A QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM AND APPLICATION IN CONTRACTOR SELECTION PROCESS

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A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Civil Engineering
Department of Civil Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2013

ระบบการประเมินโครงการก่อสร้างเชิงปริมาณโดยใช้หลายหลักเกณฑ์และการประยุกต์ใน
กระบวนการคัดเลือกผู้รับจ้าง

นางทู อันห์ เงียน

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรดุษฎีบัณฑิต
สาขาวิชาวิศวกรรมโยธา ภาควิชาวิศวกรรมโยธา
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2556

Thesis Title	A QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM AND APPLICATION IN CONTRACTOR SELECTION PROCESS
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ทู อันห์ เงียน : ระบบการประเมินโครงการก่อสร้างเชิงปริมาณโดยใช้หลายหลักเกณฑ์และการประยุกต์ในกระบวนการคัดเลือกผู้รับจ้าง. (A QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM AND APPLICATION IN CONTRACTOR SELECTION PROCESS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. วิสุทธิ์ ช่อวิเชียร, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: Assoc. Prof. Takano Shin-ei, 331 หน้า.

การประเมินความสำเร็จของโครงการก่อสร้างเป็นสิ่งสำคัญสำหรับผู้ที่เกี่ยวข้อง สำหรับผู้ดำเนินการก่อสร้างได้ประโยชน์จากการประเมินและการเปรียบเทียบเมื่อโครงการแล้วเสร็จ สำหรับหน่วยงานรัฐได้ฐานข้อมูลในการช่วยประเมินโครงการ ประเมินประสิทธิภาพของผู้รับจ้าง และแนวโน้มของประสิทธิภาพของโครงการก่อสร้าง ส่วนสำหรับเจ้าของโครงการนั้นช่วยในการพิจารณาโครงการก่อสร้างที่แล้วเสร็จและเป็นข้อมูลอ้างอิงสำหรับการวางกลยุทธ์สำหรับโครงการถัดไป ระบบการประเมินโครงการก่อสร้างเป็นเป้าหมายที่สำคัญโดยเฉพาะอย่างยิ่งสำหรับประเทศกำลังพัฒนาในการประเมินเชิงปริมาณและการนำไปใช้งานอย่างเหมาะสม ดังนั้นวัตถุประสงค์ของงานวิจัยนี้คือ การนำเสนอระบบการประเมินโครงการก่อสร้างเชิงปริมาณโดยใช้หลายหลักเกณฑ์และเพื่อเป็นฐานอ้างอิงเพื่อการคัดเลือกผู้รับจ้างในการประกวดราคางานก่อสร้าง

ในระบบการประเมินนี้ โครงการก่อสร้างถูกประเมินใน 2 ระดับ โดยระดับแรกเรียกว่า ตัวชี้วัด แต่ละตัวชี้วัดถูกประเมินตามหลักเกณฑ์ ซึ่งถือเป็นระดับที่สอง โดยประเมินเชิงปริมาณจากข้อมูลจริงของผู้เกี่ยวข้องกับโครงการก่อสร้างทุกฝ่ายเมื่อจบโครงการ ระบบถูกสร้างขึ้นโดยอาศัยทฤษฎีการประเมินหลายหลักเกณฑ์ การประเมินเชิงปริมาณและแบบจำลองเชิงเส้น มีการเก็บข้อมูลปฐมภูมิ 4 รอบใหญ่และการค้นคว้าข้อมูลเชิงเอกสารจากบริษัทผู้รับจ้างก่อสร้างเป็นเวลา 2 ปี จากการสำรวจเบื้องต้นสามารถระบุ 10 ตัวชี้วัดและ 45 หลักเกณฑ์ โดยตัวชี้วัดประกอบด้วย ระยะเวลาโครงการ ต้นทุนโครงการ คุณภาพโครงการ ระบบความปลอดภัยของโครงการ เทคนิคการก่อสร้าง ผลิตภาพ ความพอใจของผู้เกี่ยวข้อง ความยั่งยืนด้านสิ่งแวดล้อม การสื่อสาร และ ข้อพิพาทและคดีความ การสำรวจด้านความสำคัญ (Importance Survey) เพื่อระบุค่าถ่วงน้ำหนักของตัวชี้วัดและหลักเกณฑ์ต่างๆ ซึ่งผู้วิจัยได้ใช้วิธี Summing Responses, Structural Equation Modeling และ การผสมผสานระหว่าง Battelle EES และ Importance Scale Matrix ผู้วิจัยได้ตรวจสอบความสมบูรณ์ของระบบ(Testing Survey) ได้ทำการสำรวจวงกว้าง(Large Scale Survey) เพื่อ พัฒนาข้อมูลสำหรับการประเมินโครงการก่อสร้าง ผลการสำรวจสรุปได้ว่าผลลัพธ์ของระบบมีความสมเหตุสมผล สามารถอธิบายได้และสอดคล้องกับเอกสารและงานวิจัยในอดีตและพฤติกรรมของอุตสาหกรรมการก่อสร้าง ผลที่ได้สามารถนำมาใช้เป็นระดับอ้างอิงในการคัดเลือกผู้รับจ้างในกระบวนการประกวดราคาโครงการได้

ระบบประเมินโครงการก่อสร้างเชิงปริมาณโดยใช้หลายหลักเกณฑ์ (QMCPE) เป็นการประเมินเชิงปริมาณ ที่เลี่ยงอคติ สะดวกและสามารถประยุกต์ได้ โดยระบบนี้ประกอบด้วยตัวชี้วัด หลักเกณฑ์การประเมิน การถ่วงน้ำหนัก วิธีการประเมินตัวชี้วัดและหลักเกณฑ์อย่างครบถ้วน ค่าคะแนนการประเมินยังสามารถนำไปใช้ประโยชน์อย่างอื่นได้อีก ในงานวิจัยนี้ ผู้วิจัยได้พัฒนาซอฟแวร์ชื่อ VT Software โดยอาศัยหลักการของ QMCPE เพื่อช่วยให้กระบวนการประเมินทำได้รวดเร็ว สะดวก เชื่อถือได้และประยุกต์ได้อย่างเหมาะสมยิ่งขึ้น

ภาควิชา วิศวกรรมโยธา	ลายมือชื่อนิสิต ....
สาขาวิชา วิศวกรรมโยธา	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....
ปีการศึกษา 2556	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม ....

5371845321 : MAJOR CIVIL ENGINEERING
KEYWORDS: CONSTRUCTION PROJECT EVALUATION / CONSTRUCTION SUCCESS / WEIGHT ASSIGNMENT / MULTI-CRITERIA EVALUATION

THU ANH NGUYEN: A QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM AND APPLICATION IN CONTRACTOR SELECTION PROCESS. ADVISOR: ASSOC. PROF. VISUTH CHOVICHIEN, Ph.D., CO-ADVISOR: ASSOC. PROF. TAKANO SHIN-EI, Ph.D., 331 pp.

Construction project success evaluation is considered very important to all project stakeholders. For contractor, project evaluation is useful to assess and compare when project was completed. For the government management, it helps to develop a database of construction project evaluation, contractor performance, and tendency of construction project performance. For the owner, it helps to look back how project was performed and provide a reference for future project strategy. A construction project evaluation system, which was quantitative and applicable, is an urgent mission, especially in developing countries. Therefore, the objective of this research is to establish the quantitative multi-criteria construction project evaluation system, and provide a reference for contractor selection in bidding process.

In this evaluation system, construction project is evaluated in two levels. The first level is called indicator. Each indicator is assessed by criteria, second level. It considers the quantitative evaluation from all project stakeholders which is based on actual information when project was completed. In order to establish the evaluation system, multi-criteria evaluation based theory, quantitative method, linear additive models were applied. Four main surveys and documentary searching were carried out in two years at construction companies. The preliminary survey was performed to get the final list of indicators and criteria which included ten indicators and forty-five criteria. The indicators were 'Project Time', 'Project Cost', 'Project Quality', 'Project Safety', 'Technical Performance', 'Productivity', 'Stakeholder Satisfaction', 'Sustainable Environment', 'Communication', and 'Disputes & Litigation'. The importance survey was designed to achieve weight assignment for indicators and criteria. Three methods, which were Summing Responses, Structural Equation Modeling, and Combination of Battelle EES & Importance Scale Matrix, were appropriate and used for final result. Testing survey was conducted to validate and evaluate the system. Then, large scale survey was performed to develop data for construction project evaluation. The large scale survey result was reasonable, explainable, and compatible with literature review and practical performance of construction industry during investigation. This result provided a reference threshold for contractor selection process in bidding.

Finally, the quantitative multi-criteria construction project evaluation (QMCPE) system was achieved. QMCPE is quantitative, bias avoiding, easy, and applicable. QMCPE provides the complete indicators and criteria of evaluation system, their quantitative weight assignment, instruction for evaluating each indicator and criterion, their measurement scale, and their combination method. QMCPE also points out the project evaluation score for further application. The software solution was designed, named VT Software, based on the concept of QMCPE system, to make the evaluation process faster, easier, more reliable and applicable.

Department:	Civil Engineering	Student's Signature	....
Field of Study:	Civil Engineering	Advisor's Signature	....
Academic Year:	2013	Co-Advisor's Signature	....

ACKNOWLEDGEMENTS

First and foremost I offer my sincerest gratitude to my advisor, Dr. Visuth Chovichien and co-advisor, Dr. Takano Shin-ei, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject, continuous and unconditional guidance and support at each step of the study. This dissertation would not have been a real fulfillment without the backing and cooperation of these people who have supported me throughout my thesis with their patience and knowledge. I wish to express my deepest gratitude to Dr. Visuth Chovichien, he is not only an advisor but also a father, a friend, who I can share both pleasures and sadness.

I cannot have a word to describe my blessings to my deceased Mother. She stood all sacrifices and hardships for my study. Her words will always be the sound of my life. My family members deserve also the dearest gratitude for their endless love and efforts that encouraged me to realize my goals.

I would like to express my sincere gratitude to ASEAN University Network – Southeast Asia Engineering Education Development Network Project (AUN/SEED-Net) for giving me the opportunity to pursue a Doctoral's Degree in Civil Engineering in the field of Construction Engineering and Management. I also thank the International School of Engineering (ISE) at Chulalongkorn University for their supporting programs. I express my gratitude to Chulalongkorn University for providing a wonderful educational environment for studying.

I would like to show my gratitude to the professional contributions of construction companies and their representatives who participated into the survey part of the research sparing their invaluable hours to respond to survey questions. Their positive concern and contribution made this study test verify and reach its objectives.

My sincere thanks to all committee members, namely, Dr. Veerasak Likhitruangsilp, Dr. Wisanu Subsompon, Dr. Vachara Peansupap, and Dr. Natee Suriyanon. Their challenging questions and orientation on my proposal report have strengthened the framework of this research.

Finally, I would like to express my special thanks to my friends in CEM field for their helps, thanks to my family for their continuous care, love, and support. I thank you from the bottom of my heart.

I owe everlasting gratefulness to many people who pleasantly involved themselves in helping me undertake this dissertation. I offer my regards to all of those who supported me in any respect during the completion of the thesis to date.

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CHAPTER 1
INTRODUCTION

1.1 Background

The construction industry holds a key position both economically and socially. It contributes to Gross Domestic Product (GDP) and has an impact on the working population in most countries, from industrialized countries such as the United States, the United Kingdom, and Australia to developing countries such as Thailand and Vietnam. It contributes to GDP in several countries such as 10% in the United States (2008), 7.4% in the United Kingdom, 7% in Australia (2007), 10% in Thailand (2003) and 9% in Vietnam (2004). In the United States, the construction industry employed 7 million workers in October 2008, provided jobs for numerous workers. In Vietnam, the construction industry is in the developing stage, contributes 9% of GDP, and attracts a great investment of US$ 3 billion in 2004. There is no doubt about its contributions to developing countries. Therefore, construction industry is a topic of interest in both academic and practical point of view. The following section will discuss its central position in two targeted countries, Thailand and Vietnam.

Located in Southeast Asia, Vietnam is one of the fastest developing markets. For the period of 2003-2008, the average growth of the Vietnamese economy was 8% annual Gross Domestic Product (GDP). At that time, construction industry increased dramatically with 20.93% of Compound Annual Growth Rate. At the end of 2008, the total value of construction market was US$5.8 billion (Investment & Trade Promotion Center Hochiminh City, 2010). In 2009, the construction increased 11.36% compared to 2008, and contributed 6.7% to GDP. The reason for this outstanding increase was that construction materials prices had fallen and interest rates were low. That was a good time for construction projects underway. In 2010, the construction sector grew 11.06% from 2009, contributed VND139,162 billion, accounting for 7.03% GDP (General Statistical Office of Vietnam).

Foreign Direct Investment (FDI) can be viewed as an indicator of the development of Vietnam's construction industry. Over a twenty-year period, 1988-2008, total FDI registered capital was US$7.3 billion in 396 projects. Most of them concentrated in construction of apartments, offices and urban areas, as well as cement, steel and iron plants (Pham, 2008). In 2010, FDI in construction industry increased 4.4 times compared to 2009, with a capital being up to US$1.7 billion (T.Sam, 2011).

The number of construction companies increased rapidly, accompanied by the dramatic increase of employees in the sector (Pham, 2008). However, there is a movement of employees from the residential sector to the non-residential sector. While employees of the non-residential sector grow annually, their counterparts in the residential sector decreased almost period except for the 2007 growth rate of 1.1%. Up until 2008, the number of employees reached 2,394 thousand persons, increased 5.6% from 2007. The establishment of construction companies every year and the reduction of market shares among state construction enterprises are two of the main causes (Pham, 2008).

Similar to Vietnam's conditions, Thailand's construction industry has grown up speedily. In recent decades, the construction industry has become more and more important, contributing to Thailand's economic development. Two important indicators for the role of this industry are a contribution to GPD and the number of employees. Before the economic crisis in 1997, the construction industry in Thailand was predicted to grow at 34 percent. However, with the real estate collapse in 1997, construction completely stopped. After the crisis, the construction industry began growing again in tandem with the recovery of the real estate sector (EMD, 2010). As described in Figure 1.1 construction GDP has increased continuously from 2003 to 2008. In 2001, it has recovered from THB154 billion and kept rising up to THB259 billion in 2008. According to the National Economic and Social Development Board of Thailand (NESDB), 2.7% of the country's GDP in real terms was produced by the construction industry in 2009. However, in the same year, construction activities in Thailand decreased due to declined investment in private construction as a result of political uncertainty and slack in property demand. In 2008, the workers of the construction establishments in the Whole Kingdom were 364,694 persons in total. In terms of employment, the number of employees totaled 335,150 persons (Thailand, 2009).

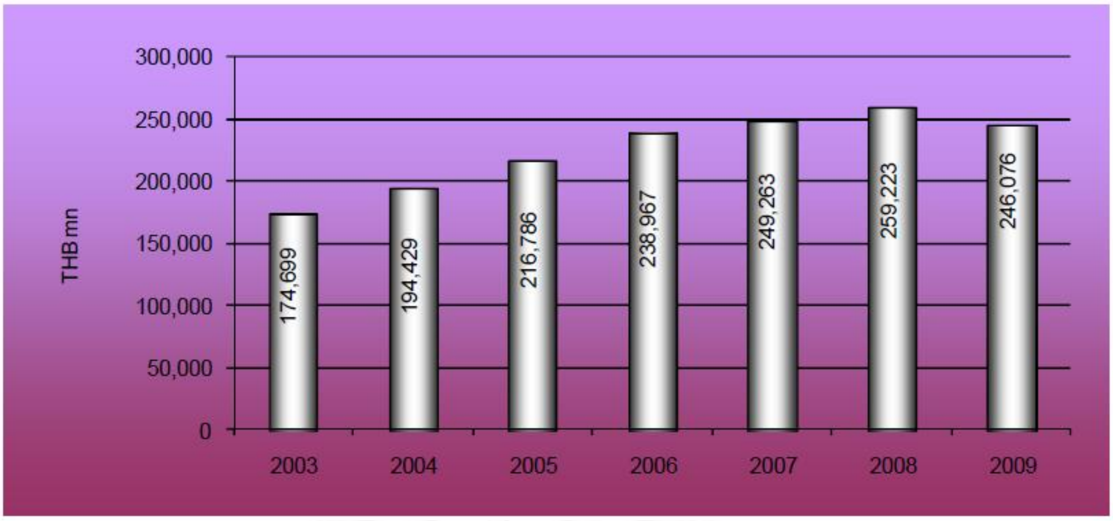


Figure 1.1 GDP of construction industry in Thailand from 2003 to 2009 (EMD, 2010)

Along with the great progress, the construction industry has faced many problems. Time delay, cost overrun, under quality, and accidents have been the major problems in construction. They cause serious consequences such as capital loss, project failure, reduction of profit-margin, and distrust of citizens in government projects, etc. (Le-Hoai et al., 2008). Failures to meet contractual duration, allocated costs, and demanded quality have led to several unforeseen negative effects on the projects. Due to poor management, the capital loss ratio in the basic construction represents up to 30 percent of the total construction capital in Vietnam (Uyen (2003) as cited by Nguyen et al. (2004)). Tabics collected the information from the Ministry of Statistics and Programme Implementation of Indian about problems facing construction industry (Tabish and Jha, 2011). Time and cost overrun are two main concerns. From their information, the number of delayed projects during the first quarter (January - March) of 2007 was 301. Their delays caused a cost overrun of Rs.300.58 billion, which was 26.09% of their initial sanctioned cost. Approximately 17.3% of 417 government contract projects in Malaysia were delayed three month or abandoned in 2005 (Sambasivan and Soon, 2007). The construction sector in Thailand and Vietnam has not escaped the problems of delays and cost overrun, two primary problems that cause project failure (Ogunlana et al., 1996; Le-Hoai et al., 2008).

Project delay and cost overrun issues have drawn the attention of numerous researchers all over the world. Many of them have focused on research into Southeast Asia's construction industries such as Ogunlana et al.; Kaming et al.; Sambasivan and Soon; Le-Hoai et al. (Ogunlana et al., 1996; Kaming et al., 1997; Sambasivan and Soon, 2007; Le-Hoai et al., 2008). As stated by Ogunlana et al. (1996), delays in developing economies including Thailand could occur due to the following problems: (1) insufficiencies or shortages mainly in the supply of resources in industry infrastructure; (2) faultiness of clients and consultants, and (3) the incompetence or inadequacies of contractors. Sambasivan and Soon (2007) found five major causes of construction delays in Malaysia including (1) improper planning; (2) site management; (3) inadequate contractor experience; (4) financial and payments of completed work and (5) subcontractors. Le-Hoai et al. (2008) pointed out the major causes which are (1) poor site management and supervision, (2) poor project management assistance, (3) financial difficulties of owner, (4) financial difficulties of contractor and (5) design changes. From several studies, more than fifty percent of the problem causes belong to contractor responsibilities.

The success or failure of the project depends on contractor selection. Many previous researchers mentioned this correlation, such as Alarcon and Mourgues (2002), Mahdi et al. (2002), and Cheng and Heng (2004). According to Alarcon and Mourgues's opinion, "Contractor selection is a decisive event for project success" (Alarcon and Mourgues, 2002). Cheng and Heng (2004) stated that "Contractor selection is one of the main decisions made from clients. In order to ensure that the project can be completed successfully, the client must select the most appropriate contractor." Because of the correlation between contractor selection and project success, a huge number of studies was conducted to develop a contractor selection method or model. The main purpose of these studies was "commensurate improvement in the success rate of construction projects" (Hatush and Skitmore, 1998).

The construction industry in almost all countries is facing the problem of unqualified or incompatible contractors to perform the projects, particularly in public projects. For a long time, this major problem causes the failure of many projects in terms of intended expectations. Cost overruns, schedule delay, under quality, conflicts, high-maintenance cost, and being rebuilt are common phenomena in projects worldwide. For these reasons, it is necessary to consider adding some extra parameters in the contractor selection process to reject inadequate contractors.

1.2 Statement of Problem

Along with the steady development in recent decades, the construction industry faces several problems which cause serious damage and loss of men and materials. Despite the fact that many studies have attempted to solve these problems, no measurable improvement has been found in the 'success' rate of construction projects (stated by Hatush and Skitmore (1998)). The construction sector still faces problems related to cost overruns, time overruns, quality, safety, claims, and litigation.

According to many researchers such as Ogunlana et al.; Kaming et al.; Sambasivan and Soon; Le-Hoai et al. (Ogunlana et al., 1996; Kaming et al., 1997; Sambasivan and Soon, 2007; Le-Hoai et al., 2008), one of the main causes comes from contractors. The problems of a contractor are site management and supervision, financial difficulties, improper planning and scheduling, inadequate contractor experience, inadequate resources, shortage of technical professionals, and hand over to subcontractors, etc. Herbsman and Ellis (1992) stated that the current bidding system imposed on the public sector is one key factor that results in those failures. Inadequate or unqualified contractors have still eluded from the current bidding procedures to win the contract and perform the projects.

There are many different models that have been applied in the evaluation of the bidding process. The literature provides a wide range of methods for selecting a contractor. Recent literature on contractor selection methods can be divided into two groups: (1) lowest evaluated bid price and (2) multi-parameter contractor selection method. The multi-parameter bidding system proposes a process in which the bidder is selected by more parameters than cost only. The major parameters suggested include cost, time, and quality. The secondary parameters are also important in selecting a contractor which are safety, durability, security, maintenance, and so forth (Herbsman and Ellis, 1992). One of the important parameters, considered in the contractor selection model by many researchers (Hatush and Skitmore, 1998; Fong and Choi, 2000; Alarcon and Mourgues, 2002; Cheng and Heng, 2004; Sipahi and Esen, 2010), is the contractor's past performance.

Past performance is a very important criterion in order to select a good service provider. This criterion is also considered in selecting a construction contractor to perform the project. It is used to anticipate contractor's performance in the future and to clarify his competence to implement a contract. For example, in contractor selection model using the multi-criteria utility theory, proposed by Hatush and Skitmore (1998), past performance holds a high ratio of 40% of the contractor's capability.

Contractor's past performance is considered an important criterion in many other contractor selection models (Birrell, 1988; Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Fong and Choi, 2000; Mahdi et al., 2002; Cheng and Heng, 2004;

McCabe et al., 2005; Watt et al., 2009; Jaskowski et al., 2010). Fong and Choi (2000) considered past performance as one of eight criteria to select a contractor in their final model which consists of tender price, past experience and performance, financial capability, resources, current workload, and safety performance as well as client/contractor relationship. They consider failure to complete contract, delay, cost incurred, and quality achievement in evaluating past performance.

Although the contractor's past performance appeared in most of the contractor selection models, it is difficult to apply this criterion in developing countries. It is difficult or impossible to require bidders to submit the evidence to show their failure, delay, additional cost, and poor-quality achievement. To overcome this difficulty, Sonmez et al. (2001) suggested assessment grades for this criterion subjectively in five levels which are "Very poor", "Poor", "Average", "Good", and "Very good". From the contractor evaluation process in Vietnam, shown in Table 1.1 below, bidders' past performance is not considered. In order to evaluate the bidders' capability, current bidding process has only considered information related to bidders' experience. For example, they required the number of projects completed in the last three years, the scale of the projects that bidders have completed, but not specifically how good the completed projects were. It is important to differentiate the two criteria, which are the numbers of past projects and how the contractor completed past projects, in the contractor selection process. One contractor may pass the criterion of the number of projects that he has completed, but he may fail the requirement of the past performance criterion if he has completed projects late, over budget, in an unsafe environment, poor quality, and dispute. Such kind of contractors should not be selected.

Table 1.1 Bidders evaluation process in Vietnam.

No.	Details
STEP1	Preliminary assessment (PASS/FAIL)
STEP2	Experience and capacity assessment (PASS/FAIL)
1	Experience
1.1	Experience in construction
1.2	Experience in similar project
1.2.1	Number of pass projects within 3 years
1.2.2	Scale of at least 1 project more than a specific amount
2	Technical capability
2.1	Capability in construction performance

No.	Details
2.2	Key person
2.3	Main equipment
3	Financial capability
3.1	Revenue in last 3 years
3.2	Cash flow guarantee from bank to provide credit for this package
3.3	Profit after tax
STEP3	Assessing the technical details (>=70 PASS, <70 FAIL)
4	Technical solution feasibility
4.1	Material supply solution
4.2	Technical solutions, construction methods for main tasks
4.3	Construction equipment solution
5	Operation solution feasibility
5.1	Site arrangement
5.2	Site management
5.3	Human Resource plan
6	Environment and safety
6.1	Safety strategy for site
6.2	Safety technology for each task
6.3	Environment
7	Quality
7.1	Plan to ensure quality
7.2	Quality of component
7.3	Quality management system
8	Schedule
STEP4	PRICE (LOWEST PRICE)

Three different types of measures of evaluating contractor or partnering are result, process, and relationship (Crane et al., 1999). Each type of them has a different use and preferred application. Among them, result measure is the most useful for making strategic adjustments and indicating project success. However, according to Crane (1999), it is also the most difficult measure based on contractor performance. Companies he has interviewed are using cost, schedule, quality, and safety as project success indicators. These indicators have some limitations. Recently, it has been difficult to apply result measures to evaluate project success in the construction field, especially in developing countries.

The reasons why developing countries could not use result measures to evaluate project success are several. According to customs, project participants who are owners, contractors, consultants, and project managers have never evaluated projects after finishing. Until now, there is no tool to perform this evaluation. An appropriate model to evaluate project success is necessary to develop a past performance database.

From the literature review, there is a wide range of articles focus on the issue of project success. However, these measuring project success models contain some problems.

Firstly, measuring project success model depends on the perception of evaluators (Chan et al., 2002). It cannot avoid bias and sensibility, so it may not be suitable for use as a database for contractor bidding information. To develop a contractor's performance database, which is used as criteria in bidding projects, especially for the public projects, we need a fair, straightforward, unbiased evaluation project success tool. If the contractor is required to evaluate projects based on their perception, they may make a biased evaluation because the results may influence their business. Therefore, it is necessary to develop a quantitative evaluation project success model.

Secondly, each model was developed based on one party’s point of view (Menches and Hanna, 2006). One project should satisfy the requirements of all parties such as owners, contractors and consultants or project managers, so project success should be evaluated from them to avoid bias. Owners, contractors and consultants concentrate on the different indexes to evaluate the project. They are also appropriate to provide different information to evaluate project success. Therefore, measuring project success model should let them evaluate the project independently and combine their evaluation to achieve the final project success evaluation.

Thirdly, some quantitative evaluation models are difficult to implement in currently developing countries. For example, in order to evaluate contractor safety performance, they suggested using OSHA assessment, or using Environmental Impact Assessment to evaluate. Therefore, a feasible evaluation of project success should be studied to practice in developing countries. It should consider which indicators and criteria should be used and how to evaluate them carefully based on the real information of completed projects in the quantitative way.

Previous researches lack methodology to combine the evaluation of each indicator and criterion. They provided methods to evaluate them separately. However, they did not suggest a method to combine all indexes in a final project success score. The relative weight of each indocator and criterion were also not studied.

In conclusion, a complete framework of project success evaluation should be studied. It includes the list of indicators and criteria representative for project success, measurement methodology, their important weight, and combination methodology to achieve a project success score. Furthermore, a database of project success scores in targeted countries is also necessary to provide suggestions on how to use this score in future project bidding process.

1.3 Research Objectives

From the above research problem, the following research objectives will be addressed:

- The first objective is to develop a quantitative project success evaluation system.
- The second objective is to establish a construction project success database, providing suggestions to use this score in selecting a contractor in the construction bidding process.
- The third objective is to design the application software.

1.4 Research Scope

This research is conducted under the following scope. First, this research concentrates on building projects which have more than three stories or height above ten meters; owner types focus on private projects. The proposed project evaluation system is designed to be used at the completion of construction stage. Second, the information to conduct this research will be collected in some ASEAN countries. Vietnam and Thailand represent a good proportion of ASEAN economy and thus provide a legitimate representation of the region.

1.5 Research Methodology

Research methodology consists of the following steps:

Phase 1: Conceptual model development.

Step 1: This phase systemizes relevant knowledge to specify the research gaps, clarify problem statements, and establish a clear objective to explore the topic.

Phase 2: Conducting a Preliminary Survey to achieve a framework of project success indicators and criteria.

The initial list of indicators and criteria are gathered from two sources. One is the literature review on construction project success criteria. The other source is the outcomes of the preliminary survey. This survey is performed by interviewing experts from the construction industry and examining information from completed projects.

Step 2: Conducting a preliminary survey to explore:

- Importance level of each indicator and criterion
- Ability to evaluate each of them
- Methods to assess each of them, source of information to assess
- Open questions are given to collect the criterion that is important but which has not been included in the proposed list.

Step 3: Data analysis using descriptive analysis, probability theory, and hypothesis testing using t-test. The expected outcomes of the preliminary survey include:

- List of indicators and criteria
- Feasible methods to evaluate each criterion

Phase 3: Carrying out Importance Survey to explore the relative weight of each indicator and criterion.

Step 4: Interviewing respondents to explore the relative weight of each criterion and asking the possible provider for each criterion.

Summing Responses, Structural equation modeling (SEM), and Combination of Battelle EES & Importance Scale Matrix (BEES & ISM) Method are applied in this step.

Step 5: Data analysis to achieve relative weight of all indicators and criteria, and to develop the quantitative model.

Analyze data from step 4 to discover the important weight of each indicator and criterion. The technique of summing responses, SEM, and BEES & ISM methods will be applied. Paired sample t-test was used to compare the results of these methods. Then, standardized results from three methods were calculated to achieve the final value of relative weight.

The quantitative model includes: criteria to evaluate project success, the important weight of them, and the methodology to combine them.

Phase 4: Criteria Evaluation Scale and Testing proposed model

In this phase, the scale to evaluate each criterion will be designed based on the literature review, perception of experts, and data of the companies. The proposed model is evaluated by three completed projects.

Step 6: Data collection from completed projects:

Completed projects will be evaluated using the proposed model. To check the validity of the proposed model, the qualitative evaluation from independent parties will be used to compare between proposed quantitative and qualitative evaluation.

Step 7: Model modification if necessary.

Phase 5: Large-scale survey

In this phase, the information from thirty-one completed projects is collected.

Step 8: Evaluating past projects by developed model to achieve a database.

Step 9: Analyzing the result of the past project to indicate the suggestions for future bidding process application.

Phase 6: Application development using PHP programming language

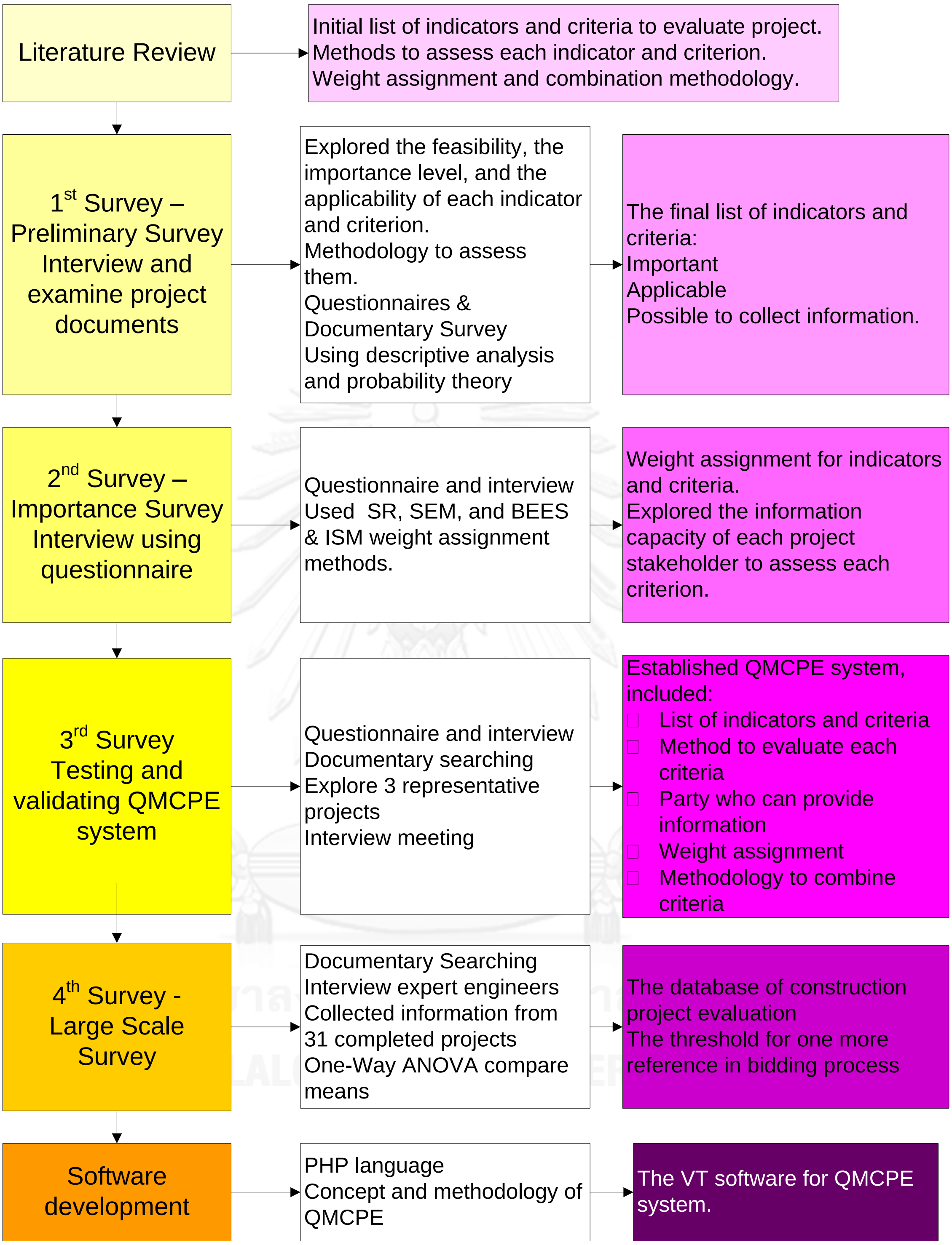


Figure 1.2 Research methodology

1.6 Research Outline

This thesis is a reflection of the entire research process and findings, which is divided into the following chapters:

Chapter 1 describes an overview of the research process and its contributions, particularly the context of research, research problem, research objectives, scopes and limitations, methodology, and research benefits.

Chapter 2 presents the research issues along with a review of literature on the bidding system in the construction industry, the definition of project success, the project evaluation system, its importance and benefits, multi-criteria evaluation based theory, weight assignment methodology, and clarification of research questions.

Chapter 3 describes the proposed Quantitative Multi-criteria Construction Project Evaluation System (QMCPE) in detail. It describes the proposed QMCPE system and benefits, indicators and criteria in this system, weight assignment methodology, combination methodology.

Chapter 4 discusses the research methods and anticipated outcomes of each research stage. In particular, this chapter details the employed research instruments, data collection methods, data analysis techniques, and expected research outcomes.

Chapter 5 presents a detailed discussion on the preliminary survey. It explains the reasons for conducting a preliminary survey, the survey data collection methods, the analysis of the possible evaluation system of construction project success.

Chapter 6 focuses on the detailed process of the importance survey. It includes the survey data collection methods, descriptive analysis, and results of weight assignment of all indicators and criteria. The relative weight of indicators and criteria are the results of five methods which are Summing Responses, Structural Equation Modeling, and Combination of BEES & Importance Scale Matrix method.

Chapter 7 presents a very detailed scheme of the project evaluation system. It includes the definition and meaning of each indicator, the foundation to evaluate each criterion, the evaluation scale to assess them, and the methodology to analyze and evaluate project success. This chapter also describes the application of the proposed model to evaluate the success level of three completed projects.

Chapter 8 describes a large-scale survey to collect information from completed projects. The purposes of this survey are developing a project's success database and exploring the relationship between project success and project characteristics. These relationships will provide suggestions to the owner in the contractor selection process. In order to validate the evaluation system, the proposed evaluation outcome will be compared with the qualitative evaluation from project stakeholders.

Chapter 9 introduces application software which is written by PHP programming language. It includes project evaluation, criteria weight assignment, and project stakeholder historical data.

Chapter 10 concentrates on the research conclusions and implications. A summary of the main findings is also included along with implications for theory, methodology, and implementation of the findings. Finally, research limitations and potential areas are addressed for future studies.

1.7 Research Benefits

The research is expected to contribute to methodologies and practices related to projecting success evaluation and bidding process in the construction industry.

In theory, the first contributions are the system for construction project evaluation. Although there are many measurement models from previous studies to evaluate project success, the expected system from this research contributes additional components. The frameworks are developed from three sources which are the literature review (theory), previous documents of completed projects (industrial sources), and experts and respondents (academic and human opinions). Therefore, they are fully representative and objective.

A complete guideline to measure project success score is expected to be completed. It includes a list of feasibility indicators and criteria, the methodology to evaluate each of them, their relative weight, and their combination methodology. Compared with previous researches, the proposed project success evaluation guideline is expected to be an innovation with several advantages. It provides a better list of indicators, quantitative and minimize bias measure, fairness, objectiveness, easiness, and applicability.

In practice, it is hoped that the current study can contribute to the improvement of project success rate. This research is expected to bring benefits to all project stakeholders. For contractors, the system is useful to assess a project when it is completed and to compare one project with other projects in their companies. It helps to improve their companies and to achieve continuous improvement. For government management, the system was extremely valuable. It helps to develop a database of construction project evaluation, contractor performance, tendency of construction project performance, and tendency of importance level of indicators and criteria. From that, government could better manage, control, and improve policies. For owners, the system helps to look back on how a project was performed. It is a reference for future project strategy.

CHAPTER 2
LITERATURE REVIEW

This chapter provides basic knowledge and theory about the project evaluation system and bidding system in construction industry. It begins with the review of bidding system and current criteria used in contractor selection process. By considering the bidding system in some representative countries, the existing problems are pointed out to find the solutions. Then, the second section reviews the definition of project success and construction project success and discussion of the capacity to evaluate project success. The third section focuses on indicators and criteria utilized to evaluate the success of construction projects. After that, the fourth section discusses the previous project measurement systems, discussion of their advantages, disadvantages, and difficulties in application. The fifth section reviews multi-criteria evaluation based theory and its application in current research. Then, the sixth section presents some weight assignment methods which can be applied in this research. A research framework is finally formulated to achieve the research objectives.

2.1 Bidding System in Construction

2.1.1 Bidding System

Construction bidding is defined as "the process that the supplier will undertake in order to arrive at a successful bid which secures a contract with the client. It contains activities which start as soon as a lead has been detected, continue with the response to the invitation to tender and finish after winning or losing the opportunity" (Turner, 2003). Jervis and Levin (1988) put bidding in the consent between offer and acceptance. Tender is considered a proposal to implement the work within an accepted amount of money by bidders. This offer is subject to acceptance by the owner at any time until the offer expires.

To thoroughly understand the bidding system, it is important to clarify the meaning of position and role of bidding in project life cycle. The cycle starts with awareness of planning and ends with the disposal of that facility. The relationship between these components is linear with interacting procedures for each, which is illustrated in Figure 2.1.

The most common construction delivery method is traditional procurement. This process starts with an owner choosing an architect, who is in charge of preparing construction documents. This preparation of documents is based on drafting standards, and the documents will often be released publicly or informally to a selected group of contractors. The contractors, once being notified, will prepare a bid on the project they believe that reflects the total cost of construction. This bid includes a wide range of subcontractor bids for each specific trade. This method is used to competitively bid for most government contracts. However, the procurement may start differently, bidding before design and specification in Design-Build (DB or Turnkey) contract.

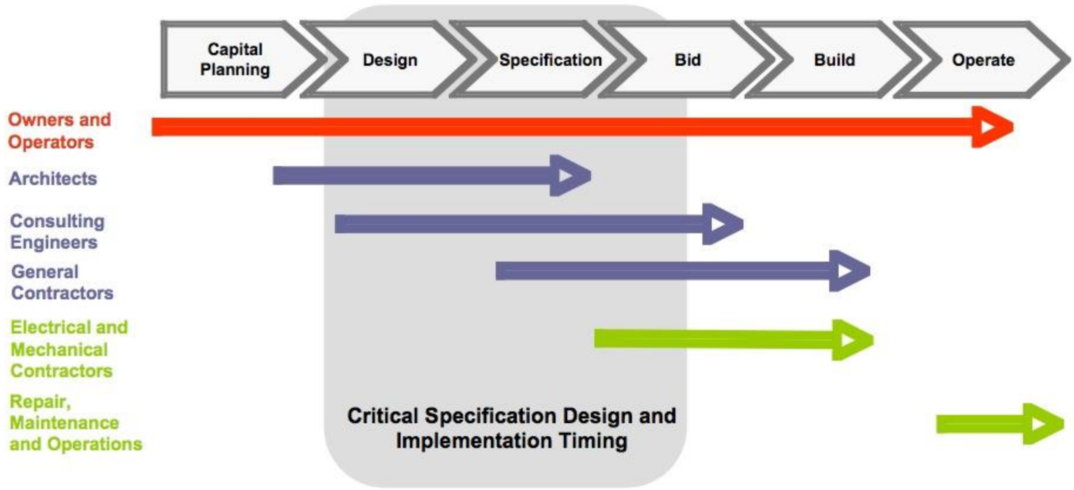


Figure 2.1 Construction project life cycle

In this cycle, the bidding component holds a central position and plays a decisive role in project success. The different roles of the bidding for parties in construction are:

<u>For owners:</u> In general, bidding procurement activities help them find contractors who are able to provide highest benefits to the project with the most reasonable cost. It means optimizing the two goals for owners, such as cost and profit. Bidders have to compete to obtain the award of the contract. The competition between the bidders does not create more products, but can enhance product quality and reduce prices, hence investment is used effectively. Bidding can help to demonstrate owners' reputation through organizing fair competition and transparent auction.

For contractors: Bidding creates a competitive equitable environment. From there they can present the talent and bravery to solve the requirements of the investment projects. It also increases the capacity for contractors.

For the country: Bidding is the most effective method to achieve efficient use of capital expended by government. It helps to achieve the best project and improve the country's infrastructure.

Design-bid-build (DBB), the design-build (DB), the construction manager as constructor approach, and a negotiated approach are some of the common methods of construction project delivery. All of them can be used to plan, design, and implement a given construction project successfully, and each has its own advantages and disadvantages.

In recent decades, there are innumerable techniques that have been explored and applied in construction work. They are expected to increase project productivity in order to finish projects on time. However, still no commensurate improvement has been found in the success rate of construction projects, particularly in developing countries. Delays in schedule, cost overruns, quality and safety-related problems, contradiction among parties, claims, and litigation still exist. From Hatush and Skitmore (1998), current bidding procedures and contractor selection need to be improved by further methods.

2.1.2 Competitive Bidding

In the general bidding process, an owner may select a contractor through competitive bidding, negotiation, or a combination of these methods. There are different types of competitive bidding including lowest-bidder system and non-lowest-bidder system (Sadi et al., 1998). These traditional practices and procedures for selecting contractors are based on the former way of thinking since 1940s (Holt et al., 1994).

Competitive bidding is required in almost all public projects and majority of private projects. This is originally dated back to the American tradition since 1847 (Herbsman and Ellis, 1992). The principles of this process are effective, fair and equal (Jervis and Levin, 1988). Competitive bidding is expected to avoid the extravagance, corruption, and other inappropriate practices of public officials. It aims at the lowest possible price, ensuring that public moneys are used efficiently and ensuring fairness. All bidders compete on an equal foundation. They are given the same information and time duration to submit bids accordingly. Jervis and Levin stressed all bidders "must be comparing apples and apples, not apples and oranges".

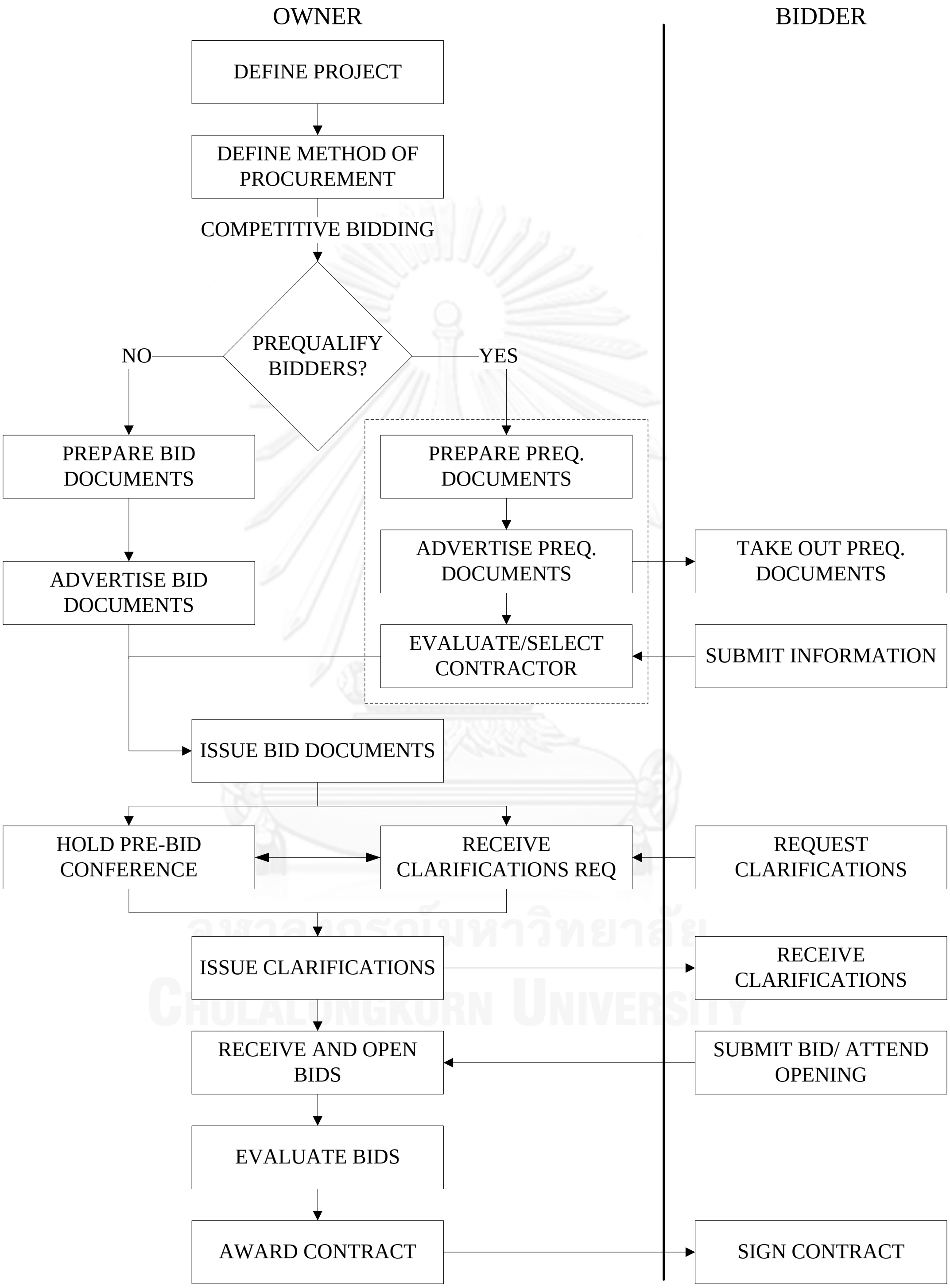


Figure 2.2 Competitive bidding process

The most common procedure and interactions during the competitive bidding are described in Figure 2.2. The bidding process begins with soliciting bids and ends with awarding the contract to the most appropriate bidder. The bid package contains the solicitation establishing the procedures to be followed. It also supports information about bid form, time and place to submit and open bid, and rules to follow.

In competitive bidding, the most common method used to select contractors is lowest price system. “Lowest price” bidding system is the main concept of competitive bidding which has been applied for more than a century all over the world. For example, in the United States, it was the main principal statutes, which has been practiced since 1847. Up to now it is more than 150 years of traditional bidding system. Awarding the contract based on only one criterion, bid price, is one of the major factors causing problems in projects (Holt et al., 1994). Normally, when submitting lowest price, contractors expect more benefits by claims and compensation. It is risky for them and causes contradiction between contractor and owner because of the fact that an owner seldom appreciates additional cost. For this reason, the project may be interrupted, delayed, or may have unsatisfied quality. However, it is not easy to change this process.

Due to the limitation of the lowest-bidder system, some countries are using Non-Lowest Bidder system, in which bidder is selected not based on the lowest price only as in France, Italy, Portugal, and Peru (Herbsman and Ellis, 1992; Sadi et al., 1998). The basic idea is that the most reasonable bid, not the lowest, is the best bid of the system. This system has some variations in application including Danish system, Limited by Average Bids and Owner’s Estimate, Nearest to the Average of All Bids Received, and so forth.

Average of All Bids Received is used in some European countries. In this system, the owner will calculate the average bid value (ABV) once he has received all of the offers. The contract will be awarded to the nearest offer to ABV. This system tries to avoid low bidders who have not studied the project carefully, and also avoid high bidders who do not have enough experience and capability. However, in this system, the owners do not consider carefully additional information from bidders such as level, degree and type of experience of successful bidders.

In Limited by Average Bids and Owner’s Estimate, owner considers both ABV and estimated cost by their own resources and experience. The contract will be awarded to the bidder who is not only less than ABV but also less than the owner’s estimate. This method requires the bidders to take more understanding of project documents. It may give an owner some indication of the seriousness of an offer.

The Danish system, developed in Europe, provides a simple formula to select the most reasonable offer from the competitive bids. Firstly, this system rejects two extreme offers which are the highest and lowest. The remaining offers are considered to get the new highest offer (NH), new lowest offer (NL), and the average of remaining offers (A) to calculate the new average (NA). The offer ranked first above this new average is then treated as realistic and acceptable. The formula is as follows:

$$NA = (NL + 4A + NH)/6$$

The competitive bidding system is widespread in both public and private projects because its concept protects the owner from extravagance, corruption, compromised, and unscrupulousness. However, its drawbacks are numerous such as time, quality, and safety (Herbsman and Ellis, 1992; Hatush and Skitmore, 1998; Wong et al., 2001). This concept causes several problems such as abnormally low bids, unqualified contractors, bid rigging, dispute about project duration and quality, and so on. Fong and Choi (2000) judged that “the lowest bidders have failed to complete projects due to financial difficulties or other common grounds” after considering the evidence from Hongkong’s new reports. The acceptance lowest bidder is used to lower their cost thanks to reducing their work quality and the compensation from submitting claims. In general, the lowest bid price system drives project owner to risky situations. For these reasons, a major change is needed.

2.1.3 Evaluation Criteria in Bidding Process

There are a number of different models that have been applied in the evaluation of bidding process. The literature provides a wide range of methods for selecting contractors. These methods are separated into two types of evaluating bid in construction industry. The first is lowest evaluated bid price which has been discussed in the previous section, and the other is multi-parameter method which will be presented in detail in this section.

Multi-parameter bidding system is a new concept developed. This concept proposes a process in which more parameters are applied in bidder selection than just cost. The suggested major parameters include cost, time, and quality. The secondary parameters are also important in selecting contractors which are safety, durability, security, maintenance, and so forth. Selecting parameters and their important weight depend on the owner and are different in projects. This method expresses the advantages to help the owner get the best product for their investment if they could be applied popularly.

In 1992, Herbsman and Ellis presented a multi-parameter bidding system (Herbsman and Ellis, 1992). This system suggests a contractor selection process in which more parameters are considered than just one element – cost in competitive bidding system. Some main parameters are cost, time, and quality. Other secondary parameters are safety, durability, security, maintenance, and so forth. They demonstrate multi-parameter concept by example. In this example, public agency evaluated bidders using four parameters which are cost, time, quality and safety. It is important to stress that Herbsman and Ellis just presented the concept of the system, they did not propose the method for selecting the parameters and related weight in the system. In the limitation, parameters will be chosen by the owner. This is unilateral and perceptible.

Table 2.1 Weights of criteria and sub-criteria of the case study

Bid amount (0.55)	Advance payment (0.05) Capital bid (0.75) Routine maintenance (0.10) Major repairs (0.10)	Management capability (0.1)	Past Performance and quality (0.40) Project management (0.20) Experience of technical personal (0.20) Knowledge (0.20)
Financial soundness (0.15)	Financial stability (0.30) Credit rating (0.20) Bank arrangements (0.15) Financial status (0.35)	Safety record (0.05)	Safety (0.20) Experience (0.30) Safety OSHA (0.30) Safety accountability (0.20)
Technical ability (0.1)	Experience (0.20) Plant and equipment (0.45) Personal (0.30) Ability (0.05)	Reputation (0.05)	Past failures (0.30) Length of time in business (0.10) Past client/ contractor relationship (0.40) Other relations (0.20)

Hatush and Skitmore (1998) introduced a model of contractor selection in which multi-criteria utility theory is used. It involved about five criteria with a total of twenty-four sub-criteria which were shown in Table 2.1 above. After forming the utility function of each sub-criterion, the evaluation score of each item will be converted to be utility value. And then, the overall utility values of bidders are calculated by each decision maker in order to rank bidders. Multi-criteria utility technique is quite useful in evaluating different characteristics of bidders. However, this is more influenced by risk responses of decision maker's personality.

A framework for evaluating bidders in lump sum contracts using multi-parameter was developed by Alsugair (1999). The framework concerned factors involved in bid evaluation, impact and relative weight of these factors. Conducting multiple interviews with experts, the final framework included thirty-six factors grouped into nine classes. They consist of financial evaluation of the bid, bid understanding, accomplishment of bid documents, location of projects, contractor capability, contractor experience, organization reputation, and submission of alternative offers. However, the study was limited in expressing the way to divide the importance weight among nine classes and among all factors. The authors stated that "Values of each factor's impact and weight depend upon the type of the owner sector and the assessment of the bid evaluator". Therefore, a systematic and persuasive method in selecting factors and their weight is necessary to explore.

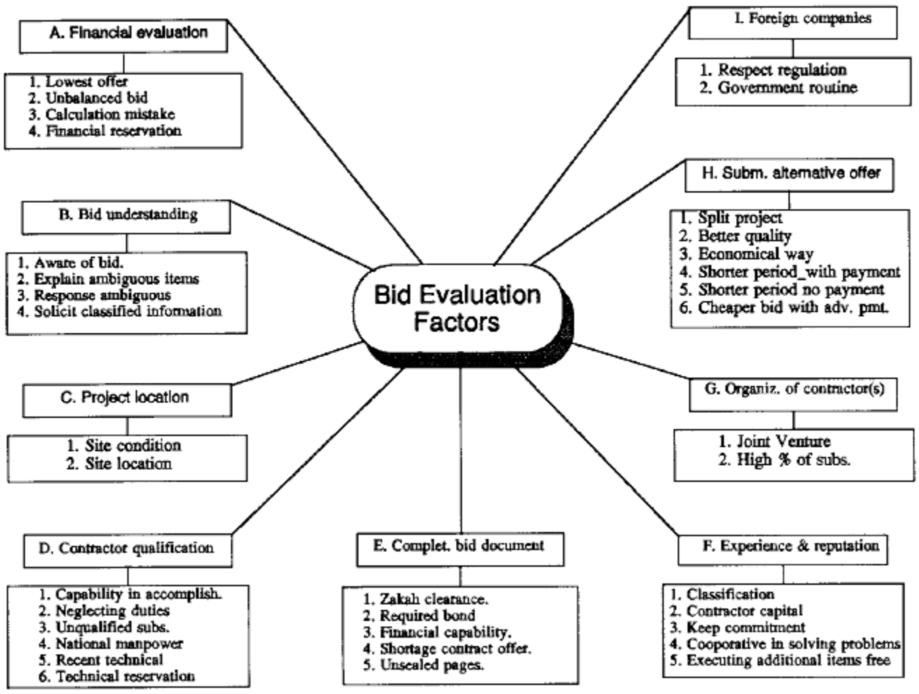


Figure 2.3 Bid evaluation factors by Alsugair (1999)

Following multi-parameter concept, a hierarchy of selecting the most capable contractor which includes eight criteria was presented by Fong and Choi (2000). Criteria was selected and revised from sixty-eight criteria collected from the literature review. The authors also carefully supported the rationale for the preferred criteria for contractor selection. These final criteria included tender price, financial capability, past performance, past experience, resource, current workload, past client/contractor relationship, and safety performance. The reasons for selecting each criterion are described in Table 2.2 below.

Table 2.2 Rationale for the choice of criteria for questionnaire survey – contractor selection (Fong and Choi, 2000)

A. Price	The lowest tender price tends to attract a client's interest as superior to other criteria
B. Financial capability	It focuses on the financial stability and backing of contractors. Insufficient financial standing of a successfully selected contractor can lead to late completion and unsatisfactory quality of work
1. Financial statement	Ratio analysis accounts and turnover history are tools of ratio analysis aimed at assessing the financial standing of a contractor Apart from these, financial ratios such as liquidity ratio deserve to be analyzed Other relevant financial ratios from various financial statements should be included
2. Financial references	Financial references, including credit reference and credit rating, are all evidence to show the degree of a contractor's financial stability for loan
C. Past performance	Past performance is a guide to likely future performance, and illustrates a contractor's ability to execute a contract
1. Failure to have contract completed	The reasons for failure to complete a contract are complicated, but this is an apparent warning of the reliability of a contractor

2. Delay	Late completion induces rental loss and additional interest
3. Additional cost	Client may not be able to afford overruns in cost
4. Actual quality achieved	Good quality outcome is a result of comprehensive quality control (QC) program and QC policy
D. Past experience	Accumulated experience in tackling difficulties is an asset of an entity, since unanticipated problems will be encountered during construction
1. Scale of projects completed 2. Types of project completed	Technical skill, size, image and reputation are reflected by the scale and type of projects carried out or completed
3. Experience in local area	Length of time in business shows a contractor's experience, but experience in foreign projects may not be advantageous to a local project
E. Resource 1. Physical resource 2. Human resource	Adequate and suitable physical and human resources help to foresee whether a contractor is likely to satisfactorily carry out the contract
F. Current workload	Whether the resources will be available for a particular project depends on the workload during construction duration
G. Past client/contractor relationship	Serious past disagreements and disputes cause deteriorations in mutual trust. Transfer of information and willingness to compromise are weakened
H. Safety performance	Poor safety awareness, safety precautions, and policy are huge costs, and may result in delays

Results from Wong et al. (2001) pointed out the tendency and clients' opinions regarding using multi-parameter or lowest price selection. They revealed that the clients in both public and private projects took more interest in multi-parameter, so the industry is changing the direction to apply more multi-parameter approach. In their research, eight groups of specific project criteria were manpower resources, plant and equipment resources, project management capabilities, geographical familiarities, location of home office, capacity, project execution of the proposed project, other specific project criteria, and technical-economic analysis. They stressed that "The levels of importance assigned for each criterion might attach importance to clients' decision-making during contractor selection process and thus for the success of a project".

After Fong and Choi's research, another research group argued that selection contractor process suggested by Fong and Choi was based on an assumption about the independence of criteria (Cheng and Heng, 2004). This assumption was not completely accurate. The criteria affected each other in some way. For example, past performance and past experience strongly influenced together, and they impacted on safety performance. Therefore, Cheng and Heng (2004) suggested an improved process using Analytic Network Process technique which was more suitable in the interdependent relationship among criteria selection as shown in Figure 2.4 below. However, the current study still used the hierarchical model suggested by Fong and Choi and considered (or examined) more interdependent influences among criteria.

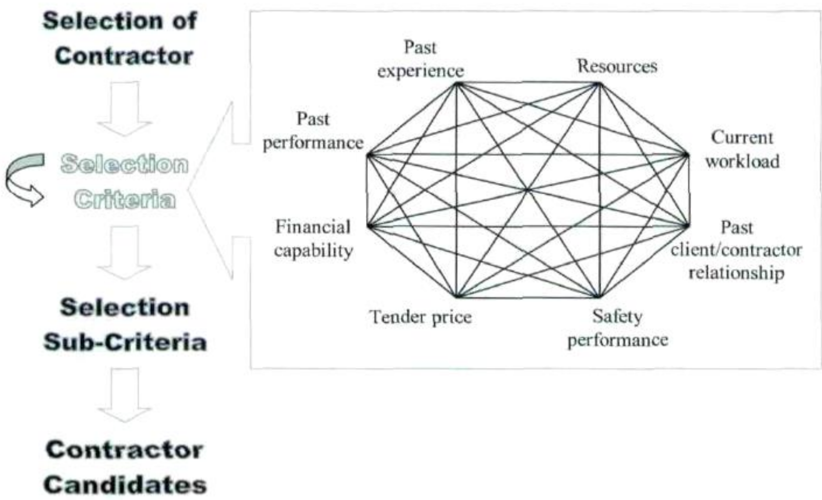


Figure 2.4 The ANP network component by Cheng and Heng (2004)

A multi-criteria decision support system (MCDSS) for the selection of the most appropriate contractor was developed by Mahdi et al. (Mahdi et al., 2002). Besides the bid price, a total of 90 criteria were applied in evaluating bidders. These factors grouped under five categories which were (1) experience, (2) past performance, (3) financial stability, (4) current capabilities, and (5) work strategy. The criteria were evaluated to determine their relative degrees of importance using Analytic Hierarchy Process along with Delphi method. MCDSS reduced limitation due to individual judgment and increased fairness in bidder selection. However, it was a complex process with a system of ninety criteria. Additionally, by using Delphi and Analytic Hierarchy Process, the comparison and relative weight of criteria were based on people's feelings and emotions as well as their thoughts, which could change according to the situation. One more limitation was that the list of criteria and their relative weight were not distinguished for different types of projects, owners and contracts.

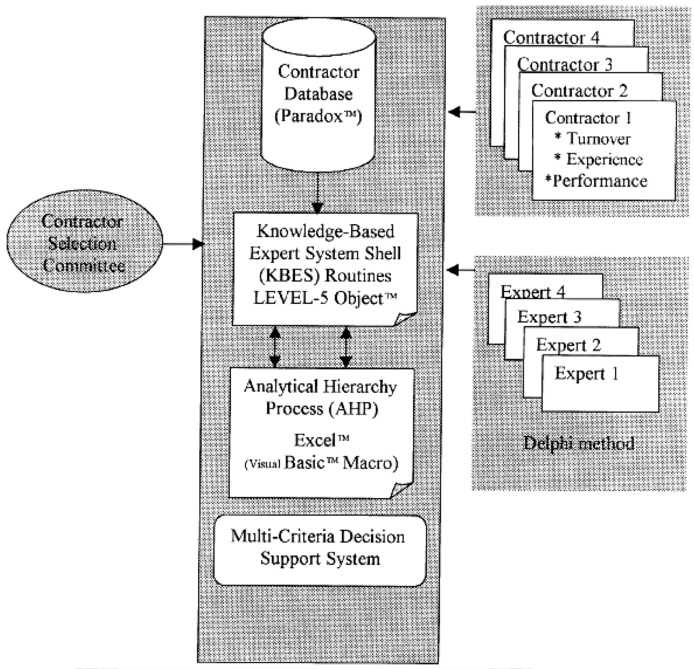


Figure 2.5 The proposed contractor selection system of Mahdi, Riley et al. (2002)

Alarcon and Mourgues (2002) considered bid price and contractor performance as two main elements in contractor selection. In their research, contractor's performance in bidding a project are combined by score of cost, schedule, quality and safety which are predicted from strategic states vector in General Performance Model (GPM). They also suggested that more elements in the evaluation such as technical evaluation of the bids are necessary in order to complete the proposed system.

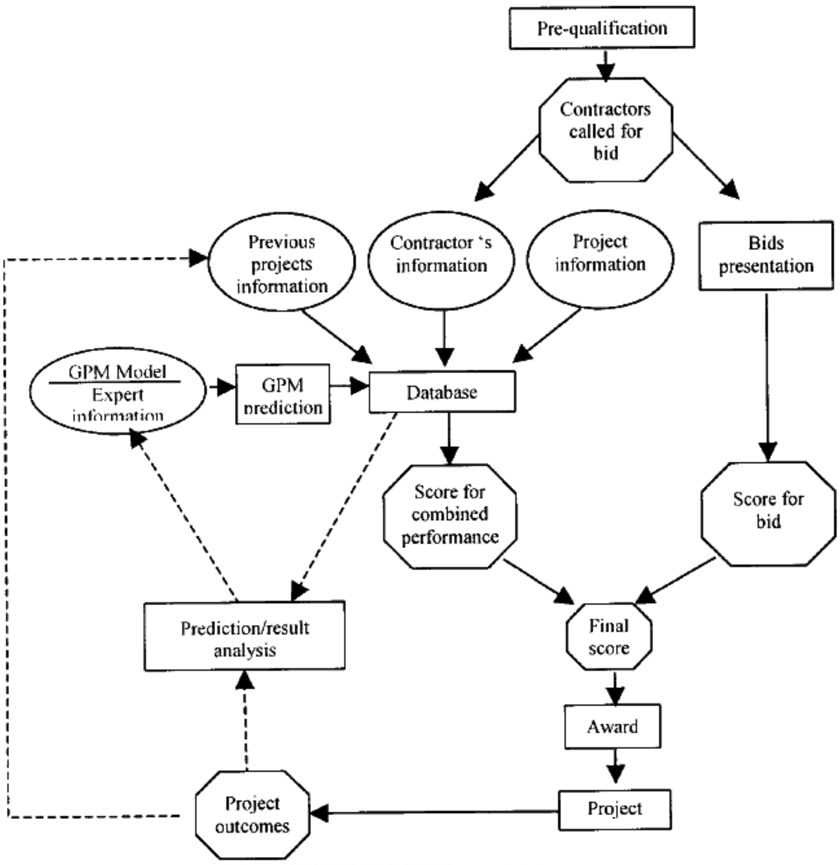


Figure 2.6 Proposed model for contractor selection of Alarcon and Mourgues (2002)

A research conducted by Watt et al. (2009) suggested principal evaluation categories of criteria for contractor selection. Two components were incorporated in this study based on its literature review and exploratory survey. Initially, sixteen categories of criteria were mapped and used to analyze by threshold test. The final result was an establishment of eight categories comprising Workload/Capacity, Organizational Experience, Past Performance, Client-Supplier Relations, Project Management Expertise, Technical Expertise, and Method/Technical Solution. This research provided a solid foundation for further study about criteria for contractor selection. However, missing Tender Price in the principal categories from the result of study is a contradiction with almost all previous researches, which considered Tender Price was a heavily weighted criterion for selection of contractor.

Recently, a multi-criteria model for bidding evaluation was developed by Sipahi and Esen (2010). In this model, the final score to evaluate bidders is the combination of bid price and evaluation score with a ratio of 70:30. In addition, the authors suggest discount factors to bid prices from the result of the evaluation process to provide a comparative advantage. However, it should be noted that the criteria and relative weights are established by using Analytic Hierarchy Process technique. Therefore, this relative importance of evaluation criteria is still based on opinions of some experts when they were asked in the questionnaire survey for pair-wise comparison. For each project, this process has to be repeated, so it is quite complex and obstructs the implementation.

Continued from multi-criteria, Pastor-Ferrando et al. (2010) suggested a hierarchy model including twenty one criteria. Their suggested approach for selection and weighting criteria based on Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP). This approach was applied in two real public projects and the results from AHP and ANP were compared. It is interesting that the results presented significant differences. From the experts' opinions, Analytic Network Process results were better than Analytic Hierarchy Process. This approach is unique for each project and actually not easy to conduct. For example, in order to select and weight criteria for one project, an AHP model required forty-three comparisons including in one questionnaire with complete matrices. Another ANP model was developed using two questionnaires with semi-complete matrices, and 220 comparisons and eighty-four comparisons for cluster prioritization. Moreover, the experts' roles were very important for the correct management of the AHP and ANP models. For these reasons, not many project owners conduct this approach before selecting and weighting criteria in bidding.

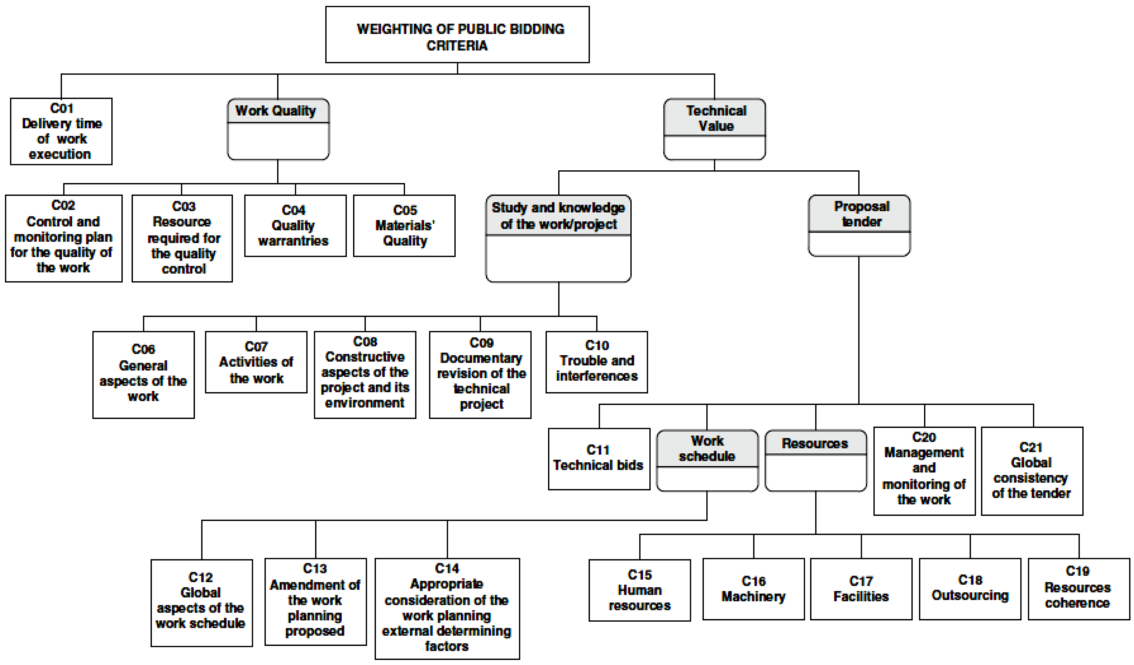


Figure 2.7 AHP model by Pastor-Ferrando et al. (2010)

Table 2.3 Case study results from AHP and ANP model of Pastor-Ferrando et al. (2010)

Criteria	*AHP*		*ANP*		*Criteria*
Delivery time of work execution	**C01**	**0.143**	**C11**	**0.215**	Technical bids
Study and knowledge of constructive aspects of the project and its environment	**C08**	**0.135**	**C08**	**0.131**	Study and knowledge of constructive aspects of the project and its environment
Study and knowledge of documentary revision of the technical project	**C09**	**0.119**	**C09**	**0.118**	Study and knowledge of documentary revision of the technical project
Study and knowledge of general aspects of the work	**C06**	**0.115**	**C10**	**0.088**	Study and knowledge of troubles and interferences
Study and knowledge of troubles and interferences	**C10**	**0.088**	**C07**	**0.078**	Study and knowledge of Activities of the work
Study and knowledge of Activities of the work	**C07**	**0.078**	**C06**	**0.063**	Study and knowledge of general aspects of the work
Global coherence of the tender (or bid)	C21	0.073	C02	0.059	Control and monitoring plan for the quality of the work
Technical bids	**C11**	**0.058**	C04	0.044	Quality warranties
Control and monitoring plan for the quality of the work	C02	0.052	C14	0.034	Appropriate consideration of the work planning external determining factors
Materials' quality	C05	0.04	**C01**	**0.03**	Delivery time of work execution
Quality warranties	C04	0.037	C05	0.027	Materials' quality
Management and monitoring	C20	0.015	C21	0.022	Global coherence of the tender (or bid)
Resources required for the quality control	C03	0.013	C17	0.021	Facilities
Amendment of the work planning proposed	C13	0.008	C16	0.019	Machinery
Appropriate consideration of the work planning external determining factors	C14	0.008	C13	0.015	Amendment of the work planning proposed
Human resources	C15	0.005	C20	0.012	Management and monitoring
Global aspects of the work schedule	C12	0.004	C19	0.01	Resources coherence
Resources coherence	C19	0.004	C12	0.006	Global aspects of the work schedule
Facilities	C17	0.002	C15	0.004	Human resources
Machinery	C16	0.001	C03	0.004	Resources required for the quality control
Outsourcing	C18	0.001	C18	0.001	Outsourcing

In general, the multi-parameter bidding system provides the mechanisms for utilizing and integrating different criteria in order to make sensible decisions. The previous models are based on experts' assessments, multi regression, cluster analysis, multi-attribute utility theory, multivariate discrimination, fuzzy set theory, Analytic Hierarchy Process, Analytic Network Process and so on. From Table 2.4 below, in the list of criteria used to select contractors from previous researches, the contractor's past performance is very important and should be applied in the bidding process. For this reason, a project success measurement is a tool to perform this mission.

