DEVELOPMENT OF A WEB-BASED SYSTEM FOR MANAGING SUPPLIERS' PERFORMANCE IN CONSTRUCTION PROJECTS

By

LI ZI QIAN

A dissertation submitted to the Department of Surveying,
Faculty of Engineering and Science,
Universiti Tunku Abdul Rahman,
in partial fulfillment of the requirements for the degree of
Master of Science
November 2013

ABSTRACT

DEVELOPMENT OF A WEB-BASED SYSTEM FOR MANAGING SUPPLIERS' PERFORMANCE IN CONSTRUCTION PROJECTS

Li Zi Qian

Suppliers play an important role in the success of construction projects as they are the ones who carry out the actual construction work and complete the project by supplying their skills and knowledge (i.e. service) or material. Therefore, getting the right supplier for the right job is critical towards the success of any construction project. To achieve this, however, entails efficient information and communication technology (ICT) aided information system for managing the performance of the suppliers. Most of the local construction companies are found to be unaware of the benefits brought about by such systems and still resort to handle majority of the tasks manually. This research was aimed at the development of a Web-based system that can help to better manage suppliers' performance to assist in the selection of suppliers and to facilitate the leveraging of suppliers' knowledge for the benefit of the on-going projects.

Literatures on the importance of managing suppliers' performance, criteria for supplier selection, existing practice for supplier selection, importance of knowledge sharing and reward of knowledge sharing were reviewed. Twelve semi-structured interviews were conducted with the practitioners in the

industry to explore the current approaches for supplier selection, the way of managing suppliers' performance, and also to identify the end-users' requirements on the methodology for managing suppliers' performance and knowledge sharing. The case studies revealed that the custom-designed computer applications used by the case study companies for the selection and management of suppliers' performance are not comprehensive in terms of the features. The systems do not capture the historical data on the performance of the suppliers for the selection purpose. This information is critical to reveal the reliability of the suppliers and also to allow them to improve their performance. In addition, the systems require the user to scan and then upload the written documents to the system. This is not only time consuming but also inconvenient.

The system developed consists of a Web-based database to store the relevant information with modules for managing the criteria for supplier selection, knowledge capture and evaluation, and managing suppliers' performance across projects. In order to improve the functionality of the system, the system was tested and evaluated by the participants from the construction companies interviewed before. Positive feedbacks were received with an overall score of 3.8 out of 5.0. Simply put, the system can facilitate the informed decision making on the selection of the most suitable suppliers based on the records captured in the system. It allows the continuous improvement to the project at different stages by allowing suppliers to share their knowledge as to how improvements can be made. Further studies may involve the development of an improved version of this prototype application where it caters for the need

to select and manage the performance of different types of suppliers with different sets of criteria.

ACKNOWLEDGEMENTS

appreciate their willingness to allocate time for the interview albeit their existing heavy workload.

Finally, I managed to finish and achieve my aim with a lot of hardworks and patience. I got through my postgraduate studies. The pride doesn't belong to me only. It goes to everybody who had rendered and shared their ideas, advice and helping hands directly or indirectly.

Thank you all.

APPROVAL SHEET

This dissertation entitled **"DEVELOPMENT OF A WEB-BASED SYSTEM FOR MANAGING SUPPLIERS' PERFORMANCE IN CONSTRUCTION PROJECTS"** was prepared by LI ZI QIAN and submitted as partial fulfillment of the requirements for the degree of Master of Science at Universiti Tunku Abdul Rahman.

Approved by:

_____

(Assistant Prof. Dr. TAN HAI CHEN)   Date: 15 November 2013
Supervisor
Department of Surveying
Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

_____

(Assistant Prof. Dr. CHIA FAH CHOY)   Date: 15 November 2013
Co-supervisor
Department of Surveying
Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

FACULTY OF <u>ENGINEERING AND SCIENCE</u>

UNIVERSITI TUNKU ABDUL RAHMAN

Date: <u>15 NOVERMBER 2013</u>

SUBMISSION OF DISSERTATION

It is hereby certified that <u>***Li Zi Qian***</u>
(ID No: <u>***10 UEM 02133***</u>) has completed this dissertation entitled " <u>*DEVELOPMENT OF A WEB-BASED SYSTEM FOR MANAGING SUPPLIERS' PERFORMANCE IN CONSTRUCTION PROJECTS*</u> " under the supervision of <u>Dr Tan Hai Chen</u> (Supervisor) from the Department of <u>Surveying</u> , Faculty of <u>Engineering and Science</u> , and <u>Dr Chia Fah Choy</u> (Co-Supervisor) from the Department of <u>Surveying</u> , Faculty of <u>Engineering and Science</u> .

I understand that University will upload softcopy of my dissertation in pdf format into UTAR Institutional Repository, which may be made accessible to UTAR community and public.

Yours truly,

_____

(*Li Zi Qian*)

DECLARATION

I _____LI ZI QIAN_____ hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

_____

(LI ZI QIAN)

Date _____15 NOVEMBER 2013_____

TABLE OF CONTENTS

Page

CHAPTER

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

This chapter introduces briefly the justification and background for the need to manage the performance of the suppliers and the importance to facilitate knowledge sharing among the suppliers. It also outlines the research methodology developed, provides the aim and objectives of this research and a guide to its contents.

1.1 Background

In construction industry, the client or developer normally does not involve directly in the actual construction work of the project. Instead, the client is dependent on the skills and resources of the supplier to carry out the actual construction work and the project is very often procured through appointing consultants to prepare the design and then subsequently awarding the contract to a contractor through tender to deliver the project based on the design. The contactor, who is contractually bound to deliver the project on time and to the standard, in turn also counts on his subcontractors and material suppliers to help fulfilling his commitment under the project at varying degrees.

Suppliers, in the context of this research, are defined to cover the contractor, consultants, material suppliers and subcontractors who have contributed their skills and knowledge (i.e. service) or materials into a construction project. Without the suppliers doing their part, the project may never be completed, not to mention on time and according to the requirements of the client. Therefore, there is a need for a mechanism to manage the performance of suppliers for the purpose of contract awarding and also facilitates continuous improvement throughout the duration of the project. As the "suppliers" have basically included all the parties directly and indirectly engaged by the client/ developer to carry out tasks to accomplish a project, the importance of careful selection of suppliers for the purpose is obvious.

Knowledge management (KM) has been receiving growing attention by the construction industry in view of the potential benefits brought about by KM, evident by the number of research done and also of its successful implementation in construction companies. KM is generally regarded as "the processes that involve the creation, acquisition, communication, sharing, application of knowledge to meet the emerging and existing needs" (Zin and Egbu, 2010). It is also about how to identify and exploit existing and acquired knowledge that can bring about a sustainable environment and value creation for the organisation (Zin and Egbu, 2010). For the Malaysian construction industry that has experienced various changes in the last decade and expanded its market across other countries in the region, its exposure to both challenges and risks is growing but its performance has not improved proportionately (Abdul-Rahman and Wang, 2010). Abdul-Rahman and Wang (2010) feel that

this is partly attributed to the lack of a knowledge-based approach to construction. In other words, the local construction companies should better leverage on their knowledge to maintain their competitive edge and to improve their performance.

KM is considered as a relatively new management tool in the Malaysian construction industry. Only, a number of construction companies are at the initial phase of formal KM implementation albeit it is reported that the importance and benefits of KM have been gradually recognised (Abdul Rahman and Wang, 2010). In fact, KM is important to construction industry since its fundamental is "to manage the various projects knowledge in a proper, formal and structured way" (Carrillo et al., 2000).

