEPMP can be used to play a supporting role to project manager's estimation. I understood from you that case library have hundred over projects for four types of building projects. It is necessary to investigate if the case library exposes a gap in the case coverage. As we all known, an incomplete case library will not be capable to respond to all possible project scenario that may arise in the reality. I suggested you to increase more projects in the case library to improve CASEPMP competency. Our marketing department usually has more than 50 projects in the database to help them do the estimation. So it is not advisable to use CASEPMP to the actual estimation.

Q4: Are case library representative for reasoning?

R4: It is necessary to increase the project number in the case library to improve the representativeness

Q5: What do you think to use CBR as the quantitative model for CASEPMP? Do you think indexing case module, retrieval cases module, calculated cases module, test and validation module are suitable?

R5: I understood the concept of CBR based on your explanation. To me, CBR is to solve new problem by adapting solutions that were used to solve old problems. This approach offers a paradigm that is close to the way project manager estimate project time and cost. I estimate time and cost based on the most similar old projects. The model design and logic is viable and concept is easy to understand. I agreed with the indices used in CASEPMP. The retrieval case module, calculated module, test and validation module is appropriate to for the task to find out the most similar old project and the corresponding similarity. The test and validation module is viable. It is exactly same as the process I adapt the estimation results to suit the particular circumstances of the current project.

Q6: What is the potential benefit of CASEPMP? E.g. increase consistency for tender document preparation, more objective estimation, improved accuracy, greater efficiency, cost reduction, better training or rationalize the tender preparation process?

R6: I think CASEPMP can be used as an innovative technology for future tender document preparation provided it has improved its cases coverage.

Respondent C:

Q1: In your opinion, what are the most important Critical Success Factors?

R1:Quality assurance system is very important; it is the system to ensure achievement of quality objective. During the constructions process, the quality assurance system is critically important. Usually, self-checking is the most effective way. For example, the structural work is essential work of the project. The concrete work usually is constructed by the outsourcing specialists. Project manager must record properly, be clear to the details like which part was done by which person. For example, in one project, project manager found the verticality and the main structure of the overall total deviation exceeded the allowed plane bending norms two millimeters. Despite the minor error, they still requested the specialist to rework. It ensured the project quality standard and made the outsourcing specialists realized that quality is their survival skill. Some project team formulated hundred over rules and regulations to ensure the project quality.

Scheduling technology such as Critical Path Management (CPM) and Program (or Project) Evaluation Review Technique (PERT) is important CSFs. We will organize the project subcontract by using scheduling technology, not only sub contractor, whoever is responsible for certain part of project, such as plumbing and sanitary services, air-conditioning and mechanical ventilation services, fire protection systems, and electrical systems etc. Scheduling technology is helpful to control construction time.

I do not think technology is the most important CSFs. Technology is only one aspect of project, a technologically viable project does not mean a successful project.

Q2: [Introduction of CASEPMP] Do you find CASEPMP useful for estimating the project time and cost for the purpose of preparing tender document?

R2: CASEPMP is useful to estimate the project cost and time for the purpose of preparing tender document.

Q3: In what way(s) might CASEPMP be used for? E.g. actual estimating, supporting project managers' estimation, check manual estimation, staff training etc.

R3: CASEPMP can be used for supporting project managers' estimation and check manual estimation. As an advanced Artificial Intelligence model, CASEPMP will help the traditional estimation method for tender document preparation.

Q4: Are case library representative for reasoning?

R4: As explained by you, CASEPMP stored the Luban and Greatwall projects. However, it is not developed for one contractor only, the incompatibility of information from one contractor to another will cause the difficulty to input CSFs and become an obstacle for the representativeness of caselibrary. So I would be conservative for the representativeness of its case library.

Q5: What do you think to use CBR as the quantitative model for CASEPMP? Do you think indexing case module, retrieval cases module, calculated cases module, test and validation module are suitable?

R5: I understood CBR concept . It is a suitable tool to establish CASEPMP. I think the whole design and modules of CASEPMP is viable and suitable.

Q6: What is the potential benefit of CASEPMP? E.g. increase consistency for tender document preparation, more objective estimation, improved accuracy, greater efficiency, cost reduction, better training or rationalize the tender preparation process?

R6: I think CASEPMP can increase consistency for tender document preparation if the author can develop it to be compatible to all contractors.

Respondent D:

Q1: In your opinion, what are the most important Critical Success Factors?

R1: I always talk to my subordinate and my project team that: only quality and safety can make us survive. Quality assurance system can ensure achievement of quality objective, Safety management is very important，prevention is primary. In the daily safety management, strict self-checking system is critical to project success. In addition, the subcontractor and outsourcing specialist must be briefed and educated the safety management system, the rules and regulations. The safety responsibility agreement must be signed with them. Every aspect of safety management has person in charge. Project manager and subcontractor need interactions and unite to one integrated team to implement streamlined organization.