Table 2.4 Summary of criteria used in selecting contractor

Criteria	Authors
Project	
Cost / Bid price	(Herbsman and Ellis, 1992; Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alsugair, 1999; Cagno et al., 1999;

	Fong and Choi, 2000; Alarcon and Mourgues, 2002; Mahdi et al., 2002; Cheng and Heng, 2004; Lai et al., 2004)
Schedule	(Herbsman and Ellis, 1992; Cagno et al., 1999; Alarcon and Mourgues, 2002; Lai et al., 2004; Pastor-Ferrando et al., 2010)
Quality	(Herbsman and Ellis, 1992; Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alarcon and Mourgues, 2002; Lai et al., 2004; Pastor-Ferrando et al., 2010)
Safety	(Herbsman and Ellis, 1992; Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Cagno et al., 1999; Fong and Choi, 2000; Alarcon and Mourgues, 2002; Cheng and Heng, 2004; Lai et al., 2004; McCabe et al., 2005)
Durability	(Herbsman and Ellis, 1992)
Security	(Herbsman and Ellis, 1992)
Maintenance	(Herbsman and Ellis, 1992)
Contractor's	
Experience	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alsugair, 1999; Fong and Choi, 2000; Alarcon and Mourgues, 2002; Mahdi et al., 2002; Cheng and Heng, 2004; McCabe et al., 2005; Watt et al., 2009; Jaskowski et al., 2010)
Past Performance	(Birrell, 1988; Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Fong and Choi, 2000; Mahdi et al., 2002; Cheng and Heng, 2004; McCabe et al., 2005; Watt et al., 2009; Jaskowski et al., 2010)
Financial	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alsugair, 1999; Fong and Choi, 2000; Alarcon and Mourgues, 2002; Mahdi et al., 2002; Cheng and Heng, 2004; Tan et al., 2007; Jaskowski et al., 2010)
Current capacities	(Fong and Choi, 2000; Mahdi et al., 2002; Cheng and Heng, 2004; McCabe et al., 2005; Watt et al., 2009)
Work strategy	(Mahdi et al., 2002)
Technical	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alsugair, 1999; Cagno et al., 1999; Alarcon and Mourgues,

	2002; Tan et al., 2007; Watt et al., 2009; Pastor-Ferrando et al., 2010)
Knowledge	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alarcon and Mourgues, 2002; Tan et al., 2007; Pastor-Ferrando et al., 2010)
Organization/ Resource	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Alsugair, 1999; Fong and Choi, 2000; Cheng and Heng, 2004; Lai et al., 2004; McCabe et al., 2005; Tan et al., 2007; Watt et al., 2009; Jaskowski et al., 2010; Pastor-Ferrando et al., 2010)
Past client/ contractor relationship	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Fong and Choi, 2000; Cheng and Heng, 2004; Tan et al., 2007; Watt et al., 2009)
Bid understanding/ Bid document	(Alsugair, 1999; Cagno et al., 1999; Lai et al., 2004; Pastor-Ferrando et al., 2010)
Reputation/certified systems	(Hatush and Skitmore, 1997; Hatush and Skitmore, 1998; Lai et al., 2004; Tan et al., 2007; Watt et al., 2009; Jaskowski et al., 2010)
Contract clause	(Cagno et al., 1999)

2.1.4 Bidding System in Vietnam

In recent decades, the Vietnam bidding and contracting system in construction industry has improved. The bidding system is being promoted for cost reduction and higher transparency to improve effectiveness in using state capital. Although bidding system has just been applied, bidding system brought some measureable achievements. Averages of 30 thousand packages that use state capital were made, corresponding to about US$4 billion to US$5 billion per year. An estimated amount of up to US$400 million per year is saved for government by the bidding system, about eight to ten percent per year. However, bidding is a new area in Vietnam. In the implementation process, it could not avoid embarrassing mistakes. It causes loss of state financial resources.

The bidding process is being reformed to meet the needs of integration and to attract international investment. Current legal documents related to bidding and contracting system are:

- Construction Law No. 16/2003/QH11,
- Bidding Law No. 61/2005/QH11 of the National Assembly,
- Law No. 38/2009/ QH12 of the National Assembly, amending and supplementing a number of articles of the laws concerning capital construction investment, and
- Degree No. 85/2009/ND-CP guiding the bidding law and the selection of construction contractors under the construction law.

According to Bidding Law No. 61/2005/QH11 of the National Assembly, forms of selection of contractors include Open bidding, Limited bidding, Direct appointment of contractor, Direct procurement, Competitive quotation in procurement of goods, Self-implementation, and Selection of contractor in special cases.

In open bidding, there should be no restrictions on the number of participating bidders. Before the bidding invitation documents are issued, bidders are informed about participation by a published notice from the party in charge of calling for bids. This party is expected to provide bidding invitation documents to any bidders who want to participate in the bidding process. These documents must not show any signs of restriction or favor which lead to unfair competition to the participating bidders.

Limited bidding is applied in projects which have highly technical requirements or techniques. It is requested from foreign donors providing the financing source. Only a minimum of five capable and experienced bidders who participate in the bidding will be invited when limited bidding is held. If the number is less than five, the investor has to be approved by an authorized person for holding this limited bidding or another form of contractor selection will be required instead.

Direct appointment of contractor shall apply in cases of an event of force majeure, appointment from foreign donors, bidding packages belonging to national confidential projects, or bidding packages similar with the previous projects. In order to conduct a direct appointment, contractor must have an acceptable level of capability and experience to meet the requirements. Before a contractor is directly appointed, the estimated budget of the bidding package must be approved in accordance with regulations.

Direct procurement shall apply in case a contract was signed for a package with similar contents within the previous six months. In direct procurement, the bidder selected in the bidding process shall be invited to carry out the earlier tender package with similar contents.

For purchased goods package price with an amount of less than two billion Vietnam dongs and common items, competitive quotation shall be implemented. This form is rarely used for construction packages.

Self-implementation as a form shall be adopted when the investor, also a contractor, has sufficient capability and experience to undertake the bidding package of the project which is managed and used by that same investor. In order to practice this self-implementation, the estimated budget for the bidding package must be accepted in accordance with regulations. The body who supervises the implementation of the bidding package must have no relationships with the investor organizationally and/or financially.

In recent years, bidding process in Vietnam has several problems related to legal framework, practical application from companies, and evaluating bidding methods. Direct appointment of contractor is widely applied in non-governmental projects, and self-contained bidding process causes collusion among bidders. Concerning bidding preparation, the quality of the solicitation bidding documents is low and inadequate, failing to meet the requirements for the selection of contractors. The requirements set out in the solicitation are unspecific, the evaluation criteria are impulsive and directed at a number of contractors that lose competitiveness and transparency in the selection process. With respect to bidding submission, most bidders are making bids in the module assembly technology. The information provided in bids includes both personnel and construction methods, and it may be changed after awarding the contract.

The great challenge to the bidding system in Vietnam is the evaluation methods for selecting the contractor. The evaluation process for construction lacks standards and appropriate methods to assess capability and experience of the bidders. Bid evaluation is still subjective. The specified technical evaluation of the construction bid package does not meet the requirements of the selection of construction contractors. Construction methods proposed in the bids are not close and without care, and lack accuracy and practicability. Therefore, the real performance after awarding the contract is different totally. Furthermore, bidding system lacks specific guidance in determining the price evaluation of tenders for construction packages. The process of organizational assessment of tenders for construction takes a long time, increasing the time bidding and construction implementation package.

2.1.5 Bidding System in Thailand

Current legal documents related to bidding and contracting system in Thailand are:

- Office of the PM Regulations B.E. 2535 (1992) amended 6 times (latest: 2002).
- Office of the PM Regulations regarding Electronic Procurement B.E. 2549 (2006).
- Ministry of Interior Regulations regarding procurement for local administrative organizations B.E. 2538 (1995); 2548 B. repealed.
- Large state enterprises and public organizations established under their own Act have their own procurement regulations (based on the OPM Regulations of B.E. 2535).
- Act regarding public tendering offenses B.E. 2542 (1999) covering both public officials and private sector.
- Regulation of the Audit Committee on Fiscal and Budgetary Discipline B.E. 2544 (2001).

There are six methods in Thailand's bidding system. They are open bidding, price search, negotiation, open electronic bidding, special case method, and special method. These methods can be grouped into two categories with one being methods without competition (negotiation, special method, and special case methods), and the other with competition (price search, open bid, and open electronic bidding). Based on value threshold, bidding methods consist of:

- Less than 100,000 Baht: Negotiation for procurement.
- Between 100,000 Baht and 2 million Baht: Price search.
- Over 2 million Baht: Open and open electronic bidding for procurement.
- Special method for procurement for which there is justification (Article 23 and 24) for procurement above100,000 Baht.
- Special case method used by government agencies.

Similar to Vietnam's system, the bidding system in Thailand also has several problems. The main problem is inefficient use of public funds. The document system encumbered with numerous rules, loopholes, and opportunities for corruption. Another challenge that needs to be solved is transparency.

Table 2.5 Bidding problems in targeted countries

Country	Bidding systems	Criteria for awarding a contract	Problems
Thailand	Negotiation Price search Open bidding Special method Special case method Open electronic bidding		Inefficient use of public funds. Transparency The system document is full of cumbersome rules, loopholes and opportunities for corruption.
Vietnam	Open tendering Limited tendering: foreign donor providing the financing source, highly technical requirements. Direct appointment: force majeure, foreign donor, national confidential project. Direct procurement: similar previous tender packages. Competitive quotation: less than 2B VND and commonly used of goods. Self-implementation Special cases	Technical capability Financial capability Experience Price Conversion of prices to equal footing basic regarding technical, financial, and commercial aspects. The evaluation factors and their weight should be announced in advance	Direct appointment Self-contained bidding process causes collusion. The quality of the solicitation bidding documents is low and inadequate The requirements set out in the solicitation are unspecific, the evaluation criteria are impulsive Lose competitiveness and transparency Without care bidding submission. The evaluation process lacks of standards and appropriate methods to assessed capability

			and experience of the bidders

The summaries of bidding system in targeted countries and their problems are shown in Table 2.5 above. The contractor evaluation process indicates that bidders' past performance is not considered. In order to evaluate the bidders' capability, the current bidding process has only considered information related to bidders' experience. For example, they required the numbers of projects done in last three years, scale of projects that bidders have completed, but not specifics about how good the completed projects are. It is important to differentiate two criteria, which are the numbers of past projects and how the contractor has completed past projects, in the contractor selection process. One contractor may pass the criterion of the number of projects that he has completed, but he may fail the requirement of the past performance criterion if he completed projects late, over budget, in an unsafe environment, poor quality, or dispute. Such contractors should not be selected. For these reasons, contractor performance should be added as a significant criterion in the contractor selection process. A construction project evaluation system is necessary to achieve this mission.

2.2 Correlation between Selecting Contractor and Project Success

The success or failure of project depends on contractor performance. So, the level of project successfulness could be used to evaluate contractors, and reference for their future bidding. Many previous researchers mentioned this correlation as Alarcon and Mourgues (2002), Mahdi et al. (2002), Cheng and Heng (2004). According to Alarcon and Mourgues' opinion, "Contractor selection is a decisive event for project success" (Alarcon and Mourgues, 2002). Cheng and Heng (2004) stated that "Contractor selection is one of the main decisions made from clients. In order to ensure that the project can be completed successfully, the client must select the most appropriate contractor." Because of the correlation between contractor selection and project success, a huge number of studies were conducted to develop a contractor selection method or model. The main purpose of these studies was "commensurate improvement in the success rate of construction projects" (Hatush and Skitmore, 1998).

This correlation is asserted, but this assertion comes from the subjective opinions of researchers. An objective research to demonstrate this correlation is important. What research needs to conduct is not only showing this correlation but also pointing out how the relationship between Multi-parameter for selecting contractor and project success is. One research, conducted by Hatush and Skitmore (1997), explored the relationship between selection criteria and project success factors. Project success factors in their study included time, cost and quality. Data collected by interviewing from a sample of six experienced construction professionals. The results from Delphi technique demonstrated that all contractor selection criteria are perceived to affect at least one project success factor. This study was an evidence of this relationship. However, it had some limitations, which are the number of samples, the success factors mentioned as only three as discussed above, and data collected from respondents' perception. Therefore, this research only asserted the relationship between contractor selection and success factors from the respondents' opinions.

The construction industry in almost all countries is facing the problem of selecting unqualified or incompatible contractors to perform the projects, particularly in public projects. In the long term, this major problem causes many projects' failure regarding intended expectation. Cost overruns, schedule delay, under quality, conflicts, high maintenance cost, and having to be rebuilt are the normal problems that occur frequently in most of projects. For these reasons, an improvement of the bidding system with more criteria is an urgent mission.

2.3 Concept of Project Success in Construction Industry

2.3.1 Definition of Project Success

Project success is a difficult concept because of the project's complexity and dynamic. Until now, there is no accepted universal definition of project success. Definition of project success may vary depending on each industry, project team, or individuals' point of views (Parfitt and Sanvido, 1993). It is different among participants, scope of services, project size, and time-dependent (Shenhar and Levy, 1997). "An architect may consider success in terms of aesthetic appearance, an engineer in terms of technical competence, an accountant in terms of dollars spent under budget, a human resources manager in terms of employee satisfaction, and a chief executive officers rate their success in the stock market" (Freeman and Beale 1992 cited in Shenhar and Levy (1997)). However, according to Parfitt and Sanvido (1993), project success definition is different for each participant, but it is based on the basic concept of the overall achievement of project goals and expectations. These goals and expectation includes technical, financial, educational, social, and professional issues.

Shenhar and Levy (1997) provided a definition of project success from Cleland (1986) that "Project success is meaningful only if considered from two vantage points: the degree to which the project's technical performance objective was attained on time and within budget, and the contribution that the project made to the strategic mission of the enterprise".

De Wit (1988) provided a definition of project success as "the project is considered an overall success if the project meets the technical performance specification and/or mission to be performed, and if there is a high level of satisfaction concerning the project outcome among key people in the parent organization, key people in the project team and key users or clientele of the project effort".

Liu and Walker (1998) defined project success at two levels. The first level is project's goals concerning time, budget, functionality/quality/technical specification, safety and environmental sustainability. The second level is the satisfaction of the claimant(s).

2.3.2 Definition of Construction Project Success

In the construction industry, the concept of project success varies among different projects depending on participants, project size, scope of services, and the time required to implement a project. Nevertheless, there are common threads across the industry concerning the perceptions and expectations of the designer, owner, or contractor. Contractor selection is an important event for project success. The purpose of all models which are studied to select contractors is to help the owner achieve project success. Therefore, project success can be considered as a reflection to evaluate how good the contractor selection process is.

So far it is still difficult to get an agreement on the concept of project success. As discussed above, it depends on many factors, especially human perceptions. The concept of "project success score" is developed specifically for this research. "Project success score" is a quantifiable number that can represent the level of project success when the project is completed, how well the project outcome is compared with proposed project objectives. This concept can be used to assess and compare the completed projects, which are in the same category of project type, project scale, and capital type. Future projects can benchmark against previous projects.

2.3.3 Project Success and Project Management Success

A distinction should be made between project success and project management success. They are often confused, but they are not the same. De Wit (1988) showed many examples from their research on about 650 completed projects in the USA, and concluded that "a project can be a success despite poor project management performance and vice versa". They stressed that "good project management can contribute towards project success but is unlikely to be able to prevent project failure" (De Wit, 1988). Project management plays an important role in project success, but there are many factors which are out of direct control which may affect project success. Project management is considered successful if it satisfies a number of requirements. They include effective planning, the involvement of a skillful project manager, adequate time to define a project thoroughly, correct planning, reliable and sufficient information flows, changing activities to adapt to frequent changes in the project, meeting employees' expectations regarding performance and rewards, and identifying mistakes in project implementation in order to make timely adjustments (Munns and Bjeirmi, 1996). From this narrow definition of successful project management, it is believed that the concept of project success encompasses more than project management success, and they are not directly correlated.

2.3.4 Project Success Criteria and Project Success Factor

According to Oxford Advanced Learner's Dictionary, criterion means "a standard or principle by which something is judged, or with the help of which a decision is made"; whereas a factor is "one or several things that cause or influence something". So, the concept of "project success criteria" and "project success factor" are different, but sometimes they are misunderstood. From this definition, a set of criteria project success establishes the groundwork of project success judgement. It includes a set of standards or principles which are used to judge the project. On the other hand, project success factors are the set of several things that cause or influence project outcomes, which contribute to the project success or failure.

Up to this time, most studies have focused on project success factors. These published articles include Sanvido et al. (1992), Hatush and Skitmore (1997), Chan et al. (2001), Chan et al. (2004), Chu et al. (2004), Nguyen et al. (2004), Salminen (2005), Chan et al. (2010), and Tabish and Jha (2011). Chua et al. (1999) suggested a set of sixty-seven factors related to project success and categorized them in four groups which were project characteristics, contractual arrangements, project participants, and interactive processes. The Table 2.6 below describes these factors in details.

Table 2.6 Success-related factors developed by (Chua et al., 1999)

Project aspect (1)	Success-related factor (2)
Project characteristics	(1) Politcal risks; (2) economic risks; (3) impact on public; (4) technical approval authorities; (5) adequacy of funding; (6) site limitation and location; (7) constructability; (8) pioneering status; (9) project size
Contractual arrangements	(10) Realistic obligations/clear objectives; (11) risk identification and allocation; (12) adequacy of plans and specifications; (13) formal dispute resolution process; (14) motivation/incentives
Project participants	(15) PM competency; (16) PM authority; (17) PM commitment and involvement; (18) capability of client key personnel; (19) competency of client proposed team; (20) client team turnover rate; (21) client top management support; (22) client track record; (23) client level of service; (24) Capability of contractor key personnel; (25) competency of contractor proposed team; (26) contractor team turnover rate; (27) contractor top management support; (28) contractor track record; (29) contractor level of service; (30) capability of consultant key personnel; (31) competency of consultant proposed team; (32) consultant team turnover rate; (33) consultant top management support; (34) consultant track record; (35) consultant level of service; (36) capability of subcontractors key personnel; (37) competency of subcontractors proposed team; (38) subcontractors team turnover rate; (39) subcontractors top management support; (40) subcontractors track record; (41) subcontractors level of service; (42) capability of suppliers key personnel; (43) competency of suppliers proposed team; (44) suppliers team turnover rate; (45) suppliers top management support; (46) suppliers track record; (47) suppliers level of service
Interactive Processes	(48) Formal design communication; (49) informal design communication; (50) formal construction communication; (51) informal construction communication; (52) functional plans; (53) design complete at construction start; (54) constructability program; (55) level of modularization; (56) level of automation; (57) level of skill labors required; (58) report updates; (59) budget updates; (60) schedule updates; (61) design control meetings; (62) construction control meetings; (63) site inspections; (64) work organization chart; (65) common goal; (66) motivational factor; (67) relationships

It is important to stress that, the concept used in this research is the project success criteria. The criteria will be described as the set of indicators and criteria of project success. Again, this research will not focus on what factors influence or contribute to project success or failure. It completely concentrates on the principles or standards by which the project is judged.

2.4 Project Success Measurement

The problem of whether the project success can be measured or not has been addressed by many researchers a long time ago. From De Wit (1988), measuring success is complex because it depends on the stakeholders' points of view and it is time dependent. A project can be perceived as a success for one party but a failure for another. De Wit (1988) believed the concept that "one can objectively measure the success of a project is an illusion". Nevertheless, he pointed out that it is possible and valuable to evaluate project at the post-completion stage. He also provided evidence, the Project Management Institute conference help in Montreal in 1986, to demonstrate the possibility of success measurement. The purpose of this conference was to examine the importance of good measurement indicators of project success. It received the earlier version of papers related to “measuring success” implying a message that project success is possible to determine.

Result measure, process measure, and relationship measure are three types of measures of the partnering in the construction industry (Crane et al., 1999). All of them are important and strong in their proper place. Among them, result measure is the most difficult to evaluate, but it is the most useful for future strategy adjustments. According to the proposed objective of this research, from this point forward, project success is considered at the completed stage.

Contractor selection is another important event for project success. The purpose of all models which are studied to select contractors is to help owners achieve project success. Therefore, project success can be considered as a mirror in evaluating how good the contractor selection process was. This section will consider the measurement of project success proposed by previous researches in order to develop a construction project evaluation system. From the literature review, the problem of project success measurement was considered in three aspects which are the list of indicators and criteria in measurement, the methodology to assess each indicator and criterion, the important weight of each indicator and criterion, and the methods to combine them.

The first group of researchers created a solid foundation for this study when they described the whole picture of project success measurement index (De Wit, 1988; Songer et al., 1997; Liu and Walker, 1998; Crane et al., 1999; Lim and Mohamed, 1999; Tukel and Rom, 2001; White and Fortune, 2002; Bryde and Robinson, 2005; Ahadzie et al., 2008; Al-Tmeemy et al., 2011). They collected the indexes from previous researches or industry and then asked the perception of respondents. Most of them were based on the importance scale to evaluate the important level of each. These studies provided a good reference. However, these researchers have not carried out the applicability or information that is used to gather the capacity of these indexes. Furthermore, each study is developed based on one party’s point of view such as owners, contractors, or project managers.

Project objectives are the most appropriate criteria for project success. The success or failure of a project is determined based on the degree to which these objectives are being met. From De Wit (1988), the criteria for project success are restricted to time, cost, and quality. He also discussed the results on construction project success from a pilot study at the University of Texas. According to the results, construction project success is frequently measured by six criteria including budget performance, schedule performance, and project stakeholders' satisfaction.

A list of six criteria for success was developed from Songer et al. (1997). They are 'On budget', 'On schedule', 'Meets specifications', 'Conforms to user's expectations', 'High quality of workmanship', and 'Minimizes construction aggravation'. 'On budget' refers to the completion of project within the contracted cost. 'On schedule' means this completion is achieved prior to or on the date as shown in the contract. 'Meets specifications' suggests the ability to meet or exceed the entire owner's provided specifications of technical performance. 'Conforms to user's expectations' is the ability to meet or exceed the envisioned functional goals of the user (fitness for purpose). Finally, an ability to meet or exceed the standards required for workmanship in all areas is called 'High quality of workmanship', and using a construction process that does not causes overwhelming workload to the owner's project management staff is 'Minimizes construction aggravation'. The results from 137 qualified responses in the U.S. and U.K. showed that project success is judged based on such criteria as budget variation, schedule variation, and conformity to expectations. These criteria are consistent with the construction industry in general.

Liu and Walker (1998) suggested that a project should be evaluated at two levels. The first level is project goals, which include time, budget, functionality, quality, technical specification, safety, and environmental sustainability. The second level is satisfaction of the claimant. Crane et al. (1999) introduced about partnering measures which are result measure, process measure and relationship measure. Among them, result measure is the most important but also difficult to perform. So, they provided an example framework to evaluate results which included cost, schedule, safety, quality, and litigation. Lim and Mohamed (1999) discussed a framework for evaluating project success similar to the framework suggested by Crane et al. (1999). Besides time, cost, quality and safety, Lim and Mohamed (1999) added performance and satisfaction to their model. After nearly ten years, environmental impact has become an important index in evaluating project success (Ahadzie et al., 2008). Recently, the concept of project success has broadened. The importance of the roles of project schedule, budget, quality, safety, and satisfaction in project success measurement is in no doubt. Al-Tmeemy et al. (2011) added four indexes to this framework which are functional requirement, technical specification, revenue and profit and market share.

During a ten year period, from 1990 to 2000, more than twenty studies were conducted to establish project success criteria. The summaries from Chan et al. (2002)

showed the list of criteria which was used in previous studies as shown in Table 2.7 above. They are separated into objective measures and subjective measures. Related to objective measures, four criteria occurred in most of studies are Time and cost, ‘Budget/ Financial performance/ Profitability, Health and Safety, and Quality. Other five measures are Meeting technical performance specifications, Project objectives/ goal attainment, Completion, Functionality, and Productivity/ efficiency, rarely appear. In the subjective measures group, only one criterion, Satisfaction of Client/Customer, Contractor, and project management team satisfaction, is concerned in almost all studies. Seven other criteria are only mentioned in one or two studies. They are Expectation/aspiration, Dispute resolution satisfaction/conflict management, Absence of conflicts/legal claims, Professional image, Aesthetics, Educational/social/professional aspects, and Environmental sustainability.

Table 2.7 Summary of project success criteria over 1990-2000 (Chan et al., 2002)

	Objective measures			Subjective measures													
Previous studies	Time and cost	Budget/ financial performance/ profitability	Health and safety	Quality	Meeting technical performance specifications	Project obectives/ goal attainment (technical)	Completion	Functionality	Productivity/ efficiency	Satisfaction of client/ customer, contractor, project manager/ team satisfaction	Expectation/ aspiration of client, contractor, project manager/ team satisfaction	Dispute resolution satisfaction/ conflict management	Absence of conflicts/ legal claims	Professional image	Aesthetics	Educational, social, and professional aspects	Environ-mental sustain-ability
Maloney (1990)	√			√					√								
Norris (1990)		√															
Freeman and Beale (1992)	√	√		√	√				√	√							
Riggs et al. (1992)	√			√	√												
Tayler (1992)	√	√	√	√					√								
Parfitt and Sanvido (1993)	√	√	√	√	√			√		√	√		√	√		√	
Albanese (1994)							√										
Bushait and Almohawis (1994)	√		√	√													
Naoum (1994)	√			√						√							
Kumaraswamy and Thorpe (1995)	√		√	√						√					√		√
Larson (1995)										√			√				
Chan (1996)	√			√				√		√							
Shenhar et al. (1997)	√	√		√													
Liu and Walker (1998)			√			√					√						√
Al-Meshekeh and Langford (1999)						√						√					
Chua et al. (1999)	√			√													
Atkinson (1999)	√			√													
Lim and Mohamed (1999)	√		√	√			√			√							
Brown and Adams (2000)	√			√													
Cheung et al. (2000)	√			√							√						

The second group of researchers not only presented a list of indicators and criteria but also described the methodology to evaluate each of them. They are Shenhar and Levy (1997); Chan et al. (2002); Chan and Chan (2004); and Tabish and Jha (2011).

De Wit (1988) discussed three methods of measuring project success which are collected from available literature. The first method by Might and Fisher describes about 'Overall', 'Cost', 'Schedule', 'Tech 1', 'Tech 2', and 'Tech 3'. The relative weight of technical performance, cost performance, and schedule performance in turn are 54%, 23%, and 22%. The detailed meanings of them are:

- 'Overall': the subjective measure that is perceived by the respondents as related to the overall success.
- 'Cost': the cost over/underrun that is measured as part of the initial estimate (in percentage).
- 'Schedule': the schedule over/underrun that is measured as part of the initial estimate (in percentage).
- 'Tech 1': technical success that is subjectively assessed relative to the initial plan.
- 'Tech 2': technical success that is subjectively assessed with respect to other development projects in the company.
- 'Tech 3': the subjective assessment of technical success that is measured in respect of the technical problems identified in the process.

The second method is based on three criteria for project success including project functionality (financially, technically, or otherwise), project management (budget, schedule, and technical specification), and contractors' commercial performances (short-term and long-term). This method looks extremely difficult. This method suggests that the satisfaction of people who are directly involved in Government programs can be understood as the basis of judging the success of these programs. Thus, criticism is then viewed as a sign of success.

In 1997, a group of researchers (Shenhar and Levy, 1997) provided a framework of project success which included four distinct dimensions. These dimensions considered both short-term and long-term measures. Short-term measures were project efficiency (time and cost), and impact on the customer (meeting performance measures, functional requirements, and technical specifications). Long-term measures were business direct success, and preparation for the future. They suggested a seven-point scale to evaluate each index.

In 2002, with numerous articles on project success in the area of success factors, Chan et al. (2002) performed a summary of these criteria over the period of 1990 to 2000. This summary is described in Table 2.7 above. They also suggested criteria for measuring performance of Design/Build projects which include both objective and subjective measures. Objective measures include time, cost, health and safety, and profitability, while subjective measures include quality, technical performance, functionality, productivity, satisfaction, and environmental sustainability. Time is measured by time overrun, construction time, and speed of construction. Three indexes to evaluate cost are cost overrun and unit cost. Accident rate per 1,000 workers is used to assess health and safety. Quality is judged by total net revenue over total costs. Other indexes can be evaluated by subjective seven-point Likert scale. In general, the method established from Chan et al. (2002) is quite simple to understand and easy to apply to the construction industry.

Continuing from the same basic idea with Chan et al. (2002), in 2004, Chan and Chan (2004) suggested a set of key performance indicators (KPIs) for measuring construction success. It includes objective and subjective indicators which are discussed in detail and practically. Subjective indicators are construction time, speed of construction, time variation, unit cost, percentage net variation over final cost, net present value, accident rate, and environmental impact. Subjective measurements are quality, functionality, client satisfaction, design team's satisfaction, and construction team's satisfaction. In the first group, mathematical formulae are used to calculate respective values while a seven-point scale is used to assess subjective opinions in the second one. In general, they provide a good set of indicators and a useful framework for measuring and comparing project success.

Recently, Tabish and Jha (2011) developed a project success measurement for public projects. Their framework included three norms which are overall success, anti-corruption norms, and financial norms. For each index, they suggested using a nine-point Likert scale to evaluate.

The third group of studies concentrated on exploring the important weight and methodology to combine all indexes. They are Griffith et al. (1999); Chua et al. (1999); Shawn et al. (2004); Menches and Hanna (2006); and Shahrzad Khosravi (2011). These studies are very important in developing this research framework. However, each of them has some small problems, making it difficult to apply them in developing countries.

A success index equation was developed by Griffith et al. (1999). Their equation considered four main variables with the following definition:

- Budget Achievement (33%): Budget achievement is understood as commitment to the authorized budget. This achievement is measured by the difference between the budget at the time of project completion and the authorized budget.
- Schedule Achievement (27%): Schedule achievement is commitment to the authorized schedule for the mechanical completion. This achievement is measured by the difference between the schedule in practice and the project's authorized schedule.
- Design Capacity (12%): Design capacity is defined as the rate of facility's nominal output (tons per year, barrels per day, kilowatts, etc.) to size of equipment and mechanical as well as electrical systems in engineering and designing. It is measured by the design capacity achieved after six months of implementation compared to the planned design capacity at the time the project was authorized.
- Plant Utilization (28%): Plant utilization is defined as the percentage of days in a year for which the actual products are produced utilizing project plant. Similar to design capacity, it is measured by the percent of utilization after six months of implementation in comparison to that of planned utilization at the authorization.

Each variable is identified based on different units. The percentage above or below the authorized amount is used to measure the budget. Percentage above or below the authorized schedule is used to measure the actual schedule. Days producing products versus planned as a percentage is used to measure the utilization, and the percentage of actual units of products compared to the planned amount is used to measure the design capacity. Based on the extent to which each variable is actually performed given the project's original plan, every variable was regrouped into three separated values so as to combine all these values into one index later. Weighting of them is calculated by summing up all responses for four variables. However, this framework is developed specifically for facility projects. In order to apply in construction building, it requires more indicators.

After two years, another group of researchers, Shawn et al. (2004), developed a Construction Project Success Survey (CPSS) instrument. Their instrument included classic objective measures such as cost, schedule, quality, performance, safety, and operating environment. They used the seven point Likert scale to score each criterion. Especially, in their instrument, respondents' perception about how important of each issue was determinated to calculate. However, the instrument which included thirty-two issues related to six groups of criteria as mentioned above with the seven scale of answering made it difficult and confusing for respondents. The result is still subjective because it depends on the perception of respondents.

A quantitative measurement method of successful performance was developed by Menches and Hanna (2006). They provided a process for converting a qualitative evaluation of successful performance to a quantitative measurement. This method is the nearest base for conducting the project success framework in this research. At the end, six factors were selected for the measurement index, including:

- Actual percent of profit;
- Percent of schedule overrun;
- Amount of time to complete work;
- Communication between team members;
- Cost variation;
- Changing work hours.

This method is suitable for contractor's point of view. On the owner's side, these criteria are not enough to cover their entire objective for evaluating project success. However, this research provides an effective method to convert qualitative parameter to quantitative and the concept of probability of successful performance.

The summary list of indicators and criteria from previous studies is described in Table 2.8 below. It also explains the evaluation methodology that previous researchers suggested be used for each index.

Table 2.8 Summary list of indicators and criteria and their evaluation methods from literature review

List of indicators and criteria	Evaluation Methods
Cost Cost overrun	Cost over/ underrun as a percentage of the initial estimate (De Wit, 1988; Songer et al.,

List of indicators and criteria	Evaluation Methods
Unit cost Rework costs Budget contingencies (Shenhar and Levy, 1997; Liu and Walker, 1998; Chua et al., 1999; Crane et al., 1999; Tukel and Rom, 2001; White and Fortune, 2002; Bryde and Robinson, 2005; Ahadzie et al., 2008; Al-Tmeemy et al., 2011; Shahrzad Khosravi, 2011)	1997; Crane et al., 1999; Chan et al., 2002; Menches and Hanna, 2006). Measured against authorization cost budget: 1-Over, 3-At, 5-Under (Griffith et al., 1999). Unit cost: cost $/ gross floor area m2 (Chan 1996 - (Chan et al., 2002))(Chan and Chan, 2004) Rework costs: The subjective assessment from -3 to +3 (Shawn et al., 2004) Budget contingencies: The subjective assessment from -3 to +3 (Shawn et al., 2004)
Schedule Time overrun (time variation) Construction time Speed of construction Material availability Equipment availability Labor availability Work hours (Shenhar and Levy, 1997; Liu and Walker, 1998; Chua et al., 1999; Crane et al., 1999; Tukel and Rom, 2001; White and Fortune, 2002; Bryde and Robinson, 2005; Ahadzie et al., 2008; Al-Tmeemy et al., 2011; Shahrzad Khosravi, 2011)	Time over/ underrun as a percentage of the initial estimate = (construction time – revised contract period)/Revised contract period (De Wit, 1988), Naoum 1994 (Songer et al., 1997; Crane et al., 1999; Chan et al., 2002; Chan and Chan, 2004; Menches and Hanna, 2006). Measured against authorization schedule: 1-Over, 3-At, 5-Under (Griffith et al., 1999). Construction time=Practical completion date – Project commencement date (Chan 1996 - (Chan et al., 2002))(Chan and Chan, 2004) Speed of construction: gross floor area (m2)/ construction time in days (Al-Meshekeh and Langford - (Chan et al., 2002)) Material availability: The subjective assessment from -3 to +3 (Shawn et al., 2004) Equipment availability: The subjective assessment from -3 to +3 (Shawn et al., 2004) Labor availability: The subjective assessment from -3 to +3 (Shawn et al., 2004)

List of indicators and criteria	Evaluation Methods
	Work hours: percentage change in work hours (Menches and Hanna, 2006)
Quality (Liu and Walker, 1998; Chua et al., 1999; Crane et al., 1999; White and Fortune, 2002; Ahadzie et al., 2008; Al-Tmeemy et al., 2011; Shahrzad Khosravi, 2011)	Integration of three elements: defects, on-time delivery, and budget compliance (Saarinen and Hobel 1990 - (Chan et al., 2002)). Degree of conformance to predetermined standard of performance (Sanvido et al 1992 - (Chan et al., 2002)). Performance of cost, schedule and safety (Stevens 1996 - (Chan et al., 2002)). Subjective assessment by seven-point scale (Chan and Chan, 2004). Amount of rework required (Crane et al., 1999).
Health and Safety (Liu and Walker, 1998; Crane et al., 1999; White and Fortune, 2002; Ahadzie et al., 2008; Shahrzad Khosravi, 2011)	Accident rate per 1,000 workers = number of injures or accidents/employment size x 1,000 (Chan et al., 2002; Chan and Chan, 2004). Compiling safety statistics such as lost time incidents (Crane et al., 1999).
Profitability (Al-Tmeemy et al., 2011)	Measured as total net revenue/total costs (Chan et al., 2002; Menches and Hanna, 2006). Value and profit measured by NPV (Chan and Chan, 2004) but can't obtain this information.
Technical Performance (Liu and Walker, 1998; Tukel and Rom, 2001; Bryde and Robinson, 2005; Al-Tmeemy et al., 2011)	The subjective assessment of the technical success relative to the initial plan (De Wit, 1988). The subjective assessment of the technical success relative to other development projects in the firm (De Wit, 1988).

List of indicators and criteria	Evaluation Methods
	Technical problem identification process (De Wit, 1988). Meeting specifications (Songer and Molenaar 1997 - (Chan et al., 2002)).
Functionality (Liu and Walker, 1998; Al-Tmeemy et al., 2011)	Measured by degree of conformance of all technical performance specifications (Chan et al., 2002). Conformance to expectation of members (Songer and Molenaar 1997 - (Chan et al., 2002))(Songer et al., 1997). Subjective assessment by seven-point scale (Chan and Chan, 2004).
Rework (Tukel and Rom, 2001)	
Productivity	The subjective assessment (Chan et al., 2002).
Satisfaction Owner Contractor Project Stakeholder	The subjective assessment (Chan et al., 2002) (Chan and Chan, 2004). (Shenhar and Levy, 1997; Liu and Walker, 1998; Tukel and Rom, 2001; White and Fortune, 2002; Bryde and Robinson, 2005; Ahadzie et al., 2008; Al-Tmeemy et al., 2011; Shahrzad Khosravi, 2011)
Environmental Sustainability (Liu and Walker, 1998; Ahadzie et al., 2008)	The subjective assessment (Chan et al., 2002): good, acceptable, unacceptable. Application of ISO14000, or EIA score, total number of complaints receiving during the construction...but author cannot collect information (Chan and Chan, 2004)
Communication between team members	Below average = 1, slightly below average=2, average=3, slightly above average=4, above average=5 (Menches and Hanna, 2006)

List of indicators and criteria	Evaluation Methods
Litigation (Crane et al., 1999) Outstanding claims Conflicts	
Anti-corruption norms (Only for public projects)	Nine-point scale (Tabish and Jha, 2011)
Financial norms (Only for public projects)	Nine-point scale (Tabish and Jha, 2011)
Market Share (Construction companies side)	(Shenhar and Levy, 1997; Al-Tmeemy et al., 2011)
Reputation (Construction companies side)	(Al-Tmeemy et al., 2011)
Competitive Advantage (Construction companies side)	(Al-Tmeemy et al., 2011)
Operating Characteristics (Facility construction projects)	Measured against planned utilization: 1-Under, 3-At, 5-Over (Griffith et al., 1999).

2.5 Multi-Criteria Evaluation Based Theory

Multi-criteria analysis (MCA) establishes preferences between the options that the body that makes decision has identified in consideration of an explicit set of objectives, and for which measureable criteria are developed to evaluate the possibility of achieving objectives. The main role of the techniques is to deal with the difficulties that decision makers have encountered in consistently solving large amount of complex information.

Different from unproven judgements of analysts, MCA has many advantages:

- It is open and direct.
- The selection of objectives and criteria made by any decision making group can be justified depending on the analysis and can be replaced if they are found to be irrelevant.

- Established techniques are taken into consideration to develop applicable and explicit scores and weights. These scores and weights can also be checked in terms of reference across other sources of information with relative values, and corrected if necessary.
- The sub-contraction of performance measurement can be done by experts without asking for support from the decision making body.
- MCA can offer important means of communication for the decision making body itself and act as a coordinator between that body and the wider community.
- MCA provides an audit trail when scores and weights are used.

There are many different MCA procedures. Some common procedures are Direct analysis of the performance matrix, Multi-attribute utility theory, Linear additive models, The Analytic Hierarchy Process (AHP), Outranking methods, Qualitative data inputs, and MCA methods based on fuzzy sets. Principally MCA procedures and other procedures are distinguished based on how the basic information is processed in the performance matrix. A number of cases are more relevant for MCA procedures than others.

In order to select a technique in MCA process, the following criteria should be used:

- Internal consistency and logical soundness
- Transparency
- Ease of use
- Data requirements which are inconsistent with the importance of the issue being considered
- Realistic time and manpower resource requirements for the analysis process
- Ability to provide an audit trail, and
- Software availability, where needed.

Direct analysis of the performance matrix can be used for a limited amount of information about options' relative merits. If any of the options are dominated by others, the initial step can be seen. Multi-attribute utility theory provides the model that comes closest to universal acceptance. A linear additive model shows the combination of an option's values on many criteria to become a single value. This is done by multiplying the value score of each criterion by the weight of that criterion, and then adding all those weighted scores together. AHP suggests a linear addictive model but the weights and scores achieved by alternatives are derived from procedures in the standard format of the model, which are based on pairwise comparisons between criteria and options respectively.

Different from the approaches discussed above is the approach of Outranking methods. These methods, developed in France, have been applied and successful to some extent in a number of European countries. The methods have improved used outranking to identify and eliminate 'dominated' alternatives. However, dominance in the outranking frame of references uses weights to give more influence to specific criteria than others, which has a different meaning compared to the idea of straightforward dominance in the Direct analysis.

Decision makers who work in the Government often have to deal with problems in which preference weights or information in the performance matrix consists of qualitative judegements. To respond to these problems, a number of methods have been developed and used, among which are Qualitative data input procedures. Another group focuses on the approximation to the linear additive model. Accordingly, they are relatively transparent despite the involvement of significant amounts of data processing.

Fuzzy sets tend to take the ideas that the natural language we use in discussion is not precise. Options are not as simple as 'attractive' or 'expensive', but more vague such as 'fairly attractive' or 'rather expensive'. These qualified assessments are then captured by fuzzy arithmetic using the idea of a membership function. Through this an option would lie between 0 and 1 and belong to the set of 'attractive' options with a given degree of membership.

The above procedures are just some common procedures in MCA. The following tables show the summaries of their principles, characteristics, and examples (Wager, 2007).

Table 2.9 Summaries of MCA methods (Wager, 2007)

	Characteristics	Examples
Quantitative methods	▪ Require quantitative information about scores of each criterion.	▪ Weighted summation; ▪ Value and utility analysis; ▪ Ideal point method; ▪ Outranking methods; ▪ Analytical hierarchy process.
Qualitative methods	▪ Only qualitative information on scores or a mixture of quantitative and qualitative scores is available	▪ Evamix; ▪ Regime; ▪ Permutation.

	Characteristics	Examples
Discrete methods		
Single criterion methods	▪ convert impacts concerning the different criteria into one criterion or attribute.	▪ Multiple attribute utility theory (MAUT) ▪ Analytical hierarchy process (AHP) ▪ Evaluation matrix (Evamix)
Outranking methods	▪ less strong assumptions (about existence of utility functions, additivity, …); ▪ allow for incomparability of options; ▪ avoid complete ranking being identified too early (interaction between model and decision makers is encouraged); ▪ aim is not so much to identify an optimal solution but rather to facilitate the identification of compromise solutions in a transparent and fair way.	▪ ELECTRE III ▪ Regime ▪ NAIADE
Continuous methods		
Programming methods	▪ programming methods do not choose from a finite number of alternatives, but the alternatives are generated during the solution process on the basis of a mathematical model formulation.	▪ Multi-Objective-Programming (MOP) ▪ Goal Programming (GP)

	Characteristics	Examples
Vectorial models	▪ based on the assumption that all feasible solutions of a decision problem can be represented as vectors in a vectorial space of dimension equal to the number of evaluation criteria. ▪ may prove helpful when only qualitative information is available, or lead to a considerable loss of information when quantitative data also exist.	▪ Regime
Superiority graph models	▪ based on concept of partial comparability; ▪ treat preferences as ordered outranking relations.	▪ ELECTRE group

Additive models	▪ i.e. models that establish a performance norm, which is usually linear.
	▪ preassumptions:
	  ▪ all decision alternatives are comparable;
	  ▪ transitivity of preference and indifference relations holds.
		▪ Analytical hierarchy process (AHP)
		▪ Multi attribute utility approach
		▪ ADAM type

In brief, MCA models have a number of shortcomings originating from the methodological assumptions as follows:

- No solution can optimize the criteria all at once. Consequently decision makers have to seek elevant solutions. This means that when conflicting evaluation criteria are taken into consideration, a multi-criteria problem appears to be ill-structured mathematically.
- Considering the relations of preference and indifference in this approach is not sufficient. This exists because a better action than another for some criteria is usually worse for others, resulting in many incomparable pairs of actions regarding a dominance relation.

Different appraisal objectives in different contexts apply different multi-criteria methods. Despite being designed for application in a variety of problems, most of these methods can be suitable and effective only in a number of specific decision situations. In the construction project evaluation situation, MCA is the most suitable method.

2.6 Linear Additive Models and Quantitative Multi-Criteria Evaluation

There are several different multi-criteria evaluation procedures. In order to select a technique in this process, some criteria should be used in consideration. They are application in the practice, user acceptance, data requirements, ease of use, their applicability, and utility of results related to the problem situations (Tsamboulas et al., 1999). A comparison among the most suitable methods was conducted by Tsamboulas et al (1999). They concluded that each method presents a series of unique features allowing for a high degree of flexibility, consistency, and reliability. Selection depends on the problem situations. They asserted some positive aspects of linear additive method. It is well structural, simple, straightforward, and easy to follow. Linear additive model copes better with real world situation and offers decision closest to human rational approach. The important thing is that it could be applied to any number of projects and any number of criteria. Therefore, linear additive method is an appropriate method for construction project evaluation.

Linear additive models suggest the combination of an option's values of many criteria into one overall value. These models multiply the value score of each criterion by the weight of that criterion, and then add all those weight scores together. The following Figure 2.8 below explains the detailed steps of applying MCA (Dodgson et al., 2009).

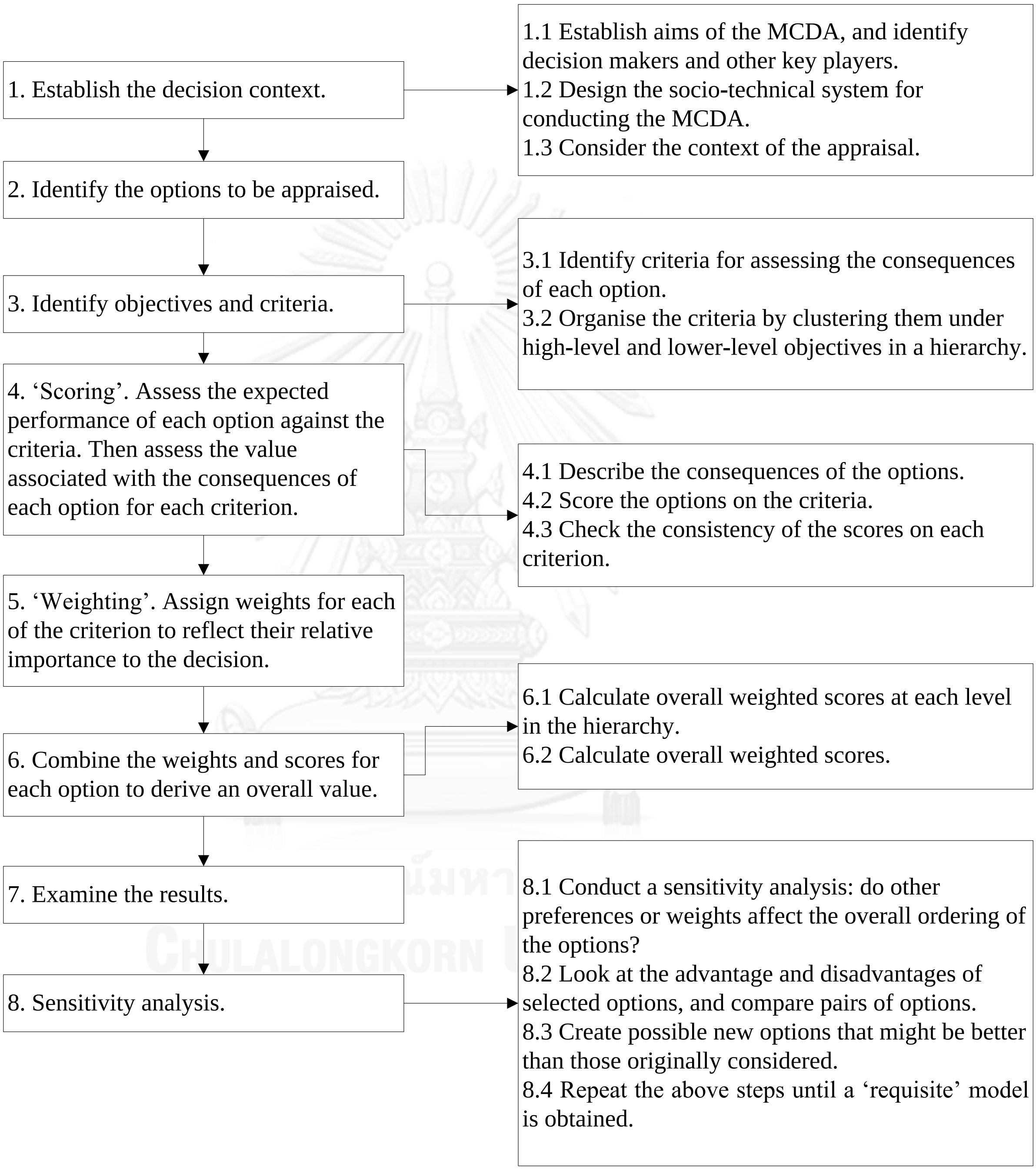


Figure 2.8 The detailed steps of applying MCA (Dodgson et al., 2009)

In the MCA process, the steps of Identifying criteria, Scoring, Weighting, and Combination are extremely important.

Identifying criteria is very important. Criteria are specific, measurable objectives. Criteria show many ways by which options create values. In the event that options are already given, identifying criteria in a 'bottom-up' way means to discern the difference between the options and others in ways that matter. In contrast, asking about the achieved aim, purpose, mission, or overall objectives is a 'top-down' approach, with overall objectives being given in a number of situations. In the area of construction project success, the literature review of previous studies is a valuable foundation for identifying the criteria.

In general, multi-criteria in MCA may be evaluated in different units. Combining money, ticks, stars, and ratings to attain an overall assessment is impossible. A scoring system is thus necessary. The main idea is to have scales representing preferences for the consequences constructed, then to measure the scales' relative importance, and to calculate weight averages across the preference scales. This can be done in many ways with relative preference scales such as Linkert scales being one of the most useful approaches.

Weighting criteria reflects their relative importance to the decision. It is still impossible to combine the preference scales since a unit of preference on one may be unequal to a unit of preference on another. There is a formal equivalence between equating the units of preference and judging the relative importance of the scales. As a result, with the appropriate weighting procedure, the process is meaningful to those making judgements. There are several methods to assess the relative weight. These are detailed in the following section.

The overall preference score for each option is simply the weighted average of its scores on all the criteria. Letting the preference score for criterion j be represented by s_i and the weight for each criterion by w_i, then n criteria the overall score is given by:

$$S_i = w_1 s_1 + w_2 s_2 + ... + w_n s_n = \sum_{i=1}^{n} w_i s_i \qquad (2.1)$$

In words, multiply a score on a criterion by the importance weight of the criterion, do that for all the criteria, and then sum the products to give the overall preference score for that indicator. Then repeat the process for the remaining indicators. After achieving a score for each indicator, conduct a similar process to calculate the overall score for the supper level.

2.7 Weight Assignment Methodology

Weight means the rationing of the rule hierarchy. It reflects the intention and preference of respondents, and affects the consequences of the system. Weight assignment has a central position in the MCA process. The choice of weight assignment method is crucial of final project. There are two constraints in the weight value: first, the weight value is between 0 and 1; second, the sum of the weight value in a hierarchy should be equal to 1. The bigger the value, the more important it is, and vice versa.

Weighting methods included subjective weighting method, objective weighting method, and combined weighting method. These were the Delphi method, the Analytic of Hierarchy Process method, the Analytic Network Process method, the Factor Analysis method, and the Entropy method. The selection of a method is depended on objectives and purposes. In the area of construction success measurement as mentioned in the previous section, descriptions such as ranking, summing up, and Analytic of Hierarchy Process method were applied. They belong to the subjective weighting method which implied several disadvantages. Consequently, an objective weighting assignment was necessary; it was a more logical and accurate system.

2.7.1 Subjective Weighting Method

The subjective weighting method takes one’s judgement of the significance of the indicator into consideration to develop its weight assignment. Accordingly, experts’ experience and subjective judgement serve as the means for weight determination. Different experts correspond to the different weights. In this method, the scope of experts is expanded, and experts are selected carefully to prevent subjectivity and arbitrariness from the process of the subjective weighting method. However, pitfalls are still obvious. One advantage of this method is the ability to reasonably decide the order of the indicator depending on the real situation.

Some common subjective weighting methods are Direct Weighting Technique, Delphi method, and AHP method.

Direct Weighting Technique: One of the roughest methods of weight assignment is the direct weighting technique (Dodgson et al., 2009). With this technique, weight assignment is achieved based on direct assessment of the importance of one parameter over another, in which the extent to which the parameter actually contributes to the total score of the alternatives is not considered (Chambal et al., 2003).

Delphi Method: The main procedures of Delphi method is as follows: first, experts are informed about the comprehensive indicator system along with explanations in messages. After that, the importance level of indicator is evaluated in accordance with the value range. The data should be then analyzed to decide whether the process is repeated according to the rate of divergence when the experts' opinions are retrieved. If certain experts have very different opinions from others, they are asked to reconsider their judgements until a common agreement for weight determination is reached. Experts play a role in the Delphi method, but this method is time consuming and is a rather complicated process.

Analytical Hierarchy Process (AHP): AHP is a method that combines both quantitative and qualitative properties. Three layers including objective layer, criteria layer, and scheme layer are decomposed from the whole evaluated object based on/after the division of the complex system into different layers. After indexes are compared together, a matrix is created to determine the weight of the indicator. Analysis using this method is considered more accurate than the Delphi method (Dodgson et al., 2009). The advantages and disadvantages of the AHP have become subjects of discussion among many specialists in MCA. It is obvious that the pairwise comparison form of data input is straightforward and convenient for the users. However, there are concerns about the theoretical foundations of the AHP and a number of its properties, among which is the rank reversal phenomenon. This phenomenon causes a reversal in the ranking of two options that are unrelated in any way to a new option when it is added to the list of the options being evaluated. This is seen by many as being inconsistent with the rational evaluation of options thereby questioning the underlying theoretical basis of the AHP.

2.7.2 Objective Weighting Method

The objective weighting method is recommended in order to minimize the artificial interference that occurs in the process of weight assignment. According to this method, variation extent and its influence on other indicators should be used to assign the weight of the indicator. The original information should come from the objective environment. The weight of indicators should be assigned by means of the information the indicator possesses. The commonly used objective weighting method includes Entropy method, Factor Analysis (FA), Structural Equation Modeling (SEM), Fuller

Triangle Method, combination of Battelle EES and Importance scale matrix (BEES & ISM).

Entropy Method: The concept of entropy means the chaos degree of the system. The thought that the biggest entropy could be found in the system when all the consequences appear at the same probability has become a premise for measuring the importance of the indicator by way of entropy. The bigger entropy the indicator processes, the less important it would be. As a result, the indicator should be assigned by the small weight.

Factor Analysis (FA): FA is the first multivariate technique because it plays a unique role in the application of other multi-criteria technique (Tabachnick and Fidell, 2006; Hair et al., 2010). The major purpose of this interdependent technique is to delineate the underlying structure of the variables in the analysis. By this way, FA can show the interrelation between the indicator and the criterion.

Structural Equation Modeling (SEM): SEM was an alternative technique for exploring the interrelationship among factors in multiple layers of linkages between variables. SEM proved an effective statistical technique in developing the causal model for explaining a dependent variable with high quality information (Tabachnick and Fidell, 2006; Hair et al., 2010). SEM consists of two main parts: causal model between independent variables and dependent variables, and the measurement model showing the relationship among variables. This technique is applied by using AMOS 16.0 software.

Fuller Triangle (FT) Method: The method is based on the forming of triangular matrices of parameter pairs within which parameter weighting is performed. It is a quick but rough weighting method (Agarski et al., 2012). FT is one kind of pairwise comparison methods.

Combination of Importance Scale Matrix (ISM) and Battelle Method: ISM is a method that unranks pairwise comparison of each parameter with the remaining other (n-1) parameters, then leaving that parameter, next parameter is compared with the remaining (n-2) parameters, and so on using the importance scale (consider the total number of parameters as n). To define the scale, the definition of relatively important terms used is kept in view. The matrix of preference obtained from that is then analyzed using 'eigenvector' method to arrive at the weight of each parameter in the matrix (Goyal and Deshpande, 2001). Battelle environmental evaluation system (BEES) method involves ranked pairwise comparison of parameters, wherein initial ranking plays a major role. Once ranking is done, the first parameter in the ranked list is compared with the second parameter, the second with the third, and so on (Goyal and Deshpande, 2001). In the combination method, without any initial ranking of the selected parameters, ISM method logic is used for pairwise comparison of parameters importance, and then normalization of weight is done following BEES method. This combined approach is developed in order to have a simple, more exhaustive but unbiased way to obtain parameter's weight without using complicated statistical (eigenvector) procedure.

2.8 Summary of Literature Review

According to literature review, construction project evaluation was necessary and could be measured. The problem of whether a project's success could be measured or not has been addressed by many researchers over time. Although measuring success was complex because it depended on the stakeholders' point of view and was time dependent, it was possible and valuable to evaluate projects at post-completion stage. A huge number of recent studies in the literature review were strong evidence to demonstrate this issue.

Construction project success evaluation was assessed as very important. It was interesting and studied by a vast amount of researchers. The first group of researchers created a solid foundation for this study when they described the whole picture of project success measurement indexes. The second group of researchers not only presented the list of indexes but also described the methodology to evaluate each index. The third group of researchers concentrated on exploring the important weight and methodology to combine all indexes.

Previous measuring project success models contained some problems. Firstly, measuring project success models depended on the evaluators' perception. Secondly, each model was developed based on one party's point of view. Thirdly, some quantitative evaluation models were difficult to practice in developing countries. Lastly, previous studies lacked the methodology to combine the evaluation of each index. These problems made project evaluation models in previous studies difficult to disseminate in the construction industry. Therefore, a better framework for project success evaluation is needed.

A direct correlation between contractor selection and project success was found. Project success could be used as one of the criteria in bidding future projects. The current contractor evaluation process lacked this criterion. In order to evaluate the bidders' capability, current bidding process has only considered information related to bidders' experience. For example, they required the number of projects done in last three years, the scale of the projects that bidders completed, but did not require specifics about how good the completed projects are. Therefore, the construction evaluation system could provide the reference for bidding process.

In order to achieve an innovative system, multi-criteria evaluation based theory was the most appropriate and had many advantages. Linear additive method was selected for combination. Weight assignment was one of the important processes in multi-criteria evaluation. Weighting methods included subjective weighting method, objective weighting method, and combined weighting method. Objective weighting method was used to achieve the quantitative multi-criteria evaluation system. They were Summing Responses, Structural Equation Modeling, and combination of Battelle EES & Importance scale matrix.

CHAPTER 3
PROPOSED QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM

3.1 Proposed Quantitative Multi-Criteria Construction Project Evaluation System

As reviewed in the previous chapter, construction project evaluation has been assessed as very important. However, previous measuring project success models contained some problems such as depending on the evaluators' perception, being based on one party's point of view, having difficulties in application, missing quantitative weight assignment methodology, and lacking methodology to combine the evaluation of each index. Therefore, this research established a Quantitative Multi-criteria Construction Project Evaluation System (QMCPE System).

The QMCPE system is expected to provide complete indicators and criteria of evaluation system, their weight assignment, instruction for evaluating each indicator and criterion, their measurement scale, and combination method. Compared with previous studies, the proposed QMCPE system is expected as an innovation with some advantages. It considers the evaluation from all parties in the project. Each party is responsible for evaluating a group of indicators and criteria with respect to their responsibility and capacity to provide information. It is important to stress that, this system is expected to point out the project success scoring, so it not only instructs the way to evaluate each indicator and criterion but also shows the method to combine them into one representative success score.

The proposed QMCPE system is expected to provide a quantitative result of project evaluation which is unbiased, fair and objective, easy and applicable. The quantitative results come from quantitative evaluation of indicators and criteria and their quantitative weight assignment. It helps to avoid bias as occurs when comparing human sensibility. From the literature review, there are two groups of indexes which are objective and subjective. In the QMCPE system, it is hoped that the subjective evaluation can be minimized to achieve a fair and objective system.

As discussed in the statement of problem section, some quantitative evaluation models from past studies were difficult to practice in developing countries because their indexes were not applicable. The proposed QMCPE system is expected to solve this problem. Furthermore, project evaluation database is strong evidence to show the applicability of the system. The conceptual model of this research is shown in Figure 3.1 below.

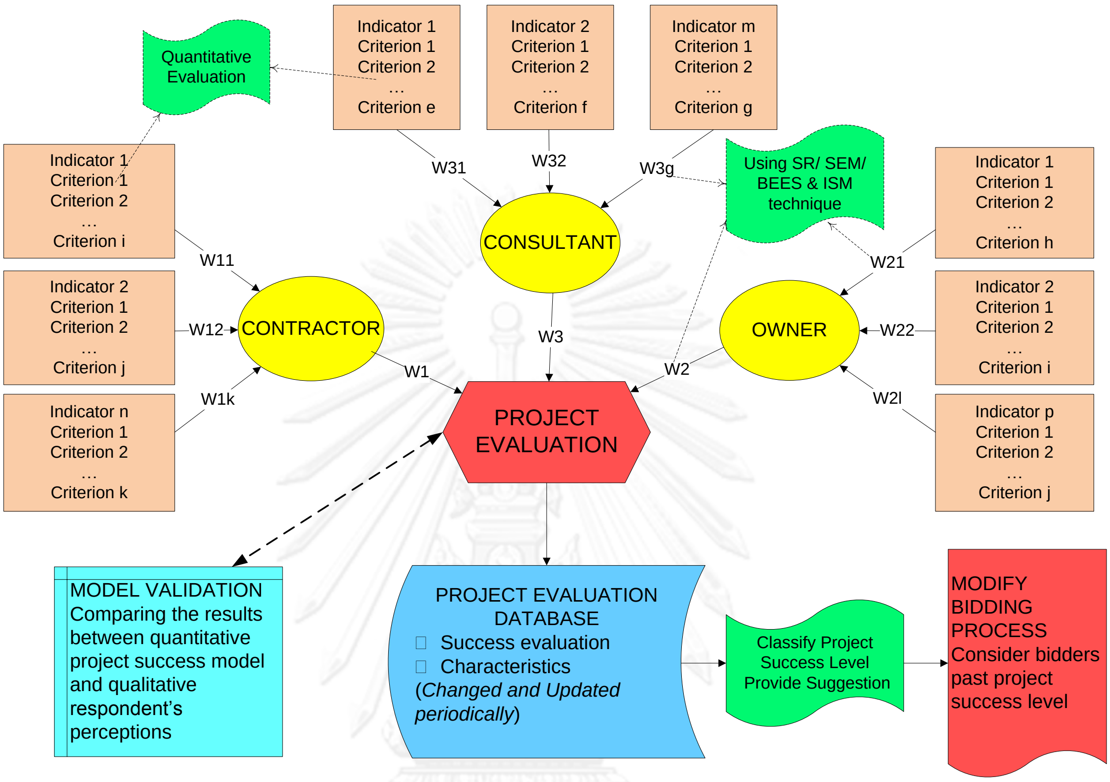


Figure 3.1 Research conceptual model

The QMCPE system is expected to bring many benefits to all project stakeholders. For contractors, the QMCPE system will be used to assess projects when they are completed, and to compare one project with other projects in their company. This evaluation helps to improve their companies, and achieve continuous improvement. For the Government management, the QMCPE system is expected to be extremely valuable. It will help to develop a database of construction project evaluation, contractor performance, tendency of construction project performance, and tendency of the importance level of indicators and criteria. From that, Government could better manage, control, and improve policy. For the owner, the QMCPE system is a tool to look back on how a project performed. It can be a reference for future project strategy.

According to the research objectives, the QMCPE system is expected to provide one more reference for the contractor selection process in bidding. Based on the construction evaluation database achieved by the QMCPE system, a threshold for contractor selection could be suggested. This threshold would depend on some characteristics of projects such as project contract price, project contract duration, project type, project capital source, and project area.

3.2 Indicators and Criteria in the QMCPE System

In the QMCPE system, the construction project is evaluated at two levels. The first level is called indicator. Each indicator is assessed by criteria, the second level. The initial list of indicators and criteria of the QMCPE system was collected from literature review. It included eleven indicators and fifty-one criteria. The indicators were 'Project Cost', 'Project Time', 'Project Quality', 'Project Safety', 'Technical Performance', 'Productivity', 'Waste Materials', 'Stakeholders Satisfaction', 'Sustainable Environment', 'Communication', and 'Disputes & Litigation'. The initial list of indicators and criteria is described in Table 3.1 and Figure 3.2 below. The final list of indicators and criteria of the QMCPE system was achieved after conducting preliminary survey in Chapter 5.

The QMCPE system is expected to provide a quantitative measurement for criteria in evaluating construction projects. Each criterion is measured quantitatively. For example, in order to evaluate cost performance, five criteria were 'Cost Variation', 'Unit Cost', 'Reworks Cost', 'Expenses Incurred', and 'Cost for Contingencies'. 'Cost Variation' was measured by the difference between contract price and final price. It was similar to the method suggested from previous studies (De Wit, 1988; Songer et al., 1997; Crane et al., 1999; Chan et al., 2002; Menches and Hanna, 2006). 'Unit Cost' was the construction cost per gross floor area (Chan et al., 2002; Chan and Chan, 2004). 'Reworks Cost', 'Expenses Incurred', and 'Contingencies Cost' were evaluated differently compared with Shawn et al. method (Shawn et al., 2004). Shawn et al. provided a subjective assessment from (-3) to (+3) to evaluate 'Reworks Cost', 'Expenses Incurred', and 'Contingencies Cost'. The QMCPE system will use the percentage of reworks cost, expenses incurred, and contingencies cost per initial estimated cost to evaluate them. Therefore, it could minimize the subjectivity and bias in evaluation.