1.2 Rationale for the Research

Supplier management is one of the most important activities of the companies in a supply chain. Having the right suppliers can significantly reduce the purchasing cost and help to introduce improvement in competitiveness (Saen 2007; Xia and Wu, 2007). It is also critical for just-in-time delivery to reduce unnecessary waste (Dainty and Brooke, 2004). Conversely, having suppliers with poor performance is easy to deteriorate the supply chain's fiscal and functional position (Sarkar and Mohapatra, 2006; Araz and Ozkarahan, 2007), which may lead to delays as well as poor customer service (Chan and Kumar, 2007).

As a result, it is not surprising that a number of research projects that look into the selection of suppliers in the construction industry have been initiated or conducted. For instance, Arslan et al. (2008) have developed a Web-based sub-contractor evaluation system namely WEBSES that allows sub-contractors to be evaluated online based on a set of criteria. Ng et al. (2002) propose a conceptual framework for an e-Reporting system that enables performance related data of contractors at project level to be submitted, compiled and checked, and subsequently disseminated to relevant users in the industry obviously for contractor selection purpose. There are also attempts to harness what artificial intelligence can offer through the use of multi-criteria decision-making (MCDM) method for contractor selection instead of the over-simplistic lowest-bid-win approach (e.g. Mahdi et al., 2002; Cheng and Li, 2004; Topcu, 2004; Kaklauskas et al., 2007). In other industries, there is also the utilisation of case-based reasoning (CBR) to assist in the selection of the best supplier based on past records (e.g. Choy et al., 2003; Humphreys et al., 2004).

The aforementioned research is mainly focused on capturing the information on suppliers' performance to facilitate better supplier selection process. However, there is no evidence that mechanisms are available to feedback to the suppliers their performance as recorded in the system. The importance of such mechanisms is apparent as without it the supplier does not have an opportunity to clarify and defend themselves should the information that was used for the evaluation be inaccurate or if he has in fact addressed the issues that gave him a low score (and these improvements have not yet been

reflected in the records). In addition, without access to his own record in the system the supplier has no opportunity to improve himself based on the feedback given and the result of the evaluation. Clearly, this feedback mechanism has to be built into the system for managing suppliers' performance.

Another mechanism that can also be incorporated into this kind of system is one that is able to capture the knowledge of suppliers on how improvements can be made to an existing/on-going project. This may form part and parcel of the criteria for evaluating the performance of suppliers and rewarding them as appropriate. The need for an approach which is capable of managing the suppliers' performance across projects for selection purpose and help leverage on their valuable knowledge, however, has not been adequately addressed. This research therefore addresses the importance of developing a system that can fulfil the aforementioned requirements.

1.3 Aim and Objectives

This research aims to develop a Web-based system for managing the performance of suppliers to assist the selection of supplier. The system includes also the mechanism for capturing the knowledge of suppliers on how the existing on-going project can be further improved, which will also be taken into account for the evaluation of their performance. The aim is achieved through the following objectives:

i) To study the existing practice of the Malaysia construction industry in managing suppliers to identify the areas that information and communication technology (ICT) may contribute to better management of the whole process and the relevant information,

ii) To develop a Web-based system for better managing the performance record and knowledge about/of suppliers that will improve the existing mechanism for the selection of supplier with the aid of ICT; and

iii) To test and evaluate the effectiveness of the system.

1.4 Research Methodology

This section outlines the research methodologies adopted for gathering the essential information for the purpose of the research, and for the development as well as the evaluation of the system developed. The details are as follows.

The review of relevant literatures started from the key terms and concepts related to the research. The literatures about this topic were located by referring different materials and databases, including those can be located from the academic library and internet websites. Journals, articles, conference proceedings, books, magazines, dictionaries and government official reports are preferred to obtain relevant data. The literatures reviewed was focused on supplier management, particularly looking at the current practices on supplier

selection, the management of suppliers' performance, the criteria for supplier selection and also the knowledge sharing in construction industry. The literatures were organised by abstracting and taking notes on the important points. Later, a review was written that reports the summaries of the literatures.

This was followed by a series of semi-structured interviews involving practitioners in the industry, whose positions range from the project manager to the contract manager of construction companies in Malaysia. The purpose of conducting the interview was to find out the current practice of supplier selection, the way of managing suppliers' performance, the criteria used for supplier selection and the details of the custom-developed system for the purpose, if available. The targeted construction firms cover both contractor and developer. The construction firms are public listed on the main board of Kuala Lumpur Stock Exchange. This is to ensure both main contractor's and developer's perspectives on the relevant issues are obtained. The appointments of the interviews were made via telephone, sending formal request for an interview and email.

Semi-structured interview was preferred to allow more in-depth information to be obtained than a survey. The outcomes of the interviewees were quickly transcribed after the interview. In addition, the information was also recorded with the aid of camera, print screens of the systems used by the interviewees' companies. Sometimes, hard copy of relevant documents was also provided by the interviewees. This information was then analysed in order to identify the shortcomings of current practice and how these could be further

improved. This was subsequently used for the development of a framework for the Web-based Suppliers' Performance Management System.

The system developed is based on the Web-based platform to facilitate cross-platform and ease of access to the system. It provides an efficient means for managing suppliers' performance through the Web and allows the suppliers' knowledge to be leveraged for the benefit of the on-going projects. The Web-based system comprises four modules, i.e. that for supplier selection, evaluation of supplier's performance, communication with suppliers on their performance score and knowledge sharing. The prototype system developed was tested and evaluated mainly by the participants from the construction companies interviewed before. The functions of the system were first demonstrated to the participants. Subsequently, the participants were allowed to experiment with the system by themselves. The result of evaluation and suggestions for improvements were analysed to identify room for improvements that can be made to the system.

1.5 Scope and Limitations

In order to study the current practice on how the local construction companies managing their suppliers' performance, 13 big construction firms which are listed in the main board of Kuala Lumpur Stock Exchange (KLSE) were interviewed. However, one of the large construction company approached was reluctant to grant an interview due to their own policy of not disclosing internal practice to external parties. However, the impact on this

research is minimal as the informal but reliable internal sources confirmed the lack of ICT aided system for managing suppliers' performance system.

It is also recognised that more time is required to fully evaluate the prototype system. This will allow more parties and projects to be used in the evaluation to help improve the richness of the contents captured. Furthermore, this will enables the users to provide more constructive suggestions for improvements through personal experience of using it over a reasonably long period of time. Due to time constraint, the function that allows the suppliers to give feedback on the performance of the client organisation's project staff was not developed. Apart from this, the system only caters for the management of the subcontractors' performance by the main contractor; it does not include the function for the management of the consultants' and main contractors' performance by the client.

1.6 Report Layout and Contents

Chapter one introduces the background and justification for the need to better manage the performance of the suppliers and the importance to facilitate knowledge sharing among the suppliers. It also outlines the research methodology developed, provides the aim and objectives of this research and a guide to its contents.

Chapter two covers the definitions, the characteristics and role of supplier and then followed by the importance of managing suppliers'

performance. The criteria for supplier selection and the current practice for managing suppliers' performance as well as selection are also reviewed. The shortcoming of current approaches is also discussed.

Chapter three reviews the different perspectives and processes of knowledge management (KM). The importance of knowledge sharing and having reward for the purpose is also presented.

Chapter four explains the methodology adopted to achieve the aim and objectives of this research. It reviews the relevant research concepts which include the meaning of research and research strategy, and then presents the research design of this research.

Chapter five organises the findings and analysis of the case studies. The shortcomings of current practice and the requirements for the development of the system are also discussed. The methodology for managing suppliers' performance and knowledge sharing are explained in detail.

Chapter six covers the system architecture, development of the system as well as the operation of the prototype MySuppliers.net application. The results of the testing and evaluation are presented and analysed in detail.