In my opinion, scheduling technology such as Critical Path Management (CPM) and Program (or Project) Evaluation Review Technique (PERT) is one of the most important CSFs. According to their experience, project manager usually worked from PERT network to identify critical path based on key points and technical difficulty of projects. The non-critical path was inserted into critical path. The labour, materials and equipment were allocated to the nodes of network. Project resource was planned and schedule was controlled by making detail construction work network. For instance, in every working flow section, project manager estimate quantities of steel, formwork and concrete, and then calculate the resource demand in terms of labour, material and equipment based on their experience and quantities quota published by official government source. All these were marked in the network and broadcasted to relevant project participants, such as subcontractors, plumbing and sanitary services, air-conditioning and mechanical ventilation services, fire protection systems, and electrical systems etc. The detail PERT network could present the project time and resource allocation unambiguously to all the project participants, especially to the site personnel. The project schedule and resource allocation were clearly understood by respective parties. It is beneficial to save project resource, ensure project on time and within budget.

Technology management is to guarantee that the project can complete on time and with the customer satisfied quality standard, at same time saving cost.

Project management organization is one of the most important CSFs. For me, the most ideal project management organization is the streamline organization. Project manager own the highest authority in the whole project team and the sub contractor was all at the same level under the project manager to facilitate project manager to manage the entire team.

Q2: [Introduction of CASEPMP] Do you find CASEPMP useful for estimating the project time and cost for the purpose of preparing tender document?

R2: CASEPMP is useful to estimate the project cost and time for the purpose of preparing tender document.

Q3: In what way(s) might CASEPMP be used for? E.g. actual estimating, supporting project managers' estimation, check manual estimation, staff training etc.

R3: I think CASEPMP can be used as a supporting tool for project manager to do estimation and also check manual estimation.

Q4: Are case library representative for reasoning?

R4: Yes. Luban and Greatwall projects present the highest level of successful project in China.

Q5: What do you think to use CBR as the quantitative model for CASEPMP? Do you think indexing case module, retrieval cases module, calculated cases module, test and validation module are suitable?

R5: I think CASEPMP is a feasible model. As you explained, I think all the modules are logically viable to me. The selection of indices, i.e. CSFs, is accurate as we would use the same CSFs to estimate project time and cost. The accurate indices could affect the accuracy of retrieval. The calculated module for similarity score is feasible and the test and validation module is also viable. In all, I agree that CASEPMP is a suitable model.

Q6: What is the potential benefit of CASEPMP? E.g. increase in consistency for tender document preparation, more objective estimation, improved accuracy, greater efficiency, cost reduction, better training or rationalize the tender preparation process?

R6: Using CASEPMP can generate greater efficiency to do estimation as the current approach requires inter-departmental cooperation and spend more time. Using IT tool is helpful to reduce human power investment and thus reduce cost.

Respondent E:

Q1: In your opinion, what are the most important Critical Success Factors?

R1:In my point of view, quality assurance system is very important to seize the Luban and Greatwall prize. The system is to ensure achievement of quality objective. ISO system is an international standard. Its documentary system is very helpful to achieve project quality objective. The process control is more important to ensure every component of project achieve the quality requirement. For example, verticality and the main structure of the overall total deviation should not exceed the allowed plane bending norms.

Another important factor to project success is contract. Although most recognized that contract, especially contract clause was an important contribution to project success, contract with client serves more as a tool for contractual agreement and reference to work out the construction implementation plan but the contract with subcontractor and other outsourcing specialists is for contractor to successfully delivery the project KPIs.

Technology management is to guarantee that the project can complete on time and with the customer satisfied quality standard, at same time saving cost.

Project manager is encouraged to discuss with subcontractors, outsourcing specialists on the construction implementation plan in order for them to optimize the construction implementation plan. It has been proven that a long term cooperation relationship with subcontractors and outsourcing specialists is helpful to complete the project successfully because they will understand your requirement. The tender for subcontractor and outsourcings specialists may not be the most effective way to select appropriate partners. The good relationship is beneficial for project delivery.

Q2: [Introduction of CASEPMP] Do you find CASEPMP useful for estimating the project time and cost for the purpose of preparing tender document?

R2: CASEPMP was an academic model as there are some CSFs were excluded from the model like project manager is encouraged to discuss with subcontractors, outsourcing specialists on the construction implementation plan, a long term cooperation relationship with subcontractors and outsourcing specialists, safety management and team coherence. The four CSFs are my personel opinion and were mainly from the project management experience in Beijing. Therefore the model accuracy needed to be improved. I still prefer traditional method and that is my reluctance to try CASEPMP.

Q3: In what way(s) might CASEPMP be used for? E.g. actual estimating, supporting project managers' estimation, check manual estimation, staff training etc.

R3: N/A

Q4: Are case library representative for reasoning?

R4: N/A

Q5: What do you think to use CBR as the quantitative model for CASEPMP? Do you think indexing case module, retrieval cases module, calculated cases module, test and validation module are suitable?

R5: N/A

Q6: What is the potential benefit of CASEPMP? E.g. increase in consistency for tender document preparation, more objective estimation, improved accuracy, greater efficiency, cost reduction, better training or rationalize the tender preparation process?

R6: N/A