Table 3.1 Initial list of indicators and criteria in the QMCPE system

Indicators/ Criteria	Meaning
1. COST	The degree to which the general contexts promote the completion of a project within the estimated budget
COST1	Cost variation is ratio of net variations to final contract sum expressed in percentage term
COST2	Unit cost is a measure of relative cost and is defined by the final contract sum divided by the gross floor area.
COST3	Rework costs
COST4	Expenses incurred
COST5	Cost for contingencies
2.TIME	The degree to which the general contexts promote the completion of a project within the allocated duration
TIME1	Time variation is measured by the percentage of increase or decrease in the estimated project days, discounting the effect of extension of time granted by the client.
TIME2	Speed of construction is the relative time, which is defined by gross floor area divided by the construction time (number of days from start on site to practical completion of the project)
TIME3	Material availability: number of days construction site delay because of supplying materials
TIME4	Equipment availability: number of days construction site delay because of lack of equipment
TIME5	Labor availability: number of days construction site delay because of lack of labor
3.QUALITY	The degree to which the general contexts promote meeting of project's established requirements of materials and workmanship
QUA1	Conformity with expectations: The different level between quality expectation of owner and real project quality after completed.
QUA2	Conformity with predetermined standard: The different level between predetermined standard and real project quality.
QUA3	Implement the "Evaluate the suitability project quality certificate" in the project
QUA4	Number of defects need to rework when take over the project

Indicators/ Criteria	Meaning
QUA5	Unsatisfied works
QUA6	Time to rework under-quality works
4.SAFETY	The degrees to which the general contexts promote the completion of a project without major accidents or injuries
SAFE1	Number of death injures or accidents
SAFE2	Number of heavy accidents
SAFE3	Number of slightly accidents
SAFE4	Total safety management expenditures
SAFE5	Accidents compensation
SAFE6	Total time lost when accidents occurred
SAFE7	Evaluation of safety signs
SAFE8	Evaluation of providing safety tools and protection equipment
SAFE9	Evaluation safety level of equipment used in construction
SAFE10	Evaluation of safety training
SAFE11	Evaluation of safety responsibility staffs
5.TECH	The degree to which the general contexts promote meeting of project's established specifications
TECH1	Evaluation of the contractor's response to the technical requirements
TECH2	Evaluation of technical problem identification and solution
TECH3	Overall assessment qualifications of workers in the project
TECH4	Evaluation of the possibility of problem solving of technical staff
6.PRO	The degree to which the general contexts promote achieving effectiveness of allocated resources in order to meet the cost and time targets
PRO1	Construction productivity
PRO2	Unit labor cost per square meter
PRO3	Unit equipment cost per square meter
7.WASTE	
MATERIALS	Total materials are wasted in construction site
8.SATIS	Satisfaction describes the level of ''happiness'' of project stakeholders
SATIS1	Owner satisfaction

Indicators/ Criteria	Meaning
SATIS2	Contractor satisfaction
SATIS3	Consultant satisfaction
9.ENVI	The degree to which the general contexts promote avoiding the effects of project on the environment
ENVI1	Frequency of complaints from the environment and communities around the construction site
ENVI2	Frequency of time reminded about sanitation from the authorities
ENVI3	The number of time and duration suspended from the authorities
ENVI4	Assessing the recovery of the contractor when warned
ENVI5	Expenses for ensuring environmental sustainability
ENVI6	Expenses of overcoming the problems of environmental sanitation
10.COMMU	The degree to which the general contexts promote achieving effectiveness of communication in order to avoid misunderstanding
COMMU1	Evaluation of the communication in project
COMMU2	The frequency of misinformation or delays affecting the project
COMMU3	Information systems used in project
11.LITIGA	This index can be measured by number of outstanding claims, relationship among parties after project is completed, and information about penalties for breach of contract.
LITIGA1	Outstanding claim among parties about payment
LITIGA2	Evaluation of conflicts among parties in checking and taking over the project
LITIGA3	Evaluation of relationship between contractor and owner after project completed
LITIGA4	Performance of contractual commitments

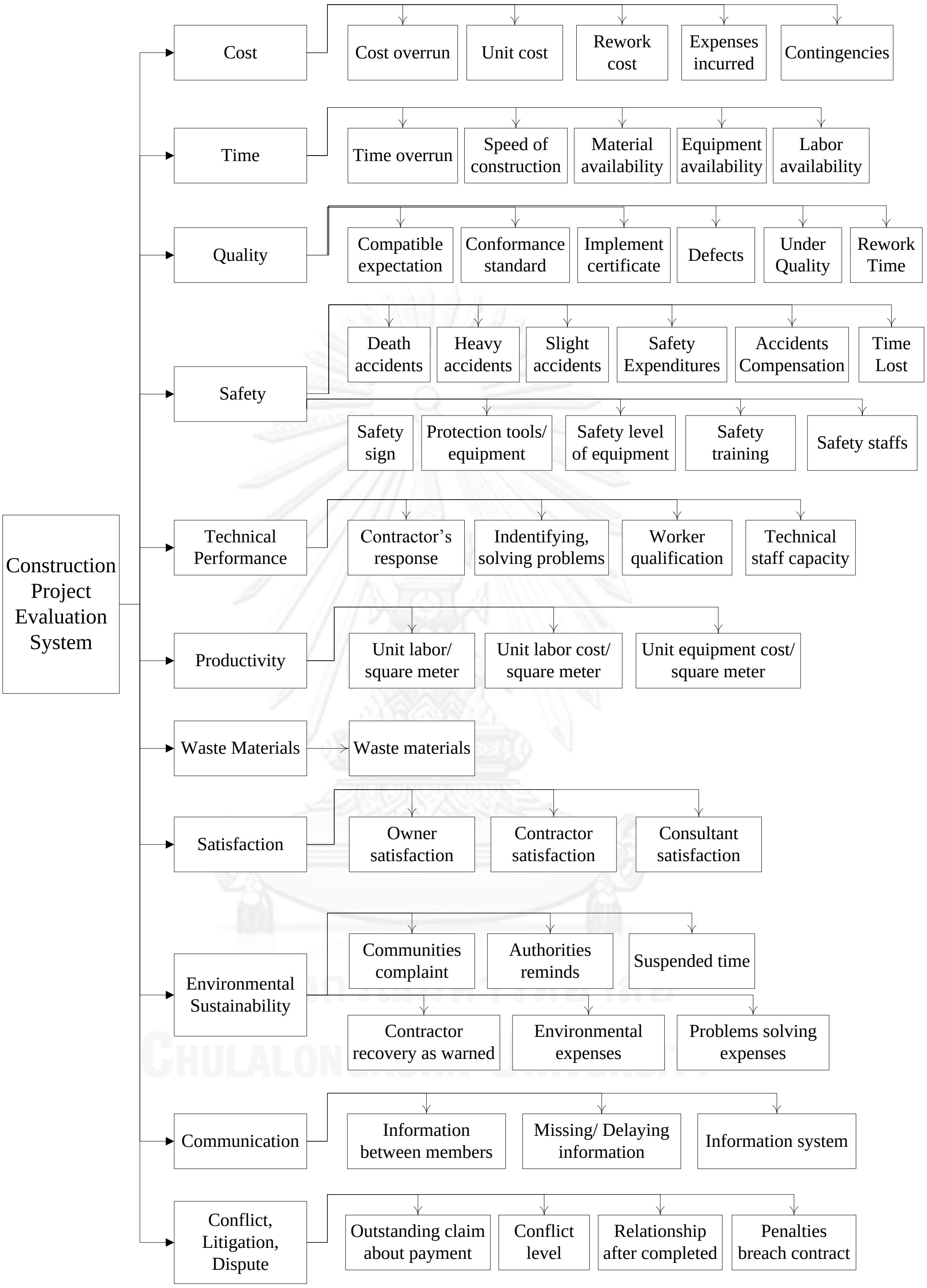


Figure 3.2 Initial list of indicators and criteria in the QMCPE system

3.3 Quantitative Weight Assignment in the QMCPE System

Weight means the rationing of the hierarchy rule. It reflects the intention and preference of respondents, and affects the consequences of the system. Weight assignment maintains a central position in multi-criteria evaluation step process. The choice of weight assignment method is crucial to the final project. There are two constraints of the weight value: first, weight value between 0 and 1; second, the sum of weight value in a hierarchy should be equal to 1. The greater value means more importance, and vice versa.

Weighting methods included subjective weighting method, objective weighting method, and combined weighting method. The selection of a method depends on objective and purpose. In the area of construction project evaluation as mentioned in literature review, the subjective weighting methods were applied. These methods implied several disadvantages. Consequently, an objective weighting assignment was necessary; it was a more logical and accurate system.

To reduce artificial interference in the process of weight assignment, the objective weighting method is proposed. Its basic idea is that the weight of each indicator should be assigned by the variation extent and its influence on the other indicators. The original information should come from the objective environment. The weight of indicators should be assigned by the value of the information the indicator possesses. From the literature review, the common used objective weighting method includes Summing Responses (SR), Factor Analysis (FA), Structural Equation Modeling (SEM), Fuller Triangle (FT) Method, and combination of Battelle Environmental Evaluation System and Importance scale matrix (BEES & ISM). Basing on the characteristics of criteria and proposed survey, three methods, which are SR, SEM, and BEES & ISM, are appropriate in this research. Their weight assignment results will be compared and analyzed to achieve the final result.

FA is the first multivariate technique because it plays a unique role in the application of other multi-criteria techniques (Tabachnick and Fidell, 2006; Hair et al., 2010). It is an interdependence technique whose primary purpose is to delineate the underlying structure among the variables in the analysis. In this way, FA can show the interrelation between the indicator and the criterion. However, the hierarchial model and group of criteria were defined clearly from the literature review. So, FA is not necessary to conduct.

SEM is an alternative technique for exploring the interrelationship among factors in multiple layers of linkages between variables. SEM proves an effective statistical technique in developing the causal model for explaining a dependent variable with high quality information (Tabachnick and Fidell, 2006; Hair et al., 2010). There are two main parts of SEM: the causal model between independent variables and dependent variables, and the measurement model showing the relationship among variables. The measurement model technique is applied in this research by using AMOS 16.0 software.

FT method is based on the forming of triangular matrices of parameter pairs within which parameter weighting is performed. It is a quick but rough weighting method (Agarski et al., 2012). One limitation of FT method is that the difference between importance levels of two criteria is not considered. The pairwise comparision concept in FT assigns the score for criterion which is more important than orther but does not mention how much one criterion is more important than other. For this reason, FT method will not be able to apply in weight assignment for proposed system.

ISM method involves unranked pairwise comparison of each parameter with the remaining other (n-1) parameters, then leaving that parameter, next parameter is compared with the remaining (n-2) parameters, and so on using the importance scale (n is the total number of parameters). This scale is defined by keeping in view the definition of the relative importance terms used. The matrix of preference thus obtained is then analyzed using 'eigenvector' method to arrive at the weight of each parameter in the matrix (Goyal and Deshpande, 2001). BEES method involves ranked pairwise comparison of parameters, wherein initial ranking plays a major role. Once ranking is done, the first parameter in the ranked list is compared with the second parameter, the second with the third, and so on (Goyal and Deshpande, 2001). In the combination method, without any initial ranking of the selected parameters, ISM method logic is used for pairwise comparison of parameters importance, and then normalization of weight is done following BEES method. BEES & ISM approach is developed in order to have a simple, more exhaustive but unbiased way to obtain parameter's weight without using complicated statistical procedure.

3.4 Combination Methodology

The proposed construction project evaluation system includes eleven indicators which are described by fifty one criteria. With a large number of variables, the system should be well structural, simple, straightforward, and easy to follow. The important thing is that the system could be applied to any number of projects and any number of criteria. Therefore, the linear additive method is an appropriate method for this problem solution.

Before proceeding with the combination, all criteria are first converted to z score of normalization. In statistics and applications of statistics, normalization can have a range of meanings. In the simplest cases, normalization of ratings means adjusting values measured on different scales to a notionally common scale, often prior to averaging. Normalization is performed by applying the discrimination principle.

After achieving the weight assignment and normalization evaluation for indicators and criteria, the overall score is calculated based on linear additive concept. The linear additive model shows how an option's values on the many criteria can be combined into one overall value. This is done by multiplying the value score of each criterion by the weight of that criterion, and then adding all those weighted scores together. The overall preference score for each option is simply the weighted average of its scores on all the criteria. In words, multiply a score on a criterion by the importance weight of the criterion, do that for all the criteria, and then sum the products to yield the overall preference score for that indicator. Then repeat the process for the remaining indicators. After obtaining the score for each indicator, conduct a similar process to calculate the overall score for the upper level.

3.5 Summary

This chapter described the proposed QMCPE system. It provided the initial concept for achieving the final QMCPE system. It indicated the initial list of indicators and criteria in the hierarchical system, their meaning and evaluation methods, their weight assignment, and their combination. The proposed QMCPE system is expected to be an innovative system which is complete, objective, quantitative, and applicable. It provides the quantitative results which come from quantitative evaluation of indicators and criteria and their quantitative weight assignment methodology. The QMCPE system is expected to bring many benefits to all project stakeholders. According to the research objectives, the QMCPE system is expected to provide another reference for the contractor selection process in bidding, which is based on construction evaluation database achieved by the QMCPE system. The following chapters will describe the methodology and research processes to establish the QMCPE system.

CHAPTER 4
RESEARCH METHODOLOGY

This chapter describes the proposed research method for developing construction project evaluation system. This chapter starts with section 4.1, summarization of research methodology. A schema of research activities and their expected outputs are described in Figure 4.1 below. This is followed by the data collection methods in section 4.2. Questionnaires design is described in section 4.3. After that, preliminary survey, importance survey, testing proposed model, and large scale survey are detailed in section 4.4, 4.5, 4.6, 4.7, respectively.

4.1 Research Methodology

Research methodology is designed in order to achieve the research objectives that are established at the beginning. It provides a clear description of the process and objectives of each process taking time, money, and research quality conditions into consideration. The main process of research methodology conforms to the Linear Additive Models process and the Quantitative Multi-criteria Evaluation. The methodology adopted for conducting this research is described below:

Phase 1: Conceptual model development.

Step 1: This phase is utilized to systemize relevant knowledge to address the research gaps, clarify the statement of problems, and develop a clear objective to explore the topic.

Phase 2: Conducting a Preliminary Survey to achieve a proposed list of indicators and criteria in the QMCPE system.

The proposed list of indicators and criteria are gathered from two sources. One is the literature review on construction project success criteria. The other source is the outcomes of the preliminary survey. This survey is performed by interviewing experts in the construction industry and examining the information from completed projects.

Step 2: Conducting a preliminary survey to explore:

- Importance level of each indicator and criterion
- Possibility of evaluating each of them

- Methods to assess each of them, source of information to assess
- Open questions are given to collect the criterion that is important but has not been included in the proposed list.

Step 3: Analyzing data using descriptive analysis, probability theory, and hypothesis testing using compare mean sample t-test. The expected outcomes of the preliminary survey include:

- List of indicators and criteria
- Feasible method to evaluate each criterion

Phase 3: Conducting Importance Survey to explore the relative weight of each indicator and criterion.

Step 4: Interviewing respondents to explore the relative weight of each criterion and asking the possible provider for each criterion.

Summing Responses, Structural Equation Modeling (SEM), and Combination of Battelle EES & Importance Scale Matrix (BEES & ISM) Method are applied in this step.

Step 5: Analyzing collected data to achieve relative weight of all indicators and criteria, and developing the quantitative model.

Data in step 4 is analyzed to find out the relative weight of indicators and criteria. The techniques of SR, SEM, and BEES & ISM methods are applied. Paired sample t-test was used to compare the results of these methods. Then, standardized results from three methods were calculated to achieve the final value of relative weight.

The quantitative model includes: criteria to evaluate project success, the important weight of them, and the methodology to combine them.

Phase 4: Criteria Evaluation Scale and Testing proposed model

In this phase, the scale to evaluate each criterion is designed, which is based on literature review, the experts' perception, and the companies' historical data. The normalization and combination methodology are described in this phase. Then, the proposed QMCPE system is tested by three completed projects.

Step 6: Collecting data from completed projects:

Completed projects will be evaluated by proposed QMCPE system. In order to check the validity of the proposed model, the qualitative evaluation from parties is used to compare between proposed quantitative and qualitative evaluation.

Step 7: Modifying model if necessary.

Phase 5: Large-scale survey

In this phase, the information from thirty-one completed projects is collected.

Step 8: Large-scale past projects evaluation by developed model to achieve a database.

Step 9: Analyzing the results of the past projects to establish the suggestions for future bidding process application.

Phase 6: Application development using the PHP programming language

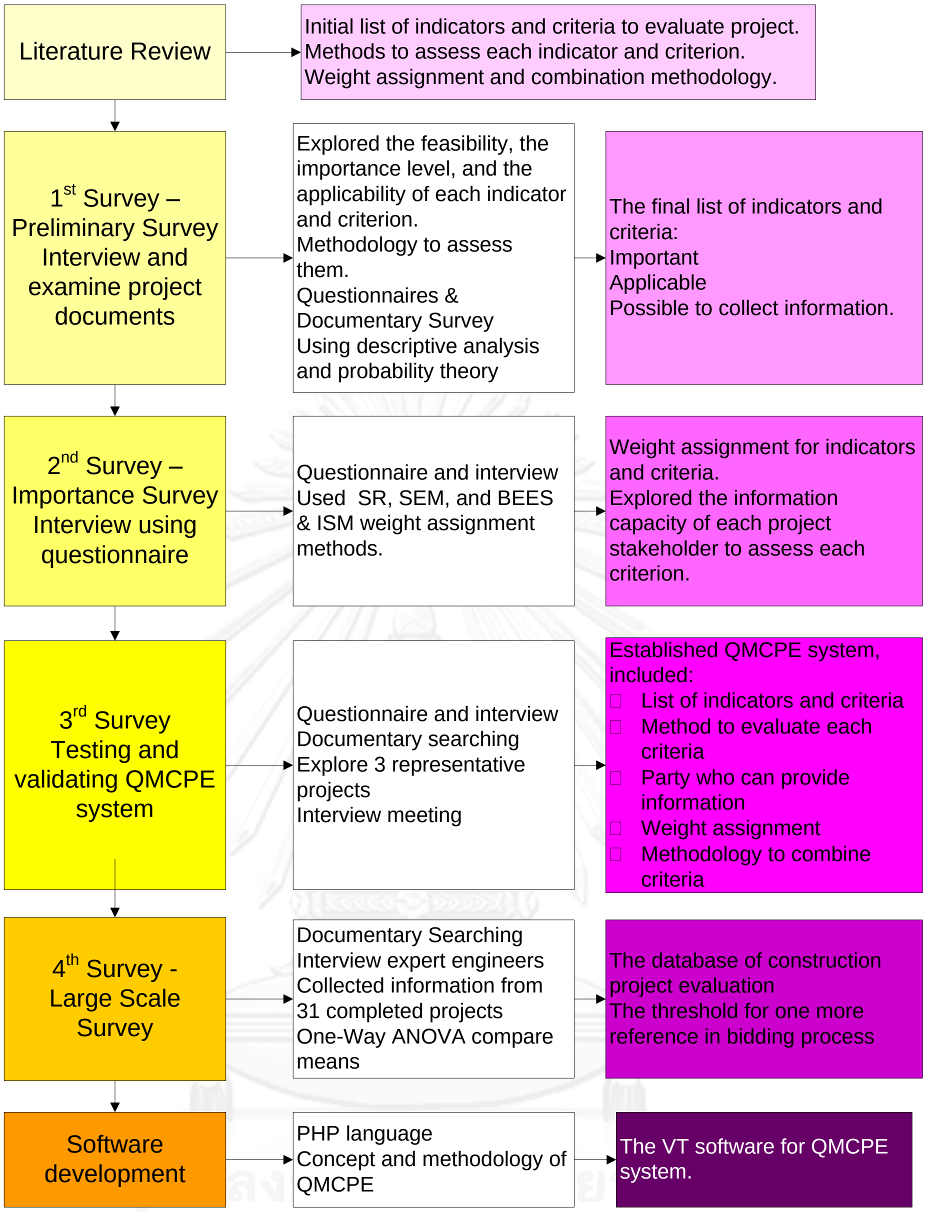


Figure 4.1 Research methodology

The research methodology process in Figure 4.1 was a master plan of procedures that should be followed to achieve the research objectives within an economical budget. Based on the purpose of the research project, six categories were determined in the process including: (1) conceptual model development; (2) preliminary survey; (3) importance survey - weight assignment; (4) testing model; (5) large scale survey – database development; and (6) application software development. Figure 4.1 illustrates the steps undertaken to achieve research objectives.

Phase I (Conceptual Model Development) – was utilized to systemize relevant knowledge to address the research gaps, clarify the problem statements, and establish a clear objective to explore the new topic. The aim of this stage is to develop a conceptual model for construction project evaluation based on the literature review undertaken in Chapter 2.

Phase II (Preliminary Survey) – was conducted to explore the feasibility of research and to select important and applicable information to evaluate the project. The result of this survey was the list of indicators and criteria which were important, available to be collected, and applicable in the construction industry.

Phase III (Importance Survey) – was proposed to collect all necessary data to determine the relative weight of each indicator and criterion. The list of criteria in the preliminary survey was used to develop a data collection tool for this survey to explore their important weight. They were assigned by three methods, which are summing responses, structural equation modeling, and combination Battelle EES & importance scale matrix method. They were objective and quantitative weight assignment methods. These three methods were parallelly calculated to obtain weight assignment, and then their results were compared and analyzed to combine the final weight.

Phase IV (Pilot Survey) – was used to test the proposed system in three representative projects. This stage presented the whole evaluation system which described details of each of the indicator evaluation processes. It included the definition, evaluation introduction, evaluation scale, and the method to analyze each indicator and criterion. Then, the QMCPE system was tested on three projects to establish validation and to make modifications, if necessary. The final result of this process was the QMCPE system.

Phase V (Large Scale Survey) – was purposed to collect projects' information according to the QMCPE system. Thirty-one projects' information was collected to develop the construction project evaluation database. From this, some relationships between project outcomes and project characteristics were determined. After that, suggestions were provided for the contractor selection process.

Phase VI (Application Software Development) – was developed to establish the software solution for the QMCPE system. It included the database of project stakeholders, weight assignment of indicators and criteria, evaluation construction project, a graphical output of tendency, history of project stakeholders, and tendency of criteria importance.

4.2 Data Collection Method

4.2.1 Survey Research

Sample survey is considered to be appropriate for this research. Selecting the suitable data collection technique is very important in order to conduct valid research (Tabachnick and Fidell, 2007). Sample survey is used because of its advantages. It is inexpensive, representative for a large population, feasible in different locations by mail, email or phone, flexible, and statistically significant. However, survey has some disadvantages that should be considered carefully. The sample is one important criterion to obtain statistically significant results. In addition, the survey requires careful and complete questions to minimize the bias and confusion of respondents, and requires accurate information about the population. In addition, the responses depend on participants' perceptions, so it cannot control their quality.

4.2.2 Data Collection Method

The data collection method has significant impacts on the validity and reliability of survey research. Its main purpose is to collect enough data from a smaller sample for analyzing the behavior of a general population. There are two ways to perform a survey which are the written questionnaire and the interview (Cozby, 2007). With the questionnaire, respondents are asked to state their own opinions, so it may take time for them to read and understand the questions. This method is generally less costly and less time-consuming than interview because it can be carried out by personal or group administration, mail or email, and internet survey. However, the interview method usually provides higher respondent rate because people are more comfortable participating in a face-to-face interview than responding to an email questionnaire. There are three ways to conduct an interview survey including face-to-face interview, telephone interview, and focus group interview. Each of them has advantages and disadvantages, and the methods can be used alone or in combination depending on the scope and depth of data requirement. According to Fellows and Liu (2008), *"the choice is between a broad but shallow, study at one extreme, and a narrow but in-depth study at the other, and a study between these extremes"*. Regarding to research objectives, construction project evaluation indicators and criteria, it requires high degree of cooperation from the respondent to obtain valid results. Therefore, the data collection instruments used in this research was questionnaire surveys in conjunction with interviews face-to-face.

4.2.3 Target Population

After establishing the method for data collection, the target population is the next important issue that needs to be selected. The better target population we have, the better representative sample for the general population obtained. The main objective of this research is to explore the construction project success evaluation system; therefore, the subject of the study will focus on project stakeholders such as owners, contractors, and consultants in construction industry, and the completed project documents and information. In detail, the target population of this study is defined as:

- Elements: Project stakeholders such as owners, contractors, and consultants
- Sampling units: Project stakeholders who are currently working in the construction industry, and completed project documents.
- Extent: Construction companies at Hochiminh City, Vietnam
- Time: 2012-2013

4.2.4 Sampling Method

There are two main techniques of sampling from a target population: probability sampling and non-probability sampling (Cozby, 2007; Hair et al., 2010). In probability sampling, every member of the population has a certain probability of being selected. In other words, the list members of a population are determined before sampling. In non-probability sampling, the possibility of any member of the population being selected is not known. Non-probability sampling technique is quite arbitrary since it does not ensure an accurately representative sample. However, it is not very costly and is convenient as compared to probability sampling. As a result, it is used commonly and appears to be applicable in many cases.

Under the probability concept, three main techniques can be applied to obtain sampling for data analysis. These three main sampling techniques are named as simple random sampling; stratified random sampling; and cluster sampling (Cozby, 2007; Hair et al., 2010). The comparison between the advantages and disadvantages of these probability sampling techniques are summarized in Table 4.1. Three types of non-probability sampling techniques are haphazard sampling, purposive sampling, and quota sampling. These techniques are also summarized in Table 4.1.

Table 4.1 Description of sampling tools (Cozby, 2007)

Technique	Descriptions	Advantages	Disadvantages
Probability sampling			
Simple random sampling	Randomly choose a number of members of the population with an equal probability.	Representative of population	Expensive. Difficult to get full list of population.
Stratify random sampling	Random sampling techniques are used to select sample members from each stratum. Each stratum represents a subgroup in the population.	Representative of population	Expensive. Difficult to get full list of population.
Cluster sampling	Randomly choose some clusters from clusters list designed, and then random sampling techniques are used to select samples from chosen clusters.	To obtain a reliable random sample, researchers do not have to select members from the list of individuals for sampling.	Expensive and difficult to obtaina completed list of all members of any selected cluster.
Non-probability sampling			
Haphazard sampling	Select a sample of population in convenience.	Inexpensive, efficient, convenient.	Bias into the sample, results may not generalize to intended population.
Purposive sampling	Obtain a sample of people who meet some pre-determined criterions.	Sample includes only purposed individuals are interested in.	Bias into the sample, results may not generalize to intended population.
Quota sampling	Obtain a sample that reflects proportions of	Inexpensive, efficient, convenient, slightly	Bias into the sample, results may not

Technique	Descriptions	Advantages	Disadvantages
	various subgroups in the population.	more sophisticated than haphazard sampling.	generalize to intended population; no method for choosing individuals in subgroups.

Because the sampling units were project stakeholders who were currently working at construction companies, it was difficult to get a complete list of target population. Besides, project outcome was a sensitive subject, so most companies refused to cooperate. Therefore, contacting and entering construction companies to interview needed personal relations. For these reasons, purposive sampling was selected as a suitable tool for this research. A number of available construction companies at Hochiminh City were selected and contacted for interview permission before conducting the survey.

4.2.5 Questionnaire Design

The questionnaire is a useful means of data collection. It is comprised of a number of questions related to the research objectives that are presented in a logical order and given to respondents for answering. To construct a good questionnaire, the researcher is required to thoroughly understand why each question is included and what type of scale should be used to measure each variable. With a well-designed questionnaire, the researcher can collect data much faster and cheaper than other data collection methods. However, constructing an effective questionnaire is a complicated task.

There are three steps in designing a questionnaire which including:

- Defining research objectives and wording for preparing and developing the questions asked.
- Constructing response categories for each question, scaling and coding of these categories to prepare for analysis after data collection.
- Reviewing both the format of the questionnaire and content of the questions to ensure relevance, attractiveness, and professionalism.

With respect to the development of questions in this study, a number of principles of good questionnaire design were taken into consideration. These principles are as follows:

- Avoid complexity,
- Avoid leading or loaded questions that cause social desirability bias,
- Avoid emotional language and prestige bias,
- Avoid ambiguity,
- Avoid double-barreled words,
- Avoid making assumptions (ask respondents who do not have relevant knowledge),
- Avoid questions that seriously require the respondent's memory,
- Avoid implicit alternatives,
- Avoid estimates,
- Avoid double-barreled questions,
- Consider the frame of reference (the respondent's viewpoint in responding to questions),
- Determine the use of multiple questions or one question,
- Stimulate respondents to answer, and
- Avoid false premises.

4.3 Preliminary Survey – Phase II

4.3.1 Survey Purposes and Research Type

The objective of the preliminary study was to determine the possibility of information collection for this research. Based on the research objectives, it was important to collect a huge amount of information from the real world construction field. This information was varied and sensitive; therefore, construction companies might refuse to provide it. For these reasons, a preliminary study was important before further main study.

The preliminary study was carried out by interviewing and documentary searching. Each visited construction company was asked to provide all documents of one typical project and allow interviews with one or two representative engineers who were most familiar with this project. All documents were examined carefully, and engineers were interviewed to find out whether or not it was possible to collect the requisite information. Furthermore, researching project documents helped to determine if more information should be used to evaluate project success that was not mentioned before.

4.3.2 Survey Tool

Before performing the feasibility study, a list of indicators and criteria was established. This list was gathered carefully from the literature review and by interviewing five experts in construction field. They were collected from more than ten years' working experience in construction companies and participation in more than five completed projects.

An interview questionnaire and document checklist was proposed for data collection at construction companies. It included three main parts. The first part was the general information of the visited company. Each company was also asked about his capacity to provide information. The companies provided the number of projects that they promised to provide for the next phase of this research. The second part was the general information of a typical completed project that was provided by each company. The third part was the list of indicators and criteria. The representative engineers, who were familiar with the project, were interviewed, and all related project documents were examined to explore providing information capacity. There were three options for providing information capacity for each indicator and criterion, which were "Project has this information and possible to provide information or evaluation opinion", "Project has this information but difficult to provide information or evaluation opinion", and "Project does not have this information or cannot provide evaluation opinion". For the second option, reasons for the difficulty need to be described. The complete interview questionnaire and document checklist which were used for the feasibility study was shown in Appendix A in the English version and in Appendix B in the Vietnamese version.

4.3.3 Population and Sample Size

During January and February 2012, data collection for this study was conducted with professionals of construction companies in Hochiminh City, Vietnam.

The necessary information was varies and sensitive, so it was difficult to convince construction companies to participate. To overcome obstacles and difficulties, a supporting letter from the Head of the Department of Construction Engineering and Management, the Head of Civil Engineering Faculty, and the President of Hochiminh City University of Technology was prepared and sent to thirty construction companies. As an encouraging sign, twenty-three companies allowed the researcher to visit and agreed to provide information. The cooperation of those companies was highly appreciated. Some companies provided two typical completed projects and two representative engineers. Finally twenty-eight interview questionnaires and document checklists were completed with high cooperation and were possible to analyze. To maintain the privacy of the visited companies, their names were coded from one to twenty-eight.

4.3.4 Data Analysis

Descriptive statistics was the first technique applied. The purpose was to obtain an overview of sample characteristics, to ensure the variables had no violation of the assumptions underlying the statistical techniques that are used in data processing, and to answer specific research questions as well as feasibility of data collection (Pallant, 2004). There are many ways to process descriptive statistics including Frequencies, Descriptive or Explore. Different procedures depended on categorical or continuous variables.

The data collected from the questionnaire surveys and interviews were analyzed with the support of the Statistical Package for Social Sciences (SPSS) program. The data analysis and the results of this survey are detailed in Chapter 5.

In order to calculate the possibility of collecting information for criteria evaluation, probability theory was applied. Probability is used to measure the likelihood or chance that an outcome of random experiment will occur. This likelihood is quantified by assigning a number from the interval [0, 1] to the outcome (or a percentage from 0 to 100%). The higher the number the more likely an outcome will occur. If the number is ‘0’ it means an outcome will not occur. A ‘1’ means that the outcome will certainly occur.

An outcome probability can be understood as our subjective probability, or degree of belief, that the outcome will occur. There is no doubt that one outcome can be assigned different probabilities by different individuals. Another understanding of probability is based on the conceptual model of repeated replications of the random experiment. The probability of an outcome is interpreted as the limiting value of the proportion of the times the outcome occurs in n repetitions of the random experiment as n increases beyond all bounds.

In probability theory, the formula of total probability is a fundamental rule relating marginal probabilities to conditional probabilities. A conditional probability is the probability that an event will occur, when another event is known to occur or to have occurred. If the events are *A* and *B* respectively, this is said to be "the probability of *A* given *B*". It is commonly denoted by $P(A|B)$, or sometimes $P_B(A)$. $P(A|B)$ may or may not be equal to $P(A)$, the probability of *A*, the conditional probability formula is:

$$P(B/A) = \frac{P(A \cap B)}{P(A)} \quad \text{for } P(A) > 0$$

As an axiom of probability, $P(A \cap B) = P(B/A)P(A)$

The law of total probability is the proposition that if $\{B_n : n = 1, 2, 3, \ldots\}$ is a finite or countable infinite partition of a sample space and each event B_n is measurable, then for any event A of the same probability space:

$$\Pr(A) = \sum_n \Pr(A/B_n)\Pr(B_n)$$

Theory of probability, specific total probability and conditional probability are applied in this research phase to explore the probability of successful data collection for further research phases.

4.4 Importance Survey – Phase III

The objective of importance study was to explore the relative weight of each indicator and criterion in the proposed list. This study was carried out by interview using questionnaire. Questionnaire, sampling technique, sample size and analysis method for importance survey are discussed in detail below.

4.4.1 Survey Tool

A list of indicators and criteria, which was obtained from the preliminary survey, was used to develop a questionnaire for the importance survey. The questionnaire contained two main sections, general information and the evaluation of the importance of the proposed indicators and criteria. First, respondents were asked their opinion about the importance of an evaluation system. Then, respondents expressed their opinions on the importance level of each indicator and criterion using a five point Likert scale:

Not important at all : rate "1"

Little important : rate "2"

Moderately important : rate "3"

Very important : rate "4"

Extremely important : rate "5"

Finally, open questions were given to collect respondents' opinions about indicators that could be important but which were not mentioned in the proposed list. The questionnaire used for this study was shown in Appendix A in English version and Appendix B in Vietnamese version.

4.4.2 Sampling Technique and Sample Size

During July to September 2012, data collection for this study was undertaken with construction professionals in Vietnam, at Hochiminh City construction sites. Convenience sampling was selected as a suitable tool for this research. A number of available construction sites at Hochiminh city were selected and contacted for interview permission before conducting the survey.

Sample size was next determined carefully because it directly influenced the accuracy of the results (Tabachnick and Fidell, 2007; Fellows and Liu, 2008; Hair et al., 2010). The sample size is determined based on the required accuracy, the likely variation of the investigated population's characteristics, and the chosen type of data analysis. The larger a sample size becomes the smaller the impact on accuracy, so there is a cut-off point beyond which the increased costs are not justified by the (small) improvement in accuracy; a sample size of 1,000 is often referred to as a cut-off point beyond which the rate of improvement in accuracy slows.

As this research intended to use SEM to assign relative weight for forty-five criteria from the preliminary survey, the sample size had to exceed five times of criteria (Tabachnick and Fidell, 2007; Fellows and Liu, 2008; Hair et al., 2010), meaning 225 for this study. From the recommendation of SEM technique, the ratio should reach at least 15 samples for each independent variable (Bacon, 1997). So with ten indicators in the model, sample size needed to be more than 150 to minimize errors and to achieve generalized research results (Hair et al., 2010). Consequently, the number of required data was 225. The necessary actual sample was calculated by dividing the determined sample size (225) by the acceptable response rate (50%). This calculation resulted in achieving the total sample of 450. Finally, questionnaires were asked to all of these 600 respondents and distributed to twenty-five construction companies. Each interview took approximately thirty to forty-five minutes.

4.4.3 Data Analysis

The data collected from the questionnaire surveys and interviews were analyzed with the support from the Statistical Package for Social Sciences (SPSS) program. The analysis included: descriptive analysis, SR, SEM, and BEES & ISM techniques. The data analysis and the results for the whole set of this survey are detailed in Chapter 6.

The main objective of this survey was the weight assignment of each indicator and criterion. An objective weighting assignment was performed in this survey for a logical and accurate system. Three methods of objective weighting group method were performed to assign the weight of each indicator and criterion. They were SR, SEM, and BEES & ISM methods. Their weight assignment results were compared by paired sample t-test and summarized to achieve the final value of relative weight. At the end of this phase, the QMCPE system was achieved. It includes the list of indicators and criteria, and their weight assignment.

4.5 The QMCPE system and Testing Survey – Phase IV

4.5.1 Survey Details

A survey was performed at construction companies to achieve the criteria evaluation scale. It was carried out by interviewing experts, documentary searching, and company historical data. The QMCPE system included the list of indicators and criteria, their relative weight, and their evaluation scale which was determined. After this step, the testing survey was conducted to evaluate and validate the proposed system. The QMCPE was tested to evaluate three representative projects. This survey was very important before conducting the large scale survey. The tool was assessed in aspects of question objectives, question wording, and questionnaire formatting to ensure its clarity, understandability and simplicity for respondents.

The testing survey was carried out by interviewing and project document searching. Each of three visited construction companies was asked to provide all documents of one typical project and up to three representative engineers who were most familiar with this project. All documents of each project were examined carefully, and the engineers were interviewed to evaluate each criterion based on the proposed system. After that, a group meeting was organized to evaluate and validate the proposed system from nine experts. This phase of survey was performed at construction companies in Vietnam during January and February 2013.

4.5.2 Data Analysis

Descriptive statistics was also applied in this phase. Different procedures depended on categorical or continuous variables. The data collected from the questionnaire surveys and interviews were analyzed with support from the Statistical Package for Social Sciences (SPSS) program. The data analysis and the results for the whole set of this survey are detailed in Chapter 7.

4.6 Large Scale Survey – Phase V

The objective of the large scale study was to collect enough valid and reliable data for developing a project evaluation database. The documentary research and interview were performed in this phase. Survey details and analysis method for large scale study are discussed in detail below.

4.6.1 Data Collection Tools

A set of necessary information and questionnaire was developed based on the construction project evaluation system. The large scale questionnaire included two main sections. Section one included ten questions related to the general information of the project. They were project name, project location, owner, contractor, consultant, contract price, contract duration, capital source, construction commencement date, project scale, and information provider. In order to protect the privacy of the data collected, all information about the name of project, owner, contractor, and consultant were coded before being presented in this research. The second section was the evaluation system of forty-five criteria. In order to achieve an accurate and objective evaluation, definition, evaluation instruction, and the scale for evaluating of each criterion were provided. The full evaluation system which was used for large scale survey was shown in Appendix E.

4.6.2 Data Collection

Purposive sampling was selected as a suitable tool for this survey. Because the sampling units were project information, it was difficult to get a complete list of target population. Besides, the necessary project outcome was sensitive, so most companies refused to cooperate. Therefore, contacting and entering construction companies were very complex without personal relations. A number of available construction companies at Hochiminh City were selected and contacted for permission.

Data collection for the large scale survey was undertaken with construction professionals in Vietnam, at Hochiminh City construction sites. In order to complete the evaluation for one project, project information related to finance, schedule, safety record, quality evaluation, resource management, and so on was collected. Furthermore, representative engineers who took full responsibility for that project were asked to complete the evaluation.

4.6.3 Data Analysis

The data collected from the survey was analyzed with support from the Statistical Package for Social Sciences (SPSS) program. The analysis includes: descriptive analysis, and analysis of variance.

Descriptive statistics was the first technique applied. The purpose was to obtain an overview of the sample characteristics, to ensure variables had no violation of the assumptions underlying the statistical techniques that were used in data processing, and to answer specific research questions. Analysis of variance between groups was applied to explore whether there is a diffirence between groups or not.

4.7 Application Software Design – Phase VI

The QMCPE system was a complex system, so it was necessary to use a software processing. It helped to improve the effect, fast process, and reliability of results. There are several different scripting languages developers have to choose from when building applications, such as ASP, JPS, Perl, CGI, and PHP. The main debate recently has been between PHP and ASPX, but it is difficult to argue against the popularity of PHP. It is used for WordPress development so PHP comes with a certain level of credibility and popularity. PHP was selected for this research.

4.7.1 PHP Programming Introduction

PHP is an open source, server-side scripting language that is mainly used for developing web applications and web services. It can be used for server-side scripting, command line scripting, and writing desktop applications.

PHP was selected for this research because of its advantages. PHP is an open source which is freely available for use, so it proves very cost effective for developers. PHP provides high compatibility with leading operating systems and web servers thereby enabling it to be easily deployed across several different platforms. Several web tasks can now be easily performed using PHP such as business websites, community websites, and e-business. Being user friendly, quick in process, extensible with an open source language and libraries, easy deployment, automatic refresh, community support offers in its community, and security are the advantages of PHP.

PHP, however, has several disadvantages. First, PHP tends to execute more slowly than assembly, C, and other compiled languages. Second, PHP is loosely typed. For developers of all skill levels, this allows room for unexpected behavior due to programmers' errors that many other languages might not permit. Third, there are many ways to do one thing and many cases where a function has ambiguous handling due to legacy support or PHP development history. However, these disadvantages do not have much influence on the application in this research. PHP is thus the choice for this research because of its many great advantages.

4.7.2 Software Component

The software solution consisted of four main modules.

Project stakeholders' information and coding module: In this module, each project stakeholder, which was owner, contractor, or consultant, was coded and recorded with all information. Their information included name, company address, and contact information. Each of them was provided with a code for further convenience use.

Indicators and criteria weighting module: This module was designed based on the concept of weight assignment presented in the previous section. Indicators and criteria were weighted by three different methods – Summing responses, Structural equation modeling, and combination of BEES & ISM method.

Construction project evaluation module: In this module, the user had to input the general information of evaluating project and performed the assessment for each indicator and criterion. The results of project success score of the current project were shown in this module.

Output present and analysis module: The software provided a graphical representation of the obtained results. First, it provided evaluation of a specific project, compared with the average value of all projects in a 'spider diagram'. Second, it presented the historical data of one specific contractor, owner, or consultant. Third, it described the tendency of project stakeholders' behavior on the importance of criteria in construction project evaluation.

4.8 Summary

This chapter described the guidelines for conducting this research. The components of questionnaire and interview survey were established. The target population, sampling technique, and sample size of the data collection method were described in detail. The research required six distinct research phases in order to develop the construction project evaluation system, namely, conceptual model development, preliminary survey, importance survey, criteria evaluation scale and testing survey, large scale survey, and software development. The data analysis and the results for the whole set of surveys are explained in Chapters 5, 6, 7, 8, 9, and summarized in Chapter 10.

CHAPTER 5
PRELIMINARY RESEARCH

This chapter describes the preliminary research to achieve the proposed model of project success evaluation. Because of the objectives and expected outcomes of research, the necessary information has to be collected from construction companies. Therefore, the preliminary research was conducted to explore the feasibility of research and to select the important and applicable information for the proposed system. Preliminary research included three main sections which were feasibility study, importance study and applicability study. Firstly, the feasibility study is discussed in section 5.1 below. The objective of the feasibility study is finding out information collection capacity for this research. Secondly, the importance and applicability study are described in section 5.2. Finally, section 5.3 presents a final list of indicators and criteria for the QMCPE system which synthesized results from all preliminary research.

5.1 Feasibility Study of Providing Information from Construction Field for Research

The objective of the feasibility study was to determine the information collection capacity for the research. Based on the proposed research objectives, developed framework and the database of project success, it was important to collect the information from real construction field. The success or unsuccess of this research depended on the whether that data collection was possible or not. The necessary information included project cost, project time, project quality, project safety, and so forth of completed projects. Construction companies could refuse to provide such information. For these reasons, a feasibility study was important before a large scale study.

The feasibility study was conducted by interviewing and documentary searching. Each visited construction company was asked to provide all documents of one typical project and one or two representative engineers who were familiar with that project. All documents were examined carefully and engineers were interviewed to determine whether the necessary information was possible to collect or not. Furthermore, researching project documents helped to discover more information which was not previously disclosed.

5.1.1 Data Collection Tools

Before performing the feasibility study, a list of indicators and criteria was established. This list was gathered from the literature review and interviews with five experts in construction field. They were more than ten years' of working experience in construction companies and participated in more than five completed projects. The initial list of indicators and criteria with their meaning were described in Table 3.1.

An interview questionnaire and document checklist was proposed for data collection at construction companies. It included three main parts. The first part was the general information of visited company. Each company was also asked about its capacity to provide information. The companies demonstrated the number of projects that they promised to provide for the next phase of this research. The second part was the general information of a typical completed project that was provided by each company. The third part was the list of indicators and criteria. The representative engineers, who were familiar with the project, were interviewed, and all of the related project documents were examined to explore providing information capacity. There were three options about providing information capacity for each indicator and criterion, which were "Project has this information and possible to provide information or evaluation opinion", "Project has this information but difficult to provide information or evaluation opinion", and "Project does not have this information or cannot provide evaluation opinion". For the second option, reasons for the difficulty were required to describe. The interview questionnaire and document checklist, which was used for the feasibility study, is shown in Appendix A in the English version and in Appendix B in the Vietnamese version.

5.1.2 Sampling Technique and Sample Size

During January and February 2012, data collection for feasibility study was undertaken with construction professionals in Vietnam, at Hochiminh City construction companies.

The necessary information was a lot and sensitive, so it was difficult to convince construction companies to participate. To overcome obstacles and difficulties, a supporting letter from the Head of the Department of Construction Engineering and Management, from the Head of Civil Engineering Faculty, and from the President of Hochiminh City University of Technology was prepared and sent to thirty construction companies. As an encouraging sign, twenty-three companies allowed the researcher to visit and agreed to provide information. The cooperation of companies was appreciated. Some companies provided two typical completed projects and two representative engineers. Finally twenty-eight interview questionnaires and document checklists were completed with the cooperation of companies, and the collected information was possible to analyze. To protect the privacy for the visited companies, their names were coded from one to twenty-eight.

5.1.3 Data Analysis

Prior to analyzing and using the sample data, it was important to check for mistakes initially. Data were screened using the complete sample (*N* = 28) prior to performing the main analyses to examine the accuracy of data entry, missing values, and fit between distributions and the assumptions of necessary analysis tools. All twenty-eight of the samples were possible to be used in general purpose. The data screening process involved a number of steps. The first step was to check for error. The second and third step were to find the error and correct the error in the data file respectively. Proofreading a random sample was used to ensure the accuracy of the data file. In addition, the Frequencies and Descriptive statistic command in SPSS Version 16 was used to detect any out of range values. None was found.

The following section describes general information in the feasibility study. It includes both company information and project's details. Company information focused on company function, company experience of completed project evaluation, and the number of projects that were ensured to provide. Project's details referred to project type, project budget, project duration, and the source of project capital. With all of the collected information, it was anticipated that the feasibility study was valid and could be a good representative sample.

Stakeholders in the feasibility study were owners, contractors, and consultants. Contractors occupied an important position; comprising more than 60% of the total visited companies. Owner and consultant companies held nearly equal percentages which were 17.86% and 21.43% in turn. The pie chart in Figure 5.1 below shows apportionment of companies' function in the feasibility study. It can be seen that all visited companies were representative and an adequate sample of the construction field in Vietnam.

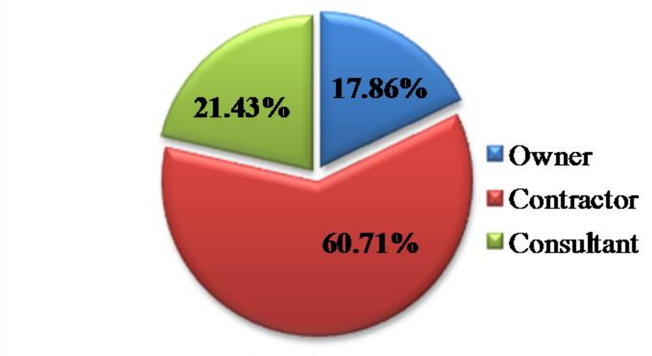


Figure 5.1 Company function in feasibility study

The objective of this research was to develop a framework for evaluating project success level. It was thus important to learn from companies what methods they used to evaluate their completed projects. One of the main parts of the interview was their experience in evaluating completed projects. However, an alarming trend was noted from their responses, only eight of the twenty-eight respondents demonstrated that their companies usually evaluate projects when they were completed. The remaining twenty respondents had never performed this activity. Furthermore, respondents, who used to evaluate completed projects, also emphasized that their evaluation was very simple, such as only comparing actual project cost and duration with what had been planned. This evaluation was only used in reporting and did not deliver any benefit to future projects. They still lacked a complete framework to achieve a worthy evaluation.

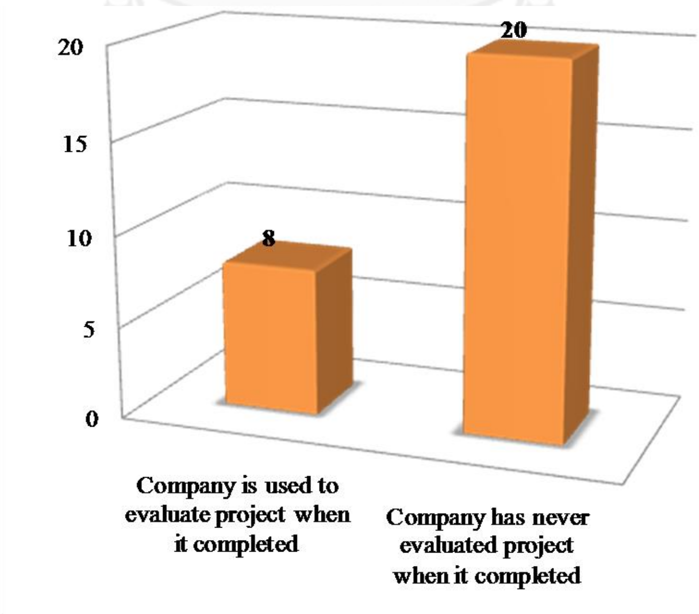


Figure 5.2 Company experience of evaluation completed project

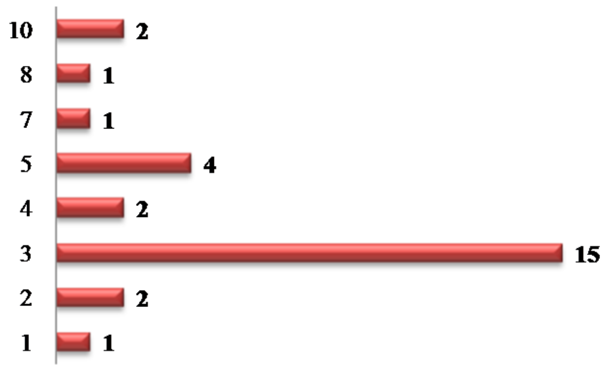


Figure 5.3 The number of projects which were ensured from company

One of the main purposes of the feasibility study was to ensure the cooperation of companies in the next phase of research. Each company guaranteed to provide information on a number of completed projects. The number of projects that each company guaranteed to provide is shown in Figure 5.3 above. A total of one hundred and thirteen projects were guaranteed to provide information.

The characteristics of projects in the feasibility study varied greatly. It depended on the convenience to the companies. They provided information on any project that they had just finished and for which all documents were ready to study. This research focused on civil projects, so all twenty-eight projects in the feasibility project were civil projects. Project budget and project duration were also quite varied. Project budgets ranged from US$30,952 to US$227,047,619. Project durations ranged from 90 days to 1095 days. The sources of project capital were also varied, and included public projects, private projects and as well as other types. The capital proportion is described in the following Figure 5.4. The variety characteristics of project in feasibility study helped to select objectives for further research phases.

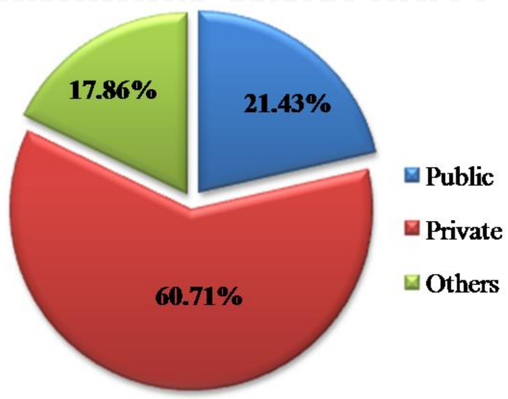


Figure 5.4 Projects capital source

5.1.4 Information Collection Capacity of Proposed Indicators and Criteria

This section discusses the availability and submit-ability of information for evaluation of each indicator and criterion. As discussed above, each of them was classified according to three groups of responses, which were "Project has this information and possible to provide information or evaluation opinion", "Project has this information but difficult to provide information or evaluation opinion", and "Project does not have this information or cannot provide evaluation opinion". Within the total of twenty-eight responses from construction companies, a summary of the number of each group and its percentage are shown in section C.1 of Appendix C, and Table 5.1 below shows the representative result of 'Project Cost'.

Table 5.1 Capacity to collect information about project cost

Information about project cost	Project has this information and possible to provide		Project has this information BUT difficult to provide		Project does not have this information	
	No.	%	No.	%	No.	%
Cost variation	28	100.0%	0	0.0%	0	0.0%
Unit cost	24	85.7%	3	10.7%	1	3.6%
Expenses incurred	26	92.9%	1	3.6%	1	3.6%
Rework Costs	17	60.7%	4	14.3%	7	25.0%
Budget for contingencies	13	46.4%	6	21.4%	9	32.1%

In order to calculate the probability of successful data collection, the theory of probability which was discussed in Chapter 4 was applied. The researcher started with the assumption that there were three possible outcomes of the data collection capacity B $\{B_1, B_2, B_3\}$, with detailed as follow:

Let B_1 denote that the project has recorded information or respondents who can provide their opinion to evaluation of a criterion. Probability of this event is $Pr(B_1)$.

Let B_2 denote that it is difficult to provide information or respondents' opinions to evaluate of a criterion. Probability of this event is $Pr(B_2)$.

Let B_3 denote that project does not have recorded information or respondents cannot provide their opinion to evaluate of a criterion. Probability of this event is $Pr(B_3)$.

The probability of events B_1, B_2, and B_3 were calculated by the percentage of twenty eight total responses from the survey.

Let A denote the successful data collection in the future survey to evaluate a criterion.

Assume that the probability of A given B_1 is 100%, $Pr(A/B_1) = 1$; the probability of A given B_2 is 50%, $Pr(A/B_2) = 0.5$, and the probability of A given B_3 is zero, $Pr(A/B_3) = 0$.

So, the probability of successful data collection in the future survey to evaluate a criterion was

$$\Pr(A) = \Pr(A/B_1)\Pr(B_1) + \Pr(A/B_2)\Pr(B_2) + \Pr(A/B_3)\Pr(B_3) \quad (5.1)$$

And, the probability of successful data collection in future survey to evaluate an indicator was

$$\Pr(Indicator) = \sum_i \Pr(A_i) \quad (5.2)$$

Apply formula 5.1 and 5.2 to obtain the results of probability of successful data collection in future surveys for all indicators and criteria. The representative results are shown in the following table, Table 5.2 and summarized in Figure 5.5 below. All results are described in section C.2 of Appendix C.

Table 5.2 Summary probability of successful information collecting

Indicator and criterion	Possible to provide information or opinion evaluation Pr(B1)	Difficult to provide information or opinion evaluation Pr(B2)	Project does not have this information or cannot evaluate Pr(B3)	Probability of successful collecting information Pr(A)
	$Pr(A/B_1) = 1$	$Pr(A/B_2) = 0.5$	$Pr(A/B_3) = 0$	
Information about project cost				**85%**
Cost variation	100.0%	0.0%	0.0%	100%
Unit cost	85.7%	10.7%	3.6%	91%
Expenses incurred	92.9%	3.6%	3.6%	95%
Rework Costs	60.7%	14.3%	25.0%	68%

Indicator and criterion	Possible to provide information or opinion evaluation $Pr(B_1)$	Difficult to provide information or opinion evaluation $Pr(B_2)$	Project does not have this information or cannot evaluate $Pr(B_3)$	Probability of successful collecting information Pr(A)
	$Pr(A/B_1) = 1$	$Pr(A/B_2) = 0.5$	$Pr(A/B_3) = 0$	
Budget for contingencies	46.4%	21.4%	32.1%	57%

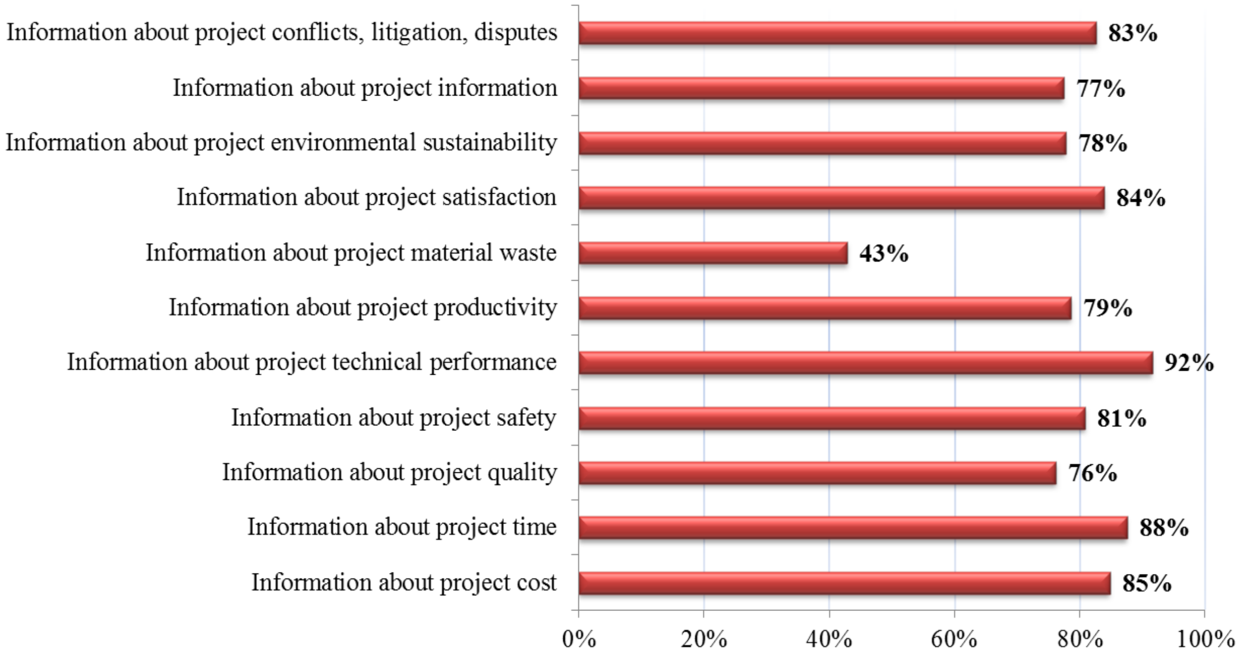


Figure 5.5 Summary probability of successful information collecting

5.2 Survey of Importance Level and Applicability of Proposed Indicators and Criteria

This survey was designed with the intent of achieving the importance level and applicability of proposed indicators and criteria in the QMCPE system. Following the feasibility study, this step was very important to make decision about which indicators and criteria should be kept in the final framework. The initial list of indicators and criteria may be difficult to apply because of its limitation as discussed above. So, the indicators and criteria in the QMCPE system should satisfy three conditions which were feasibility of collecting information, importance, and applicability.

5.2.1 Survey Details

The survey was conducted by interviewing in person using the designed questionnaire. Civil engineers, who were currently working in construction companies at Hochiminh City in Vietnam, were interviewed. They were asked about the importance level and applicability level of each indicator and criterion. The proposed list of indicators and criteria included all items that are similar to those in feasibility study.

The questionnaire included three main sections which were general information about the respondents, importance level, and applicability level. In the first section, the respondents were asked about working company, their position, their age, their experience in the construction field, their academic background, and the number of projects in which they participated. They were also interviewed about their opinion of the necessity of establishing a framework for evaluating project success as the objective of this research. Moreover, they provided their experience in evaluating project success from pass projects. In the second section, respondents expressed their opinion on the importance level of each indicator and criterion in a five point Likert scale. Under categories of “1” means not important at all, “2” means little important, “3” means moderately important, “4” means very important, and “5” means extremely important. In the third section, the applicability of each indicator and criterion was explored by using a five point Likert scale. Under categories of “1” means impossible, “2” means probably not, “3” means chances about even, “4” means probable, and “5” means almost certain. The questionnaire that was used for this study is shown in Appendix B in English and in Appendix C in Vietnamese.

This survey was conducted during February and March 2012 in Vietnam, at Hochiminh City construction companies where the interviewed civil engineers were currently working. From the survey, 125 questionnaires were distributed to ten construction companies (assume ten questionnaires were collected from each company) and twenty-five meetings were held outside these companies. In other to achieve high quality responses, a supporting letter was prepared and sent to these companies and some people before visiting. The interview took approximately thirty to forty-five minutes for each respondent who was willing to contribute opinions. Finally, forty-two questionnaires from the companies and twenty-three questionnaires from the meetings were collected. The other sixty questionnaires were not completed because the engineers in some companies were so busy with their job that they did not have time to fulfill the interview. The total of completed questionnaires was sixty five, and ratio respond was 52.0 percent.

5.2.2 Data Analysis

Data collected from the questionnaire surveys and interviews was analyzed with the support from the Statistical Package for Social Sciences (SPSS) program. Descriptive statistics was the first technique applied. The purpose was to get an overview of sample characteristics and ensure variables have no violation of the assumptions underlying the statistical techniques that are used in data processing (Pallant, 2004). There are different ways to obtain descriptive statistics including Frequencies, Descriptive or Explore. Different procedures depended on variables.

Data was screened using the complete sample (N = 65) prior to the main analyses to examine the accuracy of data entry and missing values. The data screening process involved a number of steps with the first step checking for error; second step finding the error in the data file, and third step correcting the error in the data file. The Frequencies and Descriptive statistic command was used to detect any out of range values. None was found. It was reasonable for no missing values because each respondent was interviewed carefully and checked at once to fulfill it immediately.

5.2.2.1 Respondent Profile

Of those respondents, the average age was 30.34 years and covered a wide range from 24 to 54 years old. All of them had experience from beginning to 13 year experience, average 6.46 years. Level of respondent's academic background was one factor that influenced their opinion about construction project success. In this study, respondent's background was classified into three groups. The data showed that

18.50% of the respondents had high school background, 76.90% had undergraduate qualification and 4.60% with postgraduate education. Almost all respondents had acceptable education background so they could be representative for the population.

Because of the purpose of this research, the experience about the number of completed projects is more important than the number of years they have worked. Figure 5.6 below separated respondents' experience in completed projects in three groups. The first group is respondents who have taken part in less than three completed projects, which makes up 30.80%. The second group, which included 29.20%, is respondents who have finished from three to five projects. The last group of experienced respondents, who have more than five projects completed, making up a high percentage of 40.00%.

Before conducting further analysis, respondents were asked how important a construction project evaluation is. Figure 5.7 below summarized their opinion. Among 65 valid responses, 47.70% responses believed that the proposed system was extremely important, 50.80% responses indicated it was very important, and 1.5% responses showed it was important. However, Figure 5.8 showed that 87.7% respondents had never evaluated construction project when it completed. This result implied that the proposed QMCPE system was significant and necessary to study. The further analysis should be conducted.

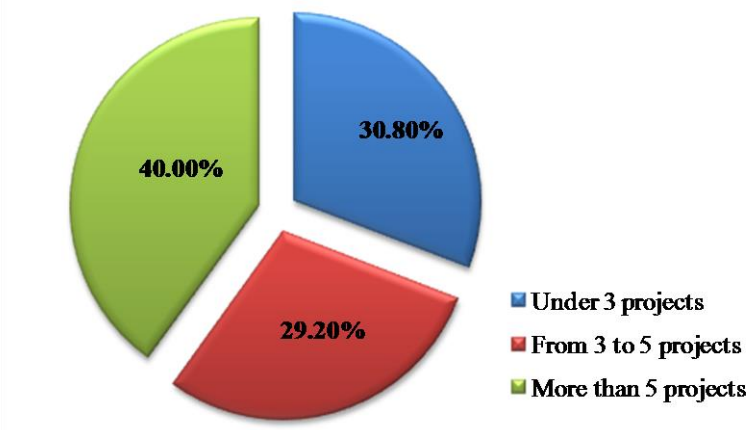


Figure 5.6 Number of projects each respondent has completed (N=65)

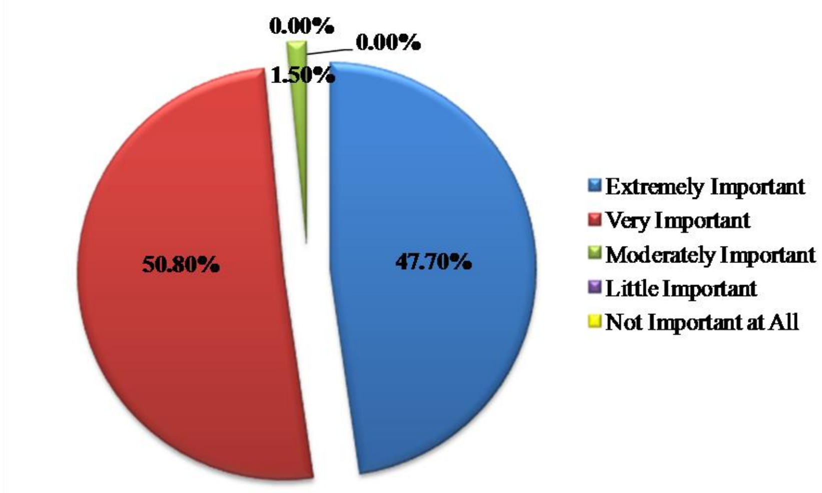


Figure 5.7 Respondents' perception about the importance of construction project evaluation system (N=65)

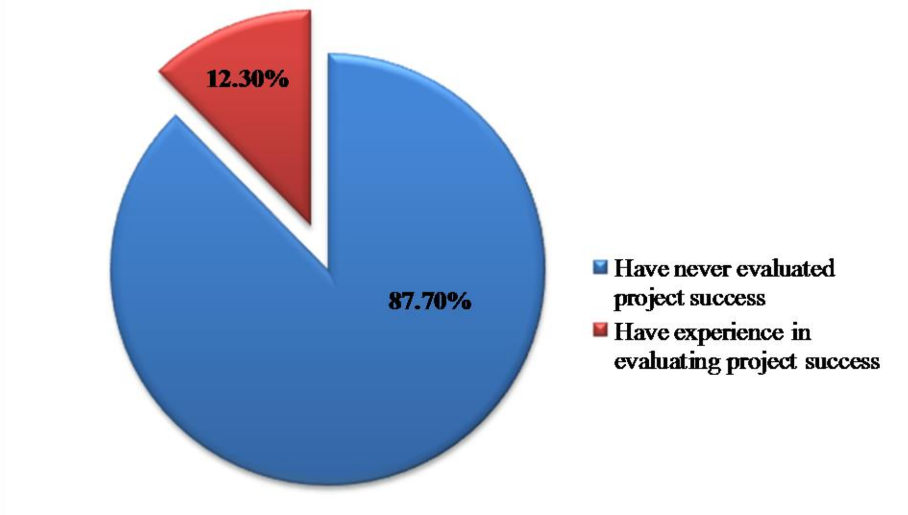


Figure 5.8 Respondents' experience in evaluating construction project (N=65)

5.2.2.2 Reliability Analysis of Scale

The second and the third section of the questionnaire were developed to explore the importance level and applicability of indicators and criteria. The respondents were asked to express their opinion and perception about that in a five point Likert scale of importance level and applicability. To ensure that the items comprising the project evaluation produced reliable scales, Cronbach's alpha coefficient of internal consistency was calculated for each scale. Each scale was compared with the acceptable value of Cronbach alpha of 0.60 (Hair et al., 2010). If the value of Cronbach alpha of each scale was higher than 0.60, it was considered acceptable and reliable to analyse the results (Hair et al., 2010). The reliability analysis of 'Project Cost' scale was described in Table 5.3 below. Reliability results of other indicators were described in section C.3 of Appendix C.

Table 5.3 Cronbach's alpha for project cost scale (N = 65)

N of Items = 5	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.684**	**0.707**
	If Item Deleted	
COST1 – Cost Variation	.677	.682
COST2 - Unit cost	.595	.648
COST3 – Rework costs	.709	.685
COST4 - Expenses incurred	.621	.669
COST5 - Cost for contingencies	.601	.674

5.2.2.3 Importance Level and Applicability Results

The results of both the importance level and the applicability level of all criteria were shown in Figure 5.9 and Figure 5.10 below. The hypothesis testing was applied to compare their means with the average value. Testing results showed that all criteria were important and applicable at 95% confidence. The descriptive and the results of hypothesis testing of the importance level and applicability level of indicators and criteria were representative described in Table 5.4 and Table 5.5 below. The completed results were shown in section C.4 of Appendix C.

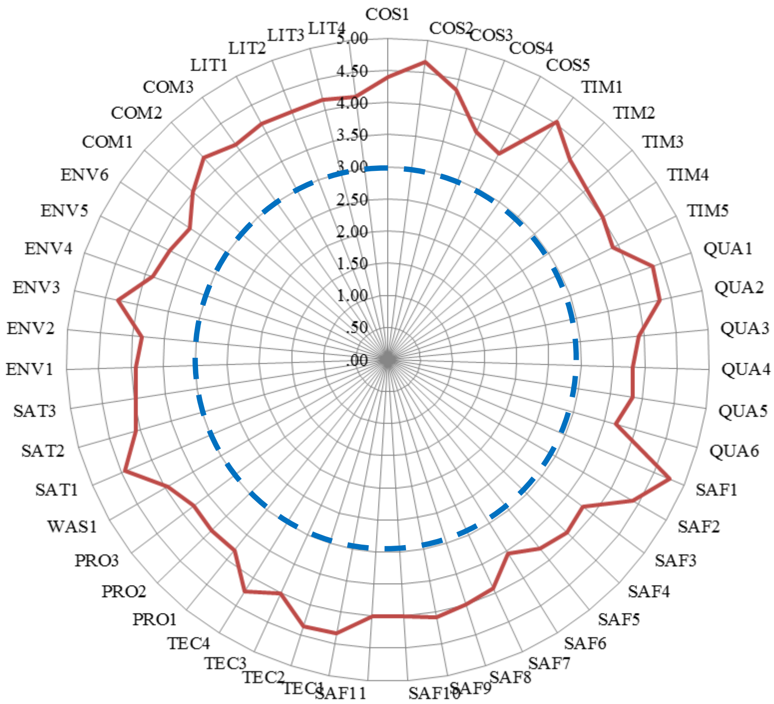


Figure 5.9 Mean of importance level of all criteria (N=65)

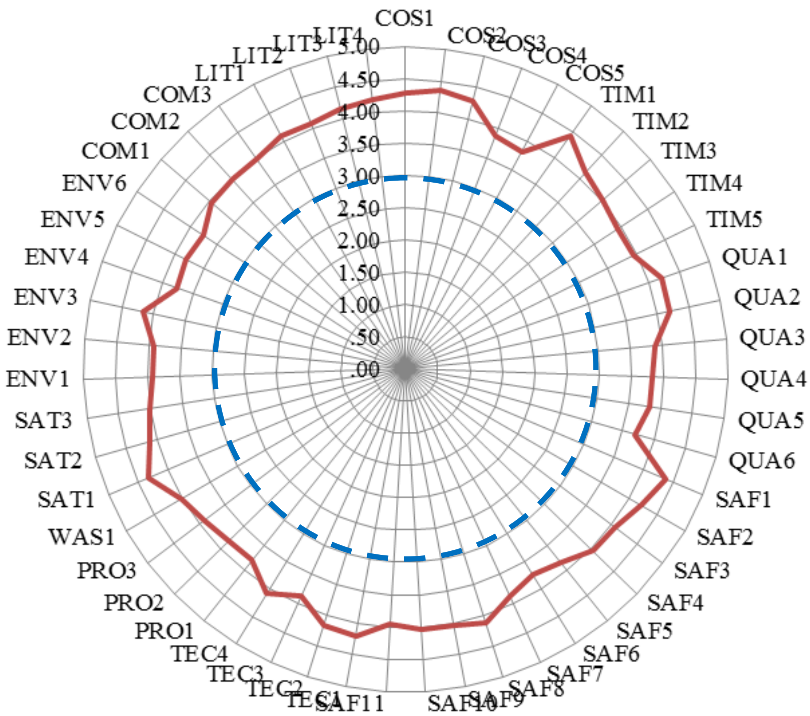


Figure 5.10 Mean of applicability level of all criterion (N=65)

Table 5.4 Descriptive statistics and testing hypothesis result of indicators and criteria in importance scale

Descriptive Statistics (N=65)					One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
COS1	2	5	4.40	.725	15.578	.000	Accept
COS2	3	5	4.66	.509	26.340	.000	Accept
COS3	2	5	4.32	.831	12.833	.000	Accept
COS4	2	5	3.80	.833	7.744	.000	Accept
COS5	2	5	3.65	.799	6.520	.000	Accept

Table 5.5 Descriptive statistics and testing hypothesis result of indicators and criteria in applicability scale

Descriptive Statistics (N=65)					One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
COS1	3	5	4.28	.573	17.966	.000	Accept
COS2	3	5	4.35	.598	18.263	.000	Accept
COS3	3	5	4.28	.600	17.167	.000	Accept
COS4	2	5	3.88	.600	11.790	.000	Accept
COS5	2	5	3.82	.610	10.784	.000	Accept

5.3 Proposed List of Indicators and Criteria in MQCPE System

The scatter plot in Figure 5.11 and **Figure *5.12*** below demonstrated the combination results between the probability of information collecting and their importance level, or their applicability level. These values dispersed clearly into two groups, which were upper and lower 60% of probability value. Therefore, there were three criteria for making decision in which indicator and criterion are used for evaluating project success. First, that indicator had a high probability to collect information, meaning that the probability of successful collecting information was higher than 60%. Second, that indicator was important from the respondents' perception; mean of importance level was higher than three. Third, that was an applicability indicator with mean value also higher than three. The representative results of the decision making of accepting or rejecting these proposed indicators and criteria were showed in Table 5.6. The whole results were detailed in section C.5 of Appendix C.