Chapter seven brings together the findings and draws conclusions from this research. It concludes also the salient points that researchers and practitioners need to take cognisance of, and identifies further work that can

be conducted to enhance the methodology and the functions of the prototype

software application.

CHAPTER 2

LITERATURE REVIEW

Chapter two covers the definitions, characteristics and roles of suppliers, and then followed by the importance of managing suppliers' performance. The criteria for supplier selection, current practice for managing suppliers' performance and selection are also reviewed. Finally, the shortcomings of current approaches are discussed.

2.1   Defining Supplier

The dynamic business environment today requires organisations to use all available resources to sustain and remain competitive. Supplier plays an indispensible role in the success of construction project (Arslan et al., 2008). According to the Compact Oxford English Dictionary (2008), to supply is to: "(1) make (something needed) available to someone; (2) provide with something needed; (3) be adequate to satisfy (a requirement or demand)." Supplier is the one or a corporation who acts as an agent, intermediary or broker that is offering a service, manufacturing a commodity or distributing, importing, exporting, selling, circulating or dealing in it, or taking part in the production (Amjad and Charles, 2003). Suppliers are the manufacturer's external organisations or business partners (Chan and Kumar, 2007). They are the one who supply their service to the project (Talluri, 2002; Wadhwa and

Ravindran, 2007), and convert the ideas to the actual construction works (Xue et al., 2007).

Tarofder and Haque (2007) define effective supplier as the one who can provide the correct amount of materials or offering a services at the right time, right price and right quality. The raw materials, components and services provided by the suppliers are normally something that an organisation does not have internally (Kuo et al., 2010). Suppliers are the vital part of a project organisation as the extensive use of subcontracting nowadays has led to the heavy reliance on them.

In construction industry, the client or developer who owns a project normally does not involve directly in the construction work of the project. Instead, the project is very often procured through appointing consultants to prepare the design and then subsequently award the contract to a contractor through tender to deliver the project based on the design. The contractor, who is contractually bound to deliver the project on time and to the standard, in turn also counts on his subcontractors and material suppliers to help fulfilling his commitment under the project at varying degrees. The main contractors are continuously engaged in the process of transforming inputs (materials, labour and capital) into outputs (constructed facility). Other parties involved in the process include subcontractors, craftsman, equipment dealers, material suppliers and financial institutions.

Collectively, the contractors, consultants, subcontractors and material suppliers can therefore all be regarded as "supplier" as they all are engaged for supplying their skills and knowledge (i.e. service) or materials to the client. The engagement of subcontractors in the construction industry is prevalent and most of the main contractors practice on it. It is very common for those trades which require particular and unique skills and are specialised in nature and the likes.

The International Labour Organisation (2001) posits that the increase in the practice of outsourcing labour has stimulated the large companies to effectively separate themselves from the actual construction work and concentrate on the service functions only. The large construction companies which are responsible for a large volume of construction work are increasingly detached from the construction site and subcontract the works to the subcontractor. The contractor conducts the transactions with subcontractors since the subcontracting work allows them to be flexible in responding to potential market's fluctuation. This approach is preferred over maintaining a large organisation to undertake the entire process (Elinwa and Joshua, 2001). Without the suppliers doing their part, the project may never be completed, not to mention on time and according to the requirements of the client.

In order to sustain in a highly competitive environment which is aggravated by globalisation, technological advancement and the increasing sophistication of customers' demand, there is a need for a mechanism for managing the performance of suppliers for the purpose of contract awarding,

facilitating continuous improvement, accelerating business growth and also to meet the clients' needs consistently at an acceptable cost throughout the duration of the project.

2.2   Importance of Managing Suppliers' Performance

Hammami et al. (2014) and Wu et al. (2010) note that supplier's performance is an operational measure of the important success factors, such as product quality, cost, delivery performance, service, responsiveness to change requests, and the overall performance. It is also treated as a measure of how well the supplier utilises his available resources to achieve the specific goals and to enhance competitive advantage. Managing supplier performance is a management philosophy that extends traditional intra enterprise activities by integrating trading partner efficiency with the optimisation goals (Xue et al., 2007). The importance of managing supplier performance is as follows:

2.2.1   Cost Reduction

Supplier selection is always seen as the most important activity of a purchasing department and company (Florezlopez, 2007). Selecting the right suppliers not only reduces the purchasing cost but also help improves the company competitiveness (Sanayei et al., 2010; Chen and Wu, 2013). Getting the right suppliers can help to ensure that unnecessary cost can be eliminated, project is on the right track, and the problems like client requirement cannot be met or project cannot be completed are avoided (Saen, 2007; Xia and Wu,

2007). Liao and Kao (2010) further explain that the linkage among the parties and the supply chain effect would create significant cost-cutting opportunities as long as the suppliers are managed properly.

Hwang (2005) points out that managing suppliers' performance can ensure the supplier to deliver on time so as to reduce site operation cost and inventory. This is particularly important to the company who spends a high portion of their cash on hand on raw materials as the material costs are sufficient to affect the cash flow (Ting and Cho, 2008). Parmigiani et al. (2011) also content that engagement of supplier with poor performance is difficult to benefit the client in term of cost saving.

2.2.2   Decreased Production Development Lead Time

Getting a suitable supplier can significantly decrease production lead time at different stages of the project (Fredendall and Hill, 2001; Wang and Yang, 2009). This can be achieved by bringing in suppliers with market-leading technology into the design process at an early stage to attain wider concurrency between activities, so as to promote fast project developments (Danese, 2013). Good suppliers are more likely to deliver their service or products on time which is critical in minimising disruption in the site operations (Vandervalk and Wynstra, 2005).

2.2.3   Reduction of Risk

Chen and Wu (2013) notice that unnecessary risk can only be predicted when suppliers' performance is continuously managed. By doing so, it could ensure supplier to deliver and produce only needed inventory for the project so that the storage space is saved, waste is minimised (Tan, 2001) and inferior condition on site is avoided (Hammami et al., 2014). Chen et al. (2006) and Sambasivan and Yau (2007) notice that irresponsible suppliers always work beyond their capability as these suppliers are often seen handling work on more than one site. As such, late delivery, unable to perform according to the specification and bring unwanted risk to project are among the common problems caused by them (Kumar et al., 2004). Noulmanee et al.'s (1999) study reveals that supplier can only be prevented to work beyond their capability if their performance is well managed. It is critical that the suppliers have sufficient resources to cope with the demand of the project.

2.2.4   Better End Product Quality and Customer Satisfaction

Talluri (2002) and Humphreys et al. (2007) point out that managing supplier performance helps to ensure the quality of the end product. To achieve this, suppliers need to be monitored continuously so that any defects during construction stages can be identified and rejected (Vandervalk and Wynstra, 2005; Chen and Wu, 2013). Customer satisfaction and long-term business can be retained only if the end product's quality is assured (Tan, 2001). Related to this, the lack of a systematic approach for the selection of

sub-contractor would generally cause problems in quality of the work which often fails to meet customer's requirements (Arslan et al., 2008). These would lead to long-term mutual benefit (Xue et al., 2007) where supplier secures with the job and clients are satisfied with the end product's quality.

2.2.5 Preventing the Deterioration of Supply Chain

Selection of suppliers involves a great variety of uncontrollable and unpredictable factors that make it complicated. The success of a corporation often relies on its ability to select the right suppliers (Bevilacqua et al., 2006). Chen and Wu (2013) note that any deficiency in the selection process may lead to the deterioration of the chain due to poor work quality, poor customer service and etc. This incurs more expenses for rectifying the problems brought about (Kumar et al., 2004). Araz and Ozkarahan (2007) warn that the deterioration of supply chain tends to give negative impacts to the whole supply chain's fiscal and operational position. This is particularly true for the industries that normally subcontract a big proportion of works to other companies (Ng et al., 2009).

2.2.6 To Enjoy Mutual Benefits Brought About

Many contractors prefer to work with the same supplier for their subcontracting work because mutual benefits are easier to achieve and close relationship is likely to be built up (Gadde and Snehota, 2000). Suppliers are always regarded as the preferred external resource for co-operation, slightly

ahead of customers (Schiele, 2006). There is a need to develop reliable and long term relationship with supplier (Khalfan and McDermott, 2007). A close-relationship, in turn, is essential to establish trust between clients and suppliers (Male and Mitrovic, 2005). Once the trust is built, it is much easier to avoid operations disruption (Ruiztorres and Mahmoodi, 2006). Other benefits brought about include building a strong barrier to competitors to entry (Chen et al., 2006), to capture the synergy of intra and intercompany integration towards business excellence (Lambert and Cooper, 2000). This will then contribute to increased production efficiency, service performance, product design quality, productivity and the ability to respond rapidly to customer needs (Sarkis and Talluri, 2002).

2.2.7   Improved Company Competitiveness

Many companies have increased their level of outsourcing and currently rely more heavily on their supplier as a source of their competitive advantage (Ting and Cho, 2008). Suppliers' company competitiveness is vital to trend changes in markets, latest technology, material development and customer demand (Luo et al., 2009). Research shows that selecting an appropriate supplier can significantly strengthen corporate competitiveness (Ozgen et al., 2008; Wang and Yang, 2009; Mafakheri et al., 2011). Periodical review and managing of suppliers' performance with a set of metrics enables the identification of their weaknesses to improve their competitiveness (Ng et al., 2009; Parmigiani et al., 2011) and to meet the requirements of the ever demanding clients (Sanayei et al., 2010). Gadde and Snehota (2000) state that

managing supplier performance could build learning routines to improve company competitiveness. Related to this, Luo et al. (2009) perceive that only supplier who improves continuously (i.e. always innovative) can sustain their competitive advantage. Clients should critically evaluate their suppliers with a set of criteria or metrics that can truly reflect their suitability for a project to ensure that only suppliers with good performance are engaged, which will ultimately strengthen the competitive advantage.

2.3   Criteria for Supplier Selection

While delivering a high quality product at low cost is a typical objective of a construction project, this is difficult to achieve without good suppliers (Aretoulis et al., 2009). In this regard, even in the advanced ICT systems, the selection mechanism of good and suitable suppliers is still dependent on some underlying criteria. Traditionally, speed and price are the main criteria considered for the purpose (Ting and Cho, 2008) but more have been incorporated into the list to facilitate a comprehensive yet accurate evaluation of a supplier's suitability to a project.

Dickson's (1966) research conducted in 1960s has influenced many later research on the criteria of supplier selection and always become the source of reference. Dickson's (1966) survey involves about 300 commercial organisations and identifies 23 important factors for supplier selection. These include "quality, delivery, performance history, warranties and claims policies,

production facilities and capacity, price, technical capability, financial position, procedural compliance, communication system and others" (Dickson 1966).

Later, however, it is revealed by Cheraghi et al.'s (2004) study that there are significant changes in the relative importance of factors for supplier selection in the literatures published between 1966 to 1990 and 1990 to 2001. Some criteria have become less significant, such as "operating controls, packaging ability, training aids, desire for business, amount of past business, warranties and claims policies". Hence, Cheraghi et al. (2004) propose a new set of top 10 supplier selection criteria, which include "quality, delivery, price, repair service, technical capability, production facilities and capacity, financial position, management and organisation, reliability and flexibility". Watt et al. (2009) have conducted a similar study involving respondents mainly from the construction industry, which makes their criteria more relevant to this research. These include "organisation experience, capacity, project management expertise, past project performance, company standing, client and supplier relations, technical expertise and method solution".

Other relevant criteria identified include responsiveness (Liu and Hai, 2005), client acceptance (Pinto, 2010), ability to learn (Luo et al., 2009), company culture (Choy et al., 2003) and risk factor (Chan and Kumar, 2007). Palaneeswaran and Kumaraswamy (2001) suggest a universal model to prequalify contractor based on the practice of public project owners in Hong Kong, United States, Australia, Sri Lanka, Singapore and Canada. The prequalification criteria proposed include "responsiveness (promptness,

realism, and completeness), responsibility (conformity, performance, quality, safety, environment and partnering) and competency (resources, experience, constraints, management and organisation)".

Some researcher attempt to group the various criteria identified for the selection of suppliers into categories. For instance, it is found that Ho et al. (2010) distinguish the criteria as either quantitative or qualitative in nature. They mention that the most important criteria include "quality, delivery, cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk and safety, and environment". Liu and Hai (2005) also divide the criteria into two groups. The first group is objective criteria which include those are relevant to factual data (such as quality, delivery, responsiveness, technical capability, facility and finance). Another group includes the subjective criteria which are difficult to quantify and need to be evaluated qualitatively, such as discipline and management. They contend that a qualified and good supplier must fulfil both groups of criteria. There is a consensus between Ho et al. (2010) and Chan (2003) as the latter also groups the criteria as either quantitative (i.e. cost, and resource utilisation) and qualitative (i.e. quality, flexibility, visibility, trust, and innovativeness). However, such categorisations are not helpful in enhancing the selection of suppliers for a construction project. Therefore, the criteria identified are collated and then aligned into groups for the purpose of this research, as depicted in Table 2.1.

Table 2.1: Criteria for Supplier Selection

	Choy et al. (2003)	Cheraghi et al. (2004)	Wang et al. (2004)	Liu and Hai (2005)	Chen et al. (2006)	Hou and Su (2006)	Chan and Kumar (2007)	Xia and Wu (2007)	Sanayei et al. (2008)	Luo et al. (2009)	Watt et al. (2009)
Cost / Price	√	√	√			√	√	√	√		
Performance	√	√	√	√	√	√	√	√	√	√	√
Time / Delivery	√	√	√	√		√	√	√	√		
Supplier's Profile											
- Technical Capability		√		√	√	√	√	√		√	√
- Service	√	√	√	√		√	√	√	√		
- Financial Strength		√		√	√		√			√	
- Management		√		√						√	√
- Capacity		√		√			√	√	√	√	√
- Reputation		√									√
- Relationship		√			√					√	√
Innovation / Knowledge Contribution										√	

2.3.1 Cost / Price

Traditionally, cost is the main criterion used for the selection of suppliers (Akarte et al., 2001; Katsikeas et al., 2004) particularly in the construction industry (Watt et al., 2009). Cost or price plays an extremely important role in the success of construction projects for its direct impacts on profitability (Ting, 2004). Therefore, clients always look for suppliers who can supply a service or material at lower cost without compromising the quality (Tracey and Tan, 2001). There is also the need to look into the "out of pocket" expenses, for instance the cost of transportation, that are not very obvious and often overlooked (Kahraman et al., 2003). The rationale is very simple as ultimately the overall cost for getting all the necessary services and materials

from the suppliers will dictate the cost of a project (Chan and Kumar, 2007). If the cost of a project increases then the profit generated from the project is likely to be affected.

2.3.2 Performance

All projects are developed to adhere to some initially determined technical specifications (Pinto, 2010). Related to this, performance can be defined as the demonstrated ability of a supplier to meet the stipulated requirements or specifications (Sarkar and Mohapatra, 2006). It shows how the supplier controls, plans, manages and executes the tasks (Tracey and Tan, 2001). This is critical as clients naturally expect that the project developed on their behalf will work as intended. Poor performance of any supplier will lead to the domino effect that might impinge on the performance of the whole supply chain.