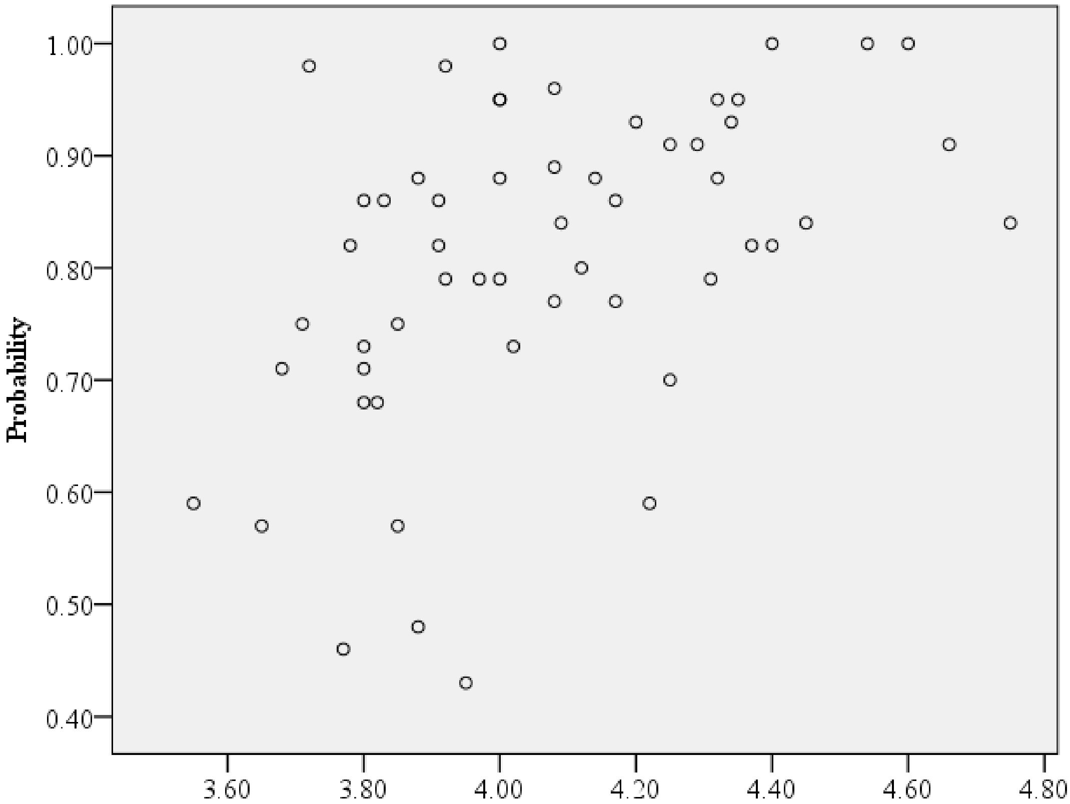


Figure 5.11 Scatter plot between probability of successful collecting information and mean of importance level

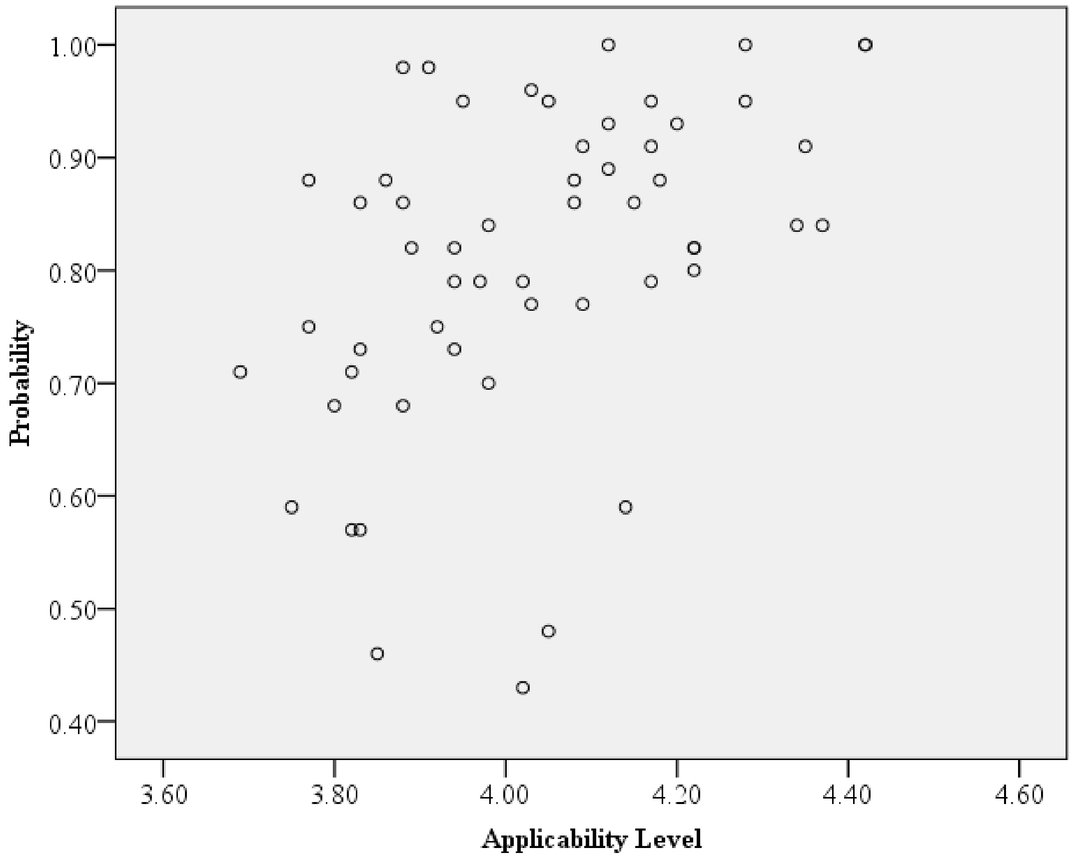


Figure 5.12 Scatter plot between probability of successful collecting information and mean of applicability level

The results in Table 5.6 below pointed out that six criteria could not be used in evaluating project success. The rejected criteria were ‘Cost for contingencies’, ‘Cost for unsatisfied works’, ‘Total expenditures for safety management in project’, ‘Total expenditures to handle and compensate accidents that occur during construction’, ‘Total time lost due to accident occurrence’, and ‘Waste materials in construction site’. These criteria were under ‘Project Cost’, ‘Project Quality’, ‘Project Safety’, and ‘Waste material’ indicators. They were rejected because they were considered difficult to collect information, their probability of successful information collecting are 57%, 57%, 48%, 46%, 59%, and 43% in turn, lower than 60% of critical value. Table 5.6 described some representative results, all results were shown in section C.5 of Appendix C.

The final proposed criteria of the QMCPE system was described in Figure 5.13. In this system, ten indicators were suggested to evaluate project success. These indicators were 'Project Cost', 'Project Time', 'Project Quality', 'Project Safety', 'Technical Performance', 'Productivity', 'Stakeholder Satisfaction', 'Sustainable Environment', 'Communication', and 'Disputes & Litigation'. In order to evaluate these indicators, a sub-system included forty five criteria was also described in Figure 5.13.

Table 5.6 Summary of results to select criteria of the QMCPE system

Variable Code	Probability of successful collecting information	Mean of Important Level	Mean of Applicability Level	Decision
COS1	100%	4.40	4.28	Accept
COS2	91%	4.66	4.35	Accept
COS3	95%	4.32	4.28	Accept
COS4	68%	3.80	3.88	Accept
COS5	57%	3.65	3.82	Reject
QUA5	57%	3.85	3.83	Reject
SAF4	48%	3.88	4.05	Reject
SAF5	46%	3.77	3.85	Reject
SAF6	59%	3.55	3.75	Reject
WAS1	43%	3.95	4.02	Reject

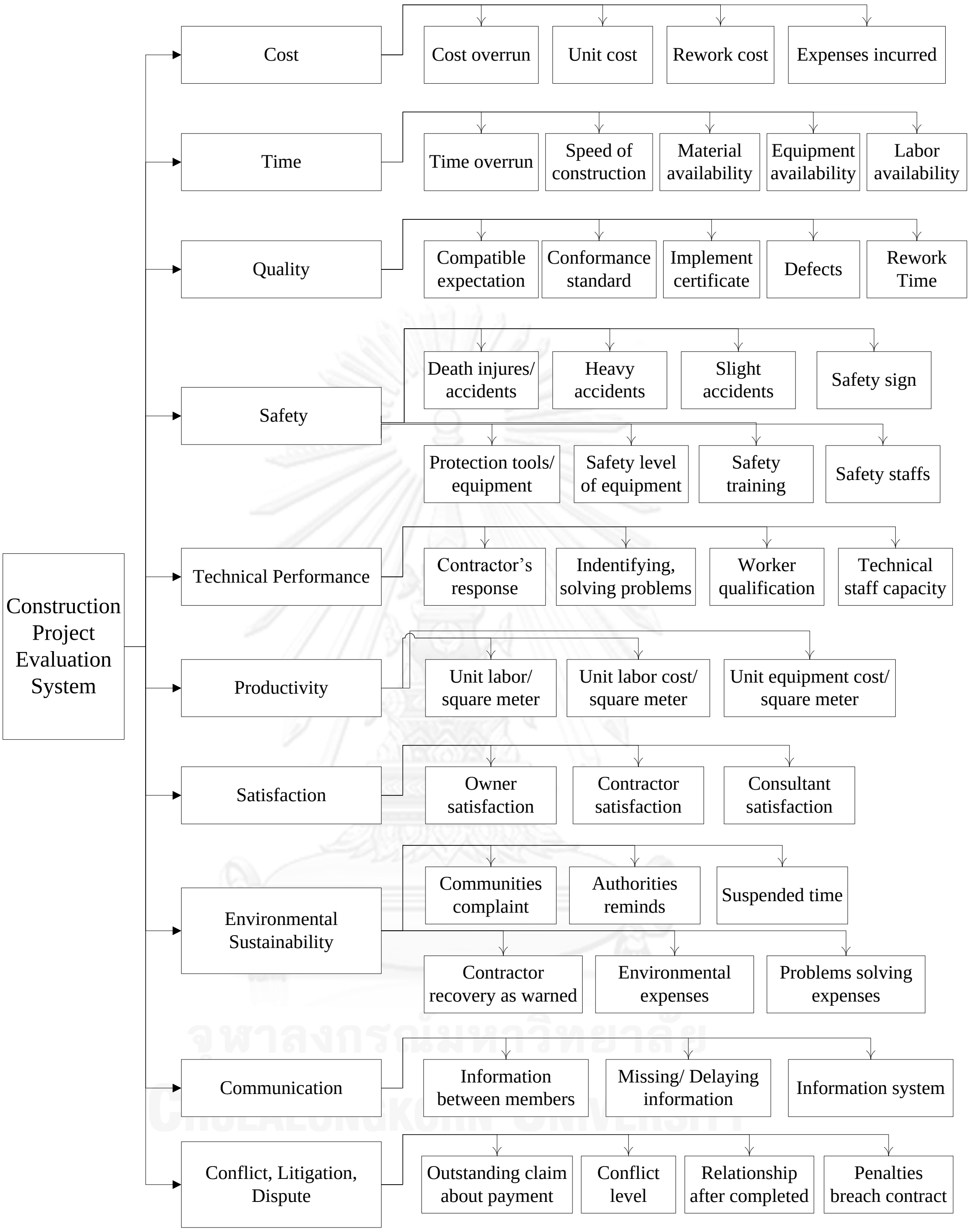


Figure 5.13 Proposed indicators and criteria of the QMCPE system

5.4 Summary

This chapter described a process to establish the final list of indicators and criteria of construction project evaluation. It was achieved after conducting feasibility study, importance study, and applicability study. Because of the objectives and expected outcomes of the research, the necessary information, which had to be collected from construction industry, was quite complex and difficult to collect. So, the feasibility study was conducted to explore the feasibility of research and achieve the final list of indicators and criteria. The initial eleven indicators and fifty-one criteria were accessed. The final indicators and criteria in this list had to satisfy three criteria, which are high capacity to collect information, high level of importance, and high degree of applicability to evaluate project success.

To achieve this objective, two surveys were performed. The first survey collected information from twenty-eight completed projects to consider the capacity to collect necessary information to evaluate project success. The second survey gathered opinions from sixty-five respondents about the importance level and applicability level of each indicator and criterion. From analysis results, one indicator and six criteria were eliminated from the list. The final list included ten indicators which were clearly described by forty-five criteria. Final indicators were ‘Project Time’, ‘Project Cost’, ‘Project Quality’, ‘Project Safety’, ‘Technical Performance’, ‘Productivity’, ‘Stakeholder Satisfaction’, ‘Sustainable Environment’, ‘Communication’, and ‘Disputes & Litigation’.

CHAPTER 6
WEIGHT ASSIGNMENT FOR INDICATORS AND CRITERIA OF CONSTRUCTION PROJECT SUCCESS EVALUATION SYSTEM

This chapter describes the research procedure to achieve the relative weight for indicators and criteria of the QMCPE system. It begins with section 6.1, explanation of the survey details which included data collection tools, data collection process, data analysis, and respondents' profile. The reliability analysis is then described in section 6.2. The results of weight assignment for indicators and criteria by Summing Responses, Structural Equation Modeling, and Combination of BEES & ISM methodology are detailed in section 6.3, 6.4, 6.5 in turn. Then, section 6.6 presents the comparison and final results of weight assignment for indicators and criteria. Finally, section 6.7 provides the summary.

6.1 General Survey Details

6.1.1 Questionnaire Design

The questionnaire contained two main sections including general information and evaluation of the importance of the proposed indicators and criteria. First, respondents were asked about the importance of an evaluation system. Then, respondents expressed their opinion on the importance level of each indicator and criterion in a five point Likert scale as mentioned in the preliminary survey. Finally, open questions were given to collect respondents' opinions about indicators that could be important but were not mentioned in the proposed list. The questionnaire was similar to the questionnaire which was used in the preliminary survey.

6.1.2 Data Collection

The survey was carried out from July to September 2012 in Vietnam. From the survey, 600 questionnaires were prepared and distributed to twenty-five construction companies. The interviews took approximately thirty to forty five minutes. Finally, only 381 questionnaires were collected, representing an average response rate of 63.50%. In the 381 questionnaires that were collected, 115 questionnaires were eliminated because they were incomplete. Consequently, the total of final valuable questionnaires was 266; the adjusted response ratio was 44.33%.

6.1.3 Data Analysis

Prior to analyzing the usable sample, it was important to check mistakes initially. Data were screened using the complete sample (N = 266) prior to the main analysis to examine the accuracy of data entry, missing values, and fit between distributions and the assumptions of necessary analysis tools. The Frequencies and Descriptive statistic command in SPSS Version 16 were used to detect any out of range values. None was found and the descriptive results were described in Table 6.1 below. Table 6.1 below only described some representative results and project cost indicator. The full results were shown in section D.1 of Appendix D.

Table 6.1 List of indicators and criteria in the QMCPE system and their descriptive analysis results (N=266)

Variable Code	Variable Meaning	Mean	Std. Deviation
1. COST	The degree to which the general contexts promote the completion of a project within the estimated budget	4.36	.794
COST1	Cost variation is ratio of net variations to final contract sum expressed in percentage term	4.17	.821
COST2	Unit cost is a measure of relative cost and is defined by the final contract sum divided by the gross floor area.	3.82	.836
COST3	Rework costs	3.59	.961
COST4	Expenses incurred	3.29	.960

The main objective of the study was the weight assignment of each indicator and criterion. An objective weight assignment was necessary; it was a more logical and accurate system. So, some representative objective weighting methods were used in this research. They are Summing Responses (RS), the Structural Equation Modeling (SEM), and the combination of BEES & ISM method. These three methods were parallelly used to calculate the weight of each indicator and criterion. After that, their results were compared and analyzed to achieve the final results.

6.1.4 Respondent Profile

Of the respondents, the average age was 30.34 years and ranged from 23 to 57 years old. All of them had experience from 1 to 29 year experience, averaging 6.46 years. The level of a respondent's academic background was one factor that influenced their opinion about construction project success. In this study, respondent's backgrounds were classified into three groups. The data showed that 6.69% of the respondents had high school background, 78.74% had undergraduate qualification, and 14.57% had postgraduate education. Almost all respondents had acceptable education background, so they could serve as a representative of the population.

Because of the purpose of this research, the number of completed projects was more important than the number of years a respondent had worked. The respondents' experience in completed projects was classified into three groups. The first group is respondents who have taken part in less than three completed projects, which makes up more than 30%. The second group, which included 27.38%, is the respondents who had finished from three to five projects. The last group of respondents, who had more than five projects completed, making up a high percentage of 42.46%.

Before conducting further analysis, respondents were asked how important a framework was in evaluating construction project success. Figure 6.1 below summarized their opinions. Among 260 valid responses, more than 84% of the responses indicated that the proposed system was important. The remaining 16% of the respondents did not highly appreciate the importance of project success evaluation framework. This result implied that the proposed framework was significant and necessary to study. Further analysis should be conducted.

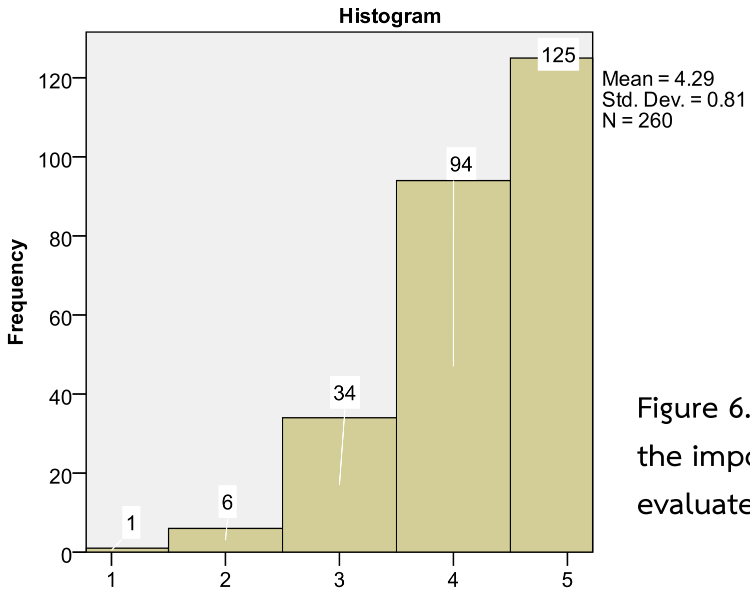


Figure 6.1 Respondents' opinion about the importance of framework to evaluate project success

6.2 Reliability Analysis of Scale

The construction project evaluation was performed by ten indicators and forty five criteria. It was necessary to ensure that these items comprise reliable measured scales. Cronbach's alpha coefficient of internal consistency was calculated for scale. The results were shown in Table 6.2 below. In respect of the scale's reliability, this scale was also found to be reliable with a high value of Cronbach's alpha 0.767 and above the threshold - 0.60 (Hair et al., 2010). Values from the column "Alpha if item deleted" in Table 6.2 suggested that all of these ten indicators provided the most reliability scale for evaluating construction project. So we should not remove any items of this scale for further analysis.

To ensure that the criteria comprising each indicator produced reliable scales, Cronbach's alpha coefficient of internal consistency was calculated for each scale of indicator. The results were shown in Table 6.3 below. The Cronbach's alpha ranging from 0.688 to 0.852, which was higher than standard value of 0.600, indicated adequate internal consistency (Pallant, 2004; Hair et al., 2010). The reliability results provided the significant confident for the scales and point out it was possible to conduct the further analysis. Table 6.3 below indicated some representative results. Section D.2 of Appendix D described the whole results.

Table 6.2 Cronbach's alpha for construction project evaluation scale (N = 266)

Cronbach's Alpha = 0.767 N of Items = 11	Cronbach's Alpha if Item Deleted
COST in evaluating project success	.763
TIME in evaluating project success	.753
QUALITY in evaluating project success	.750
HEALTH & SAFETY in evaluating project success	.739
TECHNICAL PERFORMANCE in evaluating project success	.745
PRODUCTIVITY in evaluating project success	.749
SATISFACTION in evaluating project success	.765
ENVIRONMENT in evaluating project success	.734
COMMUNICATION in evaluating project success	.742
DISPUTE & LITIGATION in evaluating project success	.746

Table 6.3 Cronbach's alpha for indicators of construction project evaluation scale (N = 266)

Items of Scale	Cronbach's Alpha	Cronbach's Alpha if Item Deleted
Indicator 1. Cost (N of Items =4)	0.688	
Cost variation		.688
Unit cost		.634
Rework costs		.579
Expenses incurred		.575
Indicator 2. Time (N of Items =5)	0.796	
Time variation		.727
Speed of construction		.711

Items of Scale	Cronbach's Alpha	Cronbach's Alpha if Item Deleted
Material availability		.715
Equipment availability		.697
Labor availability		.709

6.3 Weight Assignment Using Summing Responses Method

The weight of each indicator and criterion were calculated by dividing its' mean to sum up all means of variables in one category. Table 6.4 identified how this calculation was performed. The similar process was performed to calculate the weight for criteria in each indicator. The results of weight assignment for criteria were shown in Table 6.5 below with representative results of cost and time indicator. Other results were described in section D.3 of Appendix D.

Table 6.4 Weight assignment for indicators by Summing Responses method (N=266)

Indicators	Mean	S.D	Weight
Cost	4.357	0.794	4.357/39.462 = 0.110
Time	4.274	0.750	4.274/39.462 = 0.108
Quality	4.586	0.769	4.586/39.462 = 0.116
Health & Safety	4.274	0.901	4.274/39.462 = 0.108
Technical Performance	4.068	0.764	4.068/39.462 = 0.103
Productivity	3.545	0.869	3.545/39.462 = 0.090
Satisfaction	3.722	0.902	3.722/39.462 = 0.094
Environment	3.650	1.018	3.650/39.462 = 0.092
Communication	3.613	0.977	3.613/39.462 = 0.092
Litigation	3.372	1.046	3.372/39.462 = 0.085
SUM	39.462		1.000

Table 6.5 Weight assignment for criteria by Summing Responses method (N=266)

Criteria	Mean	Weight/Indicator	Weight/Project
Cost	4.357	0.110	
COST1	4.165	4.165/14.857 = 0.280	0.280*0.110 = 0.031
COST2	3.820	3.820/14.857 = 0.257	0.257*0.110 = 0.028
COST3	3.586	3.586/14.857 = 0.241	0.241*0.110 = 0.027
COST4	3.286	3.286/14.857 = 0.221	0.221*0.110 = 0.024
Sum	14.857		
Time	4.274	0.108	
TIME1	4.177	4.177/20.120 = 0.208	0.208*0.108 = 0.022
TIME2	3.887	3.887/20.120 = 0.193	0.193*0. 108 = 0.021
TIME3	4.075	4.075/20.120 = 0.203	0.203*0. 108 = 0.022
TIME4	3.985	3.985/20.120 = 0.198	0.198*0. 108 = 0.021
TIME5	3.996	3.996/20.120 = 0.199	0.199*0. 108 = 0.022
Sum	20.120		

6.4 Weight Assignment Using Structural Equation Modeling (SEM)

6.4.1 Goodness-of-fit Measures

Researcher typically used the following criteria to obtain the statistical significance and substantive meaning of the developed model. Table 6.6 provided a summary on the most common SEM model fit indexes. In reference to model fit, numerous goodness-of-fit indicators were used to assess the model (Tabachnick and Fidell, 2007; Hair et al., 2010). The more criteria a model satisfies, the better its fit.

Some common fit indexes, the Normed Fit Index (NFI), Non-Normed Fit Index (NNFI, also known as TLI), Incremental Fit Index (IFI), Comparative Fit Index (CFI), and root mean square error of approximation (RMSEA), will be used. The following section will report the fit indexes chosen for this study together with the justification for choosing those indexes.

Table 6.6 Cutoff criteria for several fit indexes

Indexes	Short-hand	General rule for acceptable fit	Recommend
Absolute/predictive fit			
Chi-square	χ^2	Ratio of χ^2 to *df* ≤ 2 or 3, useful for nested models/model trimming	Used
Akaike information criterion	AIC	Smaller the better; good for model comparison (nonnested), not a single model	
Browne–Cudeck criterion	BCC	Smaller the better; good for model comparison, not a single model	
Bayes information criterion	BIC	Smaller the better; good for model comparison (nonnested), not a single model	
Consistent AIC	CAIC	Smaller the better; good for model comparison (nonnested), not a single model	
Expected cross-validation index	ECVI	Smaller the better; good for model comparison (nonnested), not a single model	
Comparative fit		Comparison to a baseline (independence) or other model	
Normed fit index	NFI	>0.95 (Good); > 0.9 (Acceptable)	Used
Incremental fit index	IFI	>0.95 (Good); > 0.9 (Acceptable)	
Tucker–Lewis index	TLI	>0.95 (Good); > 0.9 (Acceptable)	Used
Comparative fit index	CFI	>0.95 (Good); > 0.9 (Acceptable)	Used
Relative noncentrality fit index	RNI	Similar to CFI but can be negative, therefore CFI better choice	

Indexes	Short-hand	General rule for acceptable fit	Recommend
Parsimonious fit			
Parsimony-adjusted NFI	PNFI	Very sensitive to model size	
Parsimony-adjusted CFI	PCFI	Sensitive to model size	
Parsimony-adjusted GFI	PGFI	Closer to 1 the better, though typically lower than other indexes and sensitive to model size	
Others			
Goodness-of-fit index	GFI	>0.95 (Good); > 0.9 (Adequate)	Used
Adjusted GFI	AGFI	>0.95 Performance poor in simulation studies	Used
Hoelter .05 index		Critical *N* largest sample size for accepting that model is correct	
Hoelter .01 index		Hoelter suggestion, *N* = 200, better for satisfactory fit	
Root mean square residual	RMR	Smaller, the better; 0 indicates perfect fit	
Standardized RMR	SRMR	<0.08	
Weighted root mean residual	WRMR	<0.9	
Root mean square error of approximation	RMSEA	< 0.06 to 0.08 with confidence interval	Used

The χ 2 statistic. This statistic is an absolute fit index indicating how well an analysis succeeded in minimizing the discrepancy between the hypothesized covariance matrix and the sample covariance matrix. The smaller the value of χ 2 the better the fit, with zero indicating perfect fit and a value with an associated probability greater than 0.05 indicating acceptable fit (Tabachnick and Fidell, 2007). However, a number of writers have raised concern about the use of this statistic as a test of model fit because of its sensitivity to data that are not multivariate normally distributed and its tendency to indicate misfit as sample size increases (because of power). Despite these reservations, it has been used here as it allows for comparisons between models, with the $\chi 2$ statistic for the hypothesized model providing a baseline value against which all subsequent tests of invariance can be compared. Furthermore, in cross-validation analysis, the $\chi 2$ difference test can be used whereby a non-significant difference between the $\chi 2$ for the calibration sample and the $\chi 2$ for the validation sample indicates no difference between the two models.

The $\chi 2$ /DF ratio. Researchers have addressed some of the limitations of the $\chi 2$ statistic by developing a number of alternative goodness-of-fit indices (Bacon, 1997; Tabachnick and Fidell, 2007). One of these indices is the $\chi 2$ /degrees of freedom ratio (reported as CMIN/DF), an index that is designed to compensate for the tendency of the $\chi 2$ test to reject models when sample sizes are large. As with the $\chi 2$ statistic, this ratio provides an indication of the efficiency of the hypothetical model in reproducing the sample data. Values of 2 or less represent a good fit (Schreiber et al., 2006).

The Root Mean-Square Error of Approximation Index (RMSEA). The RMSEA takes into account the error of approximation in the population and relaxes the stringent requirement on $\chi 2$ that the model holds exactly in the population. Values of 0.05 or less indicating the hypothetical model is a close fit to the sample data (Schreiber et al., 2006). However, some authors suggest that models with RMSEA values of 0.08 or less can be accepted (Tabachnick and Fidell, 2007; Hair et al., 2010).

The Tucker-Lewis Index (TLI). This index is an incremental (or comparative) fit index which provides a measure of improvement in fit when the hypothesized model is compared with a more restricted baseline model. TLI is recommended when the maximum likelihood estimation method is used as was the case in this study. TLI should be greater than 0.95 although values greater than 0.90 indicate reasonable fit (Schreiber et al., 2006). This index can exceed a value of 1 (i.e., it is a non-normed fit index), however, this indicates a lack of parsimony.

The Confirmatory Fit Index (CFI). The CFI is also an incremental fit index and is recommended when data are not multivariate normally distributed, as the CFI shows minimum estimation bias when this is the case. This index is normed with values constrained to fall between 0 and 1. CFI should be greater than 0.95 although values greater than 0.90 indicate reasonable fit (Schreiber et al., 2006; Hair et al., 2010).

The Goodness-of-fit index (GFI). The GFI is the goodness of fit index, which indicates the proportion of the observed covariances explained by the model-implied covariances. GFI varies from 0 to 1, but theoretically can yield meaningless negative values. By convention, GFI should be equal to or greater than 0.90 to accept the model (Schreiber et al., 2006).

The Adjusted GFI (AGFI). The AGFI is the adjusted goodness of fit index. This adjustment is to cater for the phenomenon of SEM, whereby more complex models fit the same data better than simpler models. The AGFI takes this accommodation into account by adjusting the GFI value downwards as the number of model parameters increases. AGFI varies from 0 to 1, but theoretically can yield meaningless negative values. AGFI should be at least 0.90 to accept the model (Schreiber et al., 2006).

The Normed fit index (NFI). The NFI indicates the proportion of improvement of the model relative to a null model that assumes the variables are uncorrelated. NFI ranges from 0 to 1, with value over 0.90 indicating an acceptable fit of the model to the data, and values close to 1 indicating perfect fit (Schreiber et al., 2006).

6.4.2 Weight Assignment for Indicators and Criteria Using Structural Equation Modeling

SEM was used to assign the weights to indicators and criteria. The steps of weight assignment procedure are as followed:

- Step 1: Building a measurement model based on the optimized QMCPE system from Chapter 5. SEM model was described in Figure 6.2 below. Ten constructs related to the indicators and forty-five criteria represented for criteria to evaluate project success were described in this model.
- Step 2: By using the data obtained from the data collection process, the final fitting chart was achieved with the help of specific SEM software as AMOS.
- Step 3: Normalizing the factor loading coefficients which was obtained from the fitting chart to weight the indicators and criteria.
- Step 4: If the fitting degree of the model was not up to the standard, the model should be revised, and the process was repeated until the ideal fitting chart can be reached.

In order to achieve a higher Goodness-of-Fit model, some links between errors were sequentially added based on the result from Modification Indices (MI). The final model was described in Figure 6.2. It was the optimum model that achieved the most criteria for several fit indexes without too complex relationships.

This model had the following fit coefficients: CMIN/DF = 2.88; RMSEA = 0.08. The final model satisfied more than 50% of the critical standards and was above the threshold of the most important standards. Therefore, the model was valid and could be continued to analyze the outcome of the causal effects. Figure 6.2 provided the results of testing the structural links of the proposed research model using AMOS program. The estimated path coefficients were given. All path coefficients could be considered significant at the 90% significance level providing support for all relationships. It implied that eleven proposed indicators could be used to evaluate the construction project success. In addition, these indicators were assessed by the forty six criteria as discussed above. This system accounted for over 50% of the variance in construction project success; it was an indication of the good explanatory power of the model.

Table 6.7 Path coefficient and weight assignment for indicators by SEM (N=266)

Indicators/Criteria			Estimate	S.E.	C.R.	P	Weight
Project Cost	<-	Success	0.411	0.08	5.138	***	0.110
Project Time	<-	Success	0.407	0.058	7.017	***	0.109
Project Quality	<-	Success	0.421	0.069	6.101	***	0.113
Project Safety	<-	Success	0.401	0.063	6.365	***	0.107
Technical	<-	Success	0.393	0.043	9.140	***	0.105
Productivity	<-	Success	0.329	0.051	6.451	***	0.088
Satisfaction	<-	Success	0.359	0.036	9.972	***	0.096
Environment	<-	Success	0.356	0.069	5.159	***	0.095
Communication	<-	Success	0.345	0.058	5.948	***	0.092
Dispute	<-	Success	0.310	0.069	4.493	***	0.083
		Sum	*3.732*				*1.000*

A summary of the developed structural equations, path coefficients and significance levels were provided in Table 6.7. The weights of the indicators were assigned based on the loading coefficients on the loading chart. The Figure 6.2 showed that the significant coefficient of ‘Project Cost’, ‘Project Time’, ‘Project Quality’, ‘Project Safety’, ‘Technical Performance’, ‘Productivity’, ‘Stakeholder Satisfaction’, ‘Environment’, ‘Communication’, and ‘Dispute & Litigation’ were 0.411, 0.407, 0.421, 0.401, 0.393, 0.329, 0.359, 0.356, 0.345, and 0.310 respectively, and their sum was 3.732. So the weight of each coefficient was calculated by dividing each coefficient by their sum as shown in Table 6.7. The result of criteria weight which was described in Table 6.8 was calculated in the same way.

Table 6.8 Path coefficient and weight assignment for criteria by SEM (N=266)

Criteria <--- Indicators			Estimate	Weight/ Indicator	Weight/ project
COST1	<---	Project Cost	0.720	0.289	0.032
COST2	<---	Project Cost	0.697	0.279	0.031
COST3	<---	Project Cost	0.554	0.222	0.024
COST4	<---	Project Cost	0.524	0.210	0.023
		Sum	*2.495*	*1.000*	
TIME1	<---	Project Time	0.706	0.236	0.026
TIME2	<---	Project Time	0.665	0.222	0.024
TIME3	<---	Project Time	0.656	0.219	0.024
TIME4	<---	Project Time	0.471	0.158	0.017
TIME5	<---	Project Time	0.491	0.164	0.018
		Sum	*2.989*	*1.000*	
QUA1	<---	Project Quality	0.417	0.216	0.024
QUA2	<---	Project Quality	0.416	0.216	0.024
QUA3	<---	Project Quality	0.339	0.176	0.020
QUA4	<---	Project Quality	0.417	0.216	0.024
QUA5	<---	Project Quality	0.339	0.176	0.020
		Sum	*1.928*	*1.000*	
SAFE1	<---	Project Safety	0.833	0.129	0.014
SAFE2	<---	Project Safety	0.824	0.128	0.014
SAFE3	<---	Project Safety	0.802	0.125	0.013

Criteria	<---	Indicators	Estimate	Weight/ Indicator	Weight/ project
SAFE4	<---	Project Safety	0.809	0.126	0.013
SAFE5	<---	Project Safety	0.713	0.111	0.012
SAFE6	<---	Project Safety	0.833	0.129	0.014
SAFE7	<---	Project Safety	0.824	0.128	0.014
SAFE8	<---	Project Safety	0.802	0.125	0.013
		Sum	*6.440*	*1.000*	
TECH1	<---	Technical	0.680	0.238	0.025
TECH2	<---	Technical	0.783	0.274	0.029
TECH3	<---	Technical	0.655	0.230	0.024
TECH4	<---	Technical	0.736	0.258	0.027
		Sum	*2.854*	*1.000*	
FUNC1	<---	Functionality	1.000	1.000	0.026
		Sum	*1.000*	*1.000*	0.031
PRO1	<---	Productivity	0.716	0.293	0.032
PRO2	<---	Productivity	0.852	0.348	
PRO3	<---	Productivity	0.877	0.359	0.038
		Sum	*2.445*	*1.000*	0.035
SATIS1	<---	Satisfaction	0.883	0.397	0.023
SATIS2	<---	Satisfaction	0.798	0.359	
SATIS3	<---	Satisfaction	0.543	0.244	0.016
		Sum	*2.224*	*1.000*	0.017
ENVI1	<---	Environment	0.762	0.170	0.015
ENVI2	<---	Environment	0.789	0.176	0.016
ENVI3	<---	Environment	0.686	0.153	0.016
ENVI4	<---	Environment	0.744	0.166	0.016
ENVI5	<---	Environment	0.767	0.171	0.031

Criteria <--- Indicators			Estimate	Weight/ Indicator	Weight/ project
ENVI6	<---	Environment	0.742	0.165	0.030
		Sum	*4.490*	*1.000*	
COMMU1	<---	Communication	0.753	0.334	0.032
COMMU2	<---	Communication	0.720	0.319	0.022
COMMU3	<---	Communication	0.781	0.346	0.022
		Sum	*2.254*	*1.000*	
LITIGA1	<---	Dispute	0.804	0.265	0.018
LITIGA2	<---	Dispute	0.796	0.263	0.021
LITIGA3	<---	Dispute	0.665	0.219	0.032
LITIGA4	<---	Dispute	0.767	0.253	0.031
		Sum	*3.032*	*1.000*	

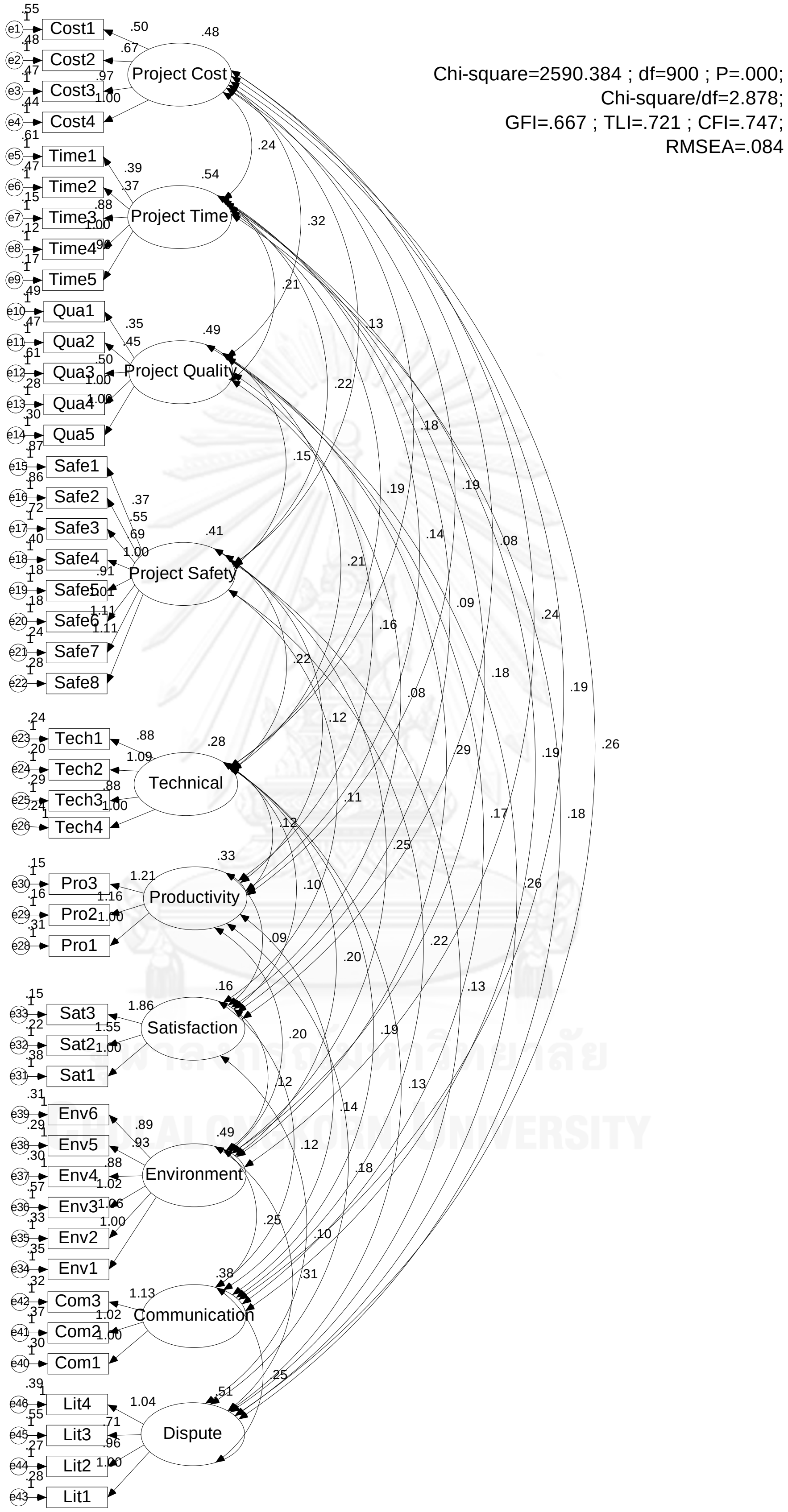


Figure 6.2 Weight assignment for indicators and criteria using SEM model

6.5 Weight Assignment Using Combination of BEES & Importance Scale Matrix Method

Battelle EES (BEES) method, Importance Scale Matrix (ISM) method, and combination of both were introduced by Goyal and Deshpande (Goyal and Deshpande, 2001).

BEES method involves ranked pairwise comparison of parameters, wherein initial ranking plays a major role. Once ranking is done, the first parameter in the ranked list is compared with the second parameter, the second with the third, and so on, and the absolute dominance is considered using Delphi technique. Experts in different fields are involved in the parameters ranking exercise. It is imperative that subjectivity in assigning PIU is unavoidable in this approach. Thus, there is a need to reduce/minimize this subjectivity in human judgement by supplementing it with some statistical/mathematical methods for weight assignment.

ISM method involves unranked pairwise comparison of each parameter with the remaining other (n-1) parameters, then leaving that parameter, next parameter is compared with the remaining (n-2) parameters, and so on using the importance scale (consider the total number of parameters as n). This scale was defined by keeping in view the definition of the relative importance terms used as presented in Table 6.9. The matrix of preference thus obtained was then analyzed using 'eigenvector' method to arrive at the weight of each parameter in the matrix.

Table 6.9 Basic concept of weight assignment using ISM method

Variation (%)	Definition	Assigned weight
<5	Two parameters i and j contribute equally to the objective	1.0
+10	Experience and judgement slightly favour parameter i over j	1.1
+30	Experience and judgement moderately favour parameter i over j	1.4
+50	Criteria strongly favour parameter i over j	2.0
+70	The evidence very strongly favours parameter i over j	3.3
+90	Experience and judgement dominantly favour parameter i over j	10.0

In the combination method, without any initial ranking of the selected parameters, ISM method logic was used for pairwise comparison of parameters importance and then normalization of weight was done following BEES method. This combined approach was developed in order to have a simple, more exhaustive but unbiased way to obtain parameter's weight without using complicated statistical (eigenvector) procedure.

Based on the approach described above, software was designed to support calculation. Table 6.11 showed the comparision between indicators and ISM weight. Each indicator was compared with the remaining other (n-1) indicators to achieve the sum total ISM weight. Then, each indicator relative weight was calculated by dividing its ISM weight to the total of ISM weight of all indicators. The calculation process and results were described in Table 6.11. The similar process was applied to calculate the weight for criteria. The results of weight assignment for criteria were shown in Table 6.10. It described some representative results, which were 'Project Cost' and 'Project Time' criteria. The results of others criteria were shown in section D.3 of Appendix D.

Table 6.10 Weight assignment for criteria using BEES & ISM method (N=266)

Indicator/ Criteria	Weight
Project Cost	**0.118**
COST1	0.036
COST2	0.033
COST3	0.030
COST4	0.027
Project Time	**0.118**
TIME1	0.027
TIME2	0.025
TIME3	0.025
TIME4	0.025
TIME5	0.025

Table 6.11 Weight assignment for indicators using BEES & ISM method (N=266)

	COST	TIME	QUAL	SAFE	TECH	PROD	SATI	ENVI	COMM	LITI	SUM	Weight
		1.94%	-4.99%	1.94%	7.10%	22.91%	17.06%	19.37%	20.59%	29.21%		
COST		1.00	0.91	1.00	1.10	1.40	1.40	1.40	1.40	1.40	11.01	0.118
	-1.90%		-6.80%	0.00%	5.06%	20.56%	14.83%	17.10%	18.30%	26.75%		
TIME	1.00		0.91	1.00	1.10	1.40	1.40	1.40	1.40	1.40	11.01	0.118
	5.26%	7.30%		7.30%	12.73%	29.37%	23.21%	25.64%	26.93%	36.00%		
QUAL	1.10	1.10		1.10	1.40	1.40	1.40	1.40	1.40	2.00	12.30	0.131
	-1.90%	0.00%	-6.80%		5.06%	20.56%	14.83%	17.10%	18.30%	26.75%		
SAFE	1.00	1.00	0.91		1.10	1.40	1.40	1.40	1.40	1.40	11.01	0.118
	-6.63%	-4.82%	-11.30%	-4.82%		14.75%	9.30%	11.45%	12.59%	20.64%		
TECH	0.91	0.91	0.71	0.91		1.40	1.10	1.40	1.40	1.40	10.14	0.108
	-18.64%	-17.06%	-22.70%	-17.06%	-12.86%		-4.76%	-2.88%	-1.88%	5.13%		
PROD	0.71	0.71	0.71	0.71	0.71		1.00	1.00	1.00	1.10	7.67	0.082
	-14.57%	-12.92%	-18.84%	-12.92%	-8.51%	4.99%		1.97%	3.02%	10.38%		
SATI	0.71	0.71	0.71	0.71	0.91	1.00		1.00	1.00	1.10	7.87	0.084
	-16.23%	-14.60%	-20.41%	-14.60%	-10.28%	2.96%	-1.93%		1.02%	8.24%		
ENVI	0.71	0.71	0.71	0.71	0.71	1.00	1.00		1.00	1.10	7.67	0.082
	-17.08%	-15.47%	-21.22%	-15.47%	-11.18%	1.92%	-2.93%	-1.01%		7.15%		
COMM	0.71	0.71	0.71	0.71	0.71	1.00	1.00	1.00		1.10	7.67	0.082
	-22.61%	-21.10%	-26.47%	-21.10%	-17.11%	-4.88%	-9.40%	-7.62%	-6.67%			
LITI	0.71	0.71	0.71	0.71	0.71	1.00	0.91	0.91	0.91		7.30	0.078

6.6 Comparison and Final Weight Assignment Result

Table 6.12 provided the summary results of weight assignment for indicators and criteria of construction project success evaluation system by five methods. They were Summing Response (SR), Structural Equation Modeling (SEM), and Combination of Battelle EES & Importance Scale Matrix (BEES & ISM).

In order to combine the results from three weight assignment methods above, some statistical analysis was significantly performed. Independent samples T-test was performed before conducting further analysis. The mean value of weight of each indicator and criterion achieved by three methods were compared in pair. The results from independent samples t-test by SPSS pointed out that the weight assignment results from the method SR, SEM, and BEES & ISM were not significant different at ninety-five percent confidence. Therefore, the final weight of indicators and criteria was the combination result from these three methods, which were SR, SEM, and BEES & ISM and summarized in Table 6.13 below. The results of project cost and project time indicators were shown in Table 6.13. Whole results of all indicators were described in section D.3 of Appendix D.

Table 6.12 Summary of weight assignment for indicators (N=266)

Indicator	SR (1)	SEM (2)	BEES & ISM (3)	% (2)-(1)	% (3)-(1)	% (3)-(2)
Project Cost	0.110	0.110	0.118	0%	6%	7%
Project Time	0.108	0.109	0.118	1%	9%	8%
Project Quality	0.116	0.113	0.131	-3%	13%	16%
Project Safety	0.108	0.107	0.118	-1%	9%	9%
Technical Performance	0.103	0.105	0.108	2%	5%	3%
Productivity	0.090	0.088	0.082	-2%	-9%	-7%
Satisfaction	0.094	0.096	0.084	2%	-11%	-13%
Environment	0.092	0.095	0.082	3%	-11%	-14%
Communication	0.092	0.092	0.082	1%	-11%	-11%
Dispute	0.085	0.083	0.078	-3%	-9%	-6%

The results of weight assignment by three methods which were SR, SEM, BEES & ISM, and the final weight assignment were described in Table 6.13. The final weight was calculated by averaging and standardizing the above three methods. Then, the ranking was shown in Table 6.14 below. The results indicated that the ranks of indicators were similar in all three weight assignment methods. It was observed that all the three methods ranked 'Project Quality', 'Project Cost', and 'Project Time' as the three most important indicators for the evaluation. This result was compatible with the background information related to project evaluation which was discussed in the literature review chapter. 'Project Safety', 'Technical Performance', and 'Project Stakeholder Satisfaction' were ranked fourth, fifth, and sixth in all three methods. The difference was not much which was shown in Table 6.13.

Other four indicators, which were 'Environment', 'Communication', 'Productivity', and 'Dispute & Litigation', were ranked seventh, eighth, ninth, and tenth in turn. This result was similar in all three methods. Even though these indicators were not ranked as the top indicators, but their portion was still high. The important weight of the last indicator, 'Dispute & Litigation', was 0.082 in final result, more than fifty percent of the first indicator, 'Project Quality' 0.120. The result indicated that these four indicators were considered more important with every passing day in construction project evaluation. The results were reasonable, explainable, and compatible with the literature review in evaluation of construction project success (Liu and Walker, 1998; Lim and Mohamed, 1999; Chan et al., 2002; Chan and Chan, 2004; Shawn et al., 2004; Ahadzie et al., 2008).

Table 6.13 Summary of weight assignment for indicators and criteria (N=266)

Indicator/ Criteria	SR	SEM	BEES & ISM	Final Weight
Project Cost	0.110	0.110	0.118	0.113
Project Time	0.108	0.109	0.118	0.112
Project Quality	0.116	0.113	0.131	0.120
Project Safety	0.108	0.107	0.118	0.111
Technical Performance	0.103	0.105	0.108	0.106
Productivity	0.090	0.088	0.082	0.087
Satisfaction	0.094	0.096	0.084	0.092

Indicator/ Criteria	SR	SEM	BEES & ISM	Final Weight
Environment	0.092	0.095	0.082	0.090
Communication	0.092	0.092	0.082	0.089
Dispute & Litigation	0.085	0.083	0.078	0.082
Project Cost	**0.110**	**0.110**	**0.118**	**0.113**
COST1	0.031	0.032	0.036	0.033
COST2	0.028	0.031	0.033	0.031
COST3	0.027	0.024	0.030	0.027
COST4	0.024	0.023	0.027	0.025
Project Time	**0.108**	**0.109**	**0.118**	**0.112**
TIME1	0.022	0.026	0.027	0.025
TIME2	0.021	0.024	0.025	0.023
TIME3	0.022	0.024	0.025	0.024
TIME4	0.021	0.017	0.025	0.021
TIME5	0.022	0.018	0.025	0.022

Table 6.14 Ranking the important weight of indicators (N=266)

Indicator	SR	SEM	BEES & ISM	FINAL
Project Cost	2	2	2	2
Project Time	3	3	3	3
Project Quality	1	1	1	1
Project Safety	4	4	4	4
Technical Performance	5	5	5	5
Productivity	9	9	9	9
Satisfaction	6	6	6	6

Indicator	SR	SEM	BEES & ISM	FINAL
Environment	7	7	7	7
Communication	8	8	8	8
Dispute & Litigation	10	10	10	10

6.7 Summary

The final weight assignment for indicators and criteria was achieved. A survey was performed, and 266 valuable data were analyzed and calculated. Weight assignment was calculated by three methods which were Summing Responses, Structural Equation Modeling, and Combination of ISM & BEES. And then, by comparing these results and statistical analysis, their weight assignment results from three methods were kept to combine and calculate the final result.

The weight assignment result was accurate, quantitative, and reliable result with less subjectivity, which was caused in responses' judgements. Moreover, this result was reasonable, explainable, and compatible with the literature review in evaluation of construction project success. For these reasons, this result could be used for further construction project evaluation in the next phase.

CHAPTER 7
QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM – TESTING SURVEY

This chapter describes the QMCPE system for construction project success. It includes the list of ten indicators which was evaluated by forty five criteria. They were achieved from the previous chapters. The indicators and criteria are organized systematically in section 7.1, which includes criteria's definition, instruction for evaluation, and measurement scale. Section 7.2 provides the combination methodology to achieve the final evaluation. Then, this system was tested by evaluating three representative construction projects. Details of testing survey are shown in section 7.3. Continuing from this section, section 7.4 gives the system validation and evaluation by users.

7.1 Quantitative Multi-Criteria Construction Evaluation System

This section organized systematically the construction evaluation system. The initial list of indicators and criteria were described in Chapter 3. And then the final list was achieved by feasibility and importance survey in Chapter 5. Their weight assignment was described in Chapter 6. A survey was performed at construction companies to achieve the criteria evaluation scale. It was carried out by interviewing experts, documentary searching, and company historical data. The finish tool to evaluate project success included the list of indicators and criteria, their relative weight; their evaluation scale was achieved. Following section explained the list of indicators, criteria, and their definition. The complete tool which included the instruction for evaluating each criterion, and their measurement scale was described in Appendix E.

7.1.1 Indicator 'Project Cost'

Indicator 'Project Cost' was designed to evaluate the degree to which the general contexts promote the completion of a project within the estimated budget. It was measured by 'Cost Variation', 'Unit Cost', 'Reworks Cost', and 'Expenses Incurred'.

'Cost Variation' was intended for evaluating the effect of budget control and management. It is measured by cost variation, means the ratio of net variations to final contract sum expressed in percentage term. 'Unit Cost' was intended for evaluating the construction effectiveness. It was based on unit cost, which was defined by the final contract sum of construction cost divided by the gross floor area. ‘Reworks Cost’ was used to evaluate waste costs in construction sites. It included rework cost, waste materials cost, tidy up cost, and loss material cost. From the preliminary study, the average amount of this cost was 5% of total cost; the maximum amount was 10% of total cost. ‘Expenses Incurred’ was purposed to evaluate expenses incurred in construction sites. Incurred costs included direct operation or production expenses, indirect expenses such as overhead, and unexpected costs as well. From the preliminary study, the average amount of this cost was 2% of the total cost; the maximum amount was 4% of the total cost.

7.1.2 Indicator ‘Project Time’

Indicator ‘Project Time’ was designed to evaluate the degree to which the general contexts promote the completion of a project within the allocated duration. It was measured by ‘Time Variation’, ‘Speed of Construction’, ‘Material Availability’, ‘Equipment Availability’, and ‘Labor Availability’.

‘Time Variation’ was intended for evaluating the schedule achievement by time variation. ‘Time Variation’ was measured by the percentage of increase or decrease in the estimated project days, excluding the effect of extension of time granted by the client. ‘Speed of Construction’ was the relative time, which was defined by gross floor area being divided by the construction time (number of days from start on site to practical completion of the project). ‘Material Availability’, ‘Equipment Availability’, and ‘Labor Availability’ were measured by the number of days a construction site was delayed because of supplying materials, equipment, and labor.

7.1.3 Indicator ‘Project Quality’

Indicator ‘Project Quality’ was designed to evaluate the degree to which the general contexts promote meeting of project’s established requirements of materials and workmanship. It was measured by ‘Quality Conformity with Expectation’, ‘Quality Standard’, Implementation of ‘Evaluate the suitability project quality certificate’, ‘Defects in Take over the Project’, and ‘Time to Rework Under-quality Works’.

‘Quality Conformity with Expectation’ was designed to evaluate the level of conformity between the quality of the original works as desired and actual completion. ‘Quality Standard’ was used to evaluate the met quality standards in the construction process. Implementation of 'Evaluate the suitability project quality certificate' was evaluated by aesthetics, performance, functional use, and sustainability of overall project outcomes. 'Defects in Take over the Project' was measured by the number of defect, level of defect, and repair capacity. 'Time to Rework Under-quality Works' was intended for evaluating the quality of construction by time to rework under-quality works.

7.1.4 Indicator 'Project Safety'

Indicator 'Project Safety' was designed to evaluate the degrees to which the general contexts promote the completion of a project without major accidents or injuries. It was accessed by 'Number of Death Injures or Accidents', 'Number of Heavy Accidents', 'Number of Slightly Accidents', 'Safety Signage Board', 'Safety Tools and Protection Equipment', 'Safety Level of Equipment', 'Safety Training', and 'Safety Responsibility Staffs'.

'Number of Death Injures or Accidents' was intended for evaluating the effect of safety management system at construction sites by means of the number of death injures or accidents happened during construction time. 'Number of Heavy Accidents' was measured by the number of heavy accidents happened during construction time. The list of accidental injuries to determine the type of heavy accidents issued together with Safety Guide. 'Number of Slightly Accidents' was assessed by the number of slightly accidents happened during construction time. Slightly accidents are the remaining accidents, which do not belong to death accidents, and heavy accidents listed in Safety Guide.

'Safety Signage Board' was intended for evaluating the organization, arrangement of safety signs at construction projects. Quantity, quality, place arrangement of safety sign were examined. Signage Board included signage board, warning tape and board, and tag scaffolding. 'Safety Tools and Protection Equipment' was used to evaluate the level of safety uniform and personal protect equipment were provided for human. They included safety uniforms and first aid facilities. 'Safety Level of Equipment' was intended for evaluating the safety level of all machines and equipment that are used in construction sites. They were cranes, trucks, excavators, bulldozers, compactors, concrete pumps, tower cranes, hoist, etc… 'Safety Training' was used to evaluate safety training at construction sites. A completed safety training system included safety training before working on construction site, safety certificate, periodic safety meetings on site, training before specific tasks, and monthly training courses. 'Safety Responsibility Staffs' was intended for evaluating safety responsibility staffs at construction site. A complete safety system includes safety department, safety committee, supervisor, and safety staff (this number will vary according to the number of workers at the site).

7.1.5 Indicator 'Technical Performance'

Indicator 'Technical Performance' was designed to evaluate the degree to which the general contexts promote meeting of project's established specifications. It was assessed by 'Contractor's Response to the Technical Requirements', 'Evaluation of Technical Problem Identification and Solution', 'Overall Assessment Qualifications of Workers in the Project', and 'Problem Solving of Contractor's Technical Staff'.

7.1.6 Indicator 'Productivity'

Indicator 'Productivity' was designed to evaluate the degree to which the general contexts promote achieving effectiveness of allocated resources in order to meet the cost and time targets. It was measured by 'Construction Productivity', 'Unit Labor Cost per Square Meter', and 'Unit Equipment Cost per Square Meter'.

7.1.7 Indicator 'Project Stakeholders Satisfaction'

Indicator 'Project Stakeholders Satisfaction' was designed to evaluate the level of 'happiness' of project stakeholders. It included 'Owner Satisfaction', 'Contractor Satisfaction', and 'Consultant Satisfaction'.

7.1.8 Indicator 'Environment'

Indicator 'Environment' was designed to evaluate the degree to which the general contexts promote avoiding the effects of project on the environment. It was evaluated by 'Evaluation of Environment and Communities around the Construction Site', 'Level and Sanctions Violations Related to Sanitation from The Authorities', 'Frequency of Time Reminded about Sanitation from the Authorities', 'Evaluate the Recovery of the Contractor When Noticed', 'Ensure Environmental Sustainability System', and 'Expenses of Overcoming the Problems of Environmental Sanitation'.

'Evaluation of Environment and Communities around the Construction Site' was assessed by the level and frequency of complaints from the environment and communities around the construction site. 'Level and Sanctions Violations Related to Sanitation from The Authorities' included decision to suspend construction, decision to administrative sanctioning, remind and requirement to compensate and repair the damages. Ensure environmental sustainability system was intended for evaluating the environmental sustainability system in a project. It is evaluated by expenses used for this system. A good system is invested in terms of time and energy, good preparation, effective plan, and active solution for each problem.

7.1.9 Indicator 'Communication' among Project Stakeholders in Project

Indicator 'Communication' was used to evaluate the degree to which the general contexts promote achieving effectiveness of communication in order to avoid misunderstanding. It was measured by 'Evaluation of the Communication in Project', 'Frequency of Missing or Late Information', and 'Information Systems' used in project. A complete information exchange system was exact, in time, sufficient, decentralized, and clear in terms of responsibilities.

7.1.10 Indicator 'Dispute and Litigation'

Indicator 'Dispute and Litigation' was measured by 'Number of Outstanding Claims', 'Relationship among Parties after Project was Completed', and 'Performance of Contractual Commitments'. The level of conflict between owner and contractor includes conflicts that can be resolved (quickly or slowly), and conflicts that cannot be resolved causing legal proceeding and refuse payment. Performance of contractual commitments was evaluated by the numbers of complaint letters and meetings.

7.2 Combination Overall Score Methodology

Linear additive method was applied to achieve overall score of construction project evaluation. As discussed in the literature review, there are several processes to calculate the multi-criteria evaluation, and the selection depends on the problem situations. Some criteria should be considered such as the practice, user acceptance, data requirements, ease of use, their applicability, and utility of results related to the problem situations (Tsamboulas et al., 1999). In practical point of view, the construction project information was quite a lot and sensitive. So, it was necessary to develop a well structural, simple, straightforward, and easy to follow system. Linear additive model was satisfied these requirements. Linear additive model copes better with real world situation and offers decision closest to human rational approach. The important thing is that it could be applied to any number of projects and any number of criteria. Therefore, linear additive method is an appropriate method for construction project evaluation.

Before proceeding with the combination, all criteria were first converted to z score of normalization. In statistics and applications of statistics, normalization can have a range of meanings. In the simplest cases, normalization of ratings means adjusting values measured on different scales to a notionally common scale, often prior to averaging. Normalization was performed by applying the discrimination principle. According to this principle, the standard score of a raw score x was:

$$z = \frac{x-\mu}{\sigma} \quad (7.1)$$

where:

x is the value of variable; μ is the mean of the variable;

σ is the standard deviation of the variable:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \quad (7.2)$$

Where: $\bar{x}$ is value of mean of all respondents of each variable; n is the number of respondents

The overall preference score for each option was simply the weighted average of its scores on all the criteria. Letting the preference score for criterion j be represented by z_j and the weight for each criterion by w_j, then n criteria the overall score was given by:

$$Z_i = w_1 z_1 + w_2 z_2 + \ldots + w_n z_n = \sum_{j=1}^{n} w_j z_j \quad (7.3)$$

Where:

Z_i is the combination score of each indicator, i = 1, 2,...11

w_j is the important weight of criteria, j = 1, 2, ..., n

z_j is the z score of each criterion

In words, multiplied a z score on a criterion by the importance weight of the criterion, performed that for all the criteria, and then summed the products to give the overall preference score for that indicator. Then repeated process was performed for the remaining indicators. After achieving the score for each indicator, conducted the similar process to calculate the overall score for upper level.

$$S = W_1Z_1 + W_2Z_2 + \ldots + W_mZ_m = \sum_{i=1}^{m} W_iZ_i \qquad (7.4)$$

Where:

S is the combination of project success score

W_i is the importance weight of indicator, i = 1, 2,...11

Z_i is the combination score of each indicator, i = 1, 2,...11

Finally, the combination project success score was converted from 0 to 100 range score using simple linear conversion formula a probability by incorporating it into a logistic response function, following equation below:

$$NewValue = \frac{(OldValue - OldMin)}{(OldMax - OldMin)} \times (NewMax - NewMin) + NewMin \qquad (7.5)$$

Where:

NewValue is the converted value of project evaluation score

OldValue is the original value of project evaluation score

OldMin is the minimum value of original value of project evaluation score

OldMax is the maximum value of original value of project evaluation score

NewMin is the minimum value of new range score

NewMax is the maximum value of new range score

7.3 Testing Survey

The testing survey was conducted to evaluate and check the validity of proposed QMCPE system. This system was applied to evaluate three representative projects. This survey was very important before conducting the large scale survey. The tool was assessed in aspects of question objectives, question wording, and questionnaire formatting to ensure its clarity, understandability and simplicity for respondents.

7.3.1 Data Collection

The testing study was carried out by interviewing and projects document searching. Each of three visited construction companies was asked to provide all documents of one typical project and up to three representative engineers who were familiar with this project. All documents of each project were examined carefully and engineers were interviewed to evaluate each criterion based on the proposed evaluation tool. This phase of survey was performed at construction companies in Vietnam during January and February 2013.

7.3.2 General Projects Information

To keep the security, three representative projects were coded as A, B, and C. These projects were performed at Hochiminh City, Vietnam. Project information was provided from three contractor companies. All of them were civil building projects and private capital sources. Their general information was shown in Table 7.1 below.

Table 7.1 Representative projects' information

Items	Project A	Project B	Project C
Commencement	June 2011	September 2010	April 2011
Contract price	3,340,825 USD	3,720,930 USD	5,953,488 USD
Contract duration	390 days	360 days	540 days
Total project area	15,646 m^2	12,000 m^2	27,735 m^2
Actual final cost	3,511,628 USD	3,860,465 USD	6,140,511 USD
Actual duration	450 days	370 days	570 days
Labor cost	477,106.94	395,348.84	1,136,985.64
Equipment cost	227,751.92	255,813.95	643,108.93
Cost variation	5.11%	3.75%	3.14%
Time variation	15.38%	2.78%	5.56%
Actual unit cost	224.44 USD	321.71 USD	221.40 USD
Productivity	35 m^2/day	32 m^2/day	49 m^2/day
Unit labor cost	30.49 USD/m^2	32.95 USD/m^2	40.99 USD/m^2

Items	Project A	Project B	Project C
Unit equipment cost	14.56 USD/m^2	21.32 USD/m^2	23.19 USD/m^2

7.3.3 Evaluation Case Study of Representative Projects

According to project information in Table 7.1 and based on the evaluation system which is described in section 7.1, project A evaluation results were detailed in Table 7.2 below. The similar process was applied to evaluate project B and C. Then, following the normalization rescaling in equation (7.1), all criteria were transformed to their z scores. The evaluation results and z scores of all criteria in project A, B, and C were summarized in Table 7.3.