Performance has been increasingly replacing quality as a criterion for the evaluation of suppliers as it is comparatively less ambiguous. For instance, a supplier who delivers a so called low quality work may not imply that the supplier underperforms since he may only furnish it according to the lower specification provided by the client. Performance, contrarily, is about the supplier's ability to supply a service or product in accordance with the specifications provided for by the client (Kerzner, 2009).

Watt et al. (2009) note that when evaluating the performance of suppliers, their records in the previous projects should be considered as well. Supplier's performance has great bearing on work quality which eventually impacts on the client's acceptance of a project (Ng et al., 2009). Therefore, it is preferable for suppliers to be evaluated based on their performance instead of the subjective quality of the work done (Pi and Low, 2005).

2.3.3   Time / Delivery

Percin (2006) and Pinto (2010) note that a project is not supposed to continue indefinitely. There must be a specified time frame where it must be completed. Any extension of time will incur additional cost due to the services, labour and machinery used. It may even lead to the imposition of liquidated and ascertained damages for late delivery. According to Cheraghi et al. (2004), the ability to meet delivery date still remain as one of the most important criteria for which the suppliers need to conform to before they can be considered as strategic partner. Conformance to this criterion is to ensure the minimisation of disruption in the operations, costs reduction and ultimately timely delivery (Pinto, 2010). A good supplier has the ability to follow the exact delivery schedule based on the client's requirement (Chan and Kumar, 2007).

2.3.4 Supplier's Profile

The supplier's profile can reflect the overall reliability and the suitability of a supplier for a project (Chan and Kumar, 2007), and his past performance (Sanayei et al., 2008). It covers the important aspects of the supplier's business which include the services offered, financial strength, technical capability, management, capacity of the resources, reputation, and relationship with the client. The details are as follows:

2.3.4.1 Technical Capability

The criterion is about whether or not a supplier possesses the necessary technical know-how and/or the required technology (e.g. plants and machinery) for a task. It is concerned with the suppliers' computer hardware, software, comprehensive computer-integrated systems (Percin, 2006), and competent staff to provide proper services as well as contribute to better product development (Bottani and Rizzi, 2008). Simply put, the supplier who has better technical capability can provide better service (Tarofder and Haque, 2007) and help the client to move into the global marketplace (Kahraman et al., 2003). Occasionally, the suppliers' ability to provide advanced technological solution, and research and development support may be critical to a project.

2.3.4.2 Service

Service is an important criterion used for evaluating the performance of suppliers (Kahraman et al., 2003). Supplier's service is often judged by the level of cooperation, swiftness of information exchange, range of technologies supported and time used to respond to client (Lee et al., 2001; Ting, 2004). It is also about the suppliers' agility in responding to the demand changes (Demirtas and Ustun, 2008; Sanayei et al., 2008), ability to meet the delivery schedule (Chan and Kumar, 2007), provision of research and development support, ease of communication, and professionalism (Kahraman et al., 2003). It is also noted that customer satisfaction, which is emphasised nowadays, is dependent on the service provided by the suppliers (Tracey and Tan, 2001; Cheraghi et al., 2004).

2.3.4.3 Financial Strength

Financial strength is a good indicator of a supplier's long term stability and reliability (Ting and Cho, 2008) which can be revealed by the basic accounting statements used for reporting corporate activity (Ting, 2004). A solid financial position helps ensure that the required performance standard can be maintained (Ng et al., 2009), no disruption to the progress of the project due to cash-flow problems, and guarantee strong back up from the firms (Percin, 2006). The financial stability of the supplier should be a major concern for supplier selection as it reveals the supplier's competency in managing assets (Sanayei et al., 2008), debts, income, cash flow, and financial

strengths or weaknesses. In construction industry, suppliers with poor financial strength may face difficulties to bear the heavy daily construction expenses (Aretoulis et al., 2009).

2.3.4.4 Management

Availability of experienced management staffs is critical in the monitoring and coordination of construction work in order to meet the targeted schedule (Ng and Skitmore, 1999). It is also important to identify the degree of alignment of the supplier's future plan and management policy with that of the client. This is mainly because the compatibility of management style may have impacts on the stability and strategic relationship between the client and the supplier (Kahraman et al., 2003). Regarding management, suppliers' ability can be observed in term on their integration, planning, problem solving, the methods used (Luo et al., 2009) and how human resources are deployed for a project (Percin, 2006). In addition, management also sets the direction for the firm and hence the key relationships with other companies (Cheraghi et al., 2004).

2.3.4.5 Capacity

Supplier's capacity refers to whether a supplier has too much work or projects at any one time (Ng and Skitmore, 1999; Cheraghi et al., 2004), how intensively the resources of a supplier are being used (Huang and Keskar, 2007), or how the workload is managed and balanced with the on hand

resources (Percin, 2006). The factors, such as the current commitments and workload, manpower available, and capacity of plants and equipments, define the overall capacity and suitability of a supplier for a new project (Huang and Keskar, 2007; Watt et al., 2009). It is crucial to confirm the capacity of the suppliers prior to the award of any project or contract. The supplier throughput capacity will determine whether the supplier is to be employed for new project since unforeseen risks are not desired by client (Luo et al., 2009).

2.3.4.6 Reputation

Reputation is the belief that the industry players and firms hold about a supplier's characteristics, abilities as a trading partner, and honesty (Suh and Houston, 2010). It can also be interpreted as the collective record of the past performance of those who has collaborated with the organisation, which requires consistency of an organisation's actions over a prolonged time (Ferris et al., 2007). A supplier's reputation may determine whether they will be employed again or otherwise (Aretoulis et al., 2009; Ng et al., 2009). It influences the decision pertaining to the choice of supplier and is a highly rated criterion (Katsikeas et al., 2004). In lieu of previous experience with a particular supplier, the existence of a good reputation can be a strong cause for the client to select him. Suh and Houston (2010) point out that engaging supplier with good reputation may lower the monitoring cost during the course of a project.

2.3.4.7 Relationship

Clients may prefer to work with suppliers they have a good relationship with. It is found that a close relationship between the client and supplier is crucial to faster project completion, increased supplier motivation, and with lesser misunderstanding and conflicts (Araz and Ozkarahan, 2007; Watt et al., 2009). Sometimes, relationship can influence the decision pertaining to the choice of supply source (Ng et al., 2009). Furthermore, if a good relationship exists the supplier is likely to be more willing to react promptly to the client's request for changes and even involved in the earlier design stages of a project. The latter allows the suppliers to shed some lights to improve the various aspects of a project which may enable a project to be delivered at a lower cost (Choy et al., 2003; Talluri and Narasimhan, 2004). A trusting and long-term relationship allows the supplier and client to enjoy the shared benefits (Chan, 2003), where the suppliers are willing to share risk and information to solve urgent issues or prior problems (Fagerstrom and Jackson, 2002), and to minimise unpredictable costs (for client) due to inaccurate monitoring and measuring (Suh and Houston, 2010).

2.3.4.8 Innovation / Knowledge Contribution

Suppliers' ability to innovate should not be overlooked for evaluation purpose (Dowlatshahi, 2000). Innovation means "change, and the change can be one of two types; firstly, change in the product or service being provided, or secondly, change in the process by which the product or service is created"

(Sturges et al., 1999) or new use of technology (Chan, 2003). These can lead to reduction of unnecessary work (Luo et al., 2009), continuous improvement (Tan et al., 2010) and competitive advantage (Ho et al., 2010). Useful ideas and feedbacks from the project team members provide a stimulus for innovation which speeds up the construction process and keeps the project team attune to the project requirements (Sturges et al., 1999). The customer demands for innovative product have created a tendency that requires suppliers to be more innovative (Percin, 2006). Only the supplier who is innovative can sustain the competitive advantages (Egbu and Robinson, 2005). There is an increasing number of construction firm emphasise on knowledge contribution as they recognise the importance and benefits brought about (Robison et al., 2004; Egbu et al., 2005).