Table 7.2 Project A Evaluation

(Explaining reason in details and scoring)

Indicator/ Criteria	Reason and Evaluation	Scale (x)
Project Cost		
COST1	Cost variation is 5.11%	2
COST2	Actual unit cost is 224.44 USD	3
COST3	Poor, from 6% - 8% of total cost	2
COST4	Adequate, around 1.5% - 2.5% of total cost	3
Project Time		
TIME1	Time variation is 15.38%	1
TIME2	Adequate, around 10% compared with standard value	3
TIME3	Poor, construction process has interrupted three times because of material supply	2
TIME4	Good, construction process has interrupted one time because of equipment availability	4
TIME5	Adequate, construction process has interrupted two times because of labor availability	3

Indicator/ Criteria	Reason and Evaluation	Scale (x)
Project Quality		
QUA1	Excellent, meet more than 99% of the required, reach above the required level	5
QUA2	Good, meet 90% - 99% of the required	4
QUA3	Excellent in implementing the “Evaluate the suitability project quality” certificate	5
QUA4	Only several defects and were repaired in a short time	4
QUA5	Under-quality works were repaired immediately	4
Project Safety		
SAFE1	Only one case of fatal occupational accidents was recorded	4
SAFE2	Three cases of heavy accidents were recorded	3
SAFE3	Sometimes occur on site, more than one case per week	3
SAFE4	Safety signs were good, included General regulation boards, Prohibited signs, Hazard warning tape and boards, and mandatory signs.	4
SAFE5	Adequate in safety tools and protection equipment for human, relative completion: more than 70% persons concerned are equipped enough helmet, harness, shoes, glasses and mask, and glove	3
SAFE6	Good in safety level of equipment, quite completion: All machine and equipment are satisfied six of eight requirements above	4
SAFE7	Good, all staffs satisfied requirements of Safety training, safety certificate, conduct periodic safety meetings on site weekly, monthly training courses	4
SAFE8	Good, has a safety management system with enough safety staff to take care of safety issues at construction site; all safety staffs are trained specially in charge of safety issues	4

Indicator/ Criteria	Reason and Evaluation	Scale (x)
Technical Performance		
TECH1	Contractor responses completely and good, meet 90 - 99% of the required	4
TECH2	Ability to identify the incidents and be able to solve the problems exactly, quickly, and effectively	4
TECH3	All key workers have appropriate qualifications, degrees and certificates; they do a good job assigned	4
TECH4	Technical staffs were able to solve the problem well; superiors need guide and support to meet the difficult and complex issues.	3
Productivity		
PRO1	34.77 square meter per day	3
PRO2	30.49 USD/m2	4
PRO3	14.56 USD/m2	4
Satisfaction		
SATIS1	Owner was quite satisfied	4
SATIS2	Contractor was quite satisfied	4
SATIS3	Consultant was quite satisfied	4
Environment		
ENVI1	Frequently complained from the environment and communities around the construction site, average of 2 to 3 times per week	2
ENVI2	Sometimes reminded about sanitation from the authorities, and required to compensate and repair the damages	4
ENVI3	Almost no reminded about sanitation from the authorities, less than 3 times during construction time	5
ENVI4	Contractor was ability to solve problems is enough, can reach the requirements	3

Indicator/ Criteria	Reason and Evaluation	Scale (x)
ENVI5	Environmental sustainability system excellent	5
ENVI6	Little expenses for overcoming the problems of environmental sanitation	4
Communication		
COMMU1	Communication in project was excellent, using web-based data developed by contractor to exchange information.	5
COMMU2	Rarely, less than seven times of missing or late information which affects the project	4
COMMU3	Information exchange is exact, in time, sufficient and quick	4
Dispute & Litigation		
LITIGA1	Have some small conflicts but can be resolved quickly	4
LITIGA2	Have a few small conflicts, which can be fixed immediately in checking and taking over the project	4
LITIGA3	Adequate relationship, may consider cooperation in the next project	3
LITIGA4	Performance of contractual commitments between owner and contractor was good, problem was sometime discussed, reminded in the period meeting	4

Table 7.3 Results of criteria evaluation of project A, B, and C

Indicator/ Criteria	Project A Scale (x)	Project B Scale (x)	Project C Scale (x)	Project A Scale (z)	Project B Scale (z)	Project C Scale (z)
Project Cost						
COST1	2	3	3	-0.757	0.081	0.081
COST2	3	3	2	-0.056	-0.056	-0.923
COST3	2	3	3	-0.930	-0.029	-0.029
COST4	3	5	3	-0.271	1.597	-0.271

Indicator/ Criteria	Project A Scale (x)	Project B Scale (x)	Project C Scale (x)	Project A Scale (z)	Project B Scale (z)	Project C Scale (z)
Project Time						
TIME1	1	4	3	-0.953	1.016	0.360
TIME2	3	2	5	0.097	-0.652	1.595
TIME3	2	4	3	-0.811	0.923	0.056
TIME4	4	3	4	0.795	-0.191	0.795
TIME5	3	4	3	0.202	1.098	0.202
Project Quality						
QUA1	5	5	4	1.601	1.601	-0.053
QUA2	4	5	4	0.053	1.707	0.053
QUA3	5	4	5	1.076	-0.258	1.076
QUA4	4	3	3	0.502	-0.470	-0.470
QUA5	4	3	5	0.522	-0.557	1.602
Project Safety						
SAFE1	4	5	5	-0.026	0.790	0.790
SAFE2	3	5	3	-0.319	1.479	-0.319
SAFE3	3	3	4	0.000	0.000	1.168
SAFE4	4	4	3	1.104	1.104	0.067
SAFE5	3	3	3	0.309	0.309	0.309
SAFE6	4	3	3	1.210	-0.130	-0.130
SAFE7	4	4	2	1.282	1.282	-0.810
SAFE8	4	3	2	1.426	0.373	-0.679
Technical Performance						
TECH1	4	5	4	0.152	1.334	0.152
TECH2	4	5	3	0.222	1.368	-0.924
TECH3	4	4	3	0.823	0.823	-0.197
TECH4	3	5	2	-0.318	1.656	-1.306

Indicator/ Criteria	Project A Scale (x)	Project B Scale (x)	Project C Scale (x)	Project A Scale (z)	Project B Scale (z)	Project C Scale (z)
Productivity						
PRO1	3	2	5	0.097	-0.652	1.595
PRO2	4	3	2	0.896	-0.030	-0.956
PRO3	4	2	3	0.534	-0.905	-0.186
Satisfaction						
SATIS1	4	3	4	1.067	0.065	1.067
SATIS2	4	2	4	1.016	-1.609	1.016
SATIS3	4	3	3	0.787	-0.322	-0.322
Environment						
ENVI1	2	2	1	-1.285	-1.285	-2.133
ENVI2	4	4	2	0.116	0.116	-2.291
ENVI3	5	4	3	0.906	-0.431	-1.769
ENVI4	3	3	5	-0.388	-0.388	2.016
ENVI5	5	3	3	1.572	-0.695	-0.695
ENVI6	4	3	4	-0.043	-1.373	-0.043
Communication						
COMMU1	5	2	5	1.373	-2.616	1.373
COMMU2	4	3	5	0.000	-1.168	1.168
COMMU3	4	2	4	0.807	-1.972	0.807
Dispute & Litigation						
LITIGA1	4	1	5	0.192	-2.361	1.043
LITIGA2	4	1	3	0.612	-2.098	-0.291
LITIGA3	3	2	4	-0.197	-1.217	0.823
LITIGA4	4	2	4	0.522	-1.637	0.522

Final project evaluation was calculated by weighted summaries step by step. First, indicators were calculated by multiplying the criteria evaluation results, in Table

7.3, with criteria weight which was summarized in Table 6.13 of Chapter 6, following the formula (7.3). Then, project score was achieved by multiplying indicators result with indicators weight, which was also summarized in Table 6.13, following the formula (7.4). Finally, the conversation was performed using formula (7.5) to achieve the final result of project evaluation. The evaluation results of project A, B, and C were described in Table 7.4.

Table 7.4 Evaluation results of representative projects

Indicators	Project A	Project B	Project C
Project Cost	44.72	63.81	49.61
Project Time	47.16	63.88	67.94
Project Quality	69.58	63.61	62.33
Project Safety	76.02	79.53	61.31
Technical	65.26	85.00	50.93
Productivity	65.84	40.51	56.09
Satisfaction	71.92	44.39	66.37
Environment	56.49	35.98	31.70
Communication	76.00	25.00	83.43
Dispute & Litigation	66.31	25.00	70.85
Total Project	73.89	59.64	67.58

7.4 Evaluating the Construction Project Success Evaluation System

The system should be evaluated before using for a large scale survey or implementing in full use. The purpose of an evaluation was to assess the system to see if it does what it was supposed to do, that it is working well, and that everyone is satisfied with it. Evaluation was conducted to validate whether the system were measurable and could fulfill the measurement requirements. According to Pyzdek and Keller (Pyzdek and Keller, 2010), a good measurement system possessed certain properties. These properties are ‘accuracy’, which means the capacity to produce a number close to the actual measured property, and ‘repetition’, which means the measurements produced being close to one another if the measurement system is applied repeatedly to the same object. Third, it should be linear, meaning that it should be able to produce accurate and consistent results over the entire range of concerns. Fourth, the measurement system should produce the same results when used by any properly trained individual. Moreover, according to Steve Copley, professor of IGCSE Center, a good system should be efficient, easy to use, and appropriate.

A focus group meeting and interview were used to evaluate and validate the system. Nine expert engineers who performed the representative project evaluation participated in the meeting. The participants included three engineers working for three contractors, two owners, two consultants, and two engineers working for construction department. They had more than five years of experience in construction field and had higher than bachelor degree background. A checklist was prepared based on the above concept to help validation process. The following questions were asked to evaluate and validate the system:

- Can the system achieve the result of measurement?
- Do all criteria and indicators fulfill your measurement requirement?
- Can you perform evaluation under the provided guideline?
- Do the evaluation results describe exactly the level of project success in your opinion?
- Can new user understand and apply the system with short time training?
- Is the system suitable for your company?
- Does the system actually meet the needs and bring benefit to your company?
- Are you ready to apply the system to your company if you can decide?

The focus group meeting achieved the positive results. All of interviewees agreed that the system could achieve the results and no one suggested other indicators and criteria. In their opinion, they and their companies could perform the evaluation by the proposed QMCPE system. However, two interviewees raised an idea that a part of construction companies is not able to perform the evaluation because they did not have the sources. For example, they did not record and classify the cost as rework cost, labor cost, equipment cost, or environment cost; they did not have the safety management to record heavy and slightly accident. A discussion was happened and then all interviewees agreed that the system could perform in some companies and some companies could not, but it was necessary in future tendency and should change step by step.

Seven interviewees responded “Yes” when they were asked “Do the evaluation results describe exactly the level of project success in your opinion?” They expressed their surprise, interest, and were satisfied with the evaluation results from the system. Two other interviewees, who were government department, had no idea about this issue because they did not perform testing survey. All of interviewees believed that engineers can understand and apply the system after they were trained one week. As discussed above, this system was applicable for all of seven companies which were visited, but it may not suitable for some companies. Hundred percent of interviewees stated that the system was significant, valuable, and brought a lot of benefits to their company if it was applied. Therefore, they asserted that they were ready to apply the system.

7.5 Summary

This chapter described the evaluation system for construction project success. The implementation of the system was introduced in five aspects: the completed indicators and criteria of evaluation system, standardization of their weighting, instruction for evaluating each indicator and criterion, their measurement scale, and combination method. The system performance was tested by three representative projects in construction field. Then, a focus group meeting was conducted to evaluate and validate the system. The meeting among nine experts in construction industry was held to reach the agreement and conclusion. First, the system was fulfilled and could perform well to achieve the project evaluation; the system results could describe the project outcome which was compatible with the experts’ perception. Second, the system was assessed that it was efficient, valuable, and appropriate to apply in construction companies. Third, all interviewees considered the perspective of system implementation and expressed their readiness to implement it in their works. For these reasons, the evaluation system was applicable and significant to disseminate. This system could thus be used in the next phase of this research in order to develop a large scale survey.

CHAPTER 8
CONSTRUCTION PROJECT EVALUATION USING QUANTITATIVE MULTI-CRITERIA EVALUATION SYSTEM - LARGE SCALE SURVEY

This chapter describes the large scale research procedure to develop the construction project evaluation database, which was based on the designed evaluation system. It begins with section 8.1, explanation of the survey details which includes data collection tools, data collection process, and data analysis. General projects' information is then described in section 8.2. After that, section 8.3 expresses the results of project evaluation. This is followed by a description of the relationship between project evaluation result and project characteristics in section 8.4. Finally, section 8.5 provides the chapter summaries.

8.1 General Survey Details

The objective of the large scale study was to collect enough valid and reliable data for developing project evaluation data. The documentary research and interview were performed in this phase. The following section described the process details.

8.1.1 Data Collection Tools

A set of necessary information and questionnaire was developed based on the QMCPE system which was achieved from the previous phase. The large scale questionnaire included two main sections. Section one included ten questions related to general information of projects. It included project name, project location, owner, contractor, consultant, contract price, contract duration, capital source, construction start date, project scale, and information provider. In order to keep information secure, all information about the name of project, owner, contractor, and consultant were coded before being presented in this research. The second section was the evaluation system of forty-five criteria. In order to achieve the accurate and objective evaluation, definition, evaluation instruction, and the scale to evaluate each criterion were provided. The complete questionnaire which was used for the large scale survey was similar to the one in testing survey which was described in Appendix E.

8.1.2 Data Collection

Purposive sampling was selected as a suitable tool for this research. Because the sampling units were project's information, it was difficult to get a complete list of target population. Besides, the necessary project outcome was sensitive so almost companies refused to co-operate. As a result, contacting and entering construction companies to interview were very complex without personal relations. In addition, this research was performed in a limited time. Twenty seven construction companies at Hochiminh City were listed and contacted for permission. Finally, sixteen contractors approved to participate in providing data.

During March-July 2013, data collection for large scale survey was undertaken with construction professionals in Vietnam, at Hochiminh City construction companies. In order to finish evaluation for one specific project, the researcher had to collect information related to finance, schedule, safety record, quality evaluation, resource management, and so on. Furthermore, the opinion of representative engineers who took full responsibility for that project was asked to finish the evaluation. It took from three days to one week to finish the evaluation for one project. Finally, information of thirty-one projects was collected to analyze. The main information was collected from seven contractors, five owners, and two consultants. Other project stakeholders for each project were also contacted when necessary to collect more information.

8.1.3 Data Analysis

The data collected from the survey was analyzed with the support from the Statistical Package for Social Sciences (SPSS) program. The analysis included descriptive analysis and analysis of variance.

Descriptive statistics was the first technique applied. The purpose was to get an overview of the sample characteristics, to ensure variables have no violation of the assumptions underlying the statistical techniques that are used in data processing, and to answer specific research questions. There are many ways to obtain descriptive statistics including Frequencies, Descriptive, and Explore. Different procedures depended on categorical or continuous variables.

Analysis of variance (ANOVA) was the second technique to achieve the research objectives addressed above. ANOVA is a statistical method used to test differences between two or more means. It was selected to explore whether existed the relationship between project characteristics and project evaluation score.

8.2 General Project Information

Thirty one projects were collected to analyze. The main information was collected from seven contractors, five owners, and two consultants. Other project stakeholders for each project were also contacted when necessary to collect more information. These projects were performed in Hochiminh City, Vietnam. All of them are civil building projects and private capital sources. They started from 2005 to 2011, and all of them were completed when the survey was performed. The number of projects each year was shown in Figure 8.1 below.

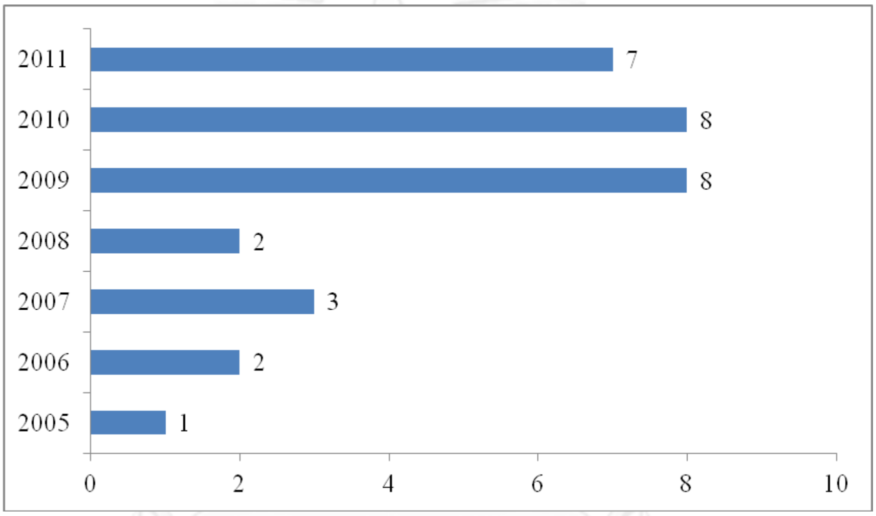


Figure 8.1 Number of projects commenced each year in large scale survey (N=31)

General project information included contract price, final price, contract duration, actual duration, cost, and time variation which were showed in section F.1 of Appendix F. The project contract price covered from 232,558 USD to 62,790,698 USD. The contract duration distributed in a wide range from 90 days to 1,440 days. Project area was from 1,606 square meters to 235,000 square meters. Figure 8.2, Figure 8.3, and Figure 8.4 below described project information. Other project information was detailed in section F.1 of Appendix F.

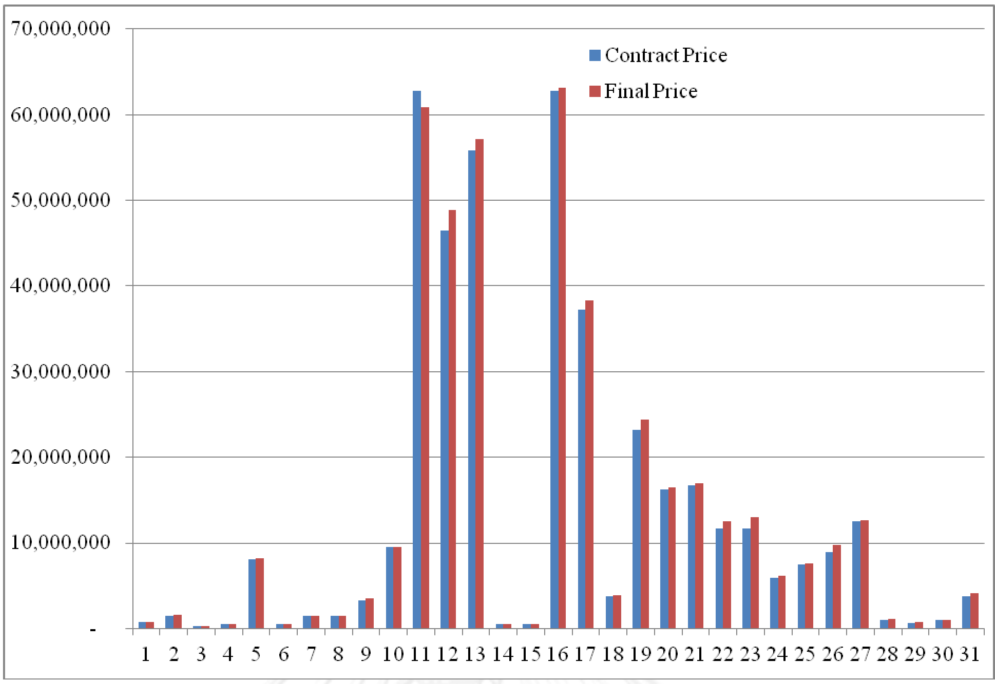


Figure 8.2 Contract price and final price of projects in large scale survey (N=31)

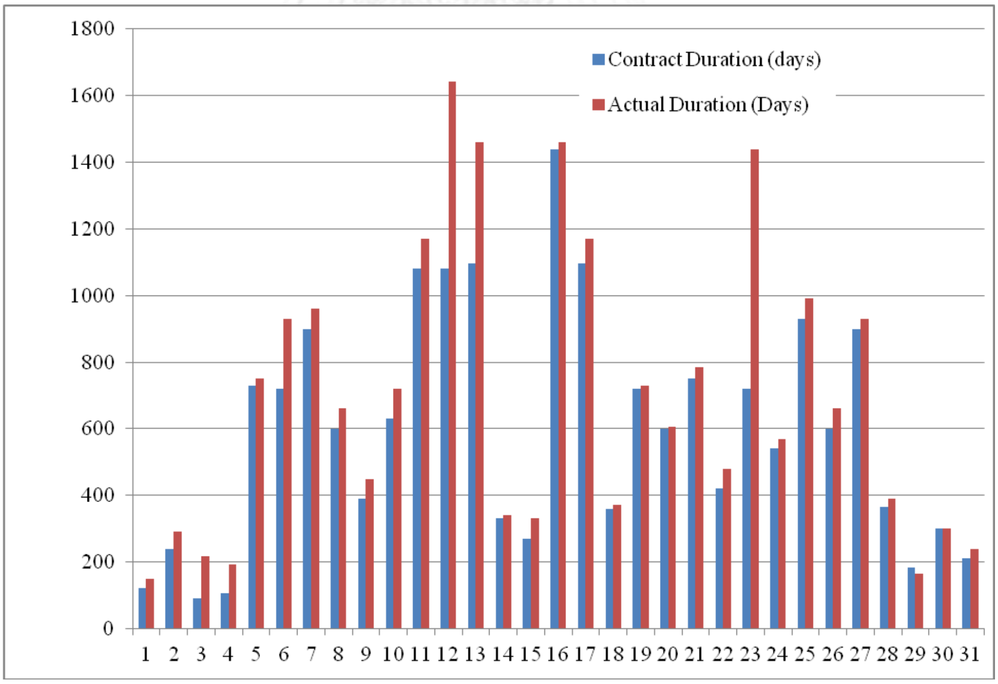


Figure 8.3 Contract duration and actual duration of projects in large scale survey (N=31)

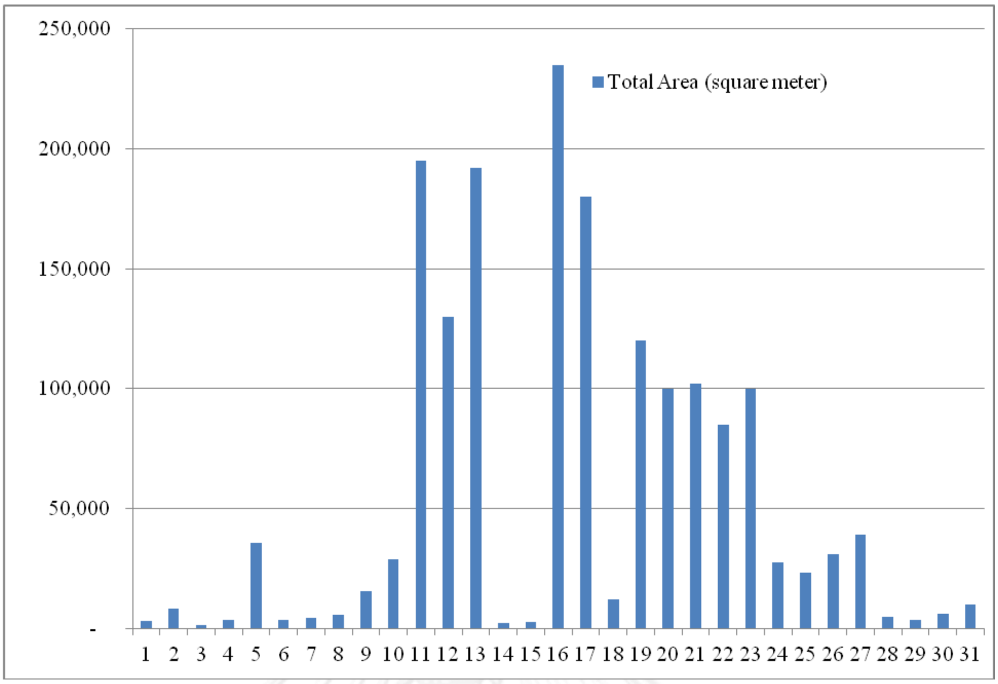


Figure 8.4 Total area of projects in large scale survey (N=31)

8.3 Project Evaluation Results Using Quantitative Multi-Criteria Construction Project Evaluation System

According to projects documentary searching and based on the QMCPE system which was described in section 7.1, evaluation results for all criteria of thirty one were achieved and summarized in section F.3 of Appendix F. Then, following the normalization rescaling in equation (7.1), all criteria were transformed to their z scores. Z scores result of each criterion was shown in section F.4 of Appendix F.

Projects were evaluated by the similar process which was used in testing phase. Each project evaluation was calculated by weighted summaries step by step. First, indicators were calculated by multiplying the criteria evaluation results in z score, with criteria weight which was summarized in Table 6.12 of Chapter 6, following the equation (7.3). Then, project score was achieved by multiplying indicators result with indicators weight, which was also summarized in Table 6.12, following the equation (7.4). Finally, the conversation was performed using equation (7.5) to achieve the final result of project evaluation. The evaluation results of some representative projects were described in Table 8.1 and Figure 8.5. The full results of thirty one projects were described in section F.2 of Appendix F. Section F.5 of Appendix F also described the evaluation of ten indicators of thirty one projects in figures.

Table 8.1 Projects evaluation results in large scale survey (N=31)

Project Code	Cost	Time	Qual	Safe	Tech	Sati	Prod	Envi	Comu	Liti	Final Project
001	60.12	38.04	25.10	53.38	25.00	44.78	39.45	28.73	58.47	56.09	33.09
002	60.12	29.91	44.95	33.92	55.13	40.71	59.45	49.49	65.90	52.38	47.97
003	74.69	33.22	31.66	39.29	41.06	56.50	39.45	30.01	42.52	46.39	36.66
004	84.37	27.91	36.84	34.86	55.13	64.15	44.39	38.82	66.38	56.39	50.62
005	65.28	50.45	29.10	70.34	45.26	46.67	51.92	59.87	42.52	52.38	49.04
006	34.41	36.76	29.10	60.41	40.80	46.67	25.00	25.00	33.52	52.38	25.00
007	39.74	60.25	64.39	69.46	75.13	58.18	46.37	41.92	85.00	57.62	67.62
008	68.68	46.42	62.23	85.00	59.33	65.84	66.37	57.24	74.90	79.76	78.19
009	44.72	47.16	69.58	76.02	65.26	65.84	71.92	56.49	76.00	66.31	73.89
010	60.10	46.36	48.95	53.38	59.59	71.59	50.55	55.53	58.47	43.16	56.93

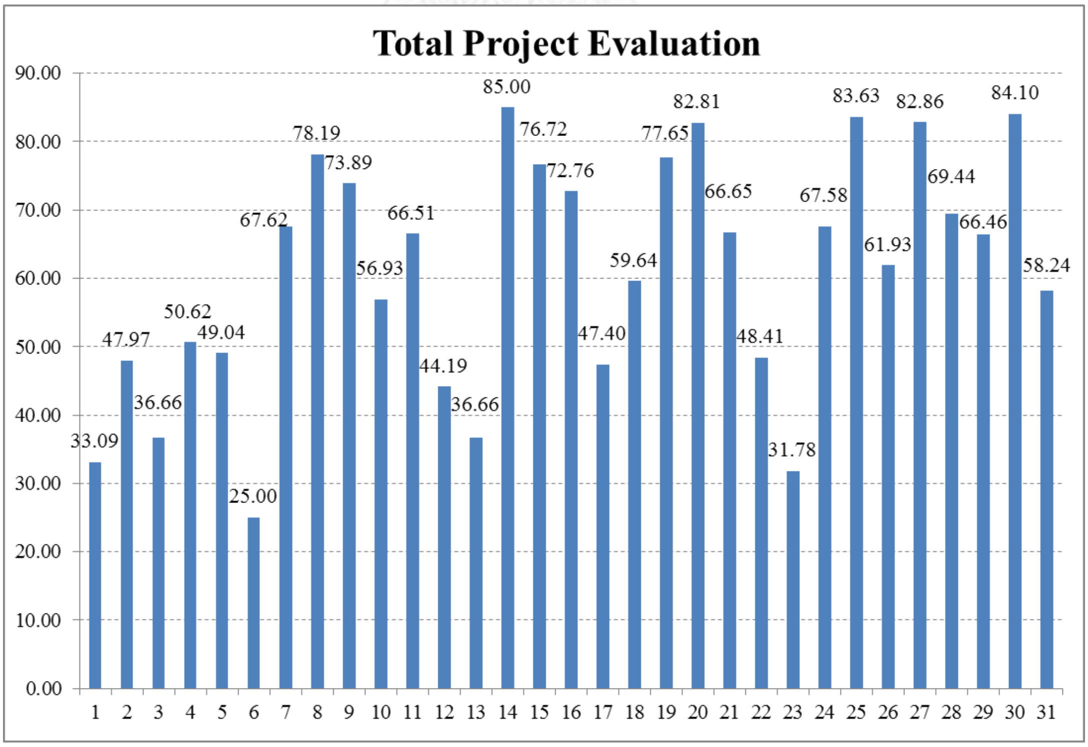


Figure 8.5 Total project evaluation result in large scale survey (N=31)

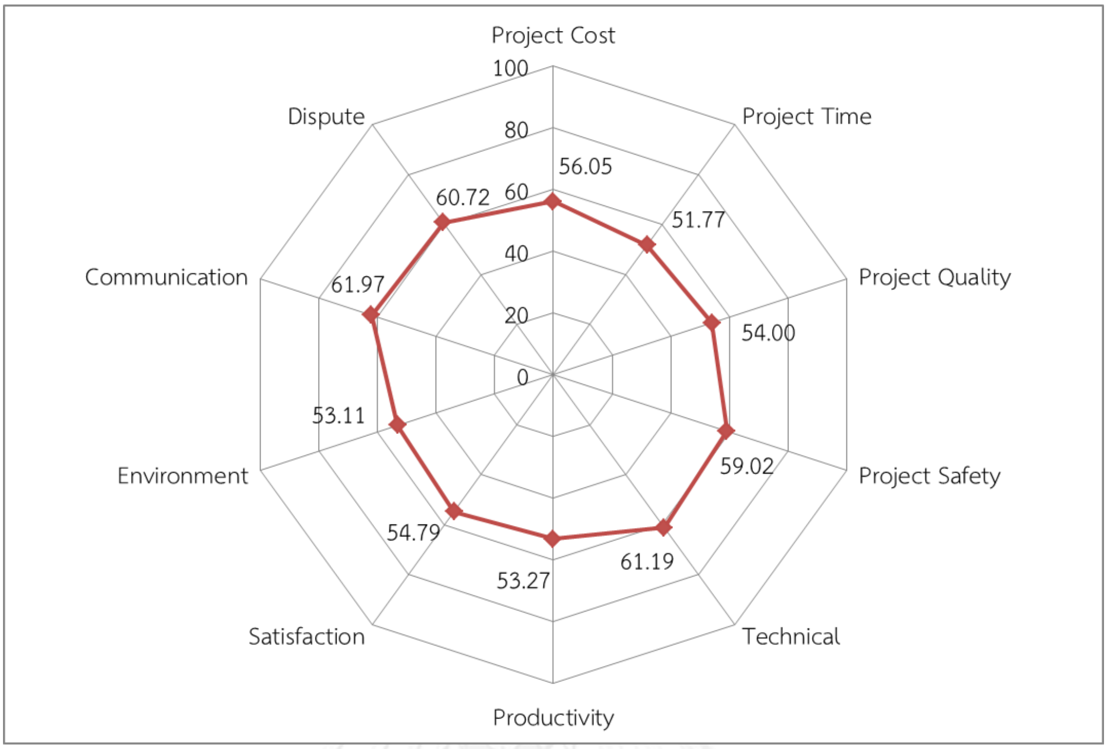


Figure 8.6 Average evaluation of eleven indicators (N=31)

The average value of construction project evaluation in this research was 60.95. The average value of each indicator evaluation was described in Figure 8.6. They ranged from 51.77 to 61.97. The highest evaluation indicator was 'Communication' (61.97). It could be explained with the development of information technology during that time. The telephone system is completed, the popular mobile phone, and the emergence of the Internet made the communication in project improved. 'Technical Performance' was 61.19, evaluated at second. 'Dispute and Litigation' in project was the third indicator, 60.72 score. 'Project Safety' (59.02), 'Project Cost' (56.05), 'Productivity' (54.79), 'Project Quality' (54.00), 'Stakeholder Satisfaction' (53.27), and 'Environment' (53.11) were respectively ranged from fourth to ninth.

The last indicator was 'Project Time' (51.77). This result was compatible with the literature review. Numerous researchers have paid attention to project delay problems all over the world (Ogunlana et al., 1996; Sambasivan and Soon, 2007; Le-Hoai et al., 2008; Tabish and Jha, 2011). From these researchers' opinion, time delay and cost overrun were two main problems in construction industry. According to Tabish and Jha (Tabish and Jha, 2011), the number of delayed projects during the first quarter (January- March) of 2007 was 301. Cost overrun from their delayed was Rs.300.58 billion, accounted for 26.09% of their original sanctioned cost. About 17.3% of the 417 government projects in Malaysia were considered 'sick' as they were delayed or abandoned more than 3 months in 2005 (Sambasivan and Soon, 2007). Therefore 'Project Time' in this duration was evaluated lowest score.

8.4 Relationship between Project Evaluation and Project Characteristic

This section discussed the average evaluation of different groups of projects. The projects in large scale survey were classified in different groups based on their contract price, contract duration, and project area. Based on the data collected, and related contract price issues, projects were classified into three groups. The first group had the contract price of less than one million, the second group ranged from one to ten million, and the third group was more than ten million United States dollars. Their proportion was showed in Figure 8.7.

Related to contract duration issue and project area issue, collected projects were also classified into three groups. Eleven projects were less than one year, eleven projects were one to two years, and the other nine projects were more than two-year contract duration. Their proportion was described in Figure 8.8. Three groups, which were classified by project area, were lower than 10,000 square meter group, from 10,000 to 100,000 square meter group, and more than 100,000 square meter group. These groups were described in Figure 8.9.

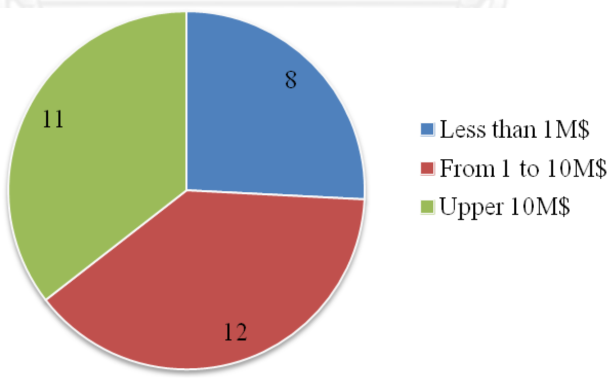


Figure 8.7 Project classification based on cost (N=31)

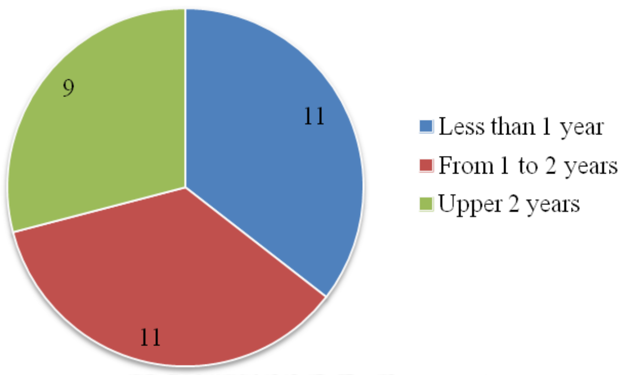


Figure 8.8 Project classification based on duration (N=31)

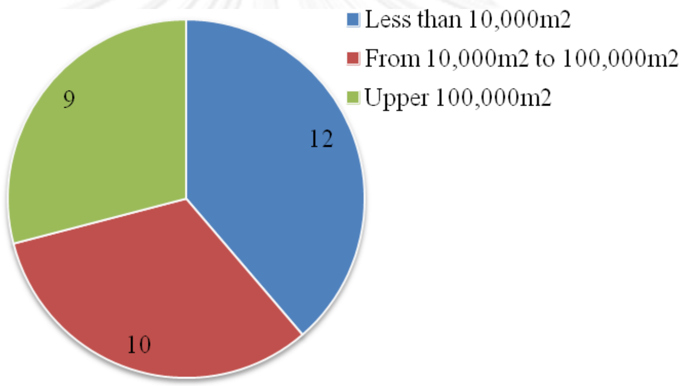


Figure 8.9 Project classification based on area (N=31)

Table 8.2 Projects evaluation result in different groups (N=31)

Group by Contract Price			Group by Contract Duration			Group by Project Area		
Project Code	Evaluation Score	Mean	Project Code	Evaluation Score	Mean	Project Code	Evaluation Score	Mean
003	36.66	57.21	003	36.66	60.72	003	36.66	60.07
006	25.00		004	50.62		014	85.00	
014	85.00		001	33.09		015	76.72	
015	76.72		029	66.46		001	33.09	
004	50.62		031	58.24		029	66.46	
029	66.46		002	47.97		006	25.00	

Group by Contract Price			Group by Contract Duration			Group by Project Area		
Project Code	Evaluation Score	Mean	Project Code	Evaluation Score	Mean	Project Code	Evaluation Score	Mean
001	33.09		015	76.72		004	50.62	
030	84.10		030	84.10		007	67.62	
028	69.44		014	85.00		028	69.44	
007	67.62		018	59.64		008	78.19	
008	78.19		028	69.44		030	84.10	
002	47.97		009	73.89		002	47.97	
009	73.89		022	48.41		031	58.24	
018	59.64		024	67.58		018	59.64	
031	58.24	64.51	008	78.19		009	73.89	
024	67.58		020	82.81		025	83.63	
025	83.63		026	61.93	59.38	024	67.58	64.22
005	49.04		010	56.93		010	56.93	
026	61.93		006	25.00		026	61.93	
010	56.93		019	77.65		005	49.04	
022	48.41		023	31.78		027	82.86	
023	31.78		005	49.04		022	48.41	
027	82.86		021	66.65		020	82.81	
020	82.81		007	67.62		023	31.78	
021	66.65		027	82.86		021	66.65	
019	77.65	59.79	025	83.63		019	77.65	
017	47.40		011	66.51	63.14	012	44.19	58.49
012	44.19		012	44.19		017	47.40	
013	36.66		013	36.66		013	36.66	
011	66.51		017	47.40		011	66.51	
016	72.76		016	72.76		016	72.76	

Project evaluation result of each group was calculated and described in Table 8.2. The analysis of variance between groups (ANOVA) was applied to explore the difference between groups. It implied the influence of project characteristics and project evaluation score. The most important result in ANOVA testing was described in Table 8.3. The whole analysis results were described in secsion F.6 of Appendix F.

Table 8.3 Results of analysis of variance between groups (N=31)

Contract Price	Sum of Squares	df	Mean Square	F	Significant
Between Groups	278.891	2	139.445	.441	.648
Within Groups	8858.183	28	316.364		
Total	9137.074	30			
Contract Duration	**Sum of Squares**	**df**	**Mean Square**	**F**	**Significant**
Between Groups	70.845	2	35.423	.109	.897
Within Groups	9066.229	28	323.794		
Total	9137.074	30			
Project Area	**Sum of Squares**	**df**	**Mean Square**	**F**	**Significant**
Between Groups	170.307	2	85.153	.266	.768
Within Groups	8966.767	28	320.242		
Total	9137.074	30			

Table 8.3 above provided both between-groups and within-groups sums of squares, degrees of freedom, and so on. The main thing should be interested in was the column marked Significant. If the Significant value was less than or equal to 0.05, then there is a significant difference somewhere among the mean scores on dependent variable for the three groups. The ANOVA results showed that these values were 0.648

(contract price group), 0.897 (contract duration group), and 0.768 (project area group). It indicated that there was no significant difference at 95% confidence among mean of these three groups. Therefore, it could be concluded that the contract price, contract duration, and project area did not influence project evaluation score.

One of the main objectives of quantitative multi-criteria construction project evaluation system was providing one more reference for contractor selection process in bidding. Using this system, the average score of collected projects were around sixty. Therefore, it was suggested that, the contractor should have higher than sixty score in his past projects to pass the criterion of contractor past performance in contractor selection process.

8.5 Summary

This chapter described the large scale survey process to develop the database of construction project evaluation. The evaluation process was performed based on quantitative multi-criteria construction project evaluation system, which was designed in the previous phase. During four months of data collection at construction companies, thirty-one projects were collected and evaluated. The average value of construction project evaluation in this research was 60.95. The average value of eleven indicators evaluation ranged from 51.77 to 61.97. Ranking eleven indicators in turn was 'Communication' (61.97), 'Technical Performance' (61.19), 'Dispute & Litigation' (60.72), 'Project Safety' (59.02), 'Project Cost' (56.05), 'Stakeholder Satisfaction' (54.79), 'Project Quality' (54.00), 'Productivity' (53.27), 'Environment' (53.11), and 'Project Time' (51.77). This result was reasonable, explainable, and compatible with the literature review and construction industry in practice during investigation.

The quantitative multi-criteria construction project evaluation system could bring several benefits and application to construction companies. One of the main objectives of the system was providing one more reference for contractor selection process in bidding. A threshold was suggested for this reference. The contractor should have higher than sixty score in his past projects to pass the criterion of contractor past performance in contractor selection process. Up to this research, the correlation between project evaluation score and project characteristics was not found.

CHAPTER 9
SOFTWARE SYSTEM FOR QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM

This chapter describes the software application of quantitative multi-criteria construction project evaluation system. It begins with the software development. Then, the software interface is described in the second section. After that, software outcomes are explained in the third section. Finally, last section presents the chapter summary.

9.1 Software Development

The quantitative multi-criteria construction project evaluation was a complex system, so it was necessary to use a software processing. It helped to improve the effect, fast process, and reliability of results. In this respect, this research developed a software solution named VT Software, based on the foundation of designed evaluation system. PHP was selected for this research because of its following advantages: open source, cross-platform, power, being user friendly, being quick, extensions, easy deployment, automatic refreshes, community support, other tools, and security. PHP still has several disadvantages such as slower and looser than some languages. However, these disadvantages do not much influence VT Software, so PHP was the choice for this research.

Three main softwares were used during VT Software designed. They were NetBeans 7.4, Xampp 1.7.1, and MySQL. NetBeans was an integrated development environment for developing primarily with Java, but also with other languages, in particular PHP, C/C++, and HTML5. It helped to write codes quicker and easier. Xampp was a free and open source cross-platform web server solution stack package, consisting mainly of the Apache HTTP Server, MySQL database, and interpreters for scripts written in the PHP and Perl programming languages. MySQL was a relational database management system and manage data contained within the databases.

The VT Software solution included four main modules:

Project stakeholders' information and coding module: In this module, each project stakeholder, which was the owner, contractor, or consultant, was coded and recorded all information. Their information included name, company address, and contact information. Each of them was provided with a code for further convenient analysis.

Weight assignment module: This module was designed based on the concept of weight assignment presented in Chapter 6. Indicators and criteria were weighted by three different methods – Summing responses, Structural equation modeling, and combination of BEES and ISM method.

Construction project evaluation module: In this module, the user had to input the general information of project and performed the assessment for each indicator and criterion. The results of project evaluation of current project will be shown in this module.

Output presentation and analysis module: VT Software provided a graphical representation of the obtained results. First, it provided evaluation of a specific project and compared it with the average value of all projects in a “spider diagram”. Second, VT Software presented the historical data of one specific contractor, owner, or consultant. Third, VT Software describes the tendency of project stakeholders’ behavior on the importance of criteria in construction project evaluation.

9.2 Software Interface

The VT Software included seven tabs such as Home, About, Category, Weight Assignment, Project Evaluation, Output, and Logout. Home tab provided general introduction about VT Software, which was shown in Figure 9.1. About tab described researcher’s biography. Category tab was designed to input project stakeholders’ information to develop a database for further needs. It had three categories for owner, contractor, and consultant to input their name, company address, and contact information. Each of them was provided with a code for further convenient analysis as displayed in Figure 9.2.

Weight Assignment tab involved three panels which were Importance Evaluation, S.E.M, and Weight Assignment Result. The user could input the responses of indicators and criteria importance level (which were discussed in Chapter 6) in the Importance Evaluation panel in Figure 9.3. Panel S.E.M showed the indicators and criteria evaluation results from the SEM method. Finally, the result of the final evaluation was showed up in the Weight Assignment Result panel as Figure 9.4. The analysis methodology under this tab was based on the weight assignment process in Chapter 6.

Project Evaluation tab included three panels which were General Information, Project Evaluation, and Project Evaluation Result. General Information panel was to input the information such as name, address, commencement day, project stakeholder, type, capital source, contract price, contract duration, area, final price, actual duration, and so on. It was described in Figure 9.5. The user needed to input the evaluation of each criterion for evaluating project in the Project Evaluation panel as Figure 9.6. This panel also provided the definition, instruction, and measurement scale for each criterion to help more convenience for users. After evaluating, the result was showed in the Project Evaluation Result panel as Figure 9.7.

The Output tab provided some statistical analysis in graphic to help users have a general view. It included Project Evaluation, History of project evaluation, and Weight Assignment Historical Data. Project Evaluation panel, which was described in Figure 9.8, provided a comparison between specific project outcomes and the average value. The users needed to input its code and the result was showed up. History of project evaluation panel in Figure 9.9 indicated historical evaluation of any project stakeholders in graphic. It implied company development tendency. This result should be combined with some information related to company strategy, construction industry environment, and government policy to understand about that company clearly. Weight Assignment Historical Data panel provided tendency of relative weight of each indicator and criterion. It described how change of the respondents' perspective about the importance level of project evaluation criteria is. Because this research performed importance survey one time, so the result could not display the tendency.

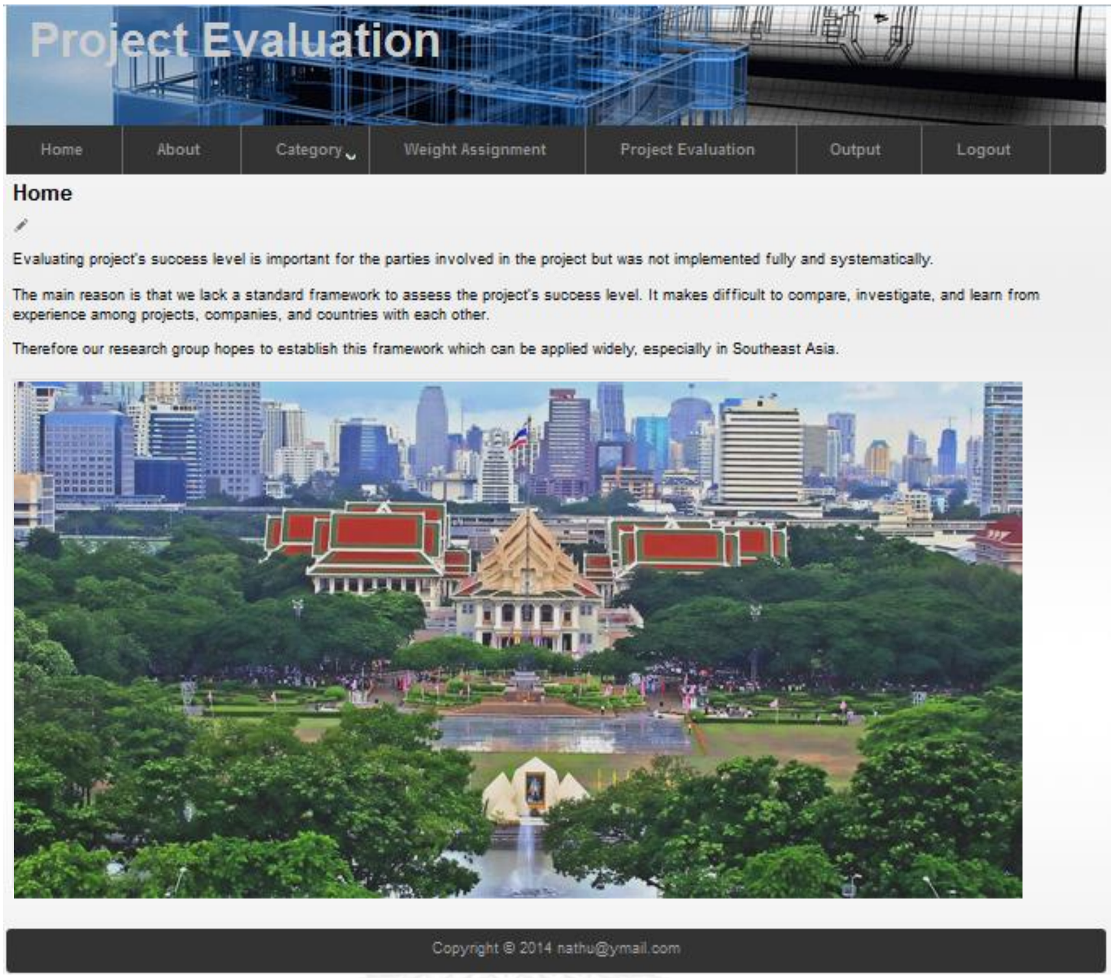


Figure 9.1 The home panel of the VT Software

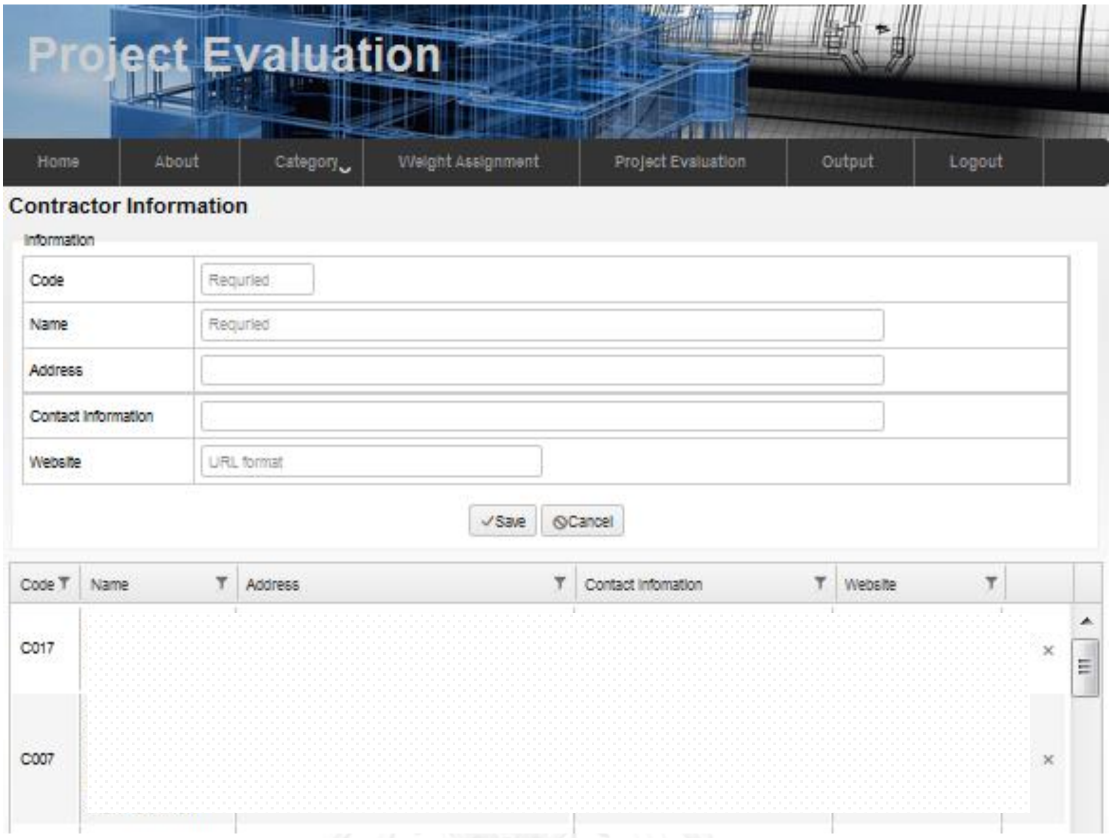


Figure 9.2 The panel for project stakeholder information in VT Software

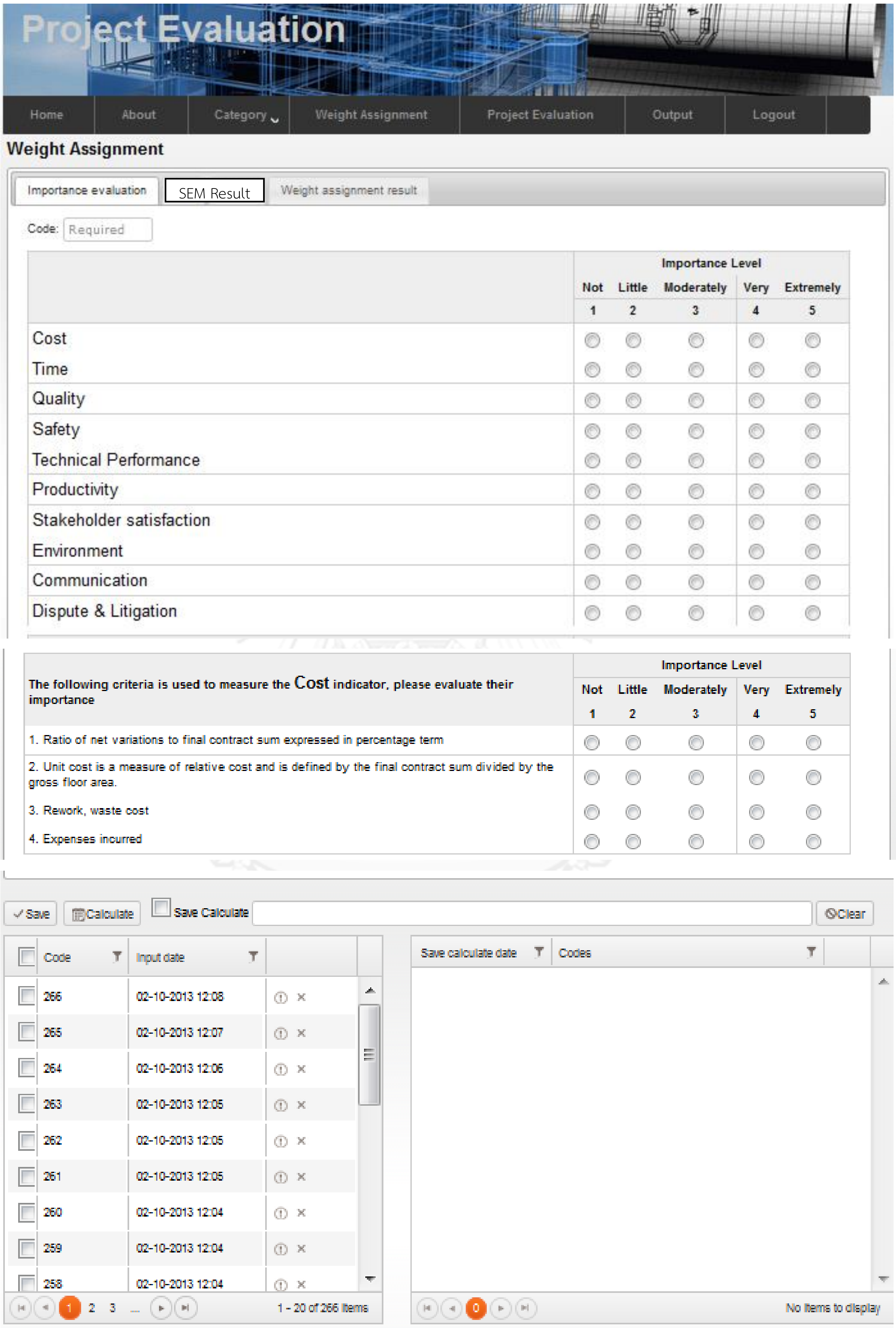
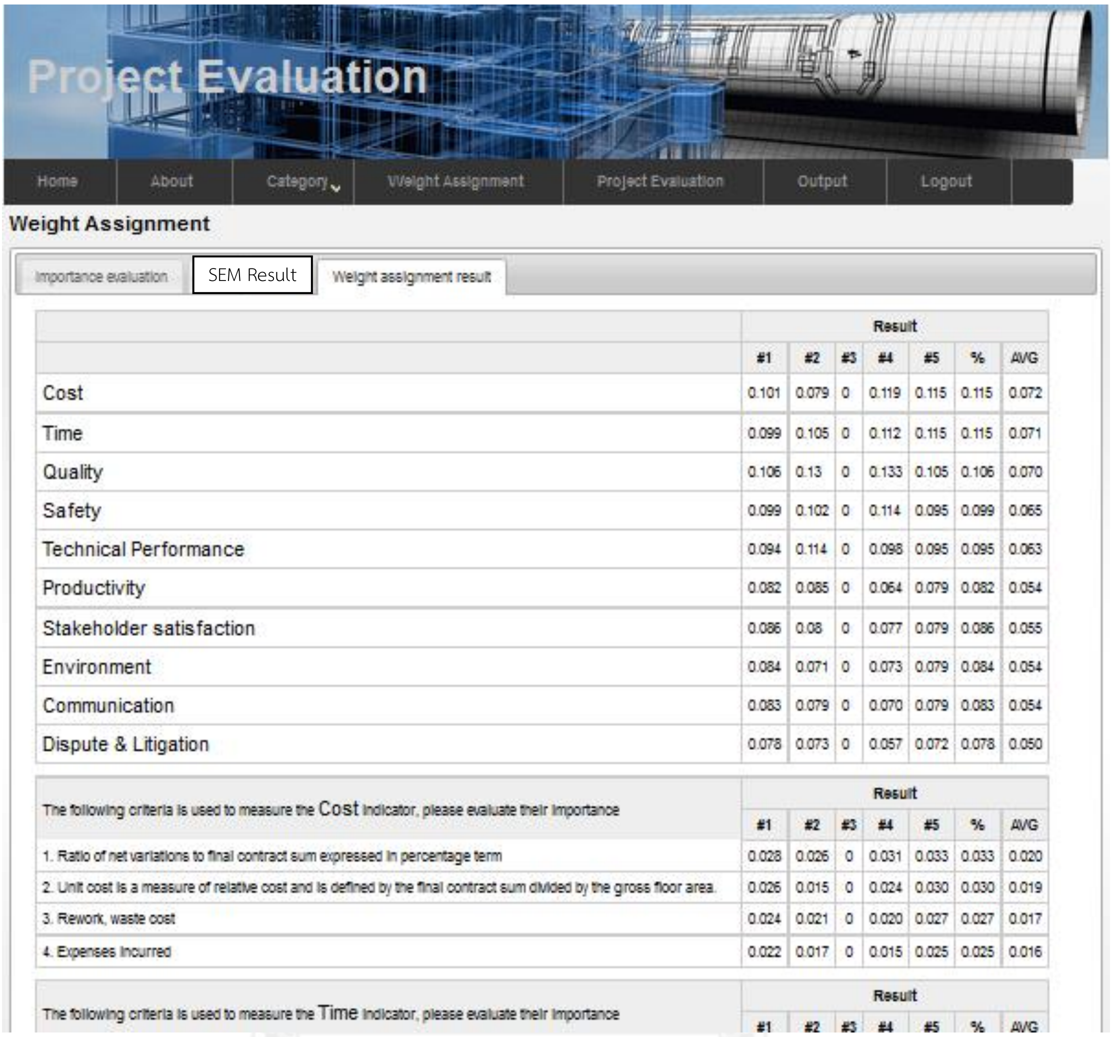


Figure 9.3 The panel for weight assignment, input indicators and criteria importance scale, in VT Software



	Result						
	#1	#2	#3	#4	#5	%	AVG
Cost	0.101	0.079	0	0.119	0.115	0.115	0.072
Time	0.099	0.105	0	0.112	0.115	0.115	0.071
Quality	0.106	0.13	0	0.133	0.105	0.106	0.070
Safety	0.099	0.102	0	0.114	0.095	0.099	0.065
Technical Performance	0.094	0.114	0	0.098	0.095	0.095	0.063
Productivity	0.082	0.085	0	0.064	0.079	0.082	0.054
Stakeholder satisfaction	0.086	0.08	0	0.077	0.079	0.086	0.055
Environment	0.084	0.071	0	0.073	0.079	0.084	0.054
Communication	0.083	0.079	0	0.070	0.079	0.083	0.054
Dispute & Litigation	0.078	0.073	0	0.057	0.072	0.078	0.050

The following criteria is used to measure the Cost indicator, please evaluate their importance	Result						
	#1	#2	#3	#4	#5	%	AVG
1. Ratio of net variations to final contract sum expressed in percentage term	0.028	0.026	0	0.031	0.033	0.033	0.020
2. Unit cost is a measure of relative cost and is defined by the final contract sum divided by the gross floor area.	0.026	0.015	0	0.024	0.030	0.030	0.019
3. Rework, waste cost	0.024	0.021	0	0.020	0.027	0.027	0.017
4. Expenses incurred	0.022	0.017	0	0.015	0.025	0.025	0.016

The following criteria is used to measure the Time indicator, please evaluate their importance	Result						
	#1	#2	#3	#4	#5	%	AVG

Figure 9.4 The panel for weight assignment, weight assignment result, in VT Software

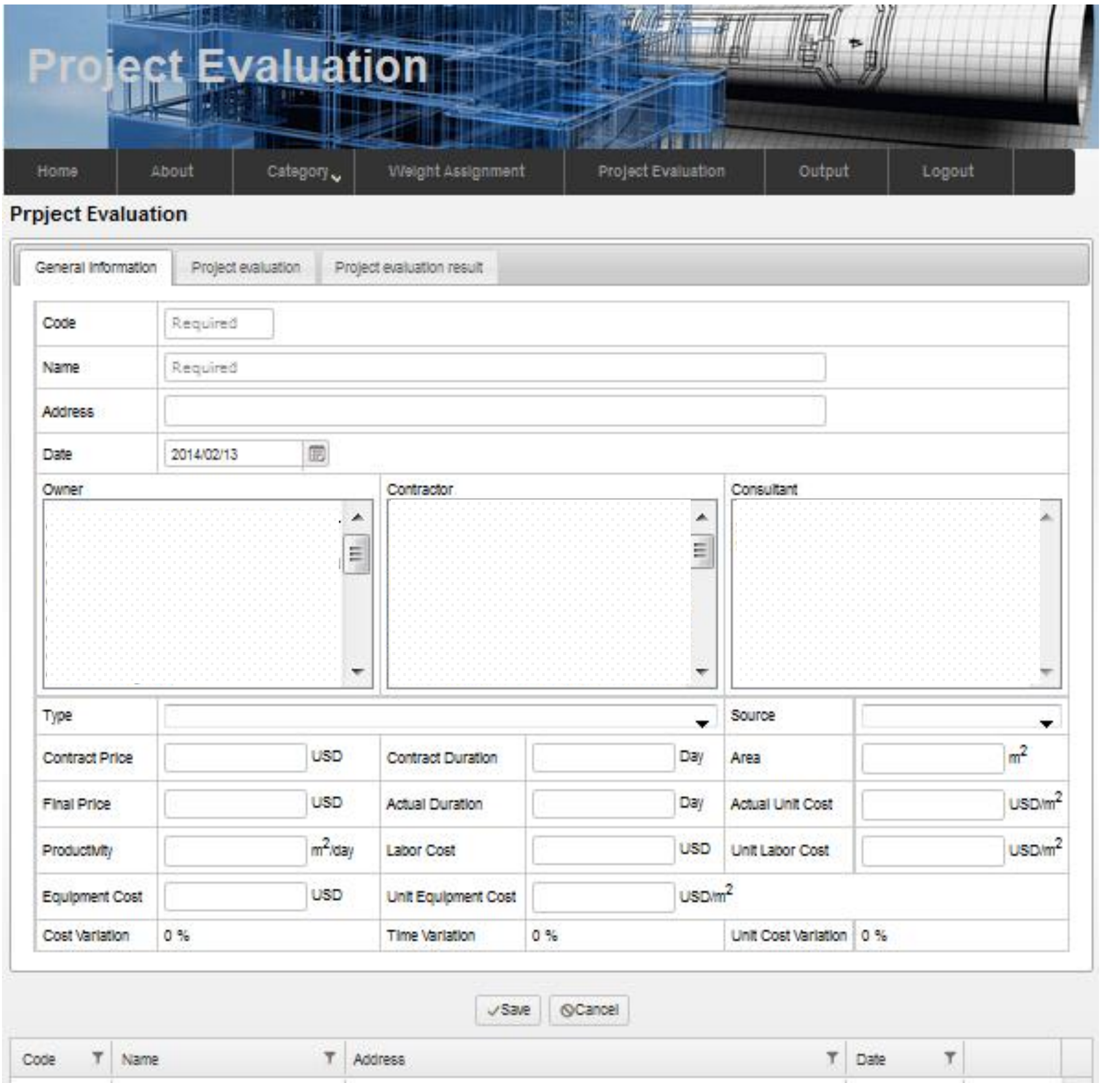


Figure 9.5 The panel for project evaluation, input general information, in VT Software

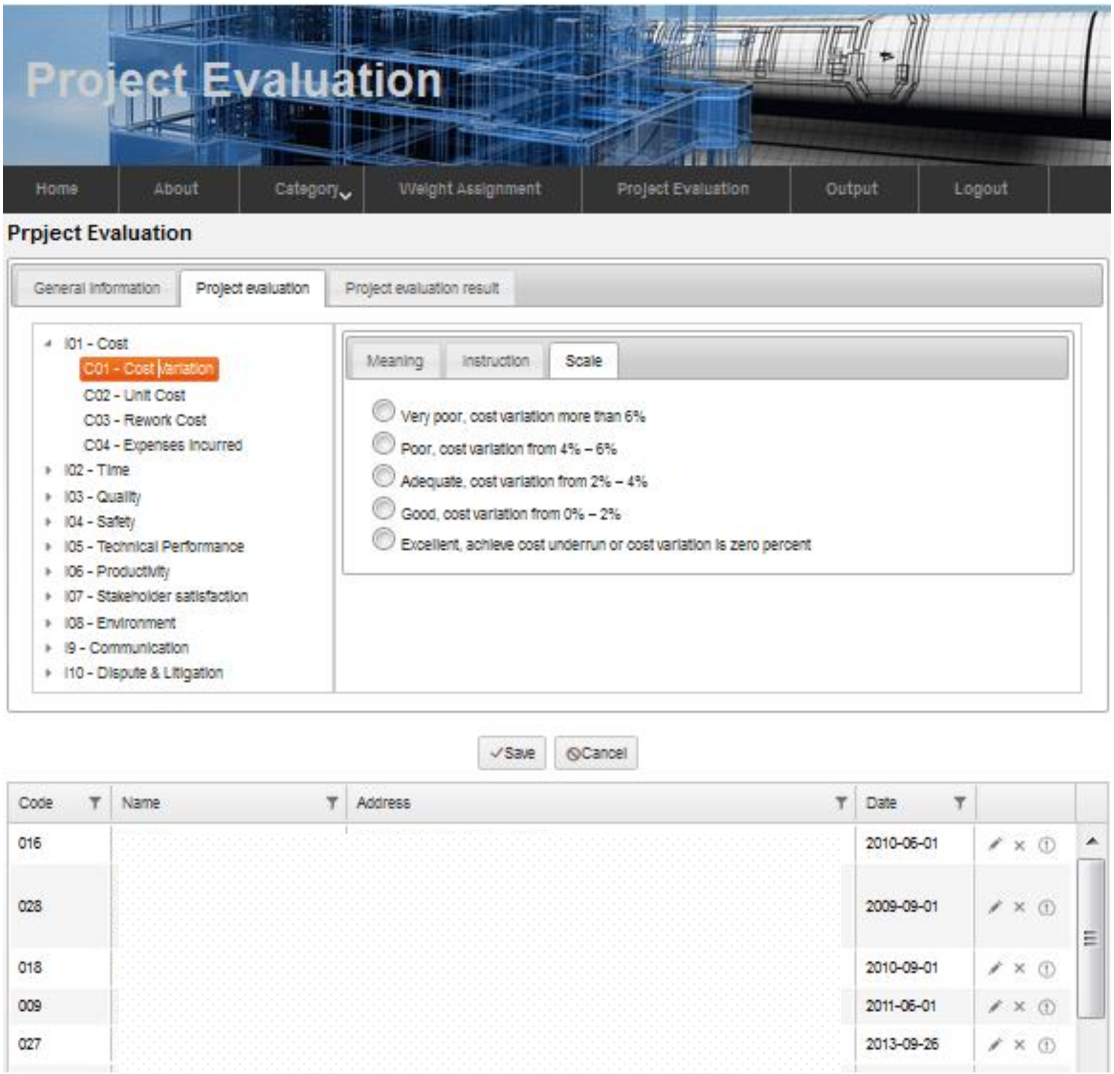


Figure 9.6 The panel for project evaluation, input criteria evaluation, in VT Software

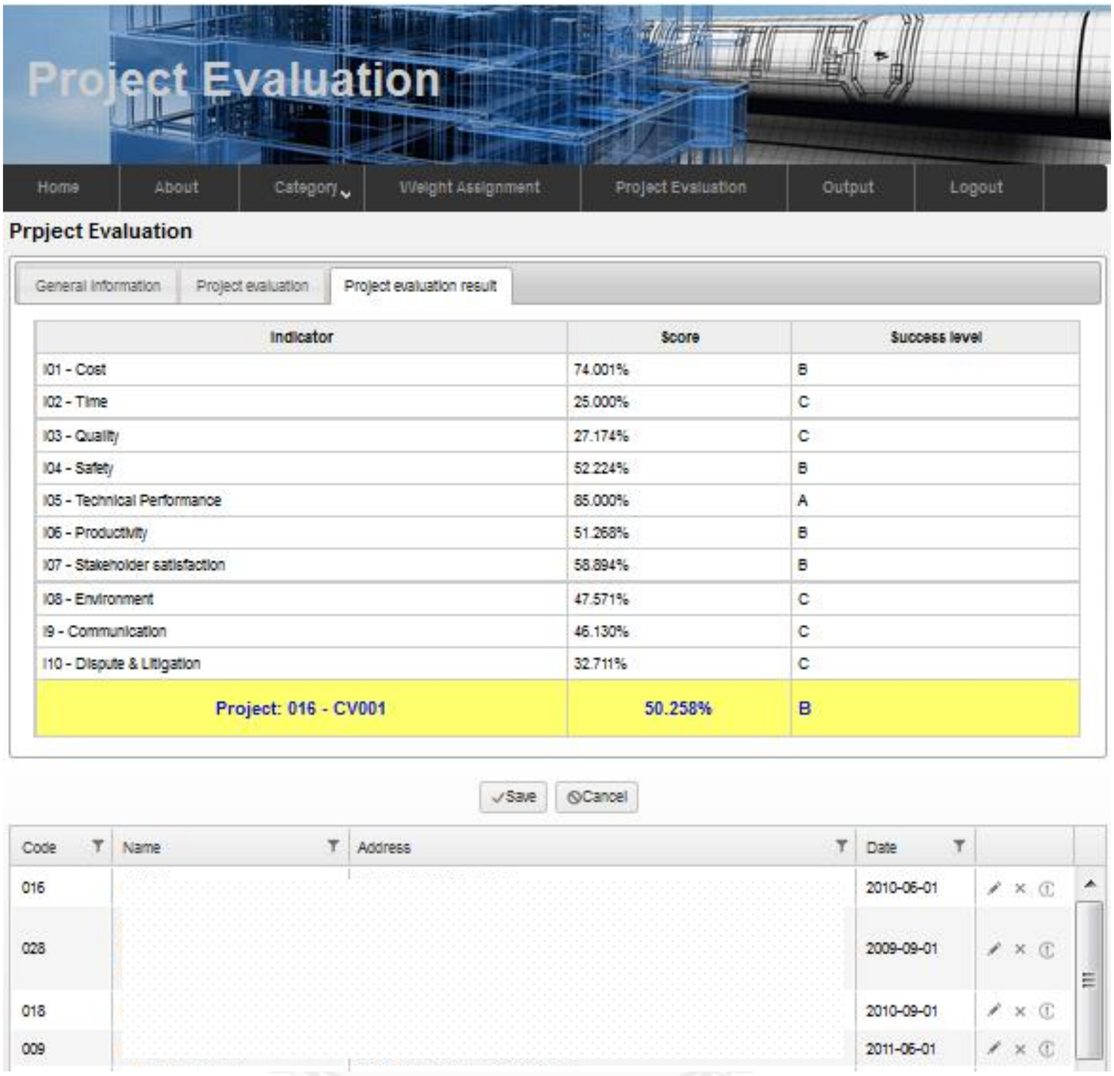


Figure 9.7 The panel for project evaluation, project evaluation result, in VT Software

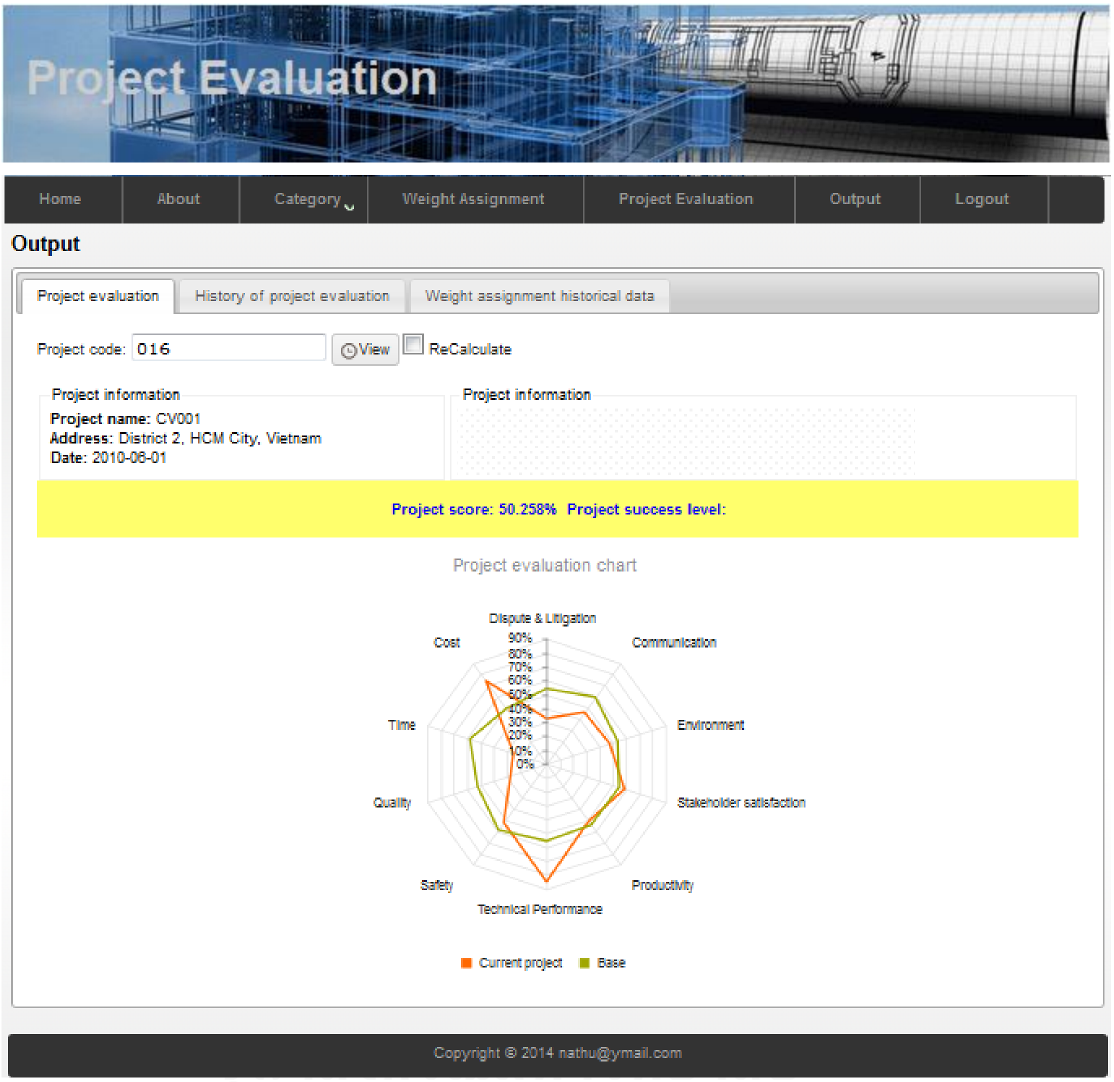


Figure 9.8 The panel for output analysis, a project evaluation results comparing with the average, in VT Software

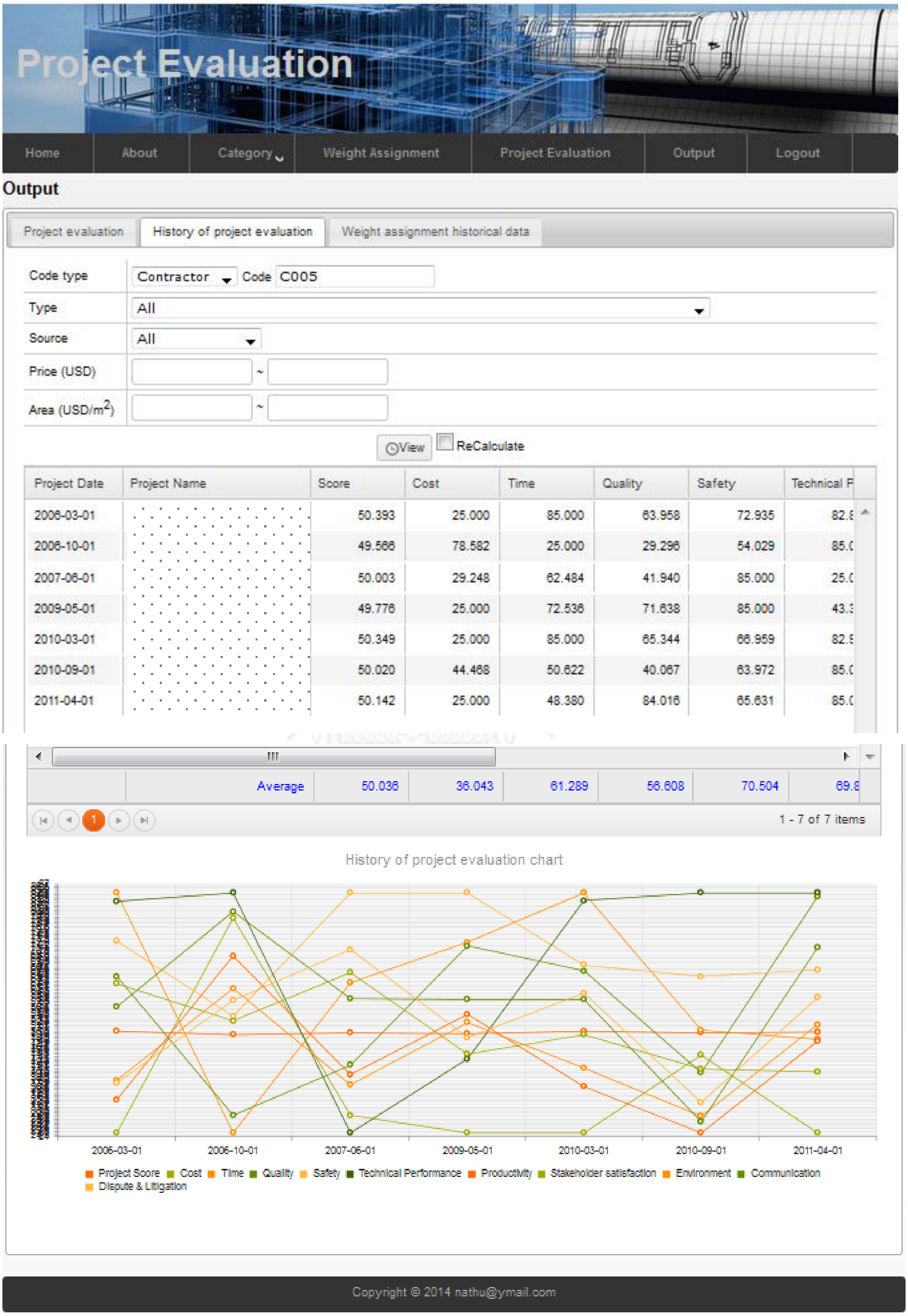


Figure 9.9 The panel for output analysis, history project evaluation of one contractor, in VT Software

9.3 Summary

This chapter described the VT Software development. It was designed based on the concept and methodology of construction project evaluation system. VT Software was designed by PHP language with the contribution of NetBeans, Xampp, and MySQL. It was hoped that VT Software could make the evaluation process faster, easier, and more reliable.