2.4   Current Practice

The process of supplier selection and evaluation is started when companies outsource part of their business. Different types of suppliers are involved in a typical project, which logically requires different set of criteria for selection and performance evaluation purpose. Therefore, these sets of criteria must be customisable based on individual company's requirements. In addition, the method adopted for the selection of the right supplier need to be adequate since it leads to the final decision on outsourcing.

As a result, it is not surprising that a number of research projects that look into the selection of suppliers in the construction industry have been

initiated or conducted. A plethora of methods for supplier selection, characterised by the use of information and communication technology, are found in the existing literatures to help the decision makers to decide a precise decision, but only a few main ones are discussed. These include Web-Based Sub-Contractor Evaluation System (WEBSES), e-Reporting system, Mathematical Programming (MP), Multi-Attribute Decision Making (MADM), Case-Based Reasoning (CBR) and Fuzzy Set Theory (FST).

2.4.1   Web-Based Sub-Contractor Evaluation System (WEBSES)

Arslan et al. (2008) develop a Web-Based Sub-Contractor Evaluation System (WEBSES) that allows sub-contractors to be evaluated online based on a set of combined criteria. The system enables the user to access it through the internet. It aims to minimise the problems that may occur in the traditional selection process such as the difficulties in adopting new technologies, lengthy negotiation process and the inefficiencies of supplier selection. The system eliminates the over-emphasis on the lowest bid by taking also other criteria into consideration. Each of the main criteria is broken-down into sub-criteria, which will then be given a weight according to the characteristics of a project. The system enables the general contractor to select the most suitable sub-contractors for the respective subcontracting works, helps to accelerate the selection process and leads to cost savings during the tendering process.

2.4.2 e-Reporting System

Ng et al. (2002) propose a conceptual framework for an e-Reporting system that enables performance related data of contractors at project level to be checked, submitted, compiled and subsequently disseminated to relevant users in the industry for contractor selection purpose. The system allows the contractors to update their company profiles and provide information for performance appraisal, which include their latest workload, financial status, claims records, etc. The evaluators will evaluate and monitor the contractors' performance based on a set of key performance criteria. Each of the key performance criteria is further divided into more specific sub-criteria to ensure that the appraisal is conducted objectively. To meet the particular requirements of the client or project, the evaluators are allowed to alter the weighting assigned to the criteria or sub-criteria. In addition, for the contractors who get the high performance scores in the latest period, their prevailing workloads will be checked. Only those with good immediate pass performance and are capable will be then invited to tendering process.

2.4.3 Mathematical Programming (MP)

Mathematical Programming optimises the interactions and trade-offs among different issues and factors of interest by considering its constraints (Sanayei et al., 2010). It allows the decision makers to determine the most suitable supplier based on the favourable conditions such as maximise profit and to minimise cost (Wu et al., 2010; Xia and Wu, 2007). Akarte et al. (2001)

state that in this method, "a weight is subjectively assigned to each criterion and the total score of each supplier equal to the sum of the assigned criteria score multiplied by the respective weights". MP consists of Data Envelopment Analysis (DEA), Linear Programming (LP), Multi-Objective Programing and others (Ho et al., 2010; Sanayei et al., 2010).

2.4.3.1 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is first coined by Charnes et al. (1978) (Cited in Cook and Seiford, 2009) responding to the need for acceptable procedures "to measure the respective efficiencies of multi-input multi-output production units". The original concept of DEA was to "provide a method whereby, within a set of corresponding decision making units (DMUs), those giving best practice could be discovered, and would become an efficient frontier" (Cook and Seiford, 2009). DEA is a mathematical programming methodology for measuring the respective efficiencies of DMU that perform the identical functions and have same types of goals and objectives (Sanayei et al., 2008; Falagario, 2012).

Garfamy (2006) uses DEA to access the relative efficiency of suppliers' performance based on the concept of total cost ownership. In the proposed model, only a single unit of output is derived although a few inputs are involved. The input variables include manufacturing cost, quality cost, technology cost, after sale service cost and price of part through random sampling. A supplier whose output charging cost is the least is regarded as

efficient supplier. Liu et al. (2000) apply DEA to compare overall supplier performance. They set price index, delivery performance and distance factor as the input in their model. They perceive quality as an indispensible criterion in supplier selection since it is the most important objective for a company. Hence, they consider quality and supply variety (the number of parts that a supplier supplies) as the output to look for a strategic orientation of filtering the incapable suppliers.

2.4.3.2 Linear Programming

Talluri and Narasimhan (2004) introduce a max–min productivity-based programming that derives the supplier performance variability measures to evaluate supplier. The concept behind the max–min approach is to enlarge the distance of the selected supplier's performance against the best set target measures. It reveals how excellent that a particular supplier can perform. A supplier who gets a high performance score is classified as a good performer. Homogenous suppliers with high performance score are grouped together to provide more choices for the user for making final selection. Ng (2008) develops a weighted linear program to address the multi-criteria supplier selection problem based on MP. The user is required to give priority to the criteria's importance rather than defining the exact weight values so that the supplier score is maximised. The partial average's value is compared and computed to obtain the supplier's score. The scores of the suppliers are then compared to identify the most suitable supplier.

2.4.3.3   Multi-Objective Programming

Multi-objective programming enables "effective adjustment of supplier specific negotiations by benchmarking each of the potential suppliers' performance against the performance of the existing ones" (Talluri et al., 2008). Wadhwa and Ravindran (2007) use multi-objective programming to compare several multi-objective optimisation methods that are used for selecting supplier. The methods include compromise programming, goal programming and weighted objective. They compare the constraints of three methods in terms of the minimisation of price, lead-time and rejects. To help the decision maker to choose a suitable approach from the set of alternatives, a plotted graph is presented to compare the constraints with the criteria. Decision maker is to select the "best compromise solution" which would maximise the subjective preferences or is in line with the project target by referring the plotted graph.

Demirtas and Ustun (2008) develop an integrated multi-objective mixed integer linear approach for the selection of the best suppliers. Performance of each potential supplier is evaluated by conducting pair-wise comparison of 14 assessment criteria. An equation is applied to calculate the benefits, opportunities, costs and risks so that the optimum number of qualified suppliers can be defined. The supplier who gets highest final score is considered as a capable supplier. Weber et al. (2000) construct a multi-objective programming model to develop optimum supplier-order quantity. An equation in the multi-objective programming model is applied to calculate the

supplier efficiency in term of low cost, better quality, fast delivery time and the impact of employing a number of suppliers. Optimum number of suppliers is then recommended.

2.4.4 Multi-Attribute Decision Making/Multi-Criteria Decision Making (MADM/ MCDM)

Sanayei et al. (2010) note that Multiple Attribute Decision Making (MADM) involves "the finding of the most suitable alternatives from a discrete set of feasible options with respect to a finite set of attributes". This method concentrates on the selection of the best alternative based on a list of criteria (Wang et al., 2009). Guo et al. (2009) contends that this method allows the user to develop policy in a systematic and defensible way. Thus, MCDM methods have been widely used in many research fields since it is able to handle complex and difficult decisions. This method includes Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Simple Multi-Attribute Rating Technique (SMART) and others (Wang et al., 2009; Sanayei et al., 2010).