CHAPTER 10
SUMMARY AND CONCLUSION

10.1 Summary

Construction project success evaluation was assessed very important. It was interesting and studied by a huge amount of researchers. The first group of researchers created a solid foundation for this study when they described the whole picture of project success measurement indexes (De Wit, 1988; Songer et al., 1997; Liu and Walker, 1998; Crane et al., 1999; Lim and Mohamed, 1999; Tukel and Rom, 2001; White and Fortune, 2002; Bryde and Robinson, 2005; Ahadzie et al., 2008; Al-Tmeemy et al., 2011). The second group of researchers not only presented the list of indexes but also described the methodology to evaluate each index. They were Shenhar and Levy (1997); Chan et al. (2002); Chan and Chan (2004); and Tabish and Jha (2011). The third group of researchers concentrated on exploring the importance weight and methodology to combine all indexes. They were Griffith et al. (1999); Chua et al. (1999); Shawn et al. (2004); Menches and Hanna (2006); and Shahrzad Khosravi (2011).

Previous measuring project success models depended on the evaluators' perception (Chan et al., 2002). Secondly, each model was developed based on one party's point of view (Menches and Hanna, 2006). Thirdly, some quantitative evaluation models were difficult to practice in the current developing countries. Lastly, previous researches lacked methodology to combine the evaluation of each index. These problems made project evaluation model in the previous studies difficult to disseminate in construction industry.

The construction industry, especially in developing countries, needed a complete framework for project success evaluation. This research was conducted to achieve this mission. The quantitative multi-criteria construction project evaluation system (QMCPE) was achieved in this research. The system provided the completed indicators and criteria of evaluation system, their weight assignment, instruction for evaluating each indicator and criterion, their measurement scale, and combination method. The QMCPE system was assessed that it was a better system, well performed, efficient, valuable, and appropriate after testing. Continuously, the QMCPE system was applied in large scale survey to develop the construction project evaluation data. Finally, the concept and methodology of the QMCPE system was used to design VT Software.

The initial list of indicators and criteria of construction evaluation was collected from the literature review and interviewing experts in construction field as discussed in Chapter 3. It included eleven indicators and fifty-one criteria. The indicators were 'Project Time', 'Project Cost', 'Project Quality', 'Project Safety', 'Technical Performance', 'Productivity', 'Waste Materials', 'Stakeholder Satisfaction', 'Sustainable Environment', 'Communication', and 'Disputes & Litigation'.

The final list of indicators and criteria of construction evaluation was achieved after conducting preliminary study in Chapter 5. Because of the objectives and expected outcomes of research, collecting necessary information from construction industry was quite complex and difficult. Therefore, the preliminary survey was conducted to explore the feasibility of research and achieve final list of indicators and criteria.

The final indicators and criteria in this list had to satisfy three criteria, which were high capacity to collect information, high level of importance, and high degree of application to evaluate project success. To achieve this objective, two surveys were performed. The first survey collected information from twenty-eight completed projects to consider data collection capacity to evaluate project success. The second survey gathered opinions from sixty-five respondents about the importance level and applicability level of each indicator and criterion. From analysis results, one indicator and six criteria were eliminated from the list. Final list included ten indicators which were clearly described by forty-five criteria. Final indicators were 'Project Time', 'Project Cost', 'Project Quality', 'Project Safety', 'Technical Performance', 'Productivity', 'Stakeholder Satisfaction', 'Sustainable Environment', 'Communication', and 'Disputes & Litigation'.

Weight assignment for indicators and criteria was achieved by carrying out importance survey in Chapter 6. In this survey, 266 valuable data were collected, analyzed and calculated. Weight assignment was calculated by three methods which were Summing Responses, Structural Equation Modeling, and Combination of BEES & ISM method. And then, by comparing these results and the statistical analysis, the results from these three methods were kept to combine and calculate the final result.

The results indicated that 'Project Quality', 'Project Cost', and 'Project Time' were the most three important aspects for the evaluation. 'Project Safety', 'Technical Performance', and 'Project Stakeholder Satisfaction' were ranked fourth, fifth, and sixth in all three methods. Other four indicators, which were 'Environment', 'Communication', 'Productivity', and 'Dispute & Litigation', were ranked seventh, eighth, ninth, and tenth in turn. The weight assignment result was accurate, quantitative, and reliable result with less subjectivity. Moreover, this result was reasonable, explainable, and compatible with the literature review in the evaluation of construction project success. For these reasons, this result could be used for further construction project evaluation in next phase.

The QMCPE system was achieved and described in Chapter 7. The implementation of the system was introduced in five aspects: the completed indicators and criteria of the evaluation system, standardization of their weight assignment, instruction for evaluating each indicator and criterion, their measurement scale, and combination method. The system performance was tested by three representative projects in construction field. Then, a focus group meeting was conducted to evaluate and validate the system. The meeting among nine experts in construction industry was held to reach the agreement and conclusion. The result indicated that, the system was an innovation, well performed, efficient, valuable, and appropriate to apply in construction companies, suitable, and necessary to disseminate.

Large scale survey was performed to develop a database for construction project evaluation. The evaluation process was performed based on the QMCPE system. During four months of data collection at construction companies, thirty one projects were collected and evaluated.

The average value of construction project evaluation in this research was 60.95. The average value of indicators evaluation was ranged from 51.77 to 61.97. The highest evaluation indicator was ‘Communication’ (61.97). ‘Technical Performance’ was 61.19, evaluated at second. ‘Dispute and Litigation’ in project was the third indicator, 60.72 score. ‘Project Safety’ (59.02), ‘Project Cost’ (56.05), ‘Productivity’ (54.79), ‘Project Quality’ (54.00), ‘Stakeholder Satisfaction’ (53.27), and ‘Environment’ (53.11) were respectively ranged from fourth to ninth. The last indicator was ‘Project Time’ (51.77). This result was reasonable, explainable, and compatible with the literature review and construction industry in practice during investigation.

The QMCPE system could bring several benefits and application to construction companies. One of the main objectives of the system was providing one more reference for contractor selection process in bidding. A threshold was suggested for this reference. The contractor should have higher than sixty score in his past projects to pass the criterion of contractor past performance in contractor selection process.

This threshold was not depended on the project chracteristics such as contract price, contract duration, or project area.

The VT Software was developed based on the concept and methodology of the QMCPE system. Because the QMCPE was a complex system, so it was necessary to use a software processing. It helped to improve the effect, fast process, and reliability of results. VT Software was designed by PHP language with the contribution of NetBeans, Xampp, and MySQL. It was hoped that VT Software could make the evaluation process faster, easier, and more reliable.

10.2 Research Discussion and Conclusion

Firstly, the construction project evaluation was necessary and could be measured. The problem of whether the project success could be measured or not have been addressed by many researchers a long time ago. According to De Wit (1988), measuring success was complex because it depended on the stakeholders' point of view and it was time dependent. A party may acknowledge project was successful but another may take the opposite view. It is successful today but may fail tomorrow. De Wit (1988) believed that it was an illusion to measure the project success objectively. However, he pointed out that it was possible and valuable to evaluate projects at post-completion stage. The Project Management Institute conference held in Montreal in 1986 received the earlier version of papers related to "measuring success", implied a message that project success is possible to determine. A huge amount of last studies in literature review and the achievement of this research were strong evidences for this conclusion.

Secondly, the construction evaluation system was an urgent mission. This conclusion was achieved from both the literature review and research surveys. In the preliminary survey, which was described in Chapter 5, among sixty-five valid responses, 47.70% responses believed that the proposed system is extremely important, 50.80% responses indicated it was very important, and 1.5% responded it was important. The similar view in importance survey was described in Chapter 6. Among 260 responses, 125 people believed that the proposed system is extremely important; 94 people thought that it is very important, and they comprised more than 84% of the responses. The remaining 16% of the respondents did not highly appreciate the importance of project success evaluation framework. However, 87.7% respondents have never evaluated construction project when it completed. These results implied that the proposed system was significant and necessary to study.

The QMCPE system, which was established in this research, was an innovative system, well performed, efficient, valuable, and appropriate to apply in construction companies, suitable, and necessary to disseminate, according to the interviewees' evaluation in group meeting. The implementation of the system was introduced in five aspects: the completed indicators and criteria of the evaluation system, standardization of weight assignment, instruction for evaluating each indicator and criterion, their measurement scale, and combination method.

Indicators and criteria weight assignment was calculated by three methods which were SR, SEM, and BEES & ISM. It was observed that all the three methods ranked 'Project Quality', 'Project Cost', and 'Project Time' as the most three important aspect for the evaluation. This result was compatible with the background information related to project evaluation which was conducted by De Wit (1988), Songer et al. (1997), Liu and Walker (1998), Chan et al. (2002), Chan and Chan (2004). 'Project Safety', 'Technical Performance', 'Project Stakeholder Satisfaction', 'Environment', 'Communication', 'Productivity', and 'Dispute & Litigation' were ranked from fourth to tenth in turn. The weight assignment result was accurate, quantitative, and reliable result with less subjectivity. Moreover, this result was reasonable, explainable, and compatible with the literature review in evaluation of construction project success.

The QMCPE system provided a quantitative measurement for criteria in evaluating construction projects. Project was evaluated by ten indicators which were achieved by fourty-five criteria. Each criterion was measured quantitatively. For example, in order to evaluate cost performance, four criteria were used which were 'Cost Variation', 'Unit Cost', 'Reworks Cost', and 'Expenses Incurred'. 'Cost Variation' was measured by the difference between contract price and final price. It was similar to the method suggested from previous researchers (De Wit, 1988; Songer et al., 1997; Crane et al., 1999; Chan et al., 2002; Menches and Hanna, 2006). 'Unit Cost' was the construction cost per gross floor area (Chan et al., 2002; Chan and Chan, 2004). 'Reworks Cost' and 'Expenses Incurred' were evaluated differently compared with Shawn et al. method (Shawn et al., 2004). Shawn et al. (2004) provided a subjective assessment from (-3) to (+3) to evaluate 'Reworks Cost' and 'Expenses Incurred'. The QMCPE system used the percentage of reworks cost and expenses incurred per initial estimated cost to evaluate them. Therefore, it could minimize the subjectivity and bias in evaluation.

The average value of construction project evaluation in this research was 60.95. The average value of indicators evaluation was ranged from 51.77 to 61.97. The highest evaluation indicator was ‘Communication’ (61.97). It could be explained with the development of information technology during that time. The telephone system is completed, the popular mobile phone, and the emergence of the Internet made the communication in project improved. ‘Technical Performance’ was 61.19, evaluated at second. ‘Dispute and Litigation’ in project was the third indicator, 60.72 score. ‘Project Safety’ (59.02), ‘Project Cost’ (56.05), ‘Productivity’ (54.79), ‘Project Quality’ (54.00), ‘Stakeholder Satisfaction’ (53.27), and ‘Environment’ (53.11) were respectively ranged from fourth to ninth.

The last indicator was ‘Project Time’ (51.77). This result was compatible with the literature review. Numerous researchers have paid attention to project delay problems all over the world (Ogunlana et al., 1996; Sambasivan and Soon, 2007; Le-Hoai et al., 2008; Tabish and Jha, 2011). From these researchers’ opinion, time delay and cost overrun were two main problems in construction industry. According to Tabish and Jha (Tabish and Jha, 2011), the number of delayed project during the first quarter (January- March) of 2007 was 301. Cost overrun from their delayed was Rs.300.58 billion, accounted for 26.09% of their original sanctioned cost. About 17.3% of 417 government projects in Malaysia were considered ‘sick’ since they were delayed or abandoned more than 3 months in 2005 (Sambasivan and Soon, 2007). Therefore ‘Project Time’ in this duration was evaluated lowest score.

One of the main objectives of the QMCPE system was providing one more reference for contractor selection process in bidding. Using this system, the average score of collected projects was around sixty. Therefore, it was suggested that, the contractor should have higher than sixty score in his past projects to pass the criterion of contractor past performance in contractor selection process. Up to this research, there was no correlation between project evaluation score and project chracteristics found. It could be concluded that the project evaluation score was not depended on some project characteristics such as contract price, contract area, and project area.

10.3 Research Contributions

This research has several implications for theory, methodology and practice related to construction project evaluation and weight assignment methodology.

In theory, this research provided an innovative practical list of indicators and criteria for project evaluation and the QMCPE system. Although there are many models from previous studies to evaluate project success, the QMCPE system in this research have contributed additional components. List of indicators and criteria was developed from three sources, which were the literature review (theory), previous documents of completed projects (industrial sources), and experts and respondents (academic and human opinions). Therefore, it was fully representative and objective. The list of criteria in the QMCPE system was ensured that they could be evaluated by real information when project completed. The criteria evaluation and combination in the QMCPE system overcome the limitations of previous studies in practical evaluation. It was an appropriate system at current status, quantitative and unbias, fair and objective, easy and applicable.

In methodology, this research introduced some weight assignment methods for weighting indicators and criteria in the QMCPE system. They were Summing Responses, Structural Equation Modeling, and Combination of BEES & ISM method. The results of this research suggested that these methods were appropriate in construction project success evaluation system. These methods followed the probability of mathematical procedures. They were reliable in weight assignment and less subjective.

In practice, this research provided many benefits which were the QMCPE system, project evaluation database, and the VT software. The QMCPE could bring a lot of benefits to all project stakeholders. For contractor, the QMCPE system was useful to assess projects when it completed, compare one project with other projects in their company. It helped to improve their companies, and achieve continuous improvement. For the government management, the QMCPE system was extremely valuable. It helped to develop a database of construction project evaluation, contractor performance, tendency of construction project performance, and tendency of importance level of indicators and criteria. From that, government could better manage, control, and improve policies. For the owner, the QMCPE system helped to look back on how a project performed. It was a reference for future project strategy.

The QMCPE system provided one more reference for contractor selection process in bidding. Based on the construction evaluation database achieved by the QMCPE system, a threshold for contractor selection was suggested. The contractor should have higher than sixty score in his past projects to pass the criterion of contractor past performance in contractor selection process. Because the QMCPE was a complex system, so VT Software was developed. It was hoped that VT Software could make the evaluation process faster, easier, and more reliable.

10.4 Limitations and Directions for Future Research

The suggestions for future research can be splitted into two groups: those concerning the essence of the QMCPE system and those concerning the data collected to develop the system.

The QMCPE system was designed corresponding to the requirements of the current construction industry environment. However, the requirements of a competitive business environment such as construction industry change day by day. Thus, in the future, the investigation of construction project evaluation may be maintained constantly and updated to catch new developments. Moreover the list of indicators and criteria, and weight assignment may be redesigned according to up to date information.

From the preliminary survey, six criteria were eliminated because of their data collection capacity. The rejected criteria were ‘Cost for contingencies’, ‘Cost for unsatisfied works’, ‘Total expenditures for safety management in project’, ‘Total expenditures to handle and compensate of accidents occur during construction’, ‘Total time lost due to accident occur’, and ‘Waste materials in construction site’. These criteria were under ‘Project Cost’, ‘Project Quality’, ‘Project Safety’, and ‘Waste material’ indicators. They were rejected because they were considered difficult to collect information. However, they were perceived as high importance level criteria (from 3.55 to 3.95). Therefore, lacking these criteria is a limitation of this system. The future studies should concern on these criteria.

The QMCPE system implementation requires a lot of project information. It may make a part construction companies encounter with the difficulties in using it. So, the decision for using this system should be made at the beginning stage of project, and may consider as a company strategy. It needs a roadmap to implement the system step by step. The support from government is extremely important to widespread this system.

Questionnaire survey was distributed to companies established in Vietnam therefore perceptions of only Vietnam companies were acquired. The conclusions of the research may be tested in different countries than Vietnam and a more global view of the construction project evaluation in practice may be determined. Adoption of a global mode may lack local requirements specific to each country; nevertheless a globally homogenized and mobile model may be designed responding to the requirements of different countries’ market environment.

This research concentrated on building projects which have more than three stores or height above ten meters, and private projects only. So, the conclusions about construction project evaluation and the suggested threshold for contractor selection in this survey compatible for this group of projects. An extensive survey on large-scale should be conducted on different types of projects to have an overview of the current construction industry environment.

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APPENDICES

APPENDIX A

QUESTIONNAIRE AND DOCUMENT CHECKLIST USED IN PRELIMINARY SURVEY (ENGLISH)

SURVEY OF POSSIBILITY OF PROVIDING INFORMATION FROM COMPLETED CONSTRUCTION PROJECTS TO ESTABLISH A QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM

Respectfully addressed to esteem company,

My name is Nguyễn Anh Thư. I'm a PhD student of Construction Engineering and Project Management field, Faculty of Civil Engineering, Chulalongkorn University, Thailand and Hokkaido University, Japan. I'm researching in topic: **Establish a framework to evaluate project's success level after project completed.**

Evaluating project's success level is important for the parties involved in the project but was not implemented fully and systematically. The main reason is that we lack a standard framework to assess the project's success level. It makes us difficult to compare, investigate, and learn from experience of each other among projects, companies, and countries. Therefore, our research group hopes to establish this framework which can apply widely, especially in Southeast Asia.

This questionnaire is designed to explore what are the main indicators and sub-indicators that should be used to evaluate project success. Answering this information is strongly depending on your working experience. We hope you will take some time for complete this survey. ***Please be assured that all information collected will be kept in strict confidence, and the results will be made available only in-group summary form without identifying individuals***. *Your genuine response and cooperation would be much appreciated.* Please, there are no correct answers; the best answers are those that honestly reflect your feelings.

Contact details:

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We hope to receive the support from you and your esteem company. Heartfelt thanks!

SURVEY OF POSSIBILITY OF PROVIDING INFORMATION FROM COMPLETED CONSTRUCTION PROJECTS TO ESTABLISH A QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM

PART 1. General Information of a typical completed project

1. Project name :………………………………. …………………

2. Project place :………………………………. …………………

3. Owner : ………………………………. …………………

4. Contractor : ………………………………. …………………

5. Project capital according to contract: ………………………………. ……

6. Construction duration according to contract: ………………………. ………

7. Project type:

☐ Civil project (appartment, condo, office, school, market, commercial central,…)

☐ Infrastructural project (bridge, road, port,…)

☐ Others, ………………………………. ……………………….

8. Investment capital type:

☐ Public fund

☐ Private

☐ Others, ………………………………. ……………………….

9. Providing information party:

☐ Owner ☐ Contractor ☐ Others:………………

10. From your previous projects, have you ever evaluated level of project success of completed projects?

☐ Yes, I have ☐ No, I have never

If "Yes", you have worked as a staff of (you may select many options)?

☐ Owner ☐ Contractor ☐ Consultant

PART 2. Possibility of providing information from completed projects

Proposed indicators and criteria	Possibility of providing information		
	Project has this information and **possible** to provide	Project has this information but **impossible** to provide, cause	Project does not have this information
I. Information about project **cost**			
1. Project cost variation			
2. Project unit cost			
3. Expenses incured			
4. Rework costs			
5. Budget for contingencies			
Others information can be used:			
II. Information about project **time**			
1. Project time variation			
2. Speed of construction (Actual duration/floor area)			
3. Material availability: Time delay because of supplying materials			
4. Equipment availability: Time delay because of lack of equipments			
5. Labor availability: Time delay because of lack of labor			
Others information can be used:			

III. Information about project **quality**

Could you provide your opinion to evaluate the different level between quality expectation of owner and real project quality after completed?

☐ Yes, It is possible ☐ It is possible, but difficult ☐ It is impossible

Could you provide your opinion to evaluate the degree of conformance to predetermined standard?

☐ Yes, It is possible ☐ It is possible, but difficult ☐ It is impossible

Information about implementing the “Evaluate the suitability project quality certificate” in the project?

☐ Yes, It is possible ☐ It is possible, but difficult ☐ It is impossible

Information about errors that need to rework when taking over the project

☐ Project has this information and **possible** to provide

☐ Project has this information but **impossible** to provide, because:…………………..

☐ Project does not have this information

Information about budget to rework unsatisfied quality requirement works

☐ Project has this information and **possible** to provide

☐ Project has this information but **impossible** to provide, because:…………………..

☐ Project does not have this information

Information about time to rework unsatisfied quality requirement works

☐ Project has this information and **possible** to provide

☐ Project has this information but **impossible** to provide, because:…………………..

☐ Project does not have this information

Proposed indicators and criteria	Possibility of providing information		
	Possible to provide information or evaluation opinion	Difficult to provide information or evaluation opinion, cause	Impossible to provide information or evaluation opinion
IV. Information about **health and safety**			
1. Number of death injures or accidents			
2. Number of heavy accidents			
3. Number of slightly accidents			
4. Total expenditures for safety management in project			
5. Total expenditures to handle and compensate of accidents occur during construction			
6. Total time lost due to accident occur			
7. Evaluation of safety signs			
8. Evaluation of providing safety tools and protection equipment			
9. Evaluation safety level of equipment used in construction			
10. Evaluation of safety training			
11. Evaluation of safety responsibility staffs			
Others information can be used:			
V. Information about **technical performance** in project			
1. Evaluation of the contractor’s response to the technical requirements of project			

2. Evaluation of technical problem identification and solution			
3. Overall assessment qualifications of workers in the project			
4. Evaluation of the possibility of problem solving of technical staff			
Others information can be used:			
VI. **Productivity**			
1. Total number of labor			
2. Total labor cost			
3. Total equipment cost			
Others information can be used:			
VII. Information about **waste materials** in project			
1. Cost of waste primary materials such as steel, coppha, scaffolding,...			
Others information can be used:			
VIII. **Satisfaction**			
1. Owner satisfaction			
2. Contractor satisfaction			
3. Consultant satisfaction			
Others information can be used:			

IX. **<u>Environmental sustainability</u>**			
1. Frequency of complaints from the environment and communities around the construction site			
2. Frequency of time reminded about sanitation from the authorities			
3. The number of time and duration suspended from the authorities			
4. Assessing the recovery of the contractor when warned			
4. Expenses for ensuring environmental sustainability			
5. Expenses of overcoming the problems of environmental sanitation			
Others information can be used:			
X. ***<u>Communication</u>***			
1. Evaluation the communication in project			
2. The frequency of misinformation or delays affecting the project			
3. Information systems used in project			
Others information can be used:			
XI. **<u>Conflicts, litigation, and disputes</u>** in project			
1. Evaluation of conflict level about settlement payment			
2. Evaluation of conflict level among parties in check and take over the project			

3. Evaluation of relationship between contractor and owner after project completed			
4. Information about penalties for breach of contract			
Others information can be used:			

Others indexes which have not mentioned above:

……

……

……

…………………………………………………………………………………………………

Number of projects information that company can provide in implementing the proposed tool for evaluating the project success level:

☐ 3 projects ☐ 3 to 5 projects ☐ 5 to 10 projects ☐ More than 10

If you don't mind, could you please provide me your contact information, (*all of your information will be secured)*:

Your name : ……………………………………………………………………………………..

Your email : ……………………………………………………………………………………..

Phone number : …………………………………………………………………………………….

RESPONDENT'S OPINION ABOUT IMPORTANCE LEVEL AND APPLICABILITY LEVEL OF PROPOSED INDICATORS AND CRITERIA IN QUANTITATIVE MULTI-CRITERIA CONSTRUCTION PROJECT EVALUATION SYSTEM

PART 1. Background Information

1. Company for which you are working:………………………………. ……………

2. Your current position :…………………………………. ……………

3. Experience working in construction field: …………. ……………………………

4. Please specify your age : …………………… ………………………………

5. Please specify your academic background

☐ Under bachelor degree ☐ Bachelor degree ☐ Upper bachelor degree

6. Number of completed projects that you have taken part in

☐ Under 3 projects ☐ 3 to 5 projects ☐ More than 5 projects

If you have taken part in completed project, you have worked as a staff of (you may select many options)?

☐ Owner ☐ Contractor ☐ Consultant

☐ Other, ………………………………………………………………………

7. From your opinion, how important a framework is to evaluate project's success level?

☐ Very important

☐ Important

☐ Not sure whether important or not

☐ Not important

8. From your previous projects, have you ever evaluated level of success of completed projects?

☐ Yes, I have ☐ No, I have never

PART 2. Importance Level and Applicability Level of Proposed Indicators and Criteria in Quantitative Multi-criteria Construction Project Evaluation System

Important scale:

Not important at all	**Little** important	**Moderately** important	**Very** important	**Extremely** important
1	**2**	**3**	**4**	**5**

Applicability scale

Impossible	**Probably Not**	**Chances about even**	**Probable**	**Almost Certain**
1	**2**	**3**	**4**	**5**

Proposed indicators and criteria	**Importance Level**					**Application Capacity**				
	Not	Little	Moderately	Very	Extremely	Impossible	Prob Not	Chances	Prob	Almost Cert
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
I. Project **cost**										
1. Project cost variation										
2. Project unit cost										
3. Expenses incurred										
4. Rework costs										
5. Budget for contingencies										
II. Project **time**										
1. Project time variation										
2. Speed of construction (Actual duration/floor area)										
3. Material availability: Time delay because of supplying materials										

Proposed indicators and criteria	Importance Level					Application Capacity				
	Not	Little	Moderately	Very	Extremely	Impossible	Prob Not	Chances	Prob	Almost Cert
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
4. Equipment availability: Time delay because of lack of equipments										
5. Labor availability: Time delay because of lack of labors										
III. Project **quality**										
1. The different level between quality expectation of owner and real project quality after completed										
2. Degree of conformance to predetermined standard										
3. Implement the “Evaluate the suitability project quality certificate” in the project										
4. Error needs to rework when taking over the project										
5. Information about budget to rework unsatisfied quality requirement works										
6. Information about time to rework unsatisfied quality requirement works										
IV. Information about **health and safety**										
1. Number of death injures or accidents										
2. Number of heavy accidents										
3. Number of slightly accidents										
4. Total expenditures for safety management in project										

Proposed indicators and criteria	Importance Level					Application Capacity				
	Not	Little	Moderately	Very	Extremely	Impossible	Prob Not	Chances	Prob	Almost Cert
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
5. Total expenditures to handle and compensate of accidents occur during construction										
6. Total time lost due to accident occur										
7. Evaluation of safety signs										
8. Evaluation of providing safety tools and protection equipment										
9. Evaluation safety level of equipment used in construction										
10. Evaluation of safety training										
11. Evaluation of safety responsibility staffs										
V. Information about **technical performance** in project										
1. Evaluation of the contractor's response to the technical requirements of project										
2. Evaluation of technical problem identification and solution										
3. Overall assessment qualifications of workers in the project										
4. Evaluation of the possibility of problem solving of technical staff										
VI. **Productivity**										
1. Total number of labor										
2. Total labor cost										
3. Total equipment cost										

Proposed indicators and criteria	Importance Level					Application Capacity				
	Not	Little	Moderately	Very	Extremely	Impossible	Prob Not	Chances	Prob	Almost Cert
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
VII. Information about **waste materials**										
1. Cost of waste primary materials such as steel, coppha, scaffolding,...										
VIII. **Satisfaction**										
1. Owner satisfaction										
2. Contractor satisfaction										
3. Consultant satisfaction										
IX. **Environmental sustainability**										
1. Frequency of complaints from the environment and communities around the construction site										
2. Frequency of time reminded about sanitation from the authorities										
3. The number of time and duration suspended from the authorities										
4. Assessing the recovery of the contractor when warned										
5. Expenses for ensuring environmental sustainability										
6. Expenses of overcoming the problems of environmental sanitation										
X. ***Communication***										
1. Evaluation of the communication in project										
2. The frequency of misinformation or delays affecting the project										

Proposed indicators and criteria	Importance Level					Application Capacity				
	Not	Little	Moderately	Very	Extremely	Impossible	Prob Not	Chances	Prob	Almost Cert
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
3. Information systems used in project										
XI. **Conflicts, litigation, and disputes**										
1. Evaluation of conflict level about settlement payment										
2. Evaluation of conflict level among parties in checking and taking over the project										
3. Evaluation of relationship between contractor and owner after project completed										
4. Information about penalties for breach of contract										

Others indexes which have not mentioned above:

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……………………………………………………………………………………………

If you don't mind, could you please provide me your contact information, (*all of your information will be secured)*:

Your name : ……………………………………………………………………………………..

Your email : ……………………………………………………………………………………..

Phone number : ……………………………………………………………………………………..

Current project you are working for: ……………………………………………………………………………………..

APPENDIX B

QUESTIONNAIRE AND DOCUMENT CHECKLIST USED IN PRELIMINARY SURVEY (VIETNAMESE)

BẢNG KHẢO SÁT

KHẢO SÁT KHẢ NĂNG ĐÁP ỨNG THÔNG TIN TỪ NHỮNG DỰ ÁN ĐÃ HOÀN THÀNH NHẰM XÂY DỰNG TIÊU CHUẨN ĐÁNH GIÁ MỨC ĐỘ THÀNH CÔNG CỦA DỰ ÁN XÂY DỰNG

Kính gửi Quí công ty và các Anh/Chị,

Tôi tên Nguyễn Anh Thư, hiện là nghiên cứu sinh chuyên ngành Công nghệ và Quản lý xây dựng liên kết giữa Trường Đại học Chulalongkorn, Thái Lan và Trường Đại học Hokkaido, Nhật Bản. Tôi đang thực hiện đề tài nghiên cứu: **Xây dựng khung tiêu chuẩn đánh giá mức độ thành công của dự án sau khi hoàn thành.**

Việc đánh giá dự án sau khi hoàn thành có ý nghĩa vô cùng quan trọng đối với các bên tham gia dự án nhưng lại chưa được thực hiện một cách đầy đủ và có hệ thống. Lý do chủ yếu là chúng ta thiếu một khung tiêu chuẩn đánh giá mức độ thành công của dự án để từ đó có thể so sánh, học hỏi, rút kinh nghiệm giữa các dự án, giữa các công ty, và giữa các quốc gia với nhau. Do đó, nhóm nghiên cứu chúng tôi hy vọng sẽ xây dựng được công cụ này với phạm vi ứng dụng là các nước trong khu vực Đông Nam Á.

Dưới đây là tập hợp các câu hỏi mà việc xem xét đánh giá chúng có liên quan rất nhiều đến kinh nghiệm thực tế trong quá trình công tác của Anh/Chị. Rất mong Anh/Chị dành chút thời gian cho việc trả lời những câu hỏi này. ***Mọi thông tin Anh/Chị cung cấp sẽ được giữ bí mật và chỉ được dùng để phục vụ cho nghiên cứu***. *Xin chân thành cảm ơn.*

Tác giả sẵn sàng chia sẻ mọi thắc mắc và kết quả nghiên cứu. Xin vui lòng liên hệ:

Nguyễn Anh Thư – Nghiên cứu sinh, ngành Công nghệ và quản lý xây dựng, trường Đại học Chulalongkorn, Thái Lan và Trường Đại học Hokkaido, Nhật Bản

Địa chỉ: Bộ môn Thi Công và Quản Lý Xây Dựng, Khoa Kỹ thuật Xây dựng, Trường Đại học Bách Khoa TPHCM, 268 Lý Thường Kiệt, P.14, Q.10, TP.HCM

Điện thoại: (08) 8647345 – (+66)85.1984750 – (+84)903.097.709

Email: nathu@ymail.com; nathu@hcmut.edu.vn

Kính mong Quí công ty và các Anh/Chị giúp đỡ hỗ trợ thông tin để tác giả có thể hoàn thành đề tài nghiên cứu một cách tốt đẹp. Xin chân thành cảm ơn!

KHẢO SÁT KHẢ NĂNG ĐÁP ỨNG THÔNG TIN TỪ NHỮNG DỰ ÁN ĐÃ HOÀN THÀNH NHẰM XÂY DỰNG TIÊU CHUẨN ĐÁNH GIÁ MỨC ĐỘ THÀNH CÔNG CỦA DỰ ÁN XÂY DỰNG

*Nhóm nghiên cứu chúng tôi đang tiến hành bước thứ nhất trong dự án, nghiên cứu tính khả thi của việc thu thập dữ liệu có thể đưa vào **Khung tiêu chuẩn đánh giá mức độ thành công của dự án sau khi hoàn thành.** Anh/Chị vui lòng cung cấp những thông tin bên dưới.*

Phần 1. Thông tin chung của một dự án tiêu biểu đã hoàn thành

1. Tên dự án :…………………………………. ……………………………

2. Vị trí :…………………………………. ……………………………

3. Chủ đầu tư : …………………………………. ……………………………

4. Đơn vị thi công : …………………………………. ……………………………

5. Kinh phí theo giá trị hợp đồng: …………………………………. …………………

6. Thời gian thi công theo hợp đồng: …………………………………. ………………

7. Loại dự án:

☐ Dự án dân dụng (chung cư, văn phòng, trường học, siêu thị, trung tâm thương mại,…)

☐ Dự án hạ tầng (cầu, đường, cảng,…)

☐ Loại khác, …………………………………. ………………………………

8. Vốn đầu tư:

☐ Ngân sách nhà nước

☐ Tư nhân

☐ Loại khác, …………………………………. ………………………

9. Đơn vị cung cấp thông tin:

☐ Chủ đầu tư ☐ Nhà thầu ☐ Đơn vị khác:…………………

10. Anh/Chị và công ty Anh/Chị công tác có từng đánh giá mức độ thành công của dự án sau khi dự án được hoàn thành hay không?

☐ Có ☐ Chưa bao giờ

Nếu đã từng đánh giá, Anh/Chị đánh giá mức độ thành công của dự án trên cương vị của đơn vị nào (Anh/Chị có thể chọn nhiều lựa chọn bên dưới)?

☐ Chủ đầu tư ☐ Nhà thầu ☐ Đơn vị tư vấn

Phần 2. *Anh/Chị vui lòng cho biết ý kiến về khả năng cung cấp những thông tin bên dưới bằng cách đánh dấu (x) vào câu trả lời thích hợp.*

Các thông số dự kiến có thể được sử dụng trong công cụ ***Đánh giá mức độ thành công của dự án***	Khả năng đáp ứng thông tin của dự án đang đề cập		
	Dự án có thông tin có thể cung cấp	Dự án có thông tin nhưng khó cung cấp, lý do	Dự án không có thông tin
I. Thông tin về ***kinh phí*** dự án			
1. Chênh lệch giữa chi phí theo hợp đồng và giá trị quyết toán			
2. Chi phí đơn vị tính trên mỗi mét vuông sàn xây dựng			
3. Chi phí phát sinh			
4. Chi phí hao phí do phải làm lại một số công việc			
5. Chi phí sử dụng cho những biến cố bất ngờ			
Thông tin khác có thể sử dụng:			
II. Thông tin về ***tiến độ*** dự án			
1. Chênh lệch giữa thời gian dự kiến hoàn thành theo kế hoạch và thực tế			
2. Tốc độ thi công tính bằng tổng thời gian trên diện tích sàn			
3. Sự đáp ứng tiến độ của vật tư trong quá trình thi công tính bằng thời gian chậm trễ do sự cung ứng vật tư			

4. Sự đáp ứng tiến độ của thiết bị trong quá trình thi công tính bằng thời gian chậm trễ do thiết bị không sẵn sàng			
5. Sự đáp ứng tiến độ của nhân công trong quá trình thi công tính bằng thời gian chậm trễ do thiếu nhân công			
Thông tin khác có thể sử dụng:			

III. Thông tin về ***chất lượng*** dự án

Anh/Chị có thể cung cấp ý kiến đánh giá mức độ khác nhau về chất lượng theo mong muốn của chủ đầu tư và chất lượng thực tế sau khi hoàn thành hay không?

☐ Có thể ☐ Có thể nhưng có chút khó khăn ☐ Không thể

Anh/Chị có thể đánh giá mức độ công trình đáp ứng các tiêu chuẩn chất lượng trong quá trình thi công hay không?

☐ Có thể ☐ Có thể nhưng có chút khó khăn ☐ Không thể

Anh/Chị có thể cho biết dự án có thực hiện đánh giá sự phù hợp chất lượng công trình hay không?

☐ Có thể ☐ Có thể nhưng có chút khó khăn ☐ Không thể

Thông tin về những lỗi cần khắc phục khi bàn giao công trình

☐ Dự án có thông tin có thể cung cấp

☐ Dự án có thông tin nhưng khó cung cấp, lý do:……………………………………………..

☐ Dự án không có thông tin trên

Thông tin về chi phí để khắc phục những chi tiết không đảm bảo chất lượng

☐ Dự án có thông tin có thể cung cấp

☐ Dự án có thông tin nhưng khó cung cấp, lý do:……………………………………………..

☐ Dự án không có thông tin trên

<table>
<tr><td colspan="4">Thông tin về thời gian để khắc phục những chi tiết không đảm bảo chất lượng
☐ Dự án có thông tin có thể cung cấp
☐ Dự án có thông tin nhưng khó cung cấp, lý do:…………………………………………..
☐ Dự án không có thông tin trên</td></tr>
<tr><td rowspan="2">Các thông số dự kiến có thể được sử dụng trong công cụ Đánh giá mức độ thành công của dự án</td><td colspan="3">Khả năng đáp ứng thông tin của dự án đang đề cập</td></tr>
<tr><td>Có thể cung cấp thông tin (hoặc) ý kiến đánh giá</td><td>Dự án có thông tin nhưng khó cung cấp, lý do</td><td>Không thể cung cấp thông tin (hoặc) ý kiến đánh giá</td></tr>
<tr><td colspan="4">IV. Thông tin về <u>an toàn lao động</u> (ATLĐ)</td></tr>
<tr><td>1. Số tai nạn lao động gây chết người</td><td></td><td></td><td></td></tr>
<tr><td>2. Số tai nạn lao động nặng</td><td></td><td></td><td></td></tr>
<tr><td>3. Số tai nạn lao động nhẹ</td><td></td><td></td><td></td></tr>
<tr><td>4. Tổng kinh phí chi cho quản lý ATLĐ trong dự án</td><td></td><td></td><td></td></tr>
<tr><td>5. Tổng kinh phí chi cho việc xử lý tai nạn lao động xảy ra trong khi thi công</td><td></td><td></td><td></td></tr>
<tr><td>6. Tổng thời gian thất thoát do tai nạn lao động xảy ra.</td><td></td><td></td><td></td></tr>
<tr><td>7. Đánh giá về biển báo ATLĐ</td><td></td><td></td><td></td></tr>
<tr><td>8. Đánh giá việc trang bị công cụ bảo hộ ATLĐ cho công nhân</td><td></td><td></td><td></td></tr>
<tr><td>9. Đánh giá việc đảm bảo an toàn trang thiết bị phục vụ thi công</td><td></td><td></td><td></td></tr>
<tr><td>10. Đánh giá việc huấn luyện ATLĐ</td><td></td><td></td><td></td></tr>
<tr><td>11. Đánh giá việc bố trí cán bộ ATLĐ</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Các thông số dự kiến có thể được sử dụng trong công cụ Đánh giá mức độ thành công của dự án</td><td colspan="3">Khả năng đáp ứng thông tin của dự án đang đề cập</td></tr>
<tr><td>Có thể cung cấp thông tin (hoặc) ý kiến đánh giá</td><td>Dự án có thông tin nhưng khó cung cấp, lý do</td><td>Không thể cung cấp thông tin (hoặc) ý kiến đánh giá</td></tr>
<tr><td colspan="4">V. Thông tin về <u>chỉ tiêu kỹ thuật</u> trong dự án</td></tr>
<tr><td>1. Đánh giá về sự đáp ứng của nhà thầu về các yêu cầu kỹ thuật của dự án</td><td></td><td></td><td></td></tr>
</table>

2. Đánh giá sự nhận biết và giải quyết các sự cố kỹ thuật kịp thời trong dự án			
3. Đánh giá chung trình độ tay nghề công nhân trong dự án			
4. Đánh giá khả năng xử lý vấn đề của cán bộ kỹ thuật			
Thông tin khác có thể sử dụng:			
VI. Thông tin về ***<u>năng suất</u>*** thi công			
1. Tổng số công lao động			
2. Chi phí nhân công theo dự toán			
3. Chi phí thiết bị và máy thi công theo dự toán			
Thông tin khác có thể sử dụng:			
VII. Thông tin về ***<u>lãng phí vật tư</u>***			
1. Chi phí do lãng phí những nguyên vật liệu chủ yếu như: sắt thép, coppha, giàn giáo,…			
Thông tin khác có thể sử dụng:			

*Các thông số dự kiến có thể được sử dụng trong công cụ **Đánh giá mức độ thành công của dự án***	Khả năng đáp ứng thông tin của dự án đang đề cập		
	Có thể cung cấp thông tin (hoặc) ý kiến đánh giá	Dự án có thông tin nhưng khó cung cấp, lý do	Không thể cung cấp thông tin (hoặc) ý kiến đánh giá
VIII. ***<u>Sự thỏa mãn</u>*** của các bên liên quan trong dự án			
1. Sự thỏa mãn của chủ đầu tư			
2. Sự thỏa mãn của nhà thầu			
3. Sự thỏa mãn của tư vấn			
Thông tin khác có thể sử dụng:			
IX. ***<u>Sự ảnh hưởng đến môi trường xung quanh</u>***			
1. Tần suất bị than phiền từ môi trường, cộng đồng quanh khu vực thi công			
2. Tần suất bị nhắc nhở về vệ sinh môi trường từ các cơ quan chức năng			
3. Số lần và thời gian bị đình chỉ thi công từ các cơ quan chức năng			
4. Đánh giá mức độ khắc phục của nhà thầu trước những nhắc nhở			
4. Chi phí cho việc đảm bảo vệ sinh môi trường xung quanh			
5. Chi phí cho việc khắc phục những vấn đề về vệ sinh môi trường			
Thông tin khác có thể sử dụng:			

X. ***Thông tin và giao tiếp*** trong quá trình thi công			
1. Đánh giá của các bên liên quan về kênh giao tiếp thông tin trong dự án			
2. Tần suất thông tin sai lệch, chậm trễ gây ảnh hưởng đến dự án			
3. Hệ thống thông tin được sử dụng trong dự án			
Thông tin khác có thể sử dụng:			
*Các thông số dự kiến có thể được sử dụng trong công cụ **Đánh giá mức độ thành công của dự án***	Khả năng đáp ứng thông tin của dự án đang đề cập		
	Có thể cung cấp thông tin (hoặc) ý kiến đánh giá	Dự án có thông tin nhưng khó cung cấp, lý do	Không thể cung cấp thông tin (hoặc) ý kiến đánh giá
XI. ***Mâu thuẫn, kiện tụng, tranh chấp*** trong quá trình thi công			
1. Đánh giá mức độ mâu thuẫn trong việc thanh quyết toán công trình			
2. Đánh giá mức độ mâu thuẫn giữa các bên trong nghiệm thu công trình			
3. Đánh giá mối quan hệ giữa chủ đầu tư và nhà thầu sau khi hoàn thành			
4. Thông tin về việc phạt do vi phạm hợp đồng như chậm tiến độ			
Thông tin khác có thể sử dụng:			

Những tiêu chí nên bổ sung ngoài những tiêu chí đã liệt kê bên trên:

………

………

………………………………………………………………………………

Sau khi hoàn thành khung tiêu chuẩn ***Đánh giá mức độ thành công của dự án,*** chúng tôi rất cần sự hỗ trợ của quí công ty và các Anh/Chị trong việc cung cấp thông tin của những dự án đã hoàn thành nhằm đánh giá khả năng ứng dụng của công cụ.

Chúng tôi xin cam đoan mọi thông tin của dự án sẽ được giữ kín, chúng tôi sẽ tiến hành mã hóa và chỉ phục vụ cho công tác nghiên cứu. Do đó, mong Anh/Chị vui lòng cho biết số lượng dự án mà công ty Anh/Chị có thể cung cấp thông tin:

☐ Đến 3 dự án ☐ Từ 3 đến 5 dự án ☐ Từ 5 đến 10 dự án ☐ Trên 10 dự án

Thông tin liên lạc:

Họ và tên :... ....

Địa chỉ email :... ....

Số điện thoại :... ....

Một lần nữa, xin chân thành cảm ơn sự giúp đỡ nhiệt tình của Anh/Chị!

Trân trọng kính chào!

ĐÁNH GIÁ MỨC ĐỘ QUAN TRỌNG VÀ KHẢ NĂNG ỨNG DỤNG CỦA CÁC THÔNG SỐ DỰ KIẾN NHẰM XÂY DỰNG TIÊU CHUẨN ĐÁNH GIÁ MỨC ĐỘ THÀNH CÔNG CỦA DỰ ÁN

PHẦN I: THÔNG TIN CHUNG

Anh/Chị vui lòng đánh dấu (X) vào câu trả lời hoặc trả lời trực tiếp cho các câu hỏi sau:

Công ty Anh/Chị đang làm việc :..

Vị trí/chức danh hiện tại của Anh/Chị : ....

Thời gian Anh/Chị công tác trong **lĩnh vực xây dựng**: ....

Xin vui lòng cho biết **tuổi** của Anh/Chị : ....

Bằng cấp học vấn cao nhất hiện tại của Anh/Chị:

☐ Dưới đại học ☐ Đại học ☐ Trên đại học

Số lượng dự án mà Anh/Chị có tham gia đã hoàn thành:

☐ Dưới 3 dự án ☐ Từ 3 đến 5 dự án ☐ Trên 5 dự án

Nếu đã từng tham gia dự án, Anh/Chị đã tham gia dự án trên cương vị của đơn vị nào (Anh/Chị có thể chọn nhiều lựa chọn bên dưới)?

☐ Chủ đầu tư

☐ Nhà thầu

☐ Đơn vị tư vấn

☐ Đơn vị khác:..

Theo Anh/Chị, công cụ để đánh giá mức độ thành công của dự án có quan trọng hay không?

☐ Rất quan trọng

☐ Quan trọng

☐ Không rõ có quan trọng hay không

☐ Không quan trọng

Anh/Chị và công ty Anh/Chị công tác có từng đánh giá mức độ thành công của dự án sau khi dự án được hoàn thành hay không?

☐ Có ☐ Chưa bao giờ

PHẦN II: ĐÁNH GIÁ MỨC ĐỘ QUAN TRỌNG VÀ KHẢ NĂNG ỨNG DỤNG CÁC THÔNG SỐ TRONG VIỆC ĐÁNH GIÁ MỨC ĐỘ THÀNH CÔNG CỦA DỰ ÁN

Anh/Chị vui lòng đánh dấu (X) vào một trong các trả lời theo các mức độ sau:

Thang đo về mức độ quan trọng:

Không quan trọng	**Ít** quan trọng	**Tương đối** quan trọng	**Khá** quan trọng	**Rất** quan trọng
1	2	3	4	5

Thang đo về khả năng ứng dụng

Không thể	**Ít** có thể	**Có** thể	**Rất** có thể
0	1	2	3

Những chỉ số dưới đây quan trọng và có khả năng ứng dụng như thế nào trong việc đánh giá mức độ thành công của dự án?	Mức độ **quan trọng**					Khả năng **ứng dụng**			
	Không	Ít	Tương đối	Khá	Rất	Không thể	Ít có thể	Có thể	Rất có thể
	1	2	3	4	5	0	1	2	3
I. ***Kinh phí*** dự án									
1. Chênh lệch kinh phí giữa giá trị hợp đồng và giá trị thanh quyết toán									
2. Chi phí đơn vị trên m^2 sàn thi công									
3. Chi phí phát sinh									
4. Chi phí hao phí do phải làm lại một số công việc									
5. Chi phí sử dụng cho những biến cố bất ngờ									
II. ***Tiến độ*** dự án									
1. Chênh lệch tiến độ giữa thời gian hoàn thành theo kế hoạch và thời gian thực tế									
2. Tốc độ thi công									
3. Thời gian chậm trễ do sự cung ứng vật tư									

Những chỉ số dưới đây quan trọng và có khả năng ứng dụng như thế nào trong việc đánh giá mức độ thành công của dự án?	Mức độ **quan trọng**					Khả năng **ứng dụng**			
	Không	**Ít**	**Tương đối**	**Khá**	**Rất**	**Không thể**	**Ít có thể**	**Có thể**	**Rất có thể**
	1	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**
4. Thời gian chậm trễ do thiết bị									
5. Thời gian chậm trễ do thiếu nhân công									
III. ***Chất lượng*** dự án									
1. Sự tương thích giữa chất lượng chủ đầu tư mong muốn và thực tế hoàn thành									
2. Sự đáp ứng các tiêu chuẩn chất lượng trong quá trình thi công									
3. Sự thực hiện đánh giá phù hợp chất lượng công trình sau khi hoàn thành									
4. Thông tin về lỗi cần khắc phục khi bàn giao công trình									
5. Thông tin về chi phí để khắc phục những chi tiết không đảm bảo chất lượng									
6. Thông tin về thời gian để khắc phục những chi tiết không đảm bảo chất lượng									
IV. ***An toàn lao động*** (ATLĐ)									
1. Tai nạn lao động gây chết người									
2. Tai nạn lao động nặng									
3. Tai nạn lao động nhẹ									
4. Tổng kinh phí chi cho quản lý ATLĐ trong dự án									
5. Tổng kinh phí chi cho việc xử lý tai nạn lao động xảy ra trong khi thi công									
6. Tổng thời gian thất thoát do tai nạn lao động xảy ra.									
7. Đánh giá biển báo ATLĐ									
8. Đánh giá việc trang bị công cụ bảo hộ ATLĐ cho công nhân									

Những chỉ số dưới đây quan trọng và có khả năng ứng dụng như thế nào trong việc đánh giá mức độ thành công của dự án?	Mức độ **quan trọng**					Khả năng **ứng dụng**			
	Không	**Ít**	**Tương đối**	**Khá**	**Rất**	**Không thể**	**Ít có thể**	**Có thể**	**Rất có thể**
	1	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**
9. Đánh giá việc đảm bảo an toàn trang thiết bị phục vụ thi công									
10. Đánh giá việc huấn luyện ATLĐ									
11. Đánh giá việc bố trí cán bộ ATLĐ									
V. ***Chỉ tiêu kỹ thuật*** trong dự án									
1. Đánh giá về sự đáp ứng của nhà thầu về các yêu cầu kỹ thuật của dự án									
2. Đánh giá sự nhận biết và giải quyết các sự cố kỹ thuật kịp thời trong dự án									
3. Đánh giá chung trình độ tay nghề công nhân trong dự án									
4. Đánh giá khả năng xử lý vấn đề của cán bộ kỹ thuật									
VI. Thông tin về ***năng suất*** thi công									
1. Tổng số công lao động									
2. Chi phí nhân công theo dự toán									
3. Chi phí thiết bị và máy thi công theo dự toán									
VII. Thông tin về ***lãng phí vật tư***									
1. Chi phí do lãng phí những nguyên vật liệu chủ yếu như: sắt thép, coppha, giàn giáo,…									
VIII. ***Sự thỏa mãn*** của các bên liên quan									
1. Sự thỏa mãn của chủ đầu tư									
2. Sự thỏa mãn của nhà thầu									
3. Sự thỏa mãn của tư vấn									
IX. ***Sự ảnh hưởng đến môi trường xung quanh***									

Những chỉ số dưới đây quan trọng và có khả năng ứng dụng như thế nào trong việc đánh giá mức độ thành công của dự án?	Mức độ **quan trọng**					Khả năng **ứng dụng**			
	Không	**Ít**	**Tương đối**	**Khá**	**Rất**	**Không thể**	**Ít có thể**	**Có thể**	**Rất có thể**
	1	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**
1. Tần suất bị than phiền từ môi trường, cộng đồng quanh khu vực thi công									
2. Tần suất bị nhắc nhở về vệ sinh môi trường từ các cơ quan chức năng									
3. Số lần và thời gian bị đình chỉ thi công từ các cơ quan chức năng									
4. Đánh giá mức độ khắc phục của nhà thầu trước những nhắc nhở									
5. Chi phí cho việc đảm bảo vệ sinh môi trường xung quanh									
6. Chi phí cho việc khắc phục những vấn đề về vệ sinh môi trường									
X. ***Thông tin và giao tiếp*** trong dự án									
1. Đánh giá của các bên liên quan về kênh giao tiếp thông tin trong dự án									
2. Tần suất thông tin sai lệch, chậm trễ gây ảnh hưởng đến dự án									
3. Hệ thống thông tin sử dụng trong dự án									
XI. ***Mâu thuẫn, kiện tụng, tranh chấp*** trong quá trình thi công									
1. Đánh giá mức độ mâu thuẫn trong việc thanh quyết toán công trình									
2. Đánh giá mức độ mâu thuẫn giữa các bên trong nghiệm thu công trình									
3. Đánh giá mối quan hệ giữa chủ đầu tư và nhà thầu sau khi hoàn thành									
4. Thông tin về việc phạt do vi phạm hợp đồng như chậm tiến độ									

Mong Anh/Chị liệt kê thêm những tiêu chí nên bổ sung ngoài những tiêu chí đã liệt kê bên trên:

………

Thông tin liên lạc:

Họ và tên :………………………………. ……………………………

Địa chỉ email :………………………………. ……………………………

Số điện thoại :………………………………. ……………………………

Dự án Anh/Chị đang tham gia:…………………………………………………………

Một lần nữa, xin chân thành cảm ơn sự giúp đỡ nhiệt tình của Anh/Chị!

Trân trọng kính chào!