2.4.4.1 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is "the measurement of pair-wise comparisons concept that relies on the judgements of experts to obtain priority scales" (Saaty, 2008). It is a robust and flexible technique that allows the decision makers to derive the preferences of criteria for selection purposes,

quantify and then aggregate those preferences (Chou et al., 2013). AHP operates by structuring the decision hierarchy from the top with the goal followed by the determination of objectives from intermediate levels until the lowest levels. "Each of the upper level elements are compared with the elements at the level immediately below with respect to it to weigh the priorities. The weighing process is continued until the final priorities of the suggested alternatives at the lowest level are derived" (Saaty, 2008).

In the state of North Carolina, AHP is used to select the best-value supplier by assigning rating to the evaluated criteria (Satty, 2008). Kokangul and Susuz (2009) state that AHP can work with other techniques, such as mathematical programming, to take into account not only qualitative and quantitative factors but also some real-world resource limitations. Xia and Wu's (2007) research applies AHP in calculating the rating of each of the suppliers by making the trade-off between tangible (e.g. product quality or defects) and intangible factors (e.g. supplier's services). They use three-point scale and rough set theory in their model to take into account qualitative judgment, which makes the comparison more intuitionists besides reducing bias in the comparison process. They manage the supplier performance by specifying the constraint of the criteria so that only the qualified suppliers are selected.

In the model introduced by Liu and Hai (2005), the AHP's pair-wise comparison is not applied to derive the relative importance ratings of the criteria. They propose a voting method to allow the user to vote the order of

the criteria instead of the weight. Then, the votes and scores will be computed to determine the rating of the suppliers. The supplier whose rating is the highest is perceived as the most suitable supplier.

Hou and Su (2006) develop a Web Services-Oriented Multi-Possibility Supplier Selection (WMPSS) system based on AHP to help manufactures to locate the suitable suppliers for the materials, components and services required for product design. There are two options available after an authorised user gaining access into the system. The user can directly access the Competitive Strategies with Product Market Positions (CSPMP) matrices to appraise or search for suppliers based on cost, speed or specialisation. Alternatively, the user can search for supplier according to the strategy used, product market position or key words related to a particular supplier. If the required information cannot be found, the user can then continue with the CSPMP matrices. The system enables the users to quickly compute, compare and select their favourite suppliers based on various requirements as depicted in the matrices.

Akarte et al. (2001) introduce a Web-based AHP system for the evaluation of casting suppliers based on 18 criteria. The user needs to log into the system and specifies the casting requirements. It is followed by the determination of relative importance weight for each of the criteria based on the casting requirements. Then, the performance rating for each of the criteria is determined by pair-wise comparison. The short-listed suppliers have to submit their quotations, including the sample delivery date, which will be

entered into the system. The supplier who obtains the highest overall performance score is quoted as a capable supplier.

2.4.4.2 Analytic Network Process (ANP)

Analytic Network Process is a generalised and less sophisticated version of AHP (Vinodh el al., 2011). The main is difference is that AHP considers only one-way hierarchical relationships among the factors, whereas ANP considers also "the possible of many relationships among the groups of factors or those within the network" (Vinodh el al., 2011). Sarkis and Talluri's (2002) ANP model for the selection of supplier includes also the organisational factors (such as culture, technology and relationship) in addition to the supplier's performance. Each of the criteria in organisational factors and supplier performance groups are examined simultaneously to determine the relative importance ratings and the most influential criterion. The supplier with the highest score is regarded as the recommended supplier. By comparison, Bayazit's model (2006) relies on the ratio scales of the criteria to derive priority. The highest overall priority indicates that the particular supplier is the best supplier. In Gencer and Gurpinar's (2007) research, they use 45 criteria for pair wise comparison and determine the possible relative importance rating. Supplier with the highest priority score is selected.

2.4.4.3 Simple Multi-Attribute Rating Technique (SMART)

According to Barla (2003), SMART is one of the popular supplier selection methods as it can analyse the suppliers' capability in detail and also identify the improvement on supplier performance. It starts with the generation of criteria for pre-screening suppliers. The criteria are set with the relative importance to obtain the expected utility value. Ranking of suppliers is then revealed and the supplier with highest score is normally selected. Barla (2003) uses the SMART approach for supplier evaluation and selection.

In Huang and Keskar's (2007) model, a total of seven criteria are used to compare the suppliers' product, suppliers' profile, safety measurement and also the environmental issue. The seven criteria are evaluated to determine its utility values to derive at the suppliers' rankings. Seydel (2005) applies SMART approach to evaluate the performance of 10 suppliers. Seydel (2005) uses mathematical formula to calculate the relative importance and the expected utility value. In the study, the outcome of SMART is then compared with the outcome of other selection methods. It shows that there is very little difference between SMART with other approach (Seydel, 2005).

2.4.5 Case-Based Reasoning (CBR)

Case-Based Reasoning is "a problem-solving approach that relies on past similar cases to find solutions to problems" (Guo et al., 2012). Utilisation of CBR is to assist in selection of the best supplier based on past record (Choy

et al., 2003; Humphreys et al., 2004). A case represents a problem situation (Ribeiro, 2003). This system traces a set of past similar cases and evaluates their similarity. Subsequently, the most similar cases are shown to the user as the possible scenarios to solve the problem (Choy et al., 2005). Choy et al. (2003) note that CBR system has a rudimentary learning capability because the systems can become more discriminatory and be improved as the number of case increases.

Choy and Lee (2002) use CBR technique to develop a generic model to deal with the supplier selection problem. The three main criteria used to form the backbone of the generic supplier selection model are quality system, technical capability and organisational profile. The model functions by capturing the past experience and past cases of the supplier and then matching the aforementioned attributes to the existing problem.

Choy et al. (2005) also propose another CBR system, i.e. Case-based Supplier Selection and Evaluation System (CSSES), which can help to retain the knowledge about the suppliers' performance. CSSES can categorise, analyse the supplier performance based on the pre-defined requirements, calculate the performance score, update the suppliers' priority and generate the new case into the database automatically. The system allows the knowledge of the suppliers, best practices created or new technology employed to be retrieved and adopted in similar projects. Other similar research includes Humphreys et al. (2004). They employ CBR to pre-qualify supplier. The

underperformed suppliers will be removed from the selection list for further comparison.

2.4.6 Fuzzy Set Theory (FST)

A fuzzy set is "a set of objects in which there is no clear-cut or predefined boundary between the objects that are or are not members of the set" (Li, 2013). The fundamental concept is that the membership of any object of the set may extend to some degree and they are often associated with a value that states the extending degree of the elements. The minimum and maximum value of the element is usually 0 and 1, while the partial membership is for those intermediate values (Bevilacqua et al., 2006).

According to Yucel and Guneri (2011), Fuzzy Set Theory (FST) is "specifically designed to mathematically represent uncertainty and vagueness, and to provide formalised tools to deal with the imprecision intrinsic to many problems". Kahraman et al. (2003) combine FST and AHP to handle the natural language expressions about the importance of each of the performance attributes, since AHP itself cannot reflect the human thinking correctly. They integrate FST to perform pair-wise criteria comparison to obtain the scores on each attribute. The supplier is selected based on the overall score and the relative goal. This model allows the integration of the qualitative data in the selection of the best supplier.

Amin and Razmi's (2009) integrate FST model for supplier management comprises three stages: supplier selection, evaluation and development. Supplier's profile, performance and service are set as the criteria for the evaluation of the suppliers. To deal with the qualitative measures of the criteria, FST is applied to quantify them. The qualitative criteria are then measured and converted to figures which can be calculated in the equation. The higher the score, the better the rank of a supplier is.

Chan and Kumar (2007) propose a Fuzzy Extended AHP (FEAHP) to deal with the different decision criteria exist for the selection of supplier. The triangular fuzzy numbers is used as a pair-wise comparison scale in that FEAHP for determining the ranking of different selection criteria and its attributes. The final priority weight of each criterion is decided by using the fuzzy principle. The highest priority would be given to the supplier with the highest weight.