APPENDIX C

DATA ANALYSIS OF PRELIMINARY SURVEY

C.1. Result of collecting information capacity

Table C.1.1 Capacity to collect information about project cost

Information about project cost	Project has this information and possible to provide		Project has this information BUT difficult to provide		Project does not have this information	
	No.	%	No.	%	No.	%
Cost variation	28	100.0%	0	0.0%	0	0.0%
Unit cost	24	85.7%	3	10.7%	1	3.6%
Expenses incurred	26	92.9%	1	3.6%	1	3.6%
Rework Costs	17	60.7%	4	14.3%	7	25.0%
Budget for contingencies	13	46.4%	6	21.4%	9	32.1%

Table C.1.2 Capacity to collect information about project time

Information about project time	Project has this information and possible to provide		Project has this information BUT difficult to provide		Project does not have this information	
	No.	%	No.	%	No.	%
Time variation	28	100.0%	0	0.0%	0	0.0%
Speed of construction	25	89.3%	2	7.1%	1	3.6%
Material availability	19	67.9%	5	17.9%	4	14.3%
Equipment availability	19	67.9%	3	10.7%	6	21.4%
Labor availability	21	75.0%	4	14.3%	3	10.7%

Table C.1.3 Capacity to collect information about project quality

Information about project quality	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Evaluate the different between expectation and real	19	67.9%	8	28.6%	1	3.6%
Evaluate degree of conformance to predetermined standard	22	78.6%	5	17.9%	1	3.6%
Implement the "Evaluate the suitability project quality certificate"	22	78.6%	4	14.3%	2	7.1%
Defects need to rework when take over the project	18	64.3%	5	17.9%	5	17.9%
Budget to rework unsatisfied works	13	46.4%	6	21.4%	9	32.1%
Time to rework unsatisfied works	18	64.3%	4	14.3%	6	21.4%

Table C.1.4 Capacity to collect information about project safety

Information about project safety	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Number of death injures or accidents	22	78.6%	3	10.7%	3	10.7%
Number of heavy accidents	22	78.6%	2	7.1%	4	14.3%
Number of slight accidents	22	78.6%	4	14.3%	2	7.1%

Total expenditures for safety management in project	11	39.3%	5	17.9%	12	42.9%
Total expenditures to handle and compensate of accidents occur during construction	9	32.1%	8	28.6%	11	39.3%
Total time lost due to accident occurring	14	50.0%	5	17.9%	9	32.1%
Evaluation of safety signs	27	96.4%	1	3.6%	0	.0%
Evaluation of providing safety tools and protection equipment	28	100.0%	0	.0%	0	.0%
Evaluation safety level of equipment used in construction	26	92.9%	2	7.1%	0	.0%
Evaluation safety training	26	92.9%	1	3.6%	1	3.6%
Evaluation safety responsibility staffs	26	92.9%	1	3.6%	1	3.6%

Table C.1.5 Capacity to collect information about project technical performance

Information about project technical performance	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Evaluation of contractor's responses to technical requirements	25	89.3%	2	7.1%	1	3.6%
Information about project technical performance Evaluation of technical problem identification and solution	25	89.3%	3	10.7%	0	.0%
Overall assessment qualifications of workers in the project	24	85.7%	1	3.6%	3	10.7%

Evaluation of the possibility of problem solving of technical staffs	24	85.7%	3	10.7%	1	3.6%

Table C.1.6 Capacity to collect information about project productivity

Information about project productivity	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Total number of labor	16	57.1%	6	21.4%	6	21.4%
Total labor cost	22	78.6%	4	14.3%	2	7.1%
Total equipment cost	20	71.4%	6	21.4%	2	7.1%

Table C.1.7 Capacity to collect information about project material waste

Information about project material waste	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
	8	28.6%	8	28.6%	12	42.9%

Table C.1.8 Capacity to collect information about project satisfaction

Information about project satisfaction	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Owner	21	75.0%	5	17.9%	2	7.1%
Contractor	23	82.1%	4	14.3%	1	3.6%
Consultant	19	67.9%	6	21.4%	3	10.7%

Table C.1.9 Capacity to collect information about project environmental sustainability

Information about project environmental sustainability	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Frequency of complaints from the environment and communities around site	20	71.4%	4	14.3%	4	14.3%
Frequency of time reminded from the authorities	19	67.9%	4	14.3%	5	17.9%
Information about project environmental sustainability - The number of time and duration suspended from the authorities	20	71.4%	4	14.3%	4	14.3%
Assessing the recovery of the contractor when warned	24	85.7%	1	3.6%	3	10.7%
Expenses for ensuring environmental sustainability	16	57.1%	8	28.6%	4	14.3%

Expenses of overcoming the problems of environmental sanitation	18	64.3%	6	21.4%	4	14.3%

Table C.1.10 Capacity to collect information about project communication

Information about project communication	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Evaluation the communication in project	18	64.3%	8	28.6%	2	7.1%
The frequency of misinformation or delays affecting the project	16	57.1%	7	25.0%	5	17.9%
Information system used in projects	20	71.4%	7	25.0%	1	3.6%

Table C.1.11 Capacity to collect information about project litigation and dispute

Information about project conflicts, litigation, disputes	Possible to provide information or opinion evaluation		Difficult to provide information or opinion evaluation		Project does not have this information or cannot evaluate	
	No.	%	No.	%	No.	%
Conflict level about settlement payment	20	71.4%	3	10.7%	5	17.9%
Conflict level among parties in checking and taking over	22	78.6%	5	17.9%	1	3.6%
Relationship between owner and contractor after completed	22	78.6%	4	14.3%	2	7.1%
Penalties for breach of contract	20	71.4%	5	17.9%	3	10.7%

C.2 Summary probability of successful collecting information

Table C.2 Summary probability of successful collecting information

Indicator and criterion	Possible to provide information or opinion evaluation $Pr(B_1)$	Difficult to provide information or opinion evaluation $Pr(B_2)$	Project does not have this information or cannot evaluate $Pr(B_3)$	Probability of successful collecting information Pr(A)
	$Pr(A/B_1) = 1$	$Pr(A/B_2) = 0.5$	$Pr(A/B_3) = 0$	
Information about project cost				**85%**
Cost variation	100.0%	.0%	.0%	100%
Unit cost	85.7%	10.7%	3.6%	91%
Expenses incurred	92.9%	3.6%	3.6%	95%
Rework Costs	60.7%	14.3%	25.0%	68%
Budget for contingencies	46.4%	21.4%	32.1%	57%
Information about project time				**88%**
Time variation	100.0%	.0%	.0%	100%
Speed of construction	89.3%	7.1%	3.6%	93%
Material availability	67.9%	17.9%	14.3%	77%
Equipment availability	67.9%	10.7%	21.4%	73%
Labor availability	75.0%	14.3%	10.7%	82%
Information about project quality				**76%**
Evaluate the different between expectation and real	67.9%	28.6%	3.6%	82%
Evaluate degree of conformance to predetermined standard	78.6%	17.9%	3.6%	88%
Implement the "Evaluate the suitability project quality certificate"	78.6%	14.3%	7.1%	86%

Defects need to rework when take over the project	64.3%	17.9%	17.9%	73%
Budget to rework unsatisfied works	46.4%	21.4%	32.1%	57%
Time to rework unsatisfied works	64.3%	14.3%	21.4%	71%
Information about project safety				**81%**
Number of death injures or accidents	78.6%	10.7%	10.7%	84%
Number of heavy accidents	78.6%	7.1%	14.3%	82%
Number of slight accidents	78.6%	14.3%	7.1%	86%
Total expenditures for safety management in project	39.3%	17.9%	42.9%	48%
Total expenditures to handle and compensate of accidents occur during construction	32.1%	28.6%	39.3%	46%
Total time lost due to accident occurring	50.0%	17.9%	32.1%	59%
Evaluation of safety signs	96.4%	3.6%	.0%	98%
Evaluation of providing safety tools and protection equipment	100.0%	.0%	.0%	100%
Evaluation of safety level of equipment used in construction	92.9%	7.1%	.0%	96%
Evaluation of safety training	92.9%	3.6%	3.6%	95%
Evaluation of safety responsibility staffs	92.9%	3.6%	3.6%	95%
Information about project technical performance				**92%**
Evaluation of contractor's responses to technical requirements	89.3%	7.1%	3.6%	93%

Evaluation of technical problem identification and solution	89.3%	10.7%	.0%	95%
Overall assessment qualifications of workers in the project	85.7%	3.6%	10.7%	88%
Evaluation of the possibility of problem solving of technical staffs	85.7%	10.7%	3.6%	91%
Information about project productivity				**79%**
Total number of labor	57.1%	21.4%	21.4%	68%
Total labor cost	78.6%	14.3%	7.1%	86%
Total equipment cost	71.4%	21.4%	7.1%	82%
Information about project waste material				**43%**
Information about project waste material	28.6%	28.6%	42.9%	43%
Information about project satisfaction				**84%**
Owner	75.0%	17.9%	7.1%	84%
Contractor	82.1%	14.3%	3.6%	89%
Consultant	67.9%	21.4%	10.7%	79%
Information about project environmental sustainability				**78%**
Frequency of complaints from the environment and communities around site	71.4%	14.3%	14.3%	79%
Frequency of time reminded from the authorities	67.9%	14.3%	17.9%	75%
The number of time and duration suspended from the authorities	71.4%	14.3%	14.3%	79%
Assessing the recovery of the contractor when warned	85.7%	3.6%	10.7%	88%
Expenses for ensuring environmental sustainability	57.1%	28.6%	14.3%	71%

Expenses of overcoming the problems of environmental sanitation	64.3%	21.4%	14.3%	75%
Information about project information				**77%**
Evaluation of the communication in project	64.3%	28.6%	7.1%	79%
The frequency of misinformation or delays affecting the project	57.1%	25.0%	17.9%	70%
Information system used in projects	71.4%	25.0%	3.6%	84%
Information about project conflicts, litigation, disputes				**83%**
Conflict level about settlement payment	71.4%	10.7%	17.9%	77%
Conflict level among parties in checking and taking over	78.6%	17.9%	3.6%	88%
Relationship between owner and contractor after completed	78.6%	14.3%	7.1%	86%
Penalties for breach of contract	71.4%	17.9%	10.7%	80%

C.3 Reliability analysis of evaluation scale

Table C.3.1 Cronbach's alpha for project cost scale (N = 65)

N of Items = 5	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.684**	**0.707**
	If Item Deleted	
COST1 – Cost variation	.677	.682
COST2 – Unit cost	.645	.649
COST3 - Expenses incurred	.595	.648
COST4 - Rework costs	.621	.669
COST5 - Cost for contingencies	.601	.674

Table C.3.2 Cronbach's alpha for project time scale (N = 65)

N of Items = 6	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.739**	**0.785**
	If Item Deleted	
TIME1 – Time variation	.736	.776
TIME2 - Speed of construction	.751	.775
TIME3 - Material availability	.628	.714
TIME4 - Equipment availability	.652	.730
TIME5 - Labor availability	.669	.738

Table C.3.3 Cronbach's alpha for project quality scale (N = 65)

N of Items = 6	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.819**	**0.800**
	If Item Deleted	
Information about project quality - Evaluate the different between expectation and real	.811	.810
Information about project quality - Evaluate degree of conformance to predetermined standard	.804	.789
Information about project quality - Implement the "Evaluate the suitability project quality certificate"	.795	.767
Information about project quality - Defects need to rework when take over the project	.762	.746
Information about project quality - Budget to rework unsatisfied works	.785	.744
Information about project quality - Time to rework unsatisfied works	.780	.746

Table C.3.4 Cronbach's alpha for project safety scale (N = 65)

N of Items = 11	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.887**	**0.872**
	If Item Deleted	
Information about project safety - Number of death injures or accidents	.882	.877
Information about project safety - Number of heavy accidents	.880	.869
Information about project safety - Number of slight accidents	.879	.860
Information about project safety - Total expenditures for safety management in project	.884	.866
Information about project safety - Total expenditures to handle and compensate of accidents occur during construction	.870	.854
Information about project safety - Total time lost due to accident occurring	.890	.873
Information about project safety - Evaluation of safety signs	.871	.853
Information about project safety - Evaluation of providing safety tools and protection equipment	.867	.848
Information about project safety - Evaluation safety level of equipment used in construction	.865	.850
Information about project safety - Evaluation safety training	.878	.856
Information about project safety - Evaluation safety responsibility staffs	.880	.854

Table C.3.5 Cronbach's alpha for project technical performance scale (N = 65)

N of Items = 4	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.827**	**0.847**
	If Item Deleted	
Information about project technical performance - Evaluation of contractor's responses to technical requirements	.819	.831
Information about project technical performance - Evaluation of technical problem identification and solution	.728	.777
Information about project technical performance - Overall assessment qualifications of workers in the project	.791	.810
Information about project technical performance - Evaluation of the possibility of problem solving of technical staffs	.783	.809

Table C.3.6 Cronbach's alpha for project productivity scale (N = 65)

N of Items = 3	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.921**	**0.914**
	If Item Deleted	
Information about project productivity - Total number of labor	.944	.958
Information about project productivity - Total labor cost	.862	.814
Information about project productivity - Total equipment cost	.849	.852

Table C.3.7 Cronbach's alpha for project satisfaction scale (N = 65)

N of Items = 3	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.837**	**0.833**
	If Item Deleted	
Information about project satisfaction - Owner	.872	.933
Information about project satisfaction - Contractor	.677	.675
Information about project satisfaction - Consultant	.740	.634

Table C.3.8 Cronbach's alpha for project environment scale (N = 65)

N of Items = 6	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.837**	**0.792**
	If Item Deleted	
Information about project environmental sustainability - Frequency of complaints from the environment and communities around site	.816	.735
Information about project environmental sustainability - Frequency of time reminded from the authorities	.794	.731
Information about project environmental sustainability - The number of time and duration suspended from the authorities	.823	.808
Information about project environmental sustainability - Assessing the recovery of the contractor when warned	.843	.768
Information about project environmental sustainability - Expenses for ensuring environmental sustainability	.778	.748
Information about project environmental sustainability - Expenses of overcoming the problems of environmental sanitation	.805	.763

Table C.3.9 Cronbach's alpha for project communication scale (N = 65)

N of Items = 3	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.642**	**0.740**
	If Item Deleted	
Information about project communication - Evaluation of the communication in project	.498	.550
Information about project communication - The frequency of misinformation or delays affecting the project	.644	.759
Information about project communication - Information system used in projects	.490	.658

Table C.3.10 Cronbach's alpha for project litigation and disputes scale (N = 65)

N of Items = 4	Importance Scale	Applicability Scale
Cronbach's Alpha =	**0.831**	**0.818**
	If Item Deleted	
Information about project conflicts, litigation, disputes - Conflict level about settlement payment	.745	.750
Information about project conflicts, litigation, disputes - Conflict level among parties in checking and taking over	.789	.787
Information about project conflicts, litigation, disputes - Relationship between owner and contractor after completed	.815	.775
Information about project conflicts, litigation, disputes - Penalties for breach of contract	.797	.773

C.4. Descriptive statistics and testing hypothesis results

Table C.4.1 Descriptive statistics and testing hypothesis result of indicators and criteria in importance scale

Descriptive Statistics (N=65)					One-Sample Test Test Value = 3; DF=64		Testing Hypothesis $\mu > 3$
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
COS1	2	5	4.40	.725	15.578	.000	Accept
COS2	3	5	4.66	.509	26.340	.000	Accept
COS3	2	5	4.32	.831	12.833	.000	Accept
COS4	2	5	3.80	.833	7.744	.000	Accept
COS5	2	5	3.65	.799	6.520	.000	Accept
TIM1	2	5	4.54	.709	17.499	.000	Accept
TIM2	3	5	4.20	.642	15.064	.000	Accept
TIM3	2	5	4.08	.756	11.479	.000	Accept
TIM4	3	5	4.02	.696	11.765	.000	Accept
TIM5	3	5	3.91	.744	9.833	.000	Accept
QUA1	3	5	4.37	.698	15.826	.000	Accept
QUA2	3	5	4.32	.687	15.525	.000	Accept
QUA3	3	5	3.91	.701	10.440	.000	Accept
QUA4	2	5	3.80	.814	7.924	.000	Accept
QUA5	2	5	3.85	.870	7.840	.000	Accept
QUA6	2	5	3.68	.868	6.288	.000	Accept
SAF1	3	5	4.75	.501	28.226	.000	Accept
SAF2	2	5	4.40	.703	16.063	.000	Accept
SAF3	1	5	3.80	.851	7.575	.000	Accept
SAF4	2	5	3.88	.740	9.558	.000	Accept
SAF5	2	5	3.77	.844	7.352	.000	Accept
SAF6	1	5	3.55	.919	4.858	.000	Accept

Descriptive Statistics (N=65)					One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
SAF7	2	5	3.92	.957	7.776	.000	Accept
SAF8	2	5	4.00	.919	8.777	.000	Accept
SAF9	2	5	4.08	.872	9.962	.000	Accept
SAF10	2	5	4.00	.901	8.944	.000	Accept
SAF11	2	5	4.00	.791	10.198	.000	Accept
TEC1	3	5	4.34	.691	15.618	.000	Accept
TEC2	3	5	4.35	.717	15.233	.000	Accept
TEC3	2	5	4.00	.729	11.061	.000	Accept
TEC4	3	5	4.25	.685	14.659	.000	Accept
PRO1	1	5	3.82	.917	7.171	.000	Accept
PRO2	1	5	3.83	.876	7.644	.000	Accept
PRO3	1	5	3.78	.910	6.952	.000	Accept
WAS1	2	5	3.95	.818	9.397	.000	Accept
SAT1	2	5	4.45	.685	17.012	.000	Accept
SAT2	2	5	4.08	.797	10.899	.000	Accept
SAT3	2	5	3.97	.790	9.892	.000	Accept
ENV1	2	5	3.92	.816	9.120	.000	Accept
ENV2	2	5	3.85	.734	9.297	.000	Accept
ENV3	2	5	4.31	.769	13.710	.000	Accept
ENV4	2	5	3.88	.761	9.296	.000	Accept
ENV5	2	5	3.80	.775	8.327	.000	Accept
ENV6	2	5	3.71	.723	7.893	.000	Accept
COM1	1	5	4.00	.810	9.952	.000	Accept
COM2	3	5	4.25	.771	13.028	.000	Accept

Descriptive Statistics (N=65)					One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
COM3	3	5	4.09	.631	13.966	.000	Accept
LIT1	3	5	4.17	.720	13.100	.000	Accept
LIT2	2	5	4.14	.846	10.856	.000	Accept
LIT3	2	5	4.17	.821	11.482	.000	Accept
LIT4	1	5	4.12	.875	10.346	.000	Accept

Table C.4.2 Descriptive Statistics and Testing Hypothesis Result of Indicators and Criteria in Applicability Scale

Descriptive Statistics (N=65)					One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
COS1	3	5	4.28	.573	17.966	.000	Accept
COS2	3	5	4.35	.598	18.263	.000	Accept
COS3	3	5	4.28	.600	17.167	.000	Accept
COS4	2	5	3.88	.600	11.790	.000	Accept
COS5	2	5	3.82	.610	10.784	.000	Accept
TIM1	3	5	4.42	.635	17.978	.000	Accept
TIM2	3	5	4.12	.673	13.448	.000	Accept
TIM3	3	5	4.03	.684	12.150	.000	Accept
TIM4	3	5	3.94	.659	11.490	.000	Accept
TIM5	3	5	3.94	.682	11.097	.000	Accept
QUA1	3	5	4.22	.673	14.561	.000	Accept
QUA2	3	5	4.18	.583	16.370	.000	Accept

	Descriptive Statistics (N=65)				One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
QUA3	3	5	3.88	.673	10.500	.000	Accept
QUA4	2	5	3.83	.601	11.139	.000	Accept
QUA5	2	5	3.83	.720	9.308	.000	Accept
QUA6	2	5	3.69	.635	8.783	.000	Accept
SAF1	3	5	4.37	.627	17.614	.000	Accept
SAF2	3	5	4.22	.649	15.090	.000	Accept
SAF3	3	5	4.08	.620	14.000	.000	Accept
SAF4	3	5	4.05	.598	14.112	.000	Accept
SAF5	3	5	3.85	.618	11.035	.000	Accept
SAF6	2	5	3.75	.730	8.331	.000	Accept
SAF7	2	5	3.88	.801	8.832	.000	Accept
SAF8	3	5	4.12	.673	13.448	.000	Accept
SAF9	3	5	4.03	.684	12.150	.000	Accept
SAF10	3	5	4.05	.738	11.428	.000	Accept
SAF11	2	5	3.95	.717	10.732	.000	Accept
TEC1	1	5	4.20	.795	12.177	.000	Accept
TEC2	3	5	4.17	.651	14.476	.000	Accept
TEC3	2	5	3.86	.704	9.861	.000	Accept
TEC4	3	5	4.09	.631	13.966	.000	Accept
PRO1	2	5	3.80	.795	8.118	.000	Accept
PRO2	2	5	3.83	.762	8.793	.000	Accept
PRO3	2	5	3.89	.732	9.835	.000	Accept
WAS1	3	5	4.02	.739	11.072	.000	Accept
SAT1	3	5	4.34	.644	16.753	.000	Accept

	Descriptive Statistics (N=65)				One-Sample Test Test Value = 3; DF=64		Testing Hypothesis μ > 3
Variable Code	Min	Max	Mean	Standard Deviation	t	Sig.	
SAT2	2	5	4.12	.740	12.241	.000	Accept
SAT3	2	5	4.02	.696	11.765	.000	Accept
ENV1	3	5	3.94	.659	11.490	.000	Accept
ENV2	3	5	3.92	.645	11.540	.000	Accept
ENV3	3	5	4.17	.675	13.971	.000	Accept
ENV4	3	5	3.77	.632	9.818	.000	Accept
ENV5	3	5	3.82	.659	9.977	.000	Accept
ENV6	3	5	3.77	.606	10.226	.000	Accept
COM1	3	5	3.97	.612	12.777	.000	Accept
COM2	3	5	3.98	.718	11.058	.000	Accept
COM3	3	5	3.98	.625	12.705	.000	Accept
LIT1	3	5	4.09	.631	13.966	.000	Accept
LIT2	3	5	4.08	.645	13.464	.000	Accept
LIT3	3	5	4.15	.690	13.484	.000	Accept
LIT4	3	5	4.22	.625	15.683	.000	Accept

C.5. Summary results to select criteria of the QMCPE system

Table C.5 Summary results to select criteria of the QMCPE system

Variable Code	Probability of successful collecting information	Mean of Important Level	Mean of Applicability Level	Decision
COS1	100%	4.40	4.28	Accept
COS2	91%	4.66	4.35	Accept
COS3	95%	4.32	4.28	Accept
COS4	68%	3.80	3.88	Accept
COS5	57%	3.65	3.82	Reject
TIM1	100%	4.54	4.42	Accept
TIM2	93%	4.20	4.12	Accept
TIM3	77%	4.08	4.03	Accept
TIM4	73%	4.02	3.94	Accept
TIM5	82%	3.91	3.94	Accept
QUA1	82%	4.37	4.22	Accept
QUA2	88%	4.32	4.18	Accept
QUA3	86%	3.91	3.88	Accept
QUA4	73%	3.80	3.83	Accept
QUA5	57%	3.85	3.83	Reject
QUA6	71%	3.68	3.69	Accept
SAF1	84%	4.75	4.37	Accept
SAF2	82%	4.40	4.22	Accept
SAF3	86%	3.80	4.08	Accept
SAF4	48%	3.88	4.05	Reject
SAF5	46%	3.77	3.85	Reject
SAF6	59%	3.55	3.75	Reject
SAF7	98%	3.92	3.88	Accept

Variable Code	Probability of successful collecting information	Mean of Important Level	Mean of Applicability Level	Decision
SAF8	100%	4.00	4.12	Accept
SAF9	96%	4.08	4.03	Accept
SAF10	95%	4.00	4.05	Accept
SAF11	95%	4.00	3.95	Accept
TEC1	93%	4.34	4.20	Accept
TEC2	95%	4.35	4.17	Accept
TEC3	88%	4.00	3.86	Accept
TEC4	91%	4.25	4.09	Accept
PRO1	68%	3.82	3.80	Accept
PRO2	86%	3.83	3.83	Accept
PRO3	82%	3.78	3.89	Accept
WAS1	43%	3.95	4.02	Reject
SAT1	84%	4.45	4.34	Accept
SAT2	89%	4.08	4.12	Accept
SAT3	79%	3.97	4.02	Accept
ENV1	79%	3.92	3.94	Accept
ENV2	75%	3.85	3.92	Accept
ENV3	79%	4.31	4.17	Accept
ENV4	88%	3.88	3.77	Accept
ENV5	71%	3.80	3.82	Accept
ENV6	75%	3.71	3.77	Accept
COM1	79%	4.00	3.97	Accept
COM2	70%	4.25	3.98	Accept
COM3	84%	4.09	3.98	Accept
LIT1	77%	4.17	4.09	Accept

Variable Code	Probability of successful collecting information	Mean of Important Level	Mean of Applicability Level	Decision
LIT2	88%	4.14	4.08	Accept
LIT3	86%	4.17	4.15	Accept
LIT4	80%	4.12	4.22	Accept

APPENDIX D

WEIGHT ASSIGNMENT FOR INDICATORS AND CRITERIA IN THE QMCPE SYSTEM

D.1. Descriptive statistic of indicators and criteria in the QMCPE system

Table D.1 List of indicators and criteria in the QMCPE system and their descriptive statistic results (N=266)

Variable Code	Variable Meaning	Mean	Std. Deviation
1. COST	The degree to which the general contexts promote the completion of a project within the estimated budget	4.36	.794
COST1	Cost variation is ratio of net variations to final contract sum expressed in percentage term	4.17	.821
COST2	Unit cost is a measure of relative cost and is defined by the final contract sum divided by the gross floor area.	3.82	.836
COST3	Rework costs	3.59	.961
COST4	Expenses incurred	3.29	.960
2.TIME	The degree to which the general contexts promote the completion of a project within the allocated duration	4.27	.750
TIME1	Time variation is measured by the percentage of increase or decrease in the estimated project days, discounting the effect of extension of time granted by the client.	4.18	.835
TIME2	Speed of construction is the relative time, which is defined by gross floor area divided by the construction time (number of days from start on site to practical completion of the project)	3.89	.739
TIME3	Material availability: number of days construction site delay because of supplying materials	4.08	.754
TIME4	Equipment availability: number of days construction site delay because of lack of equipment	3.98	.810
TIME5	Labor availability: number of days construction site delay because of lack of labor	4.00	.817

Variable Code	Variable Meaning	Mean	Std. Deviation
3.QUALITY	The degree to which the general contexts promote meeting of project's established requirements of materials and workmanship	4.59	.769
QUA1	Conformity with expectations: The different level between quality expectation of owner and real project quality after completed.	4.32	.746
QUA2	Conformity with predetermined standard: The different level between predetermined standard and real project quality.	4.28	.757
QUA3	Implement the "Evaluate the suitability project quality certificate" in the project	3.89	.855
QUA4	Number of defects need to rework when taking over the project	3.77	.880
QUA5	Time to rework under-quality works	3.65	.888
4.SAFETY	The degrees to which the general contexts promote the completion of a project without major accidents or injuries	4.27	.901
SAFE1	Number of death injures or accidents	4.55	.967
SAFE2	Number of heavy accidents	4.25	.995
SAFE3	Number of slightly accidents	3.55	.959
SAFE4	Evaluation of safety signs	4.12	.901
SAFE5	Evaluation of providing safety tools and protection equipment	4.46	.722
SAFE6	Evaluation of safety level of equipment used in construction	4.32	.778
SAFE7	Evaluation of safety training	4.24	.869
SAFE8	Evaluation of safety responsibility staffs	4.09	.892

Variable Code	Variable Meaning	Mean	Std. Deviation
5.TECH	The degree to which the general contexts promote meeting of project's established specifications	4.07	.764
TECH1	Evaluation of the contractor's response to the technical requirements of project	4.40	.678
TECH2	Evaluation of technical problem identification and solution	4.21	.731
TECH3	Overall assessment qualifications of workers in the project	3.92	.712
TECH4	Evaluation of the possibility of problem solving of technical staff	4.35	.724
6.PRO	The degree to which the general contexts promote achieving effectiveness of allocated resources in order to meet the cost and time targets	3.55	.869
PRO1	Construction productivity	3.65	.803
PRO2	Unit labor cost per square meter	3.81	.778
PRO3	Unit equipment cost per square meter	3.73	.796
7.SATIS	Satisfaction describes the level of ''happiness'' of people affected by a project	3.72	.902
SATIS1	Owner satisfaction	4.39	.735
SATIS2	Contractor satisfaction	3.79	.778
SATIS3	Consultant satisfaction	3.73	.838
8.ENVI	The degree to which the general contexts promote avoiding the effects of project on the environment	3.65	1.018
ENVI1	Frequency of complaints from the environment and communities around the construction site	3.76	.918
ENVI2	Frequency of time reminded about sanitation from the authorities	3.63	.940

Variable Code	Variable Meaning	Mean	Std. Deviation
ENVI3	The number of time and duration suspended from the authorities	3.99	1.039
ENVI4	Assessing the recovery of the contractor when warned	3.80	.827
ENVI5	Expenses for ensuring environmental sustainability	3.60	.842
ENVI6	Expenses of overcoming the problems of environment	3.59	.834
9.COMMU	The degree to which the general contexts promote achieving effectiveness of communication in order to avoid misunderstanding	3.61	.977
COMMU1	Evaluation of the communication in project	3.86	.825
COMMU2	The frequency of misinformation or delays	3.94	.878
COMMU3	Information systems used in project	3.84	.903
10.LITIGA	Measured by number of outstanding claims, relationship among parties after project is completed, and information about penalties for breach of contract.	3.37	1.046
LITIGA1	Outstanding claim among parties about payment	3.84	.890
LITIGA2	Evaluation of conflict level among parties in check and take over the project	3.79	.865
LITIGA3	Evaluation of relationship between contractor and owner after project completed	3.83	.903
LITIGA4	Performance of contractual commitments	3.74	.974

D.2. Reliability analysis of indicators evaluation scale

Table D.2 Cronbach's alpha for indicators evaluation scale (N = 266)

Items of Scale	Cronbach's Alpha	Cronbach's Alpha if Item Deleted
Indicator 1. Cost (N of Items =4)	0.688	
Cost variation		.688
Unit cost		.634
Rework costs		.579
Expenses incurred		.575
Indicator 2. Time (N of Items =5)	0.796	
Time variation		.727
Speed of construction		.711
Material availability		.715
Equipment availability		.697
Labor availability		.709
Indicator 3. Quality (N of Items =5)	0.689	
Conformity with expectations		.672
Conformity with predetermined standard		.647
Implement the "Evaluate the suitability project quality certificate" in the project		.670
Number of defects need to rework when taking over the project		.590
Time to rework under-quality works		.609
Indicator 4. Health & Safety (N of Items =8)	0.844	
Number of death injures or accidents		.840
Number of heavy accidents		.834
Number of slightly accidents		.829

Items of Scale	Cronbach's Alpha	Cronbach's Alpha if Item Deleted
Evaluation of safety signs		.825
Evaluation of providing safety tools and protection equipment		.820
Evaluation of safety level of equipment used in construction		.817
Evaluation of safety training		.815
Evaluation of safety responsibility staffs		.816
Indicator 5. Technical Requirement (N of Items =4)	0.805	
Evaluation of the contractor's response to the technical requirements of project		.760
Evaluation of technical problem identification and solution		.729
Overall assessment qualifications of workers in the project		.783
Evaluation of the possibility of problem solving of technical staff		.749
Indicator 6. Productivity (N of Items =3)	0.852	
Unit labor per square meter		.843
Unit labor cost per square meter		.751
Unit equipment cost per square meter		.759
Indicator 7. Satisfaction (N of Items =3)	0.776	
Owner satisfaction		.731
Contractor satisfaction		.630
Consultant satisfaction		.593

Items of Scale	Cronbach's Alpha	Cronbach's Alpha if Item Deleted
Indicator 8. Environment (N of Items =6)	0.881	
Frequency of complaints from the environment and communities around the construction site		.854
Frequency of time reminded about sanitation from the authorities		.851
The number of time and duration suspended from the authorities		.873
Assessing the recovery of the contractor when warned		.862
Expenses for ensuring environmental sustainability		.859
Expenses of overcoming the problems of environmental sanitation		.864
Indicator 9. Communication (N of Items =3)	0.792	
Evaluation of the communication in project		.677
The frequency of misinformation or delays affecting the project		.773
Information systems used in project		.701
Indicator 10. Dispute & Litigation (N of Items =4)	0.819	
Outstanding claim among parties about payment		.749
Evaluation of conflict level among parties in check and take over the project		.740
Evaluation of relationship between contractor and owner after project completed		.727
Information about penalties for breach of contract		.765

D.3. Weight assignment results

Table D.3.1 Weight assignment for criteria by Summing Responses method (N=266)

Variable Name	Mean	Standard Deviation	Weight/Indicator	Weight/Project
Project Cost	**4.357**	**.794**	**0.110**	**14.857**
COST1	4.165	.821	0.280	0.031
COST2	3.820	.836	0.257	0.028
COST3	3.586	.961	0.241	0.027
COST4	3.286	.960	0.221	0.024
Project Time	**4.274**	**.750**	**0.108**	**20.120**
TIME1	4.177	.835	0.208	0.022
TIME2	3.887	.739	0.193	0.021
TIME3	4.075	.754	0.203	0.022
TIME4	3.985	.810	0.198	0.021
TIME5	3.996	.817	0.199	0.022
Project Quality	**4.586**	**.769**	**0.116**	**19.906**
QUA1	4.316	.746	0.217	0.025
QUA2	4.282	.757	0.215	0.025
QUA3	3.891	.855	0.195	0.023
QUA4	3.771	.880	0.189	0.022
QUA5	3.647	.888	0.183	0.021

Variable Name	Mean	Standard Deviation	Weight/Indicator	Weight/Project
Project Safety	**4.274**	**.901**	**0.108**	**33.586**
SAFE1	4.545	.967	0.135	0.015
SAFE2	4.252	.995	0.127	0.014
SAFE3	3.553	.959	0.106	0.011
SAFE4	4.124	.901	0.123	0.013
SAFE5	4.459	.722	0.133	0.014
SAFE6	4.323	.778	0.129	0.014
SAFE7	4.237	.869	0.126	0.014
SAFE8	4.094	.892	0.122	0.013
Technical Performance	**4.068**	**.764**	**0.103**	**16.880**
TECH1	4.402	.678	0.261	0.027
TECH2	4.207	.731	0.249	0.026
TECH3	3.917	.712	0.232	0.024
TECH4	4.353	.724	0.258	0.027
Productivity	**3.545**	**.869**	**0.090**	**11.192**
PRO1	3.647	.803	0.326	0.029
PRO2	3.812	.778	0.341	0.031
PRO3	3.733	.796	0.334	0.030

Variable Name	Mean	Standard Deviation	Weight/Indicator	Weight/Project
Satisfaction	**3.722**	**.902**	**0.094**	**11.914**
SATIS1	4.391	.735	0.369	0.035
SATIS2	3.789	.778	0.318	0.030
SATIS3	3.733	.838	0.313	0.030
Environment	**3.650**	**1.018**	**0.093**	**22.361**
ENVI1	3.756	.918	0.168	0.016
ENVI2	3.628	.940	0.162	0.015
ENVI3	3.992	1.039	0.179	0.017
ENVI4	3.797	.827	0.170	0.016
ENVI5	3.598	.842	0.161	0.015
ENVI6	3.590	.834	0.161	0.015
Communication	**3.613**	**.977**	**0.092**	**11.639**
COMMU1	3.857	.825	0.331	0.030
COMMU2	3.944	.878	0.339	0.031
COMMU3	3.838	.903	0.330	0.030
Dispute & Litigation	**3.372**	**1.046**	**0.085**	**15.192**
LITIGA1	3.838	.890	0.253	0.022
LITIGA2	3.789	.865	0.249	0.021
LITIGA3	3.827	.903	0.252	0.022

Variable Name	Mean	Standard Deviation	Weight/Indicator	Weight/Project
LITIGA4	3.737	.974	0.246	0.021

Table D.3.2 Summary of SEM model results (N=266)

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments: 1035

Number of distinct parameters to be estimated: 135

Degrees of freedom (1035 - 135): 900

Result (Default model)

Minimum was achieved

Chi-square = 2590.384

Degrees of freedom = 900

Probability level = 0.000

Criteria	<---	Indicators	Estimate
COST1	<---	Project Cost	.720
COST2	<---	Project Cost	.697
COST3	<---	Project Cost	.554
COST4	<---	Project Cost	.524
TIME1	<---	Project Time	.706
TIME2	<---	Project Time	.665
TIME3	<---	Project Time	.656
TIME4	<---	Project Time	.471
TIME5	<---	Project Time	.491
QUA1	<---	Project Quality	.417

QUA2	<---	Project Quality	.416
QUA3	<---	Project Quality	.339
QUA4	<---	Project Quality	.417
QUA5	<---	Project Quality	.339
SAFE1	<---	Project Safety	.833
Criteria	<---	Indicators	Estimate
SAFE2	<---	Project Safety	.824
SAFE3	<---	Project Safety	.802
SAFE4	<---	Project Safety	.809
SAFE5	<---	Project Safety	.713
SAFE6	<---	Project Safety	.833
SAFE7	<---	Project Safety	.824
SAFE8	<---	Project Safety	.802
TECH1	<---	Technical	.680
TECH2	<---	Technical	.783
TECH3	<---	Technical	.655
TECH4	<---	Technical	.736
PRO1	<---	Productivity	.716
PRO2	<---	Productivity	.852
PRO3	<---	Productivity	.877
SATIS1	<---	Satisfaction	.883
SATIS2	<---	Satisfaction	.798
SATIS3	<---	Satisfaction	.543
ENVI1	<---	Environment	.762
ENVI2	<---	Environment	.789
ENVI3	<---	Environment	.686

ENVI4	<---	Environment	.744
ENVI5	<---	Environment	.767
ENVI6	<---	Environment	.742
COMMU1	<---	Communication	.753
COMMU2	<---	Communication	.720
Criteria	<---	Indicators	Estimate
COMMU3	<---	Communication	.781
LITIGA1	<---	Dispute	.804
LITIGA2	<---	Dispute	.796
LITIGA3	<---	Dispute	.665
LITIGA4	<---	Dispute	.767

Indicators	Estimate	S.E.	C.R.	P	Label
Project Cost	.411	.08	5.138	***	
Project Time	.407	.058	7.017	***	
Project Quality	.421	.069	6.101	***	
Project Safety	.401	.063	6.365	***	
Technical	.393	.043	9.140	***	
Productivity	.329	.051	6.451	***	
Satisfaction	.359	.036	9.972	***	
Environment	.356	.069	5.159	***	
Communication	.345	.058	5.948	***	
Dispute	.310	.069	4.493	***	
e4	.443	.055	8.037	***	
e3	.472	.056	8.462	***	
e2	.483	.048	10.119	***	

e1	.551	.051	10.830	***	
e8	.117	.018	6.381	***	
e7	.152	.018	8.431	***	
e6	.469	.041	11.345	***	
e5	.612	.054	11.372	***	
Indicators	Estimate	S.E.	C.R.	P	Label
e9	.167	.021	8.125	***	
e13	.289	.039	7.351	***	
e12	.602	.055	11.017	***	
e11	.472	.043	11.017	***	
e10	.491	.044	11.206	***	
e14	.308	.040	7.627	***	
e18	.397	.038	10.379	***	
e17	.721	.064	11.216	***	
e16	.861	.076	11.354	***	
e15	.875	.076	11.440	***	
e19	.179	.019	9.426	***	
e20	.184	.020	9.001	***	
e21	.242	.026	9.177	***	
e22	.283	.030	9.529	***	
e26	.239	.026	9.157	***	
e25	.288	.029	10.032	***	
e24	.206	.025	8.337	***	
e23	.246	.025	9.812	***	
e28	.313	.032	9.839	***	
e29	.165	.024	6.819	***	

Indicators	Estimate	S.E.	C.R.	P	Label
e30	.146	.025	5.848	***	
e31	.380	.036	10.674	***	
e32	.218	.032	6.923	***	
e33	.154	.038	4.070	***	
e34	.352	.036	9.771	***	
e35	.333	.035	9.432	***	
e36	.569	.055	10.394	***	
e40	.294	.035	8.359	***	
e41	.370	.041	8.936	***	
e42	.317	.041	7.735	***	
e43	.279	.034	8.103	***	
e44	.273	.033	8.290	***	
e45	.553	.052	10.660	***	
e37	.303	.031	9.947	***	
e38	.291	.030	9.709	***	
e39	.312	.031	9.970	***	
e46	.390	.044	8.858	***	

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	135	2590.384	900	.000	2.878
Saturated model	1035	.000	0		
Independence model	45	7659.695	990	.000	7.737

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.082	.667	.617	.580
Saturated model	.000	1.000		
Independence model	.212	.206	.170	.197

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.662	.628	.750	.721	.747
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.909	.602	.679
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

NCP

Model	NCP	LO 90	HI 90
Default model	1690.384	1541.931	1846.416
Saturated model	.000	.000	.000
Independence model	6669.695	6394.534	6951.425

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	9.775	6.379	5.819	6.968

Model	FMIN	F0	LO 90	HI 90
Saturated model	.000	.000	.000	.000
Independence model	28.905	25.169	24.130	26.232

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.084	.080	.088	.000
Independence model	.159	.156	.163	.000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	2860.384	2917.096	3344.156	3479.156
Saturated model	2070.000	2504.795	5778.919	6813.919
Independence model	7749.695	7768.599	7910.953	7955.953

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	10.794	10.234	11.383	11.008
Saturated model	7.811	7.811	7.811	9.452
Independence model	29.244	28.206	30.307	29.315

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	100	103
Independence model	37	38

Table D.3.3 Weight assignment for indicators and criteria using Combination BEES & ISM method (N=266)

Indicator/ Criteria	Weight
Project Cost	0.118
COST1	0.036
COST2	0.033
COST3	0.030
COST4	0.027
Project Time	0.118
TIME1	0.027
TIME2	0.025
TIME3	0.025
TIME4	0.025
TIME5	0.025
Project Quality	0.131
QUA1	0.024
QUA2	0.024
QUA3	0.022
QUA4	0.022
QUA5	0.022
Project Safety	0.118
SAFE1	0.022
SAFE2	0.020
SAFE3	0.014
SAFE4	0.010
SAFE5	0.010
SAFE6	0.010
SAFE7	0.010

Indicator/ Criteria	Weight
SAFE8	0.010
Technical Performance	0.108
TECH1	0.030
TECH2	0.030
TECH3	0.026
TECH4	0.019
Productivity	0.082
PRO1	0.029
PRO2	0.029
PRO3	0.029
Satisfaction	0.084
SATIS1	0.035
SATIS2	0.025
SATIS3	0.025
Environment	0.082
ENVI1	0.015
ENVI2	0.015
ENVI3	0.014
ENVI4	0.014
ENVI5	0.013
ENVI6	0.013
Communication	0.082
COMMU1	0.029
COMMU2	0.029
COMMU3	0.029
Dispute	0.078
LITIGA1	0.020

Indicator/ Criteria	Weight
LITIGA2	0.020
LITIGA3	0.020
LITIGA4	0.020

Table D.8 Summary of weight assignment for indicators and criteria (N=266)

Indicator/ Criteria	SR	SEM	BEES & ISM	Final Weight
Project Cost	**0.110**	**0.110**	**0.118**	**0.113**
COST1	0.031	0.032	0.036	0.033
COST2	0.028	0.031	0.033	0.031
COST3	0.027	0.024	0.030	0.027
COST4	0.024	0.023	0.027	0.025
Project Time	**0.108**	**0.109**	**0.118**	**0.112**
TIME1	0.022	0.026	0.027	0.025
TIME2	0.021	0.024	0.025	0.023
TIME3	0.022	0.024	0.025	0.024
TIME4	0.021	0.017	0.025	0.021
TIME5	0.022	0.018	0.025	0.022
Project Quality	**0.116**	**0.113**	**0.131**	**0.120**
QUA1	0.025	0.024	0.024	0.025
QUA2	0.025	0.024	0.024	0.024
QUA3	0.023	0.020	0.022	0.022
QUA4	0.022	0.024	0.022	0.023
QUA5	0.021	0.020	0.022	0.021
Project Safety	**0.108**	**0.107**	**0.118**	**0.111**
SAFE1	0.015	0.014	0.022	0.017
SAFE2	0.014	0.014	0.020	0.016

Indicator/ Criteria	SR	SEM	BEES & ISM	Final Weight
SAFE3	0.011	0.013	0.014	0.013
SAFE4	0.013	0.013	0.010	0.012
SAFE5	0.014	0.012	0.010	0.012
SAFE6	0.014	0.014	0.010	0.013
SAFE7	0.014	0.014	0.010	0.012
SAFE8	0.013	0.013	0.010	0.012
Technical Performance	**0.103**	**0.105**	**0.108**	**0.106**
TECH1	0.027	0.025	0.030	0.027
TECH2	0.026	0.029	0.030	0.028
TECH3	0.024	0.024	0.026	0.025
TECH4	0.027	0.027	0.019	0.024
Productivity	**0.090**	**0.088**	**0.082**	**0.087**
PRO1	0.029	0.026	0.029	0.028
PRO2	0.031	0.031	0.029	0.030
PRO3	0.030	0.032	0.029	0.030
Stakeholders Satisfaction	**0.094**	**0.096**	**0.084**	**0.092**
SATIS1	0.035	0.038	0.035	0.036
SATIS2	0.030	0.035	0.025	0.030
SATIS3	0.030	0.023	0.025	0.026
Environment	**0.092**	**0.095**	**0.082**	**0.090**
ENVI1	0.016	0.016	0.015	0.016
ENVI2	0.015	0.017	0.015	0.016
ENVI3	0.017	0.015	0.014	0.015
ENVI4	0.016	0.016	0.014	0.015
ENVI5	0.015	0.016	0.013	0.015

Indicator/ Criteria	SR	SEM	BEES & ISM	Final Weight
ENVI6	0.015	0.016	0.013	0.015
Communication	**0.092**	**0.092**	**0.082**	**0.089**
COMMU1	0.030	0.031	0.029	0.030
COMMU2	0.031	0.030	0.029	0.030
COMMU3	0.030	0.032	0.029	0.030
Litigation	**0.085**	**0.083**	**0.078**	**0.082**
LITIGA1	0.022	0.022	0.020	0.021
LITIGA2	0.021	0.022	0.020	0.021
LITIGA3	0.022	0.018	0.020	0.020
LITIGA4	0.021	0.021	0.020	0.021

APPENDIX E

EVALUATION GUIDE OF THE QMCPE SYSTEM

E.1 Indicator COST

E.1.1 COST1 – Cost Variation

Definition: This criterion is intended for evaluating the effect of budget control and management. It is measured by cost variation, means the ratio of net variations to final contract sum expressed in percentage term.

Measurement Scale:

Measurement scale of cost variation criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the best scenario of cost variation was zero; it means that they expected the construction project to finish within the planned budget. They also indicated that the average cost variation in their companies was from 2% to 4% and it was so bad if the cost variation had been more than 6%. The data from the survey also described the same result. The average cost variation was 3.41% with the standard deviation being 3.38%. Figure E.1 below described the cost variation distribution. Therefore, the measurement scale of this criterion was designed as follow.

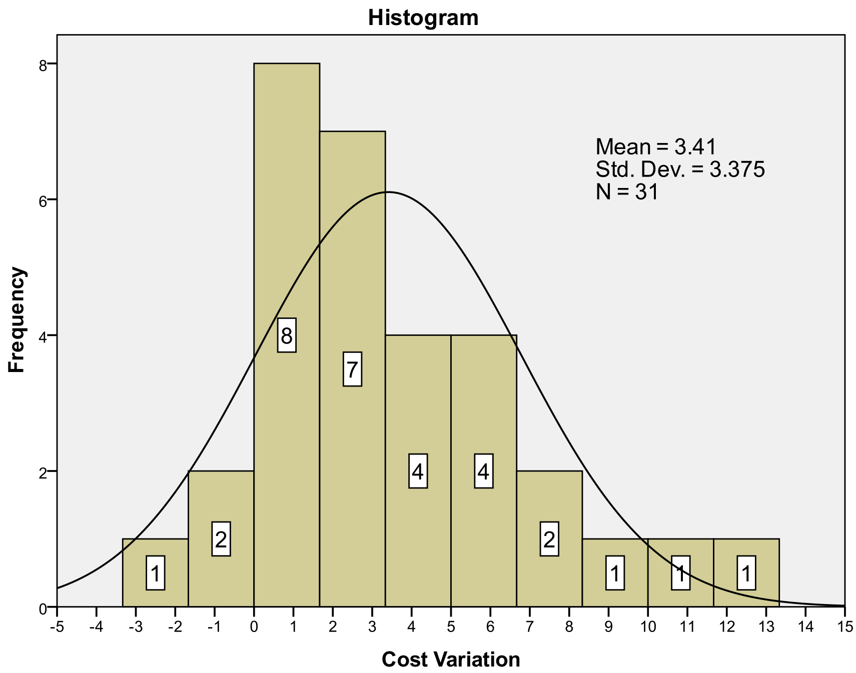

Figure E.1 Cost variation distribution (N=31)

☐ Very poor, cost variation more than 6%

☐ Poor, cost variation from 4% – 6%

☐ Adequate, cost variation from 2% – 4%

☐ Good, cost variation from 0% – 2%

☐ Excellent, achieve cost underrun or cost variation is zero percent

E.1.2 COST2 – Unit cost

Definition: This criterion is intended for evaluating the construction effectiveness. It is based on unit cost which is defined by the final contract sum of construction cost divided by the gross floor area.

Measurement Scale:

Measurement scale of unit cost criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the average unit cost was US$250, the best unit cost was US$150, and the worse unit cost was US$350. Their experiences were compatible with the survey results. The results, which were shown in Figure E.2, indicated the average value was US$239.45, standard deviation was 78.15, maximum value was US$450, and the min value was US$100. From these results, the measurement scale of this criterion was designed as follow.

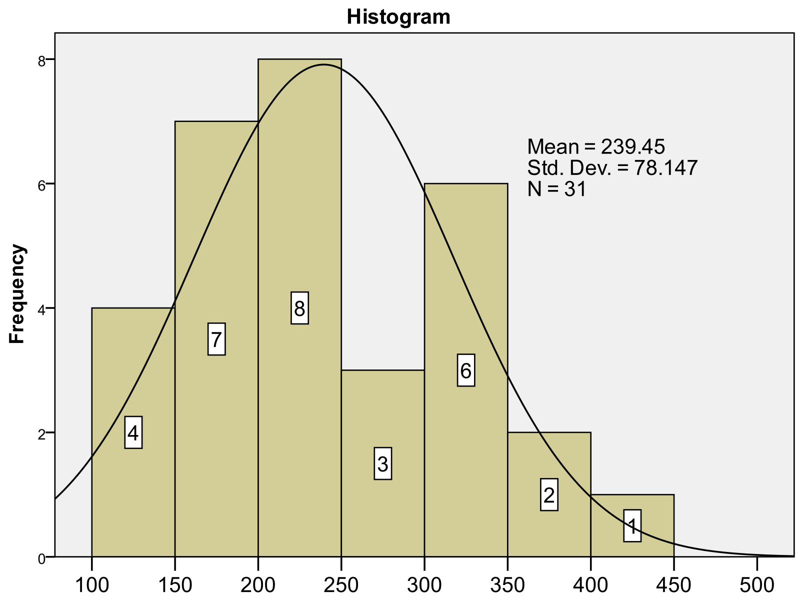

Figure E.2 Unit Cost distribution (N=31)

☐ Very poor, unit cost higher than 350$ per square meter

☐ Poor, unit cost from 300$ to 350$ per square meter

☐ Adequate, unit cost from 200$ to 300$ per square meter

☐ Good, unit cost from 150$ to 200$ per square meter

☐ Excellent, unit cost lower than 150$ per square meter

E.1.3 COST3 – Rework, waste costs

Definition: This criterion is intended for evaluating waste costs in construction site. It includes rework cost, waste material cost, tidy up cost, and loss material cost. It was evaluated by percentage of rework cost per total final project cost.

Measurement Scale:

Measurement scale of rework cost criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the best scenario of rework was zero. From the preliminary study, the average amount of this cost is 5% of the total cost; the maximum amount is 10% of the total cost. The data from the survey also described the same result. The average rework cost was 4.84% with the standard deviation being 1.55%. Figure E.3 below described the rework cost distribution. Therefore, the measurement scale of this criterion was designed as follow.

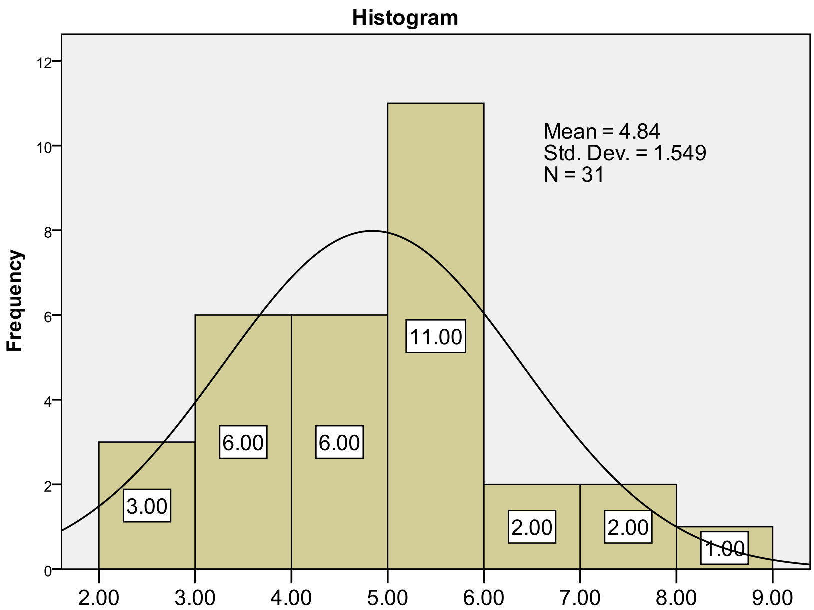

Figure E.3 Reworks Cost distribution (N=31)

- [ ] Very poor, higher than 8% of total cost
- [ ] Poor, from 6% - 8% of total cost
- [ ] Adequate, from 4% - 6% of total cost
- [ ] Good, from 2% - 4% of total cost
- [ ] Excellent, lower than 2% of total cost

E.1.4 COST4 – Expenses incurred

Definition: This criterion is intended for evaluating expenses incurred in construction site. Incurred costs may include direct operating or production expenses, indirect expenses such as overhead, and unexpected costs as well.

Measurement Scale:

From the preliminary study, the average amount of this cost was 2% of the total cost and the maximum amount was 3.5% of the total cost. From the experts, the project was excellent if the expenses incurred were lower than 0.5% and it was so bad if they were more than 3.5%. Therefore, the measurement scale of this criterion was designed as follow.

- [ ] Very poor, higher than 3.5% of total cost
- [ ] Poor, from 2.5% - 3.5% of total cost
- [ ] Adequate, around 1.5% - 2.5% of total cost
- [ ] Good, from 0.5% - 1.5% of total cost
- [ ] Excellent, lower than 0.5% of total cost

E.2 Indicator TIME

E.2.1 TIME1 – Time variation

Definition: This criterion is intended for evaluating the schedule achievement by time variation. Time variation is measured by the percentage of increase or decrease in the estimated project days, discounting the effect of extension of time granted by the client.

Measurement Scale:

Measurement scale of time variation criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the best scenario of cost variation was zero; it means that they expected the construction project to finish in schedule. They also indicated the average time variation in their companies was from 4% to 6% and it was so bad if the time variation more than 10%. The data from the survey described some different results. In the survey, the average time variation was 20% with the standard deviation being 32.46. However, it should notice that in the survey, there are some projects having time variation of more than 50%. They were unusual and could not be represented for the population. The results were shown in Table E.1. Therefore, the suggestions from experts and historical data were more conformable to design the measurement scale of this criterion.

☐ Very poor, delay more than 10% increases in the estimated project days

☐ Poor, unaccepted delay about 6% - 10% increases in the estimated project days

☐ Adequate, accepted delay amount 4% - 6% increases in the estimated project days

☐ Good, delay less than 4% increases in the estimated project days

☐ Excellent, early completion or achieve the schedule

Table E.1 Frequency of Time Variation (N=31)

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
-9.84	1	3.2	3.2	3.2
.00	1	3.2	3.2	6.5
1.00	1	3.2	3.2	9.7
1.39	2	6.5	6.5	16.1
2.73	1	3.2	3.2	19.4
2.74	1	3.2	3.2	22.6
2.78	1	3.2	3.2	25.8
3.33	1	3.2	3.2	29.0
4.80	1	3.2	3.2	32.3
5.56	1	3.2	3.2	35.5
6.45	1	3.2	3.2	38.7
6.67	1	3.2	3.2	41.9
6.85	2	6.5	6.5	48.4
8.33	1	3.2	3.2	51.6
10.00	2	6.5	6.5	58.1
14.29	3	9.7	9.7	67.7
15.38	1	3.2	3.2	71.0
21.25	1	3.2	3.2	74.2
22.96	1	3.2	3.2	77.4
25.00	1	3.2	3.2	80.6
29.17	1	3.2	3.2	83.9
33.33	1	3.2	3.2	87.1
52.04	1	3.2	3.2	90.3
81.90	1	3.2	3.2	93.5
100.00	1	3.2	3.2	96.8
142.22	1	3.2	3.2	100.0
Total	31	100.0	100.0	

E.2.2 TIME2 – Speed of construction

Definition: This criterion is intended for evaluating the speed of construction. The speed of construction is compared with standard value, which was established from each survey results.

Measurement Scale:

From the survey, the average variation between construction speed and standard value was ± 10% with the deviation 10%. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, lower than standard value more than 20%

☐ Poor, lower than standard value 10% - 20%

☐ Adequate, around ± 10% compared with standard value

☐ Good, higher than standard value 10% - 20%

☐ Excellent, higher than standard value more than 20%

E.2.3 TIME3 – Material availability

Definition: This criterion is intended for evaluating material availability. It is evaluated by the number of days construction site delay because of supplying materials

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, all of the experts agreed that, the average number of time that construction has interrupted was two. They expected the excellent material management in order to make construction process never delayed. They also indicated that it was very poor in material management if it made construction process interrupted more than three times. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, construction process has interrupted more than three times because of material supply

☐ Poor, construction process has interrupted three times because of material supply

☐ Adequate, construction process has interrupted two times because of material supply

☐ Good, construction process has interrupted one time because of material supply

☐ Excellent, it has never delayed because of material supply

E.2.4 TIME4 – Equipment availability

Definition: This criterion is intended for evaluating equipment availability. It is evaluated by the number of days construction site delay because of equipment availability

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, all of the experts agreed that, the average number of time that construction has interrupted was two. They expected the excellent equipment management in order to make construction process never delayed. They also indicated that it was very poor in equipment management if it made construction process interrupted more than three times. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, construction process has interrupted more than three times because of equipment availability

☐ Poor, construction process has interrupted three times because of equipment availability

☐ Adequate, construction process has interrupted two times because of equipment availability

☐ Good, construction process has interrupted one time because of equipment availability

☐ Excellent, it has never delayed because of equipment availability

E.2.5 TIME5 – Labor availability

Definition: This criterion is intended for evaluating labor availability. It is evaluated by the number of days construction site delay because of labor availability.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, all of the experts agreed that, the average number of time that construction has interrupted was two. They expected the excellent labor management in order to make construction process never delayed. They also indicated that it was very poor in labor management if it made construction process interrupted more than three times. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, construction process has interrupted more than three times because of labor availability

☐ Poor, construction process has interrupted three times because of labor availability

☐ Adequate, construction process has interrupted two times because of labor availability

☐ Good, construction process has interrupted one time because of labor availability

☐ Excellent, it has never delayed because of labor availability

E.3 Indicator QUALITY

E.3.1 QUA1 – Quality conformity with expectation

Definition: This criterion is intended for evaluating the level of conformity between the quality of the original works as desired and actual completion.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, meet less than 70% of the required

☐ Poor, meet 70% - 80% of the required

☐ Adequate, 80% - 90% of the required

☐ Good, meet 90% - 99% of the required

☐ Excellent, meet more than 99% of the required, reach above the required level

E.3.2 QUA2 – Quality standard

Definition: This criterion is intended for evaluating the meet quality standards in the construction process.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, meet less than 70% of the required

☐ Poor, meet 70% - 80% of the required

☐ Adequate, 80% - 90% of the required

☐ Good, meet 90% - 99% of the required

☐ Excellent, meet more than 99% of the required, reach above the required level

E.3.3 QUA3 – Implement the "Evaluate the suitability project quality certificate" in the project

Definition: This criterion is intended for evaluating the implement of "Evaluate the suitability project quality certificate" in the project. It is evaluated by aesthetics, performance, functional use, and sustainable of overall project outcome.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor

☐ Poor

☐ Adequate

☐ Good

☐ Excellent

E.3.4 QUA4 – Defects need to rework when take over the project

Definition: This criterion is intended for evaluating the defects that need to rework when taking over the project. It is evaluated by the number of defect, level of defect and repair capacity. It can also be measured by the number of defects per square meter.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ A lot of defects and they are unable or difficult to repair

☐ A lot of defects and they need a long time to repair

☐ A lot of defects and can repair in a short time

☐ Only several defects and can repair in a short time

☐ Very little defects and can repair immediately

E.3.5 QUA5 – Time to rework under-quality works

Definition: This criterion is intended for evaluating the quality of construction by time to rework under-quality works.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ They are unable or difficult to repair

☐ They need a long time to repair

☐ They need a short time to repair

☐ They can repair immediately

☐ Almost no under-quality works

E.4 Indicator SAFETY

E.4.1 SAFE1 – Number of death injures or accident

Definition: This criterion is intended for evaluating the effect of safety management system at construction site by means of the number of death injures or accident happened during construction time.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. According to the literature review, the serious level of accident was identified by both the number of accident cases and the number of people who was injured. From the survey, the following measurement scale was the final conclusion from all of the experts. Therefore, the measurement scale of this criterion was designed as follow.

☐ More than two cases of fatal occupational accidents, or more than two people killed

☐ Two cases of fatal occupational accidents, two people killed

☐ Only one case of fatal occupational accident, more than one killed

☐ Only one case of fatal occupational accident, one killed

☐ Unprecedented fatal occupational accident

E.4.2 SAFE2 – Number of heavy accidents

Definition: This criterion is intended for evaluating the effect of safety management system at construction site by means of the number of heavy accidents happened during construction time. The list of accidental injury to determine the type of heavy accident issued together with Safety Guide.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the average case of heavy accidents was three. Zero-accident was the target of all safety management system at construction site. The experts indicated that they accepted five cases of heavy accidents and the construction site, which had more than five cases of heavy accidents, was very poor and unacceptable. Therefore, the measurement scale of this criterion was designed as follow.

- [ ] More than five cases of heavy accidents
- [ ] Four or five cases of heavy accidents
- [ ] Three cases of heavy accidents
- [ ] One or two cases of heavy accidents
- [ ] Unprecedented heavy accidents

E.4.3 SAFE3 – Number of slightly accidents

Definition: This criterion is intended for evaluating the effect of safety management system at construction site by means of the number of slightly accidents happened during construction time. Slightly accidents are the remaining accidents, which do not belong to death accident, and heavy accidents listed in Safety Guide.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the average frequency of slightly accidents was three cases per month. Zero-accident was the target of all safety management system at construction site. After discussion in a group meeting, they suggested the following measurement scale to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

- [ ] Usually occur on site, more than three cases per week
- [ ] Frequently occur on site, more than one case per week
- [ ] Sometimes occur on site, more than three cases per month
- [ ] Occasionally occur, more than one case per month
- [ ] Rarely occur on site, less than one case per month

E.4.4 SAFE4 – Evaluation of Safety Signage Board

Definition: This criterion is intended for evaluating the organization, arrangement of safety signs at construction projects. Quantity, quality, and place arrangement of safety signs are examined.

Signage Board includes signage board, warning tape and board, and tag scaffolding. There are six groups of signage:

- General regulation boards: project information, general safety regulation
- Prohibited signs: shape red circle with a slash in the middle, which is located on a white background (except for the signs banned).
    - Signs prohibited for human and facilities,
    - Prohibit the signboards on,
    - Signs prohibited for construction equipment into,
    - Non-smoking signs,
    - Signs fire ban,
    - Signs prohibiting the use of mobile phones.
- Hazard warning tape and boards: Often has a triangular shape with black borders on the yellow background. It is visual and describes the danger that may appear to help people to recognize the danger to be guarded against.
    - Signs of common dangers
    - Signs of fire and explosion hazard
    - Signs of dangerous electric shock
    - Signs of danger when working with machinery: Set at the position of machinery or apparatus in general.
    - Signboards dangerous position Crane
    - Signs of danger which can slip, fall or trip legs
- Made mandatory signs: usually circle in light blue background, inside is a white visual image to describe what is required for work on the construction site.
    - Signs of labor required helmet
    - Sea of signaling required to wear protective clothing
    - Sea of signaling required to wear seat belts
- Reminders and warning signs: There is usually a rectangle on the green, pale blue or red. The sign shows the prompt or guide the work on site implementation of labor safety measures. Sea safety reminder and fire Signs risk
- Signpost, safety barricade, railing, and tag scaffolding

Measurement Scale:

☐ Very poor: has only General regulation boards

☐ Poor: has only General regulation boards and some Prohibited signs

☐ Adequate: has enough General regulation boards, Prohibited signs, and Hazard warning tape and boards

☐ Good: has General regulation boards, Prohibited signs, Hazard warning tape and boards, and mandatory signs.

☐ Excellent: has all of six groups of signage boards, they are sufficient quantity, good quality, effective arrangement

E.4.5 SAFE5 –Evaluation of providing safety tools and protection equipment for human

Definition: This criterion is intended for evaluating the level of safety uniform and personal protect equipment is provided for human. They include safety uniform and first aid facility.

Safety uniform:

- Helmet
- Harness
- Shoes and boot
- Glasses, face shield, mask and earplug
- Gloves: glove rubber, welding gloves, normal gloves
- Uniform, raincoast, highline vest
- Security tools: metal detector, emergency alarm, speaker, flashlight
- First aid facility: stretcher, first aid box, first aid facility, medicament

Measurement Scale:

☐ Very poor, extremely underequipped: persons are equipped only helmet, shoes and just some others but it is uncommon

☐ Poor, underequipped: more than 50% persons are equipped enough helmet, harness, and shoes

☐ Adequate, relative completion: more than 70% persons concerned are equipped enough helmet, harness, shoes, glasses and mask, and gloves

☐ Good, quite completion: all persons concerned are equipped enough helmet, harness, shoes, glasses and mask, gloves, and uniform

☐ Excellent, full completion: all persons concerned are equipped all of eight groups PPE above

E.4.6 SAFE6 – Evaluation safety level of equipment used in construction

Definition: This criterion is intended for evaluating the safety level of all machine and equipment that used in construction site. They are cranes, trucks, excavators, bulldozers, compactors, concrete pump, tower crane, hoist, etc… A safety system of equipment has to satisfy these following requirements:

Professional worker: Machine and equipment shall be operated by those who through guidance, training and operation.

Drivers license: All drivers must have a license to drive machine in the class corresponding to the class of machine. If only temporary driving certificate, such person shall not be allowed to drive machine.

Machines license and certificates: Before equipment to construction, all licenses and certificates of inspection machines must be considered and approved.

Inspection and maintenance: All equipment will be inspected and maintained regularly to ensure always in usable condition.

Evidence: No equipment is to operate on the site if the operator does not provide evidence that the equipment has been tested, maintenance or repair in accordance with the standards required under the provisions the law and the requirements of the manufacturer.

All machinery and equipment to the construction site carrying supplies can cause dust or pollution, such as sand, gravel, soil, peat, to ensure that materials do not spill out of the vehicle, machinery and equipment.

Machinery and equipment are fully secure parts as the original design.

Electrical systems, fuel used for machinery and equipment are arranged electrical safety and fire precautions.

Measurement Scale:

☐ Very poor, extremely under requirement: Lower than 50% of machine and equipment are satisfied requirements of Professional workers, Drivers License, Machines license and certificates

☐ Poor, under requirement: More than 50% of machine and equipment are satisfied requirements of Professional workers, Drivers License, Machines license and certificates

☐ Adequate: All machine and equipment are satisfied requirements of Professional workers, Drivers License, Machines license and certificates, Inspection and maintenance

☐ Good, quite completion: All machine and equipment are satisfied six of eight requirements above

☐ Excellent, full completion: All machine and equipment are satisfied eight requirements above

E.4.7 SAFE7 – Evaluation safety training at construction

Definition: This criterion is intended for evaluating safety training at construction site.

A completed safety training system at construction has to perform programs:

- Safety training: Before working on the site, all project personnel, including existing staff, new staff, and visitors are required to attend safety training courses conducted by safety groups.
- Safety certificate: While working on the site, all project personnel are required to attend safety training and achieve safety certified by the Ministry of Labor
- Periodic safety meetings on site: Monitoring heads must conduct regular group meetings with workers to ensure safety information is discussed. It must be carried out weekly monitoring within about 30 minutes. The objective of the meeting to ensure that: Undertake measures to be clearly understood, Risks associated with the work are evaluated and suggestions to overcome common risk, Proper procedures are followed, and Control measures and appropriate monitoring
- Safety training before specific tasks: Workers are trained to use equipment safely before operating machinery, construction equipment, or before performing a specific work

- Monthly training courses: Emergency Training Courses, Firefighting training course, First Aid Courses, Course of technical control / accident prevention
- To remind about safety every day before working on the site, all project personnel, including existing staffs and new staffs.

Measurement Scale:

☐ Very poor: Lower than 50% staffs have safety certificate, and do not conduct periodic safety meetings on site regularly.

☐ Poor: more than 70% staffs have safety certificates, and conduct periodic safety meetings on site regularly.

☐ Adequate: all staffs satisfied requirements of Safety training, safety certificate, conduct periodic safety meetings on site weekly

☐ Good: all staffs satisfied requirements of Safety training, safety certificate, conduct periodic safety meetings on site weekly, monthly training courses

☐ Excellent: all staffs satisfied all of six requirements above

E.4.8 SAFE8 – Evaluation of safety responsibility staffs

Definition: This criterion is intended for evaluating safety responsibility staffs at construction site. A complete safety system includes safety department, safety committee, supervisor, safety staff (this number will vary according to the number of workers at the site).

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information.

☐ Very poor: Almost no safety staff or anyone who is responsible for workplace safety issues

☐ Poor: has safety staff but it is desultory, does not have enough safety staff to ensure safety at construction site.

☐ Adequate: has a safety management system with enough safety staff to take care safety issue at construction site

☐ Good: has a safety management system with enough safety staff to take care safety issue at construction site; all safety staffs are trained special charge of safety issues

☐ Excellent: has a complete safety management system with enough number and quality of safety staffs; all safety staffs are trained special charge of safety issues and they are creating favorable conditions to carry out the tasks to ensure safety at construction site including material, funding, tools, and competence

E.5 Indicator TECHNICAL PERFORMANCE

E.5.1 TECH1 – Contractor's response to the technical requirements

Definition: This criterion is intended for evaluating the contractor's response to the technical requirements of project

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, meet less than 70% of the required

☐ Poor, meet 70% - 80% of the required

☐ Adequate, complete response, meet 80% - 90% of the required

☐ Complete response and good, meet 90 - 99% of the required

☐ Complete response and very good, meet more than 99% of the required in terms of difficulty, complexity, require more effort to complete

E.5.2 TECH2 – Evaluation of technical problem identification and solution

Definition: This criterion is intended for evaluating the contractor's technical problem identification and solution.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Inability to predict and identify the incidents which cause serious consequences

☐ Ability to identify the incidents but not be able to solve the problems which cause serious consequences

☐ Ability to identify the incidents and be able to solve the problems

☐ Ability to identify the incidents and be able to solve the problems exactly, quickly, and effectively

☐ Ability to predict, identify, and prevent the incidents occur

E.5.3 TECH3 – Overall assessment qualifications of workers in the project

Definition: This criterion is intended for evaluating the contractor's workers qualification in the project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ More than 50% workers lack certificates, poor qualifications

☐ Lack of qualified workers, workers don't have enough certificates as regular requires

☐ Workers have enough certificates as requirement, when working at some specific positions such as crane operation.

☐ All key workers have appropriate qualifications, degrees and certificates; they do a good job assigned

☐ High degree of specialization in each team, most workers have appropriate qualifications, degrees and certificates, they do a good job assigned

E.5.4 TECH4 – Evaluation of the possibility of problem solving of contractor's technical staff

Definition: This criterion is intended for evaluating the possibility of problem solving of contractor's technical staff.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Not be able to solve the problem, superiors frequently guide and support

☐ The ability to solve problems is not good, superiors occasional guide and support

☐ Be able to solve the problem well, superiors need guide and support to meet the difficult and complex issues.

☐ Be able to solve the problem very well, only need superiors' guidance and support in several difficult and complex problems

☐ Be able to solve the problem excellently, superiors only participate in solving problems beyond the powers

E.6 Indicator PRODUCTIVITY

E.6.1 PRO1 – Construction productivity

Definition: This criterion is intended for evaluating the construction effectiveness. It will be evaluated by the square meter constructed per day.

Measurement Scale:

Measurement scale of productivity criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the best productivity was 100 square meter per day. They also indicated the average productivity in their companies was from 25 to 50 square meter per day. The data from the survey also described the similar result. The average productivity being 61.81 square meters per day with the standard deviation was 59.85. Table E.2 below described the frequency of productivity in the survey. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, productivity lower than 10 square meters per day

☐ Poor, productivity from 10 to 25 square meters per day

☐ Adequate, productivity from 25 to 50 square meters per day

☐ Good, productivity from 50 to 100 square meters per day

☐ Excellent, productivity higher than 100 square meters per day

Table E.2 Frequency of Productivity (N=31)

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
4	2	6.5	6.5	6.5
7	2	6.5	6.5	12.9
9	2	6.5	6.5	19.4
13	1	3.2	3.2	22.6
18	1	3.2	3.2	25.8
20	1	3.2	3.2	29.0
21	2	6.5	6.5	35.5
23	1	3.2	3.2	38.7
28	1	3.2	3.2	41.9
32	1	3.2	3.2	45.2
35	1	3.2	3.2	48.4
40	1	3.2	3.2	51.6
42	2	6.5	6.5	58.1
47	2	6.5	6.5	64.5
49	1	3.2	3.2	67.7
69	1	3.2	3.2	71.0
79	1	3.2	3.2	74.2
130	1	3.2	3.2	77.4
132	1	3.2	3.2	80.6
154	1	3.2	3.2	83.9
161	1	3.2	3.2	87.1
164	1	3.2	3.2	90.3
165	1	3.2	3.2	93.5
167	1	3.2	3.2	96.8
177	1	3.2	3.2	100.0
Total	31	100.0	100.0	

E.6.2 PRO2 – Unit labor cost per square meter

Definition: This criterion is intended for evaluating the construction effectiveness. It is based on unit labor cost per square meter.

Measurement Scale:

Measurement scale of unit labor cost criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the average unit labor cost in their companies was US$40 per square meter. The data from the survey also described the similar result. The average unit labor cost was US$39.86 per square meter with the standard deviation being 10.31. Figure E.4 below described the distribution of unit labor cost in the survey. Therefore, the measurement scale of this criterion was designed as follow.

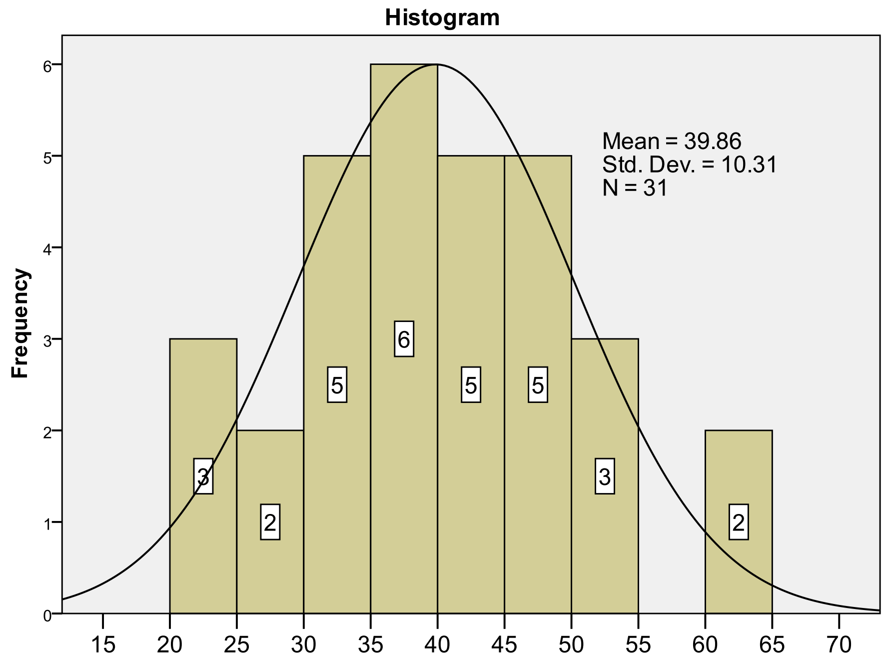

Figure E.4 Unit labor cost distribution (N=31)

☐ Very poor, unit labor cost higher than 55$ per square meter

☐ Poor, unit labor cost from 45$ to 55$ per square meter

☐ Adequate, unit labor cost from 35$ to 45$ per square meter

☐ Good, unit labor cost from 25$ to 35$ per square meter

☐ Excellent, unit labor cost lower than 25$ per square meter

E.6.3 PRO3 – Unit equipment cost per square meter

Definition: This criterion is intended for evaluating the construction effectiveness. It is based on unit equipment cost per square meter.

Measurement Scale:

Measurement scale of unit equipment cost criterion was achieved by interview experts, historical data of construction companies in survey, and survey results. From the experts and historical data, the average unit equipment cost in their companies was US$20 per square meter. The data from the survey also described the similar result. The average unit equipment cost was US$15.88 per square meter with the standard deviation being 7.22. Figure E.5 below described the distribution of unit equipment cost in the survey. Therefore, the measurement scale of this criterion was designed as follow.

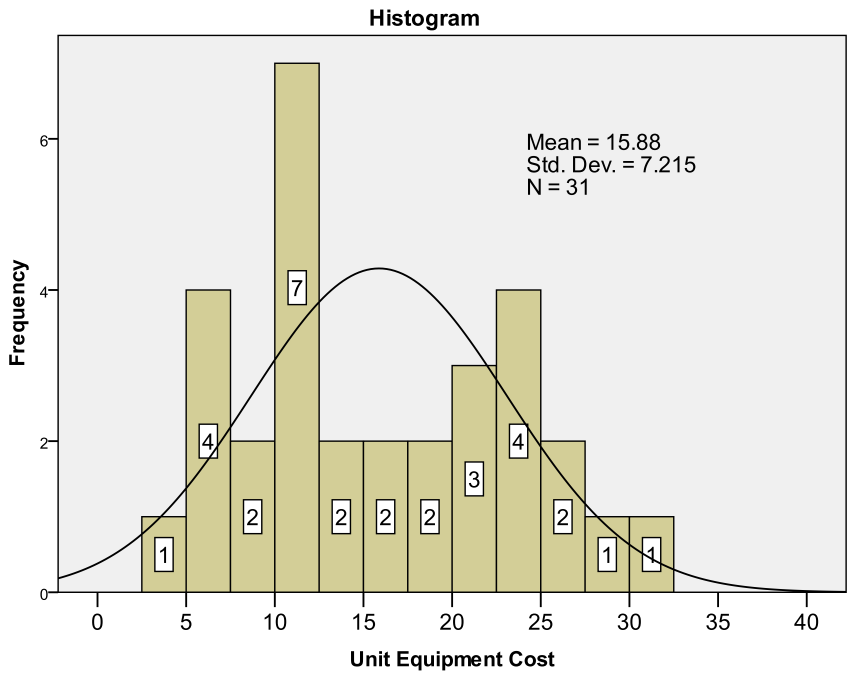

Figure E.5 Unit equipment cost distribution (N=31)

☐ Very poor, unit equipment cost higher than 25$ per square meter

☐ Poor, unit equipment cost from 20$ to 25$ per square meter

☐ Adequate, unit equipment cost from 15$ to 20$ per square meter

☐ Good, unit equipment cost from 10$ to 15$ per square meter

☐ Excellent, unit equipment cost lower than 10$ per square meter

E.7 Indicator SATISFACTION

E.7.1 SATIS1 – Owner satisfaction

Definition: This criterion is intended for evaluating the owner satisfaction overall project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. In the group meeting, the following measurement scale, which is achieved from the literature review, was discussed. All of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

- ☐ Not satisfied, very annoying
- ☐ Not satisfied
- ☐ Relatively satisfied
- ☐ Quite satisfied
- ☐ Very satisfied

E.7.2 SATIS2 – Contractor satisfaction

Definition: This criterion is intended for evaluating the contractor satisfaction overall project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. In the group meeting, the following measurement scale, which is achieved from the literature review, was discussed. All of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

- ☐ Not satisfied, very annoying
- ☐ Not satisfied
- ☐ Relatively satisfied
- ☐ Quite satisfied
- ☐ Very satisfied

E.7.3 SATIS3 – Consultant satisfaction

Definition: This criterion is intended for evaluating the consultant satisfaction overall project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. In the group meeting, the following measurement scale, which is achieved from the literature review, was discussed. All of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Not satisfied, very annoying

☐ Not satisfied

☐ Relatively satisfied

☐ Quite satisfied

☐ Very satisfied

E.8 Indicator ENVIRONMENT

E.8.1 ENVI1 – Evaluation of environment and communities around the construction site

Definition: This criterion is intended for evaluating the level and frequency of complaints from the environment and communities around the construction site.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, all of the experts agreed that, the average frequency of complaint from the environment and communities around the construction site was one time per week. They expected the excellent case that the construction site is almost not complained. Finally, all of the experts in the group meeting suggested the following measurement scale for evaluating this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Usually and repeatedly complained from the environment and communities around the construction site and had obstructed to construct.

☐ Frequently complained from the environment and communities around the construction site, average of 2 to 3 times per week

☐ Sometimes complained from the environment and communities around the construction site, average 1 time per week

☐ Occasionally complained from the environment and communities around the construction site, average 1 to 2 times per month

☐ Almost no complained from the environment and communities around the construction site, less than 1 time per month

E.8.2 ENVI2 – Level and sanctions violations related to sanitation from the authorities

Definition: This criterion is intended for evaluating the level and sanctions violations related to sanitation from the authorities. Sanctions violations includes decision to suspend construction, decision to administrative sanctioning, remind and requirement compensate and repair the damages

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, all of the experts agreed that, the average frequency of remind about sanitation from the authorities was three times during construction time. They expected the excellent case that the construction site is almost not reminded. Construction site, which have suspended construction, administrative sanctioning decisions, and required to compensate and repair the damages, was the very poor case. Finally, all of the experts in the group meeting suggested the following measurement scale for evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Frequently reminded about sanitation from the authorities, had suspended construction, administrative sanctioning decisions, and required to compensate and repair the damages.

☐ Frequently reminded about sanitation from the authorities, had administrative sanctioning decisions more than 3 times, and required to compensate and repair the damages

☐ Sometimes reminded about sanitation from the authorities, had administrative sanctioning decisions less than 3 times, and required to compensate and repair the damages

☐ Sometimes reminded about sanitation from the authorities, and required to compensate and repair the damages

☐ Almost no reminded about sanitation from the authorities, have not be sanctioned from the authorities

E.8.3 ENVI3 – Frequency of time reminded about sanitation from the authorities

Definition: This criterion is intended for evaluating the level and frequency of times reminded about sanitation from the authorities.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, all of the experts agreed that, the average frequency of remind about sanitation from the authorities was one time per month. They expected the excellent case that the construction site is almost not reminded. Finally, all of the experts in the group meeting suggested the following measurement scale for evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Usually reminded about sanitation from the authorities, average of 1 times/week

☐ Frequently reminded about sanitation from the authorities, average of 1 time per 2 weeks

☐ Sometimes reminded about sanitation from the authorities, average of 1 time per month

☐ Rarely reminded about sanitation from the authorities, average of 1 time per two month

☐ Almost no reminded about sanitation from the authorities, less than 3 times during construction time

E.8.4 ENVI4 – Evaluate the recovery of the contractor when warned

Definition: This criterion is intended for evaluating the recovery of the contractor when warned.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Not able to correct the problems, correct slowly, and cannot reach the requirements

☐ The ability to solve problems is not good, correct slowly

☐ The ability to solve problems is enough, can reach the requirements

☐ The ability to solve problems is good; reach all requirements quickly and effectively

☐ Excellent, can predict and self-test before warned, rarely be reminded

E.8.5 ENVI5 –Ensure environmental sustainability system

Definition: This criterion is intended for evaluating the environmental sustainability system in project. It is evaluated by expenses used for this system. A good system is invested time and energy, good preparation, good plan and active solutions for each problem. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information.

- [ ] Very poor
- [ ] Poor
- [ ] Adequate
- [ ] Good
- [ ] Excellent

E.8.6 ENVI6 – Expenses of overcoming the problems of environmental sanitation

Definition: This criterion is intended for evaluating expenses of overcoming the problems of environmental sanitation.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

- [ ] A great amount and costly
- [ ] A lot of
- [ ] Adequate
- [ ] Little
- [ ] Very little

E.9 Indicator COMMUNICATION

E.9.1 COM1 – Evaluation the communication in project

Definition: This criterion is intended for evaluating the communication in project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

- [ ] Very poor
- [ ] Poor
- [ ] Adequate
- [ ] Good
- [ ] Excellent

E.9.2 COM2 – The frequency of missing or late information

Definition: This criterion is intended for evaluating the frequency of missing or late information which affects to the project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

- [ ] Frequently, occur every week, serious effect to the project,
- [ ] Sometimes, occur every two week
- [ ] Occasionally, occur every month
- [ ] Rarely, less than seven times during project duration
- [ ] Almost no, less than three times during project duration

E.9.3 COM3 – Information systems used in project

Definition: This criterion is intended for evaluating the information systems used in project. A complete information exchange system is exact, in time, sufficient, decentralized and in terms of clear responsibilities.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Information exchange is not exact, unclear which causes misunderstanding

☐ Information exchange is exact but unclear, not full and late

☐ Information exchange is exact and clear, but late

☐ Information exchange is exact, in time, sufficient and quick

☐ Information exchange is exact, in time, sufficient, decentralized and in terms of clear responsibilities

E.10 Indicator DISPUTE & LITIGATION

E.10.1 LITIGA1 – Outstanding claim among parties about payment

Definition: This criterion is intended for evaluating the relationship among parties about payment. The level of conflict between owner and contractor includes conflicts that can be resolved (quickly or slowly), and conflicts that cannot be resolved, causing legal proceeding and refuse payment.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ There are serious conflicts cannot resolved, cause legal proceeding and refuse payment.

☐ There are some payment conflicts that cause extension payment schedule, or do not have payment plan, do not approve payment

☐ There are several conflicts because of extension payment schedule

☐ There are some small conflicts but can resolved quickly

☐ There is a few conflicts but it is not significant

E.10.2 LITIGA2 –Conflict among parties in check and take over the project

Definition: This criterion is intended for evaluating the relationship among parties in checking and taking over the project.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ There are serious conflicts, required to correct the problem, interruption construction

☐ There are serious conflicts, required to correct the problem, allowed to continue construction

☐ There are some small conflicts, which need a short to fix

☐ There are a few small conflicts, which can be fixed immediately

☐ There are only a few small reminders

E.10.3 LITIGA3 – Relationship between contractor and owner after project completed

Definition: This criterion is intended for evaluating relationship between contractor and owner after project completed.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Very poor, serious conflicts, legal proceeding

☐ Poor, limited partnership in future

☐ Adequate, may consider cooperation in the next project

☐ Good, maintain cooperation in the next project

☐ Excellent, strategic partner for the upcoming projects

E.10.4 LITIGA4 – Performance of contractual commitments

Definition: This criterion is intended for evaluating the performance of contractual commitments between owner and contractor. It can be evaluated by the numbers of complain letters and meeting.

Measurement Scale:

This criterion was evaluated by the experts' suggestions in the survey. These suggestions came from their experiences and completed project information. From the survey, the following measurement scale was suggested from one expert and all of the experts agreed that it was acceptable to evaluate this criterion. Therefore, the measurement scale of this criterion was designed as follow.

☐ Serious breaches, stop construction, stop payment, or terminate the contract

☐ Have more than three times of complain meeting or complain letters issued

☐ Adequate, less than three times of complain meeting or complain letters issued

☐ Good, sometimes discuss, remind in the period meeting

☐ Excellent performance of contractual commitments

APPENDIX F

LARGE SCALE SURVEY RESULTS

F.1 Projects information in large scale survey

Table F.1 Projects information in large scale survey (N=31)

Project Code	Contract Price (USD)	Final Price (USD)	Contract Duration (Days)	Actual Duration (Days)	Area (m^2)	Cost Variation (%)	Time Variation (%)
001	721,516	735,469	120	150	3,200	1.93	25.00
002	1,534,884	1,563,506	240	291	8,139	1.86	21.25
003	232,558	230,233	90	218	1,606	-1.00	142.22
004	534,884	533,488	105	191	3,521	-0.26	81.90
005	8,094,791	8,183,256	730	750	35,547	1.09	2.74
006	465,116	502,326	720	930	3,500	8.00	29.17
007	1,465,116	1,534,884	900	960	4,300	4.76	6.67
008	1,488,372	1,492,683	600	660	5,896	0.29	10.00
009	3,340,825	3,511,628	390	450	15,646	5.11	15.38
010	9,534,884	9,581,395	630	720	29,000	0.49	14.29
011	62,790,698	60,930,233	1080	1170	195,000	-2.96	8.33
012	46,511,628	48,837,209	1080	1642	130,171	5.00	52.04
013	55,813,953	57,209,302	1095	1460	192,000	2.50	33.33
014	469,800	488,843	330	339	2,479	4.05	2.73
015	481,413	486,126	270	332	2,896	0.98	22.96
016	62,790,698	63,162,791	1440	1460	235,000	0.59	1.39
017	37,209,302	38,372,093	1095	1170	180,000	3.13	6.85
018	3,720,930	3,860,465	360	370	12,000	3.75	2.78
019	23,255,814	24,427,209	720	730	120,000	5.04	1.39
020	16,279,070	16,497,459	600	606	100,000	1.34	1.00
021	16,744,186	16,976,744	750	786	102,000	1.39	4.80
022	11,627,907	12,558,140	420	480	85,000	8.00	14.29
023	11,627,907	13,023,256	720	1440	100,000	12.00	100.00

Project Code	Contract Price (USD)	Final Price (USD)	Contract Duration (Days)	Actual Duration (Days)	Area (m^2)	Cost Variation (%)	Time Variation (%)
024	5,953,488	6,140,511	540	570	27,735	3.14	5.56
025	7,441,860	7,627,907	930	990	23,144	2.50	6.45
026	8,939,535	9,767,442	600	660	31,000	9.26	10.00
027	12,558,140	12,697,674	900	930	39,000	1.11	3.33
028	1,050,221	1,101,349	365	390	5,012	4.87	6.85
029	697,674	734,884	183	165	3,392	5.33	-9.84
030	953,488	976,744	300	300	6,000	2.44	0.00
031	3,720,930	4,093,023	210	240	10,000	10.00	14.29

F.2 Project evaluation results in large scale survey

Table F.2 Projects evaluation results in large scale survey (N=31)

Project Code	Cost	Time	Qual	Safe	Tech	Sati	Prod	Envi	Comu	Liti	Final Project
001	60.12	38.04	25.10	53.38	25.00	44.78	39.45	28.73	58.47	56.09	33.09
002	60.12	29.91	44.95	33.92	55.13	40.71	59.45	49.49	65.90	52.38	47.97
003	74.69	33.22	31.66	39.29	41.06	56.50	39.45	30.01	42.52	46.39	36.66
004	84.37	27.91	36.84	34.86	55.13	64.15	44.39	38.82	66.38	56.39	50.62
005	65.28	50.45	29.10	70.34	45.26	46.67	51.92	59.87	42.52	52.38	49.04
006	34.41	36.76	29.10	60.41	40.80	46.67	25.00	25.00	33.52	52.38	25.00
007	39.74	60.25	64.39	69.46	75.13	58.18	46.37	41.92	85.00	57.62	67.62
008	68.68	46.42	62.23	85.00	59.33	65.84	66.37	57.24	74.90	79.76	78.19
009	44.72	47.16	69.58	76.02	65.26	65.84	71.92	56.49	76.00	66.31	73.89
010	60.10	46.36	48.95	53.38	59.59	71.59	50.55	55.53	58.47	43.16	56.93
011	85.00	59.55	58.13	54.80	45.26	85.00	51.92	64.71	51.05	42.69	66.51
012	55.03	36.94	38.39	53.75	39.33	79.24	37.47	53.59	58.47	42.38	44.19
013	54.94	28.71	41.63	33.08	49.20	50.74	39.45	38.58	58.47	37.92	36.66
014	54.57	69.49	70.34	49.89	80.80	52.63	65.00	85.00	83.43	85.00	85.00

Project Code	Cost	Time	Qual	Safe	Tech	Sati	Prod	Envi	Comu	Liti	Final Project
015	74.95	25.00	70.34	38.64	80.80	60.28	50.55	78.89	83.43	85.00	76.72
016	73.66	39.79	48.95	78.23	69.46	66.04	77.47	67.85	58.47	52.38	72.76
017	65.08	42.60	25.00	71.54	46.47	67.93	45.00	47.70	35.10	66.61	47.40
018	63.81	63.88	63.61	79.53	85.00	40.51	44.39	35.98	25.00	25.00	59.64
019	44.55	80.49	62.23	75.81	70.67	44.16	69.94	60.31	76.00	71.07	77.65
020	60.12	85.00	62.23	75.61	70.67	50.13	85.00	57.16	67.48	62.38	82.81
021	60.12	58.62	52.95	76.82	60.80	38.41	66.37	43.44	60.05	75.84	66.65
022	25.63	51.78	58.13	75.83	63.22	46.26	45.00	43.44	51.05	34.69	48.41
023	25.63	46.06	39.66	42.32	60.80	57.78	25.00	40.68	33.52	43.39	31.78
024	49.61	67.94	62.33	61.31	50.93	56.09	66.37	31.70	83.43	70.85	67.58
025	53.67	64.76	75.81	72.68	73.92	50.33	71.92	65.96	74.42	79.76	83.63
026	38.74	47.11	61.05	68.33	58.12	46.47	57.47	68.14	67.48	66.31	61.93
027	63.55	72.91	64.37	71.86	78.12	46.26	71.92	64.18	67.48	75.84	82.86
028	59.09	51.52	62.23	25.00	79.33	48.16	51.92	69.71	74.90	85.00	69.44
029	58.17	76.38	52.95	41.84	66.47	53.91	57.47	57.32	58.47	70.54	66.46
030	54.31	76.78	85.00	46.68	80.80	25.00	78.84	73.58	74.90	71.38	84.10
031	25.00	43.05	76.90	59.99	65.00	25.00	45.00	55.53	74.90	75.47	58.24

F.3 Criteria evaluation of thirty one projects in large scale survey

Table F.3 Criteria evaluation of thirty one projects in large scale survey (N=31)

Code	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5
001	4	3	3	3	1	2	3	2	3	3	3	3	2	3	3	5	2	2	2
002	4	3	3	3	1	1	2	4	1	4	4	4	2	3	5	2	1	2	2
003	5	3	4	4	1	3	2	3	1	4	4	3	1	2	5	5	3	1	1
004	5	4	4	5	1	3	2	1	2	4	4	4	1	2	2	3	3	2	2
005	4	4	3	3	4	1	3	3	3	3	3	3	3	3	5	5	5	3	2
006	2	1	2	3	3	1	3	1	3	3	3	3	3	3	4	3	3	3	3
007	2	2	3	2	2	3	4	3	4	5	4	4	4	4	5	3	3	3	2

Code	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5
008	3	3	5	4	2	3	3	3	2	4	4	5	4	4	5	5	4	3	3
009	2	3	2	3	1	3	2	4	3	5	4	5	4	4	4	3	3	4	3
010	3	4	4	2	1	4	2	3	3	4	4	4	3	3	2	4	3	3	2
011	5	5	4	4	2	5	3	4	2	4	4	5	4	3	2	2	2	4	4
012	2	5	2	3	1	4	2	2	2	3	3	4	3	4	5	3	3	3	2
013	3	3	4	2	1	2	2	2	2	4	3	4	3	3	1	1	3	3	4
014	2	4	3	3	4	1	5	4	4	4	4	5	5	5	4	4	4	2	2
015	4	5	3	4	1	1	2	3	1	4	4	5	5	5	5	3	3	1	1
016	3	4	4	5	5	2	1	3	1	4	4	4	3	3	4	3	2	4	5
017	3	5	3	3	2	1	4	2	3	3	3	3	3	2	5	4	3	3	4
018	3	3	3	5	4	2	4	3	4	5	5	4	3	3	5	5	3	4	3
019	2	3	1	4	5	5	4	4	3	4	4	5	4	4	3	4	3	3	4
020	4	3	3	3	5	5	4	4	4	4	4	5	4	4	5	4	2	3	4
021	4	3	3	3	3	4	2	3	4	4	4	4	4	3	2	4	5	4	4
022	1	3	1	1	1	3	1	5	4	4	4	5	4	3	5	3	4	4	3
023	1	3	1	1	1	5	1	4	2	4	4	3	3	2	3	2	3	4	1
024	3	2	3	3	3	5	3	4	3	4	4	5	3	5	5	3	4	3	3
025	3	1	4	4	2	4	4	4	3	5	5	4	4	5	4	4	3	4	3
026	1	2	2	4	2	2	4	3	2	4	4	4	5	4	5	3	2	4	3
027	4	1	4	5	4	3	4	4	4	4	5	4	4	4	5	4	3	4	3
028	2	4	3	4	2	2	5	2	3	4	4	5	4	4	3	1	3	1	2
029	2	2	5	4	5	3	4	3	5	4	4	4	4	3	5	2	3	2	1
030	3	2	4	3	5	3	4	4	4	5	5	5	5	5	4	4	3	2	2
031	1	2	1	2	1	3	2	5	1	5	5	5	4	4	5	3	2	3	3

Table F.3 Criteria evaluation of thirty one projects in large scale survey (N=31) (cont)

Code	4.6	4.7	4.8	5.1	5.2	5.3	5.4	6.1	7.1	7.2	7.3	8.1	8.2	8.3	9.1	9.2	9.3	9.4	9.5	9.6
001	3	3	3	2	2	1	2	3	2	2	4	2	3	2	3	3	3	3	3	3
002	3	1	2	4	3	3	3	4	1	3	3	3	4	3	4	5	4	3	2	4
003	2	1	1	3	3	3	1	1	3	2	5	2	3	2	3	3	4	2	2	4
004	3	1	2	4	3	3	3	2	3	3	5	3	2	3	4	4	3	2	2	5
005	3	2	2	3	3	3	2	4	1	3	4	3	3	3	4	5	5	3	3	4
006	3	3	3	3	3	2	2	3	1	3	4	1	2	2	2	3	3	3	3	3
007	4	4	3	4	5	4	4	5	3	3	4	3	3	2	1	2	4	3	5	5
008	4	4	3	3	4	3	4	5	3	4	4	4	4	3	2	4	5	3	4	5
009	4	4	4	4	4	4	3	5	3	4	4	4	4	4	2	4	5	3	5	4
010	3	3	3	4	3	4	3	4	4	4	4	2	3	4	3	4	5	3	4	4
011	3	3	4	3	3	3	2	3	5	5	4	3	3	3	4	4	5	3	4	5
012	3	2	2	2	3	2	3	4	4	5	4	2	2	3	4	4	4	3	4	4
013	3	1	2	3	3	2	4	4	2	2	5	2	3	2	3	3	3	4	4	3
014	2	3	1	5	5	4	4	4	1	3	5	3	4	4	4	5	5	5	5	5
015	2	3	1	5	5	4	4	4	1	4	5	2	3	4	5	5	5	4	4	5
016	4	4	4	4	4	4	4	5	2	4	5	4	4	5	5	5	5	2	5	4
017	3	3	3	4	3	2	2	3	1	5	5	2	3	3	5	4	5	2	3	3
018	3	4	3	5	5	4	5	5	2	3	2	3	2	3	2	4	4	3	3	3
019	4	4	4	4	5	3	4	3	5	2	1	4	3	5	3	5	4	4	4	4
020	4	3	4	5	4	3	4	4	5	2	2	4	5	5	5	3	4	4	4	4
021	4	3	3	4	4	3	3	4	4	2	1	4	4	3	4	4	4	3	3	3
022	3	4	3	5	5	1	3	5	3	3	2	2	3	3	4	4	4	3	3	3
023	3	2	2	4	4	3	3	4	5	3	2	1	2	2	3	4	5	3	2	3
024	3	2	2	4	3	3	2	4	5	2	3	4	4	3	1	2	3	5	3	4

Code	4.6	4.7	4.8	5.1	5.2	5.3	5.4	6.1	7.1	7.2	7.3	8.1	8.2	8.3	9.1	9.2	9.3	9.4	9.5	9.6
025	4	2	4	4	4	5	4	5	4	2	3	4	4	4	3	3	5	5	4	5
026	4	3	3	3	3	4	4	4	2	3	3	3	3	4	5	4	5	4	4	4
027	3	3	3	4	4	5	5	4	3	3	2	4	4	4	4	4	4	4	4	5
028	1	3	2	4	5	4	5	5	2	4	2	3	3	3	4	5	5	4	4	4
029	2	3	2	5	4	3	3	4	3	4	2	3	3	4	5	4	4	3	4	4
030	3	2	1	5	5	4	4	5	3	1	1	5	4	4	5	4	5	4	4	5
031	3	3	3	4	4	3	4	5	3	1	1	2	3	3	3	4	5	3	4	4

Table F.3 Criteria evaluation of thirty one projects in large scale survey (N=31) (cont)

Code	10.1	10.2	10.3	11.1	11.2	11.3	11.4
001	4	4	3	5	3	2	3
002	4	5	3	3	3	3	3
003	3	3	3	5	2	2	2
004	3	5	4	5	2	3	3
005	3	3	3	3	3	3	3
006	3	3	2	3	3	3	3
007	5	4	5	3	3	3	4
008	4	5	4	5	5	4	4
009	5	4	4	4	4	3	4
010	4	4	3	3	2	2	3
011	4	3	3	3	2	3	2
012	4	4	3	3	3	2	2
013	4	4	3	3	2	2	2
014	5	5	4	5	5	4	5

Code	10.1	10.2	10.3	11.1	11.2	11.3	11.4
015	5	5	4	5	5	4	5
016	4	4	3	3	3	3	3
017	3	2	3	4	3	4	4
018	2	3	2	1	1	2	2
019	5	4	4	4	4	4	4
020	4	4	4	3	3	4	4
021	4	3	4	4	4	5	4
022	4	3	3	1	2	2	3
023	3	3	2	2	3	2	3
024	5	5	4	5	3	4	4
025	5	5	3	5	5	4	4
026	4	4	4	4	4	3	4
027	4	4	4	4	4	5	4
028	4	5	4	5	5	4	5
029	4	4	3	5	4	3	4
030	4	5	4	4	3	5	4
031	4	5	4	5	5	2	5

F.4 Criteria evaluation in z-score

Table F.4 Criteria evaluation of thirty one projects in large scale survey in z-score (N=31)

Code	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5
001	0.92	-0.06	-0.03	-0.27	-0.95	-0.65	0.06	-1.18	0.20	-1.71	-1.60	-1.59	-1.44	-0.56
002	0.92	-0.06	-0.03	-0.27	-0.95	-1.40	-0.81	0.80	-1.59	-0.05	0.05	-0.26	-1.44	-0.56
003	1.76	-0.06	0.87	0.66	-0.95	0.10	-0.81	-0.19	-1.59	-0.05	0.05	-1.59	-2.41	-1.64
004	1.76	0.81	0.87	1.60	-0.95	0.10	-0.81	-2.16	-0.69	-0.05	0.05	-0.26	-2.41	-1.64
005	0.92	0.81	-0.03	-0.27	1.02	-1.40	0.06	-0.19	0.20	-1.71	-1.60	-1.59	-0.47	-0.56

Code	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5
006	-0.76	-1.79	-0.93	-0.27	0.36	-1.40	0.06	-2.16	0.20	-1.71	-1.60	-1.59	-0.47	-0.56
007	-0.76	-0.92	-0.03	-1.21	-0.30	0.10	0.92	-0.19	1.10	1.60	0.05	-0.26	0.50	0.52
008	0.08	-0.06	1.77	0.66	-0.30	0.10	0.06	-0.19	-0.69	-0.05	0.05	1.08	0.50	0.52
009	-0.76	-0.06	-0.93	-0.27	-0.95	0.10	-0.81	0.80	0.20	1.60	0.05	1.08	0.50	0.52
010	0.08	0.81	0.87	-1.21	-0.95	0.85	-0.81	-0.19	0.20	-0.05	0.05	-0.26	-0.47	-0.56
011	1.76	1.68	0.87	0.66	-0.30	1.59	0.06	0.80	-0.69	-0.05	0.05	1.08	0.50	-0.56
012	-0.76	1.68	-0.93	-0.27	-0.95	0.85	-0.81	-1.18	-0.69	-1.71	-1.60	-0.26	-0.47	0.52
013	0.08	-0.06	0.87	-1.21	-0.95	-0.65	-0.81	-1.18	-0.69	-0.05	-1.60	-0.26	-0.47	-0.56
014	-0.76	0.81	-0.03	-0.27	1.02	-1.40	1.79	0.80	1.10	-0.05	0.05	1.08	1.47	1.60
015	0.92	1.68	-0.03	0.66	-0.95	-1.40	-0.81	-0.19	-1.59	-0.05	0.05	1.08	1.47	1.60
016	0.08	0.81	0.87	1.60	1.67	-0.65	-1.68	-0.19	-1.59	-0.05	0.05	-0.26	-0.47	-0.56
017	0.08	1.68	-0.03	-0.27	-0.30	-1.40	0.92	-1.18	0.20	-1.71	-1.60	-1.59	-0.47	-1.64
018	0.08	-0.06	-0.03	1.60	1.02	-0.65	0.92	-0.19	1.10	1.60	1.71	-0.26	-0.47	-0.56
019	-0.76	-0.06	-1.83	0.66	1.67	1.59	0.92	0.80	0.20	-0.05	0.05	1.08	0.50	0.52
020	0.92	-0.06	-0.03	-0.27	1.67	1.59	0.92	0.80	1.10	-0.05	0.05	1.08	0.50	0.52
021	0.92	-0.06	-0.03	-0.27	0.36	0.85	-0.81	-0.19	1.10	-0.05	0.05	-0.26	0.50	-0.56
022	-1.60	-0.06	-1.83	-2.14	-0.95	0.10	-1.68	1.78	1.10	-0.05	0.05	1.08	0.50	-0.56
023	-1.60	-0.06	-1.83	-2.14	-0.95	1.59	-1.68	0.80	-0.69	-0.05	0.05	-1.59	-0.47	-1.64
024	0.08	-0.92	-0.03	-0.27	0.36	1.59	0.06	0.80	0.20	-0.05	0.05	1.08	-0.47	1.60
025	0.08	-1.79	0.87	0.66	-0.30	0.85	0.92	0.80	0.20	1.60	1.71	-0.26	0.50	1.60
026	-1.60	-0.92	-0.93	0.66	-0.30	-0.65	0.92	-0.19	-0.69	-0.05	0.05	-0.26	1.47	0.52
027	0.92	-1.79	0.87	1.60	1.02	0.10	0.92	0.80	1.10	-0.05	1.71	-0.26	0.50	0.52
028	-0.76	0.81	-0.03	0.66	-0.30	-0.65	1.79	-1.18	0.20	-0.05	0.05	1.08	0.50	0.52
029	-0.76	-0.92	1.77	0.66	1.67	0.10	0.92	-0.19	1.99	-0.05	0.05	-0.26	0.50	-0.56
030	0.08	-0.92	0.87	-0.27	1.67	0.10	0.92	0.80	1.10	1.60	1.71	1.08	1.47	1.60
031	-1.60	-0.92	-1.83	-1.21	-0.95	0.10	-0.81	1.78	-1.59	1.60	1.71	1.08	0.50	0.52

Table F.4 Criteria evaluation of thirty one projects in large scale survey in z-score (N=31) (cont)

Code	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	5.1	5.2	5.3	5.4	6.1
001	-0.84	1.48	-1.17	-0.97	-0.65	-0.13	0.24	0.37	-2.21	-2.07	-2.24	-1.31	-1.04
002	0.79	-1.22	-2.34	-0.97	-0.65	-0.13	-1.86	-0.68	0.15	-0.92	-0.20	-0.32	0.00
003	0.79	1.48	0.00	-2.01	-1.60	-1.47	-1.86	-1.73	-1.03	-0.92	-0.20	-2.29	-3.11
004	-1.66	-0.32	0.00	-0.97	-0.65	-0.13	-1.86	-0.68	0.15	-0.92	-0.20	-0.32	-2.07
005	0.79	1.48	2.34	0.07	-0.65	-0.13	-0.81	-0.68	-1.03	-0.92	-0.20	-1.31	0.00
006	-0.03	-0.32	0.00	0.07	0.31	-0.13	0.24	0.37	-1.03	-0.92	-1.22	-1.31	-1.04
007	0.79	-0.32	0.00	0.07	-0.65	1.21	1.28	0.37	0.15	1.37	0.82	0.67	1.04
008	0.79	1.48	1.17	0.07	0.31	1.21	1.28	0.37	-1.03	0.22	-0.20	0.67	1.04
009	-0.03	-0.32	0.00	1.10	0.31	1.21	1.28	1.43	0.15	0.22	0.82	-0.32	1.04
010	-1.66	0.58	0.00	0.07	-0.65	-0.13	0.24	0.37	0.15	-0.92	0.82	-0.32	0.00
011	-1.66	-1.22	-1.17	1.10	1.27	-0.13	0.24	1.43	-1.03	-0.92	-0.20	-1.31	-1.04
012	0.79	-0.32	0.00	0.07	-0.65	-0.13	-0.81	-0.68	-2.21	-0.92	-1.22	-0.32	0.00
013	-2.48	-2.12	0.00	0.07	1.27	-0.13	-1.86	-0.68	-1.03	-0.92	-1.22	0.67	0.00
014	-0.03	0.58	1.17	-0.97	-0.65	-1.47	0.24	-1.73	1.33	1.37	0.82	0.67	0.00
015	0.79	-0.32	0.00	-2.01	-1.60	-1.47	0.24	-1.73	1.33	1.37	0.82	0.67	0.00
016	-0.03	-0.32	-1.17	1.10	2.22	1.21	1.28	1.43	0.15	0.22	0.82	0.67	1.04
017	0.79	0.58	0.00	0.07	1.27	-0.13	0.24	0.37	0.15	-0.92	-1.22	-1.31	-1.04
018	0.79	1.48	0.00	1.10	0.31	-0.13	1.28	0.37	1.33	1.37	0.82	1.66	1.04
019	-0.84	0.58	0.00	0.07	1.27	1.21	1.28	1.43	0.15	1.37	-0.20	0.67	-1.04
020	0.79	0.58	-1.17	0.07	1.27	1.21	0.24	1.43	1.33	0.22	-0.20	0.67	0.00
021	-1.66	0.58	2.34	1.10	1.27	1.21	0.24	0.37	0.15	0.22	-0.20	-0.32	0.00
022	0.79	-0.32	1.17	1.10	0.31	-0.13	1.28	0.37	1.33	1.37	-2.24	-0.32	1.04
023	-0.84	-1.22	0.00	1.10	-1.60	-0.13	-0.81	-0.68	0.15	0.22	-0.20	-0.32	0.00
024	0.79	-0.32	1.17	0.07	0.31	-0.13	-0.81	-0.68	0.15	-0.92	-0.20	-1.31	0.00
025	-0.03	0.58	0.00	1.10	0.31	1.21	-0.81	1.43	0.15	0.22	1.84	0.67	1.04
026	0.79	-0.32	-1.17	1.10	0.31	1.21	0.24	0.37	-1.03	-0.92	0.82	0.67	0.00
027	0.79	0.58	0.00	1.10	0.31	-0.13	0.24	0.37	0.15	0.22	1.84	1.66	0.00
028	-0.84	-2.12	0.00	-2.01	-0.65	-2.81	0.24	-0.68	0.15	1.37	0.82	1.66	1.04

Code	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	5.1	5.2	5.3	5.4	6.1
029	0.79	-1.22	0.00	-0.97	-1.60	-1.47	0.24	-0.68	1.33	0.22	-0.20	-0.32	0.00
030	-0.03	0.58	0.00	-0.97	-0.65	-0.13	-0.81	-1.73	1.33	1.37	0.82	0.67	1.04
031	0.79	-0.32	-1.17	0.07	0.31	-0.13	0.24	0.37	0.15	0.22	-0.20	0.67	1.04

Table F.4 Criteria evaluation of thirty one projects in large scale survey in z-score (N=31) (cont)

Code	7.1	7.2	7.3	8.1	8.2	8.3	9.1	9.2	9.3	9.4	9.5	9.6
001	-0.65	-0.96	0.53	-0.94	-0.30	-1.43	-0.44	-1.09	-1.77	-0.39	-0.69	-1.37
002	-1.40	-0.03	-0.19	0.06	1.02	-0.32	0.41	1.32	-0.43	-0.39	-1.83	-0.04
003	0.10	-0.96	1.25	-0.94	-0.30	-1.43	-0.44	-1.09	-0.43	-1.59	-1.83	-0.04
004	0.10	-0.03	1.25	0.06	-1.61	-0.32	0.41	0.12	-1.77	-1.59	-1.83	1.29
005	-1.40	-0.03	0.53	0.06	-0.30	-0.32	0.41	1.32	0.91	-0.39	-0.69	-0.04
006	-1.40	-0.03	0.53	-1.94	-1.61	-1.43	-1.29	-1.09	-1.77	-0.39	-0.69	-1.37
007	0.10	-0.03	0.53	0.06	-0.30	-1.43	-2.13	-2.29	-0.43	-0.39	1.57	1.29
008	0.10	0.90	0.53	1.07	1.02	-0.32	-1.29	0.12	0.91	-0.39	0.44	1.29
009	0.10	0.90	0.53	1.07	1.02	0.79	-1.29	0.12	0.91	-0.39	1.57	-0.04
010	0.85	0.90	0.53	-0.94	-0.30	0.79	-0.44	0.12	0.91	-0.39	0.44	-0.04
011	1.59	1.82	0.53	0.06	-0.30	-0.32	0.41	0.12	0.91	-0.39	0.44	1.29
012	0.85	1.82	0.53	-0.94	-1.61	-0.32	0.41	0.12	-0.43	-0.39	0.44	-0.04
013	-0.65	-0.96	1.25	-0.94	-0.30	-1.43	-0.44	-1.09	-1.77	0.81	0.44	-1.37
014	-1.40	-0.03	1.25	0.06	1.02	0.79	0.41	1.32	0.91	2.02	1.57	1.29
015	-1.40	0.90	1.25	-0.94	-0.30	0.79	1.26	1.32	0.91	0.81	0.44	1.29
016	-0.65	0.90	1.25	1.07	1.02	1.90	1.26	1.32	0.91	-1.59	1.57	-0.04
017	-1.40	1.82	1.25	-0.94	-0.30	-0.32	1.26	0.12	0.91	-1.59	-0.69	-1.37
018	-0.65	-0.03	-0.91	0.06	-1.61	-0.32	-1.29	0.12	-0.43	-0.39	-0.69	-1.37
019	1.59	-0.96	-1.62	1.07	-0.30	1.90	-0.44	1.32	-0.43	0.81	0.44	-0.04
020	1.59	-0.96	-0.91	1.07	2.33	1.90	1.26	-1.09	-0.43	0.81	0.44	-0.04
021	0.85	-0.96	-1.62	1.07	1.02	-0.32	0.41	0.12	-0.43	-0.39	-0.69	-1.37
022	0.10	-0.03	-0.91	-0.94	-0.30	-0.32	0.41	0.12	-0.43	-0.39	-0.69	-1.37

Code	7.1	7.2	7.3	8.1	8.2	8.3	9.1	9.2	9.3	9.4	9.5	9.6
023	1.59	-0.03	-0.91	-1.94	-1.61	-1.43	-0.44	0.12	0.91	-0.39	-1.83	-1.37
024	1.59	-0.96	-0.19	1.07	1.02	-0.32	-2.13	-2.29	-1.77	2.02	-0.69	-0.04
025	0.85	-0.96	-0.19	1.07	1.02	0.79	-0.44	-1.09	0.91	2.02	0.44	1.29
026	-0.65	-0.03	-0.19	0.06	-0.30	0.79	1.26	0.12	0.91	0.81	0.44	-0.04
027	0.10	-0.03	-0.91	1.07	1.02	0.79	0.41	0.12	-0.43	0.81	0.44	1.29
028	-0.65	0.90	-0.91	0.06	-0.30	-0.32	0.41	1.32	0.91	0.81	0.44	-0.04
029	0.10	0.90	-0.91	0.06	-0.30	0.79	1.26	0.12	-0.43	-0.39	0.44	-0.04
030	0.10	-1.88	-1.62	2.07	1.02	0.79	1.26	0.12	0.91	0.81	0.44	1.29
031	0.10	-1.88	-1.62	-0.94	-0.30	-0.32	-0.44	0.12	0.91	-0.39	0.44	-0.04

Table F.4 Criteria evaluation of thirty one projects in large scale survey in z-score (N=31) (cont)

Code	10.1	10.2	10.3	11.1	11.2	11.3	11.4
001	0.04	0.00	-0.58	1.04	-0.29	-1.22	-0.56
002	0.04	1.17	-0.58	-0.66	-0.29	-0.20	-0.56
003	-1.29	-1.17	-0.58	1.04	-1.19	-1.22	-1.64
004	-1.29	1.17	0.81	1.04	-1.19	-0.20	-0.56
005	-1.29	-1.17	-0.58	-0.66	-0.29	-0.20	-0.56
006	-1.29	-1.17	-1.97	-0.66	-0.29	-0.20	-0.56
007	1.37	0.00	2.20	-0.66	-0.29	-0.20	0.52
008	0.04	1.17	0.81	1.04	1.52	0.82	0.52
009	1.37	0.00	0.81	0.19	0.61	-0.20	0.52
010	0.04	0.00	-0.58	-0.66	-1.19	-1.22	-0.56
011	0.04	-1.17	-0.58	-0.66	-1.19	-0.20	-1.64
012	0.04	0.00	-0.58	-0.66	-0.29	-1.22	-1.64
013	0.04	0.00	-0.58	-0.66	-1.19	-1.22	-1.64
014	1.37	1.17	0.81	1.04	1.52	0.82	1.60
015	1.37	1.17	0.81	1.04	1.52	0.82	1.60

Code	10.1	10.2	10.3	11.1	11.2	11.3	11.4
016	0.04	0.00	-0.58	-0.66	-0.29	-0.20	-0.56
017	-1.29	-2.34	-0.58	0.19	-0.29	0.82	0.52
018	-2.62	-1.17	-1.97	-2.36	-2.10	-1.22	-1.64
019	1.37	0.00	0.81	0.19	0.61	0.82	0.52
020	0.04	0.00	0.81	-0.66	-0.29	0.82	0.52
021	0.04	-1.17	0.81	0.19	0.61	1.84	0.52
022	0.04	-1.17	-0.58	-2.36	-1.19	-1.22	-0.56
023	-1.29	-1.17	-1.97	-1.51	-0.29	-1.22	-0.56
024	1.37	1.17	0.81	1.04	-0.29	0.82	0.52
025	1.37	1.17	-0.58	1.04	1.52	0.82	0.52
026	0.04	0.00	0.81	0.19	0.61	-0.20	0.52
027	0.04	0.00	0.81	0.19	0.61	1.84	0.52
028	0.04	1.17	0.81	1.04	1.52	0.82	1.60
029	0.04	0.00	-0.58	1.04	0.61	-0.20	0.52
030	0.04	1.17	0.81	0.19	-0.29	1.84	0.52
031	0.04	1.17	0.81	1.04	1.52	-1.22	1.60

F.5 Evaluation result of each indicator in large scale survey

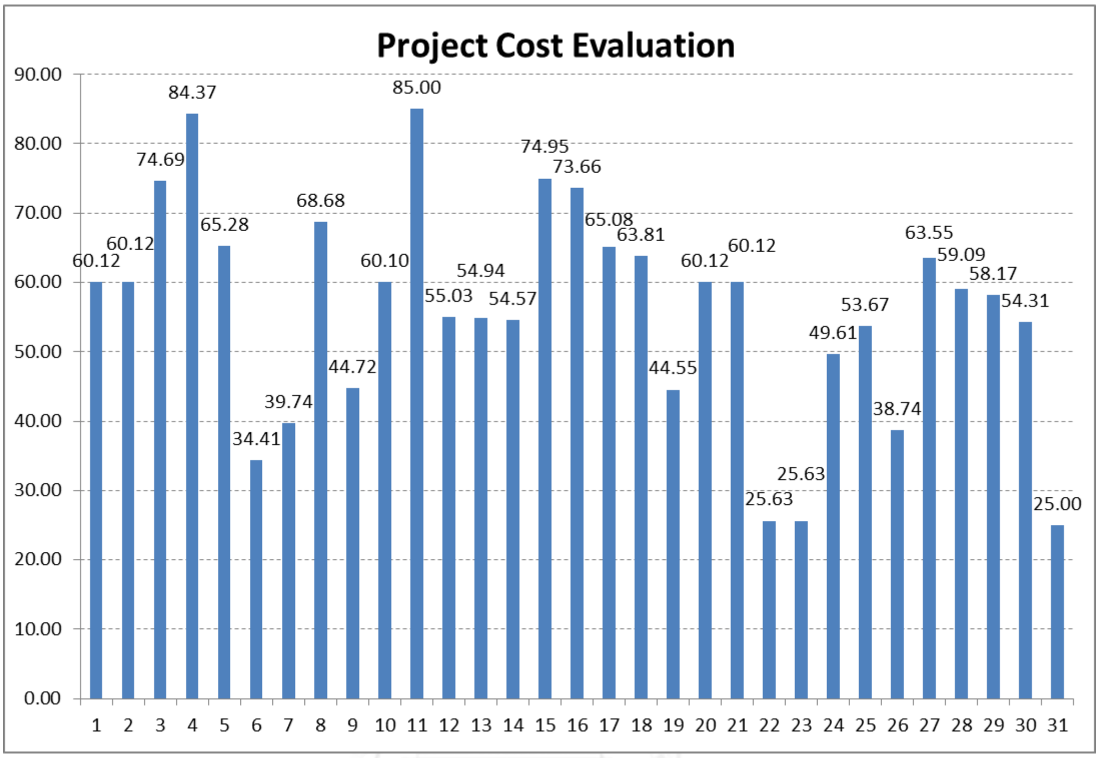

Figure F.1 Project cost evaluation result in large scale survey (N=31)

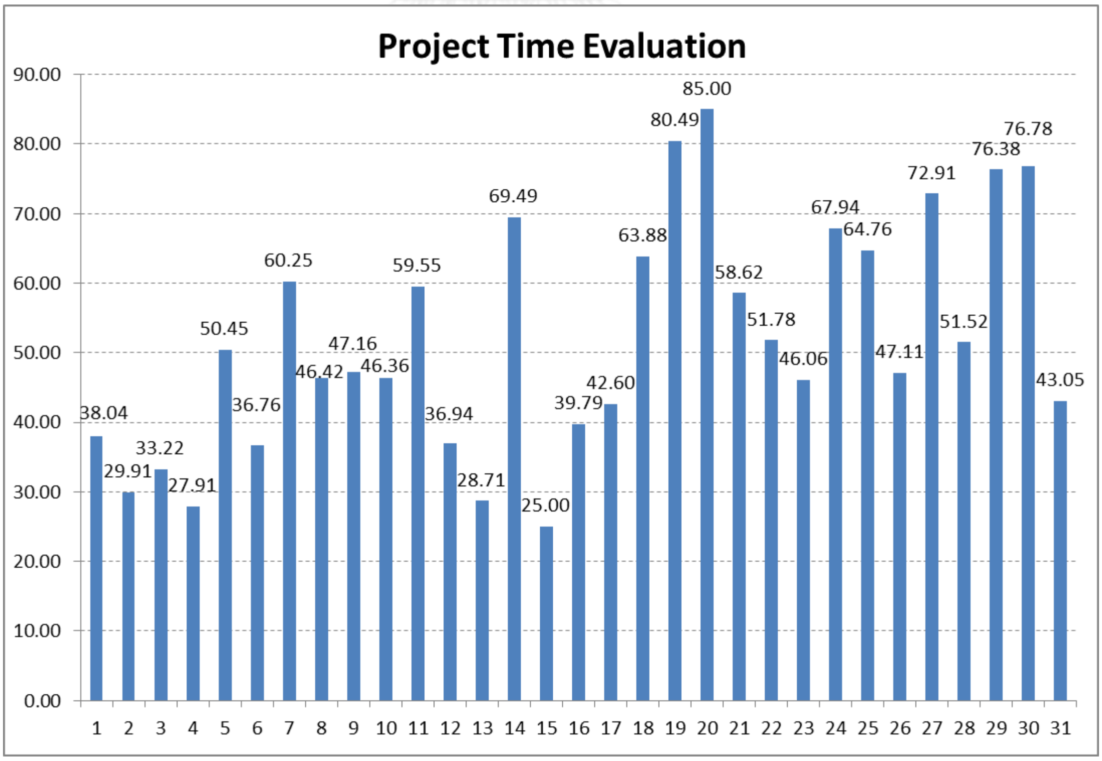

Figure F.2 Project time evaluation result in large scale survey (N=31)

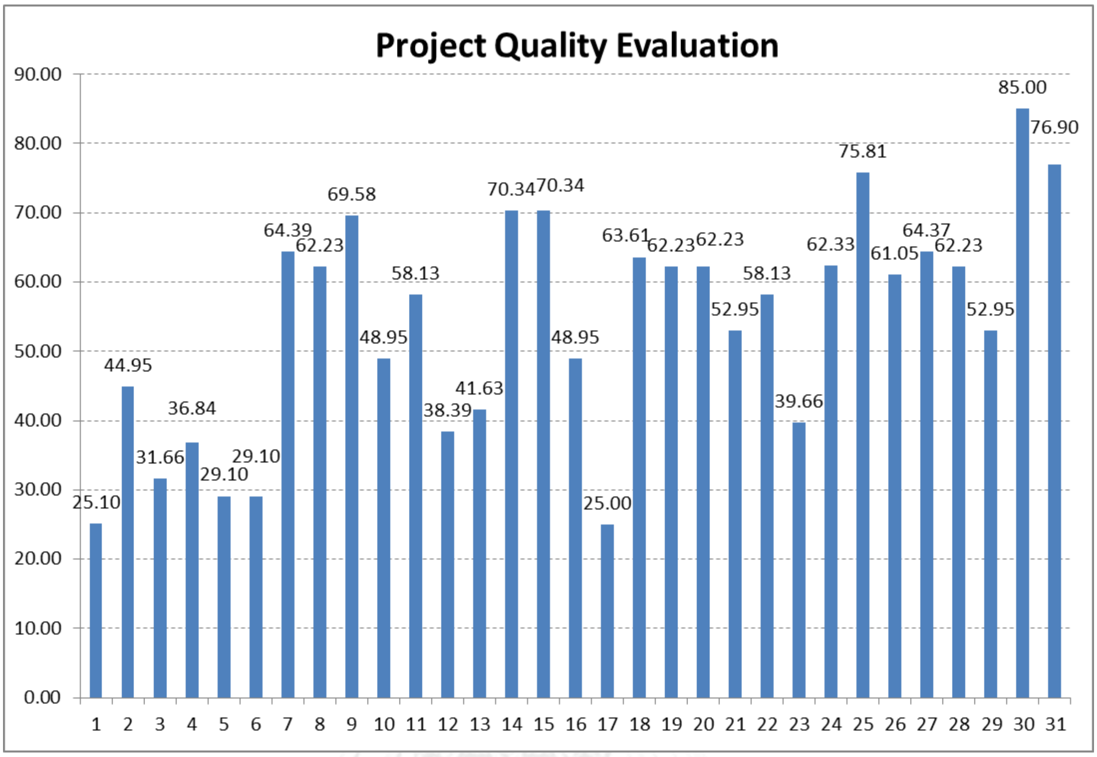

Figure F.3 Project quality evaluation result in large scale survey (N=31)

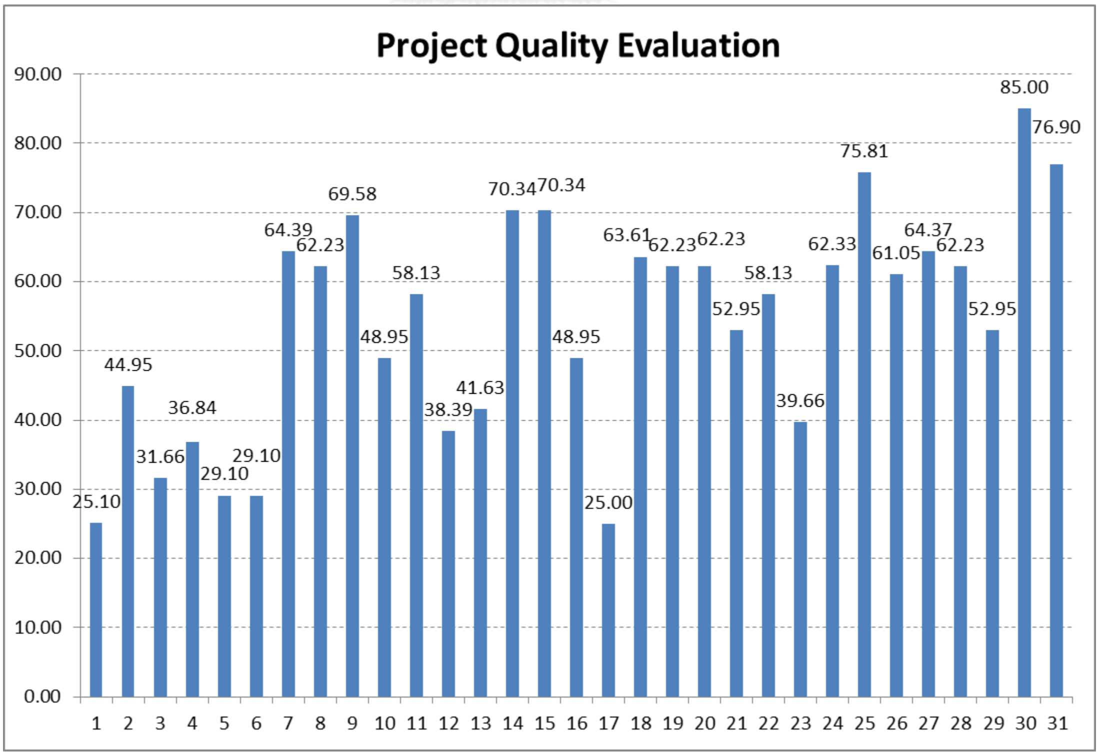

Figure F.4 Project safety evaluation result in large scale survey (N=31)

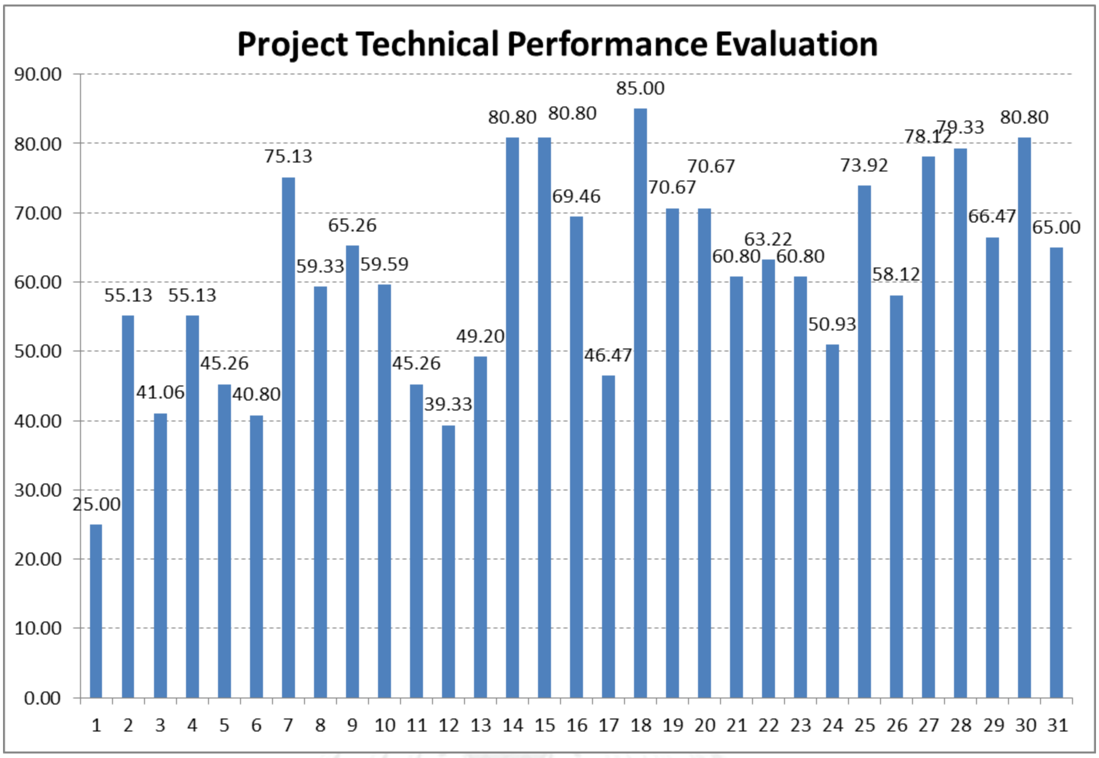

Figure F.5 Project technical performance evaluation result in large scale survey (N=31)

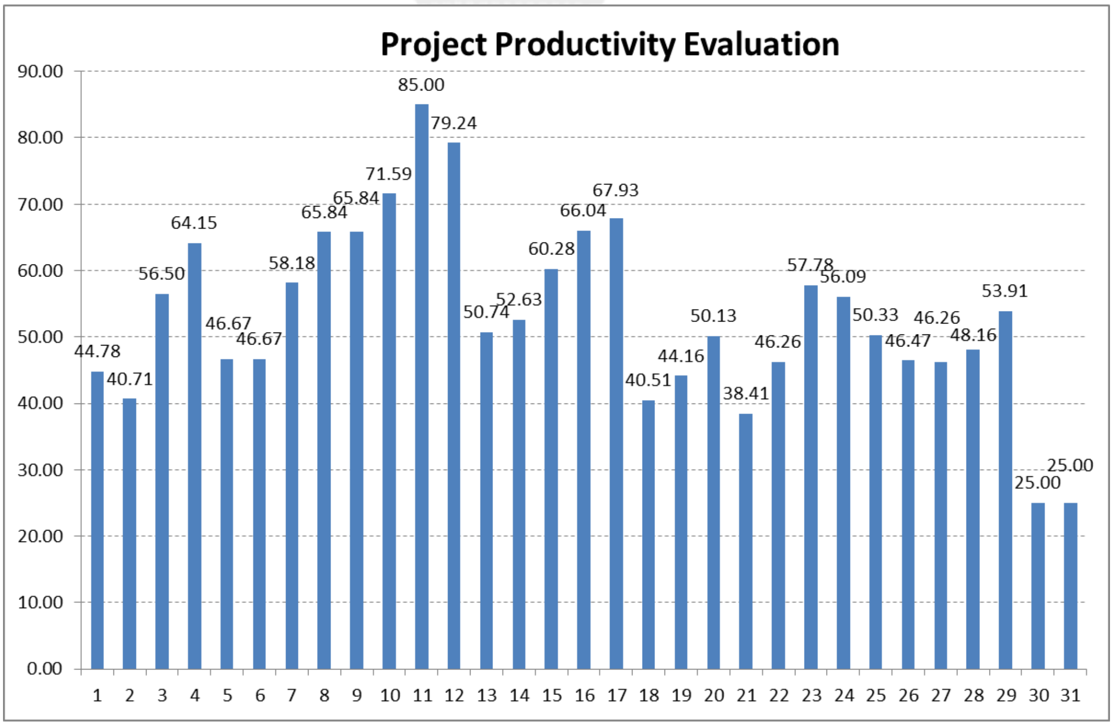

Figure F.6 Project productivity evaluation result in large scale survey (N=31)

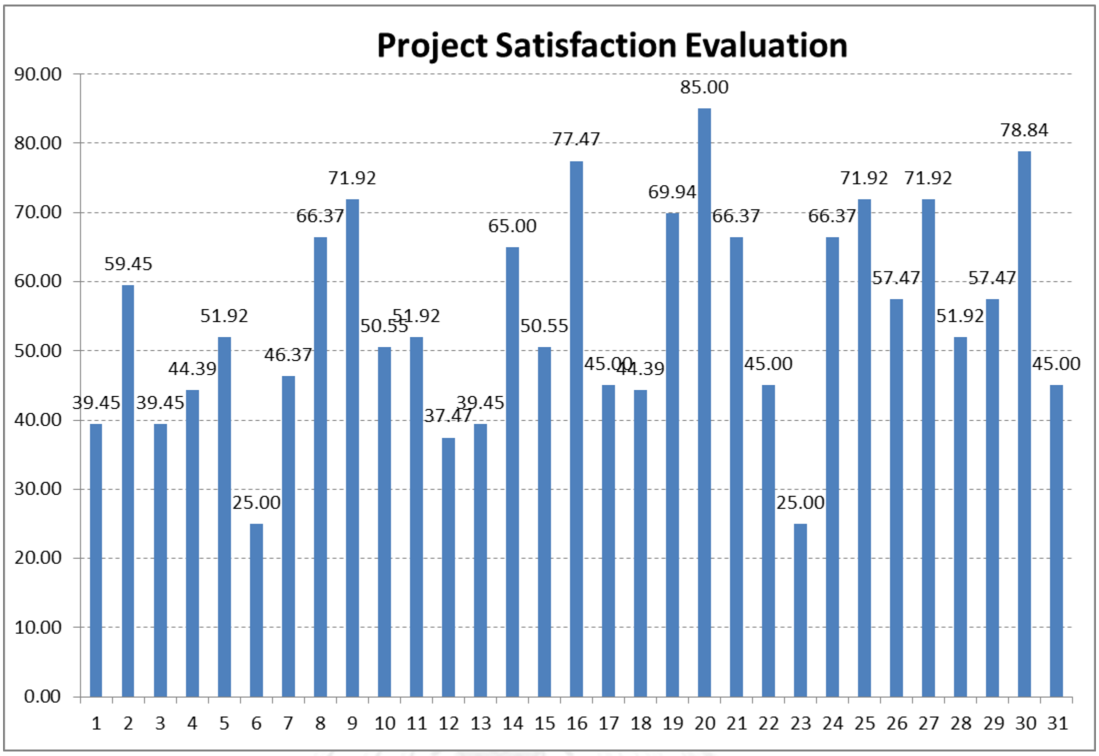

Figure F.7 Project satisfaction evaluation result in large scale survey (N=31)

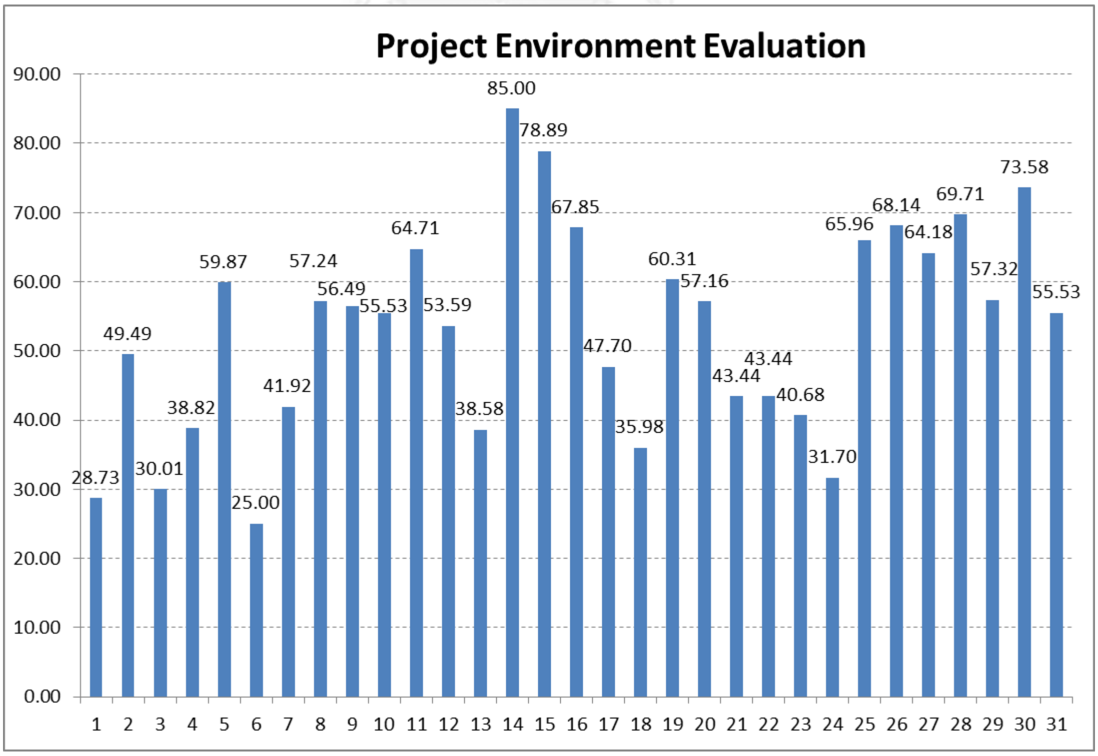

Figure F.8 Project environment evaluation result in large scale survey (N=31)

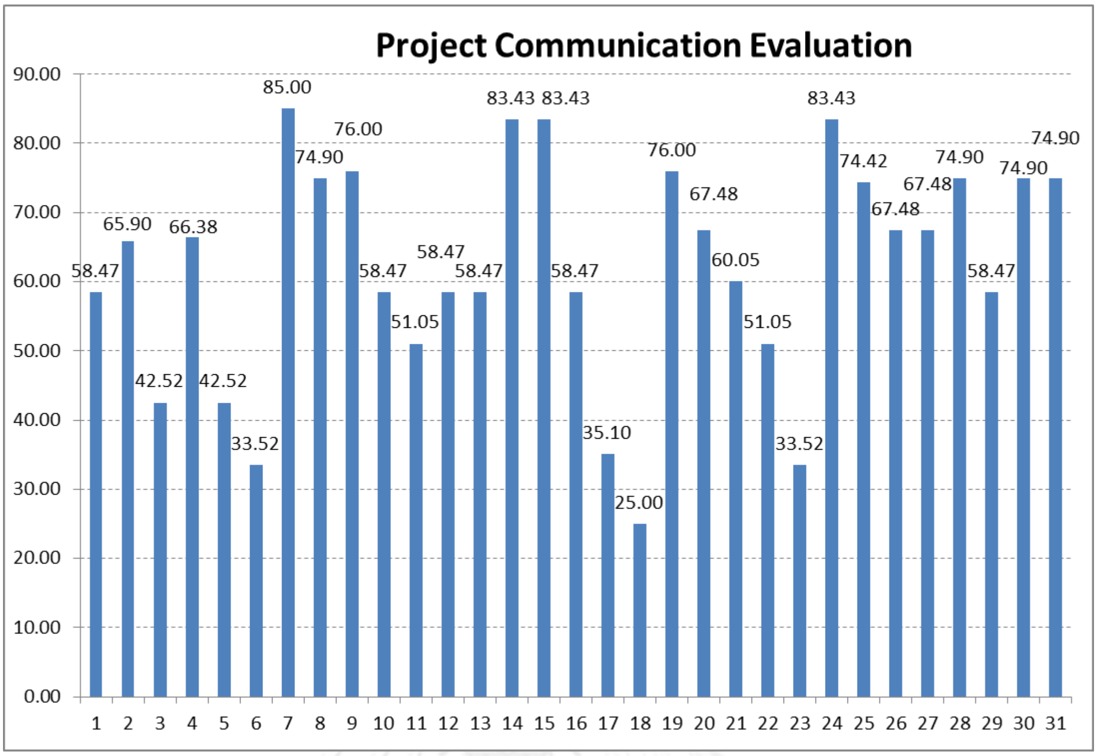

Figure F.9 Project communication evaluation result in large scale survey (N=31)

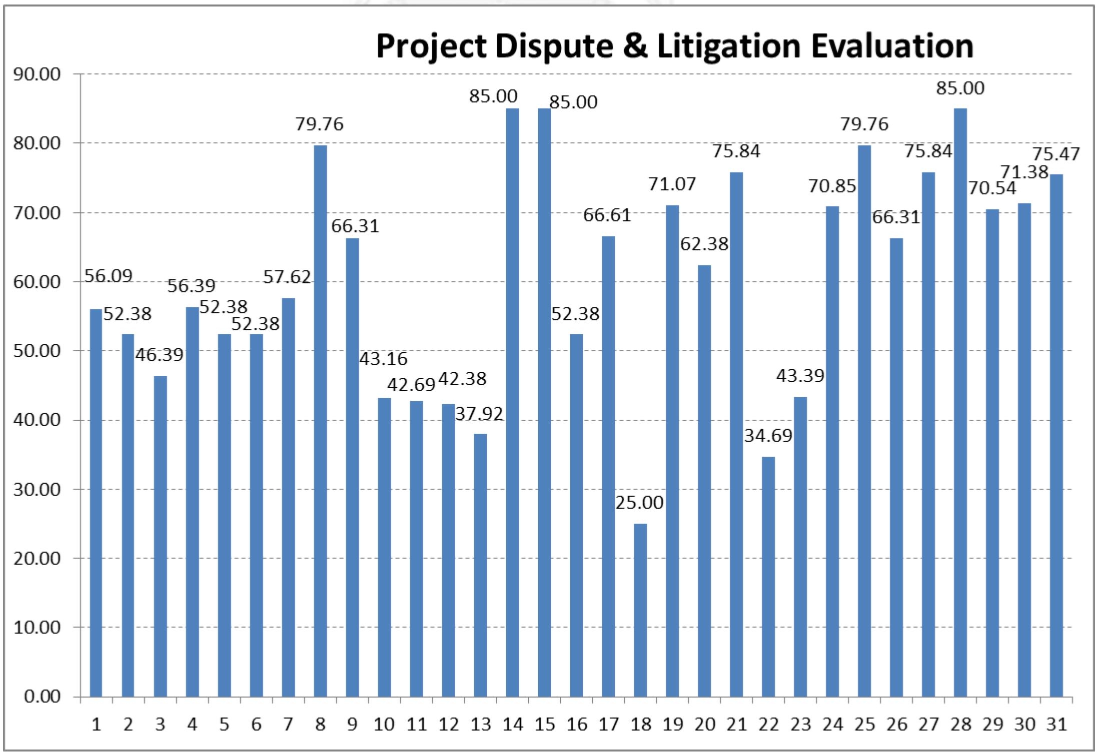

Figure F.10 Project dispute & litigation evaluation result in large scale survey (N=31)

F.6 Results of analysis of variance between groups

Contract Price Groups

Descriptive analysis

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
1.00	8	57.2063	24.04326	8.50058	37.1056	77.3069
2.00	12	64.5083	10.97161	3.16723	57.5373	71.4794
3.00	11	59.7891	18.67484	5.63068	47.2432	72.3350
Total	31	60.9494	17.45191	3.13446	54.5479	67.3508

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
7.180	2	28	.003

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	278.891	2	139.445	.441	.648
Within Groups	8858.183	28	316.364		
Total	9137.074	30			

Robust Tests of Equality of Means

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
1.00	8	57.2063	24.04326	8.50058	37.1056	77.3069
2.00	12	64.5083	10.97161	3.16723	57.5373	71.4794
3.00	11	59.7891	18.67484	5.63068	47.2432	72.3350

	Statistic[a]	df1	df2	Sig.
Welch	.482	2	14.257	.627
Brown-Forsythe	.383	2	16.632	.687

a. Asymptotically F distributed.

Contract Duration Groups

Descriptive analysis

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
1.00	11	60.7218	17.65027	5.32176	48.8642	72.5794
2.00	11	59.3827	19.22982	5.79801	46.4640	72.3015
3.00	9	63.1422	16.78188	5.59396	50.2425	76.0419
Total	31	60.9494	17.45191	3.13446	54.5479	67.3508

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.120	2	28	.888

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	70.845	2	35.423	.109	.897
Within Groups	9066.229	28	323.794		
Total	9137.074	30			

Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	.109	2	18.424	.897
Brown-Forsythe	.111	2	27.768	.896

a. Asymptotically F distributed.

Project Area Groups

Descriptive analysis

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
1.00	12	60.0725	20.74017	5.98717	46.8948	73.2502
2.00	10	64.2150	12.58089	3.97843	55.2152	73.2148
3.00	9	58.4900	18.74353	6.24784	44.0825	72.8975
Total	31	60.9494	17.45191	3.13446	54.5479	67.3508

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
2.870	2	28	.073

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	170.307	2	85.153	.266	.768
Within Groups	8966.767	28	320.242		
Total	9137.074	30			

Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	.351	2	17.527	.709
Brown-Forsythe	.275	2	25.031	.762

a. Asymptotically F distributed.

VITA

Thu Anh Nguyen, raised in Vietnam, graduated her bachelor degree in 2007 from Hochiminh City University of Technology. Since then, she has been a lecture of Faculty of Engineering, HCMUT, in Vietnam. She had been granted the scholarship by Thai Petroleum Company for her master degree at Chulalongkorn University. She had finished her master degree in 2010 in Civil Engineering major, with an emphasis in Construction Engineering and Management. Continuously, she achieved the scholarship by ASEAN University Network –Southeast Asia Engineering Education Development Network Project (AUN/SEED-Net) for her doctoral degree. The topics related to construction management that she interested in are contracting in construction business, construction business management, and safety management in construction.