2.5   Shortcomings of Current Practice

The current approaches are mainly focused on utilising the information on suppliers' performance for only the selection purpose. For instance, how the suppliers perform in terms of the delivery of the end product on time, within the budget and according to the specifications. Not to mention that to some extent, those approaches are black-box models where the logics adopted are shielded from the suppliers (Seydel, 2005). There is no mechanism available to integrate suppliers into the system that manages their performance.

Without this, the supplier does not have an opportunity to clarify and defend themselves should the information that is used for the evaluation is inaccurate or out-dated.

Furthermore, the current approaches are not interactive as they do not facilitate two-way communication between the client and suppliers. Therefore, suppliers may lose the opportunity to learn from their mistakes which lead to low rating and from the comments given by the client due to the lack of access to the system. The supplier does not have the chance to understand better their performance from the perspective of the clients and then improve themselves. Interaction between the suppliers and client in construction industry is important. Having good communication may foster learning, "develop greater confidence in one another, display cooperative and trusting behaviours and increase investments in relationship-specific assets to accomplish mutual goals that are crucial to success" (Paulraj et al., 2008).

The existing approaches appear also to concentrate more on the selection and evaluation of suppliers prior to their appointment rather than the management of suppliers' performance throughout the course of the project. The better approach is to capture the performance of the suppliers for all the projects awarded to them continuously, which will provide a more reliable source of information for their performance evaluation. To avoid creating additional paperwork or workload to the client in managing and monitoring the performance of suppliers throughout the projects, it is critical to look into how the benefits brought about by ICT can be leveraged.

Advancement in Web-based technology and proliferation of high speed Internet have led to increasing number of Web-based project management systems being developed for managing various aspects of construction projects. Related to this, Li et al.'s (2006) research reveals that a Web-based system can lead to more systematic and efficient organisation, storage and retrieval of the project performance information of the suppliers. Furthermore, it can also provide access to the users from different organisations at geographically dispersed locations, allow sophisticated manipulation of vast volumes of information, transferring information rapidly and economically (Chassiakos and Sakellaropoulos, 2008), avoid creating additional paperwork or workload and hence facilitate the necessary two-way communication between the clients and suppliers. Other potential benefits offered by Web-based system include no installation of software application required in the computer of the users and no cross operating system compatibility issues. Only an Internet connection and a Web browser are needed to access the system.

Another concern is the importance of capturing the learning from a project while it is being executed so that it can be reused during and after the project as pointed out by Kamara et al. (2003). This may enable the client and suppliers to benefit from the enriched knowledge about the construction and development of their assets, which will in turn contribute to the more effective management of facilities and other new projects. However, this has hitherto been overlooked in the current approach for managing suppliers' performance. The supplier's performance management system can in fact be designed to

capture this useful knowledge from the suppliers, with a mechanism to evaluate the impacts in order to reward them accordingly. Furthermore, the ability to contribute useful knowledge to improve existing projects can be incorporated as one of the criteria for assessing the supplier's performance. In this regard, Web-based technology is a very suitable platform can be leveraged for developing such system as it allows custom-designed modules for capturing suppliers' knowledge and managing the suppliers' performance to be developed and integrated easily.

2.6   Summary

The importance of managing suppliers' performance has been discussed. A review of the criteria for supplier selection, current practice for managing suppliers' performance and selection suggest that there is a need to share and capture the knowledge contributed by the project team members. The importance of knowledge sharing and how it should be encouraged are explained further in the Chapter 3.

CHAPTER 3

KNOWLEDGE MANAGMENT

This chapter reviews the different perspectives and processes of knowledge management (KM) as well as knowledge sharing. The advantages of knowledge sharing and the importance of rewards for knowledge sharing are also presented as well.

3.1   Defining Knowledge

In the context of knowledge management, knowledge is defined in various ways reflecting different research perspectives. Philosophical debates about Knowledge Management (KM) in general start with Plato's conceptualisation of knowledge as "justified true belief" (Goldman, 1967). The Compact Oxford English Dictionary (2008) defines knowledge as "the understanding, information and skills that gained through calculation or experience. It is also the state of knowing about a situation or particular fact".

Knowledge is a multi-faceted concept, which is embedded within many entities in an organisation including the organisation's policies, documents, culture and members themselves (Anand et al., 2010). In addition, knowledge is presented in ideas, talents, root causes, judgments, perspectives, relationships and concepts. Knowledge can be related to products, customers,

culture, processes, experiences, skills and know-how (Kalpic and Bernus, 2006).

However, knowledge can also be seen as the power to act and make decision (Galup et al., 2002). It is also defined as the things that are driven people to action and held to be true (Bourdreau and Couillard, 1999). It is considered as an entity which is at a higher level and authority than data and information (Stewart, 1997). Knowledge helps answering 'how' questions. Meaning to say, knowledge is human effort applied to information (Lee and Fariza, 2008). In the real world, however, a clear-cut distinction between knowledge, information and data is not always possible as the differences between these terns are just a matter of degree (Davenport and Prusak, 2000). Furthermore, depending on the relevance of the knowledge for one person may be interpreted as information to others and vice versa (Wang and Noe, 2010).

Some researchers define knowledge as knowledge per se (i.e. by depicting knowledge's characteristics, quality and constituents rather than contrasting it with information and data) (Davenport and Prusak, 2000). Davenport and Prusak's (2000) define knowledge as "a fluid mix of framed experience, contextual information, values and expert insight that provides a framework for incorporating and evaluating information and new experiences". Apart from this, knowledge is also defined as a series of know-how, know-who and know-what (Rennie, 1999), individual competencies, information and it is a factor of production (Randeree, 2006). However, Wang and Noe (2010)

contend that there is not much practical use in distinguishing knowledge from information. It is merely the information processed by individuals including facts, judgments, ideas and expertise relevant for team, individual and organisational performance.

3.2 Types of Knowledge

There are several dimensions of organisational knowledge; namely internal and external knowledge, tacit and explicit knowledge, and individual and group knowledge (Al-Ghassani et al., 2002). However, one of the most practical differentiations is that between explicit and tacit knowledge (Sanchez et al., 2013).

Explicit knowledge is stored or captured in an organisation's procedures, manuals and information systems, and is easily shared or communicated with other parts or people of an organisation (Robinson et al., 2005). Equally, explicit knowledge can be written down and articulated. Therefore, such knowledge can be consequently spread and shared, and externalised (Kalpic and Bernus, 2006). In addition, Quintas (2005) explains that codified or explicit knowledge may be understood by those people can extract meaning from the 'codes' with complementary knowledge. Once codified, such knowledge is data or information that may be interpreted by others.

Tacit knowledge is difficult to communicate externally stored or to share as it is in the heads of individuals (Robinson et al., 2005). It is an illusive or maybe an elusive term that its implication depends on the resources and nature of tacit ness expected (Li and Gao, 2003). Kalpic and Bernus (2006) explain that tacit knowledge is derived and developed from the practical environment; it is specific to situations and highly pragmatic in which it has been developed. According to (Anand et al., 2010), tacit knowledge is subconscious, it is used and understood but it is not identified in an aware or reflective way. Tacit knowledge could be made up of judgment, insights, mental models, know-how, beliefs and intuition, and may be shared through telling of stories, direct conversation and sharing common experiences (Kalpic, 2006).

Creation of new knowledge requires both the combination of both tacit and explicit knowledge (Sanchez et al., 2013). Egbu and Robinson (2005) state that construction project knowledge is created through the actions of project teams, individuals and construction organisations and the interactions of tacit and explicit from concept design to the hand over. For construction industry to successfully deal with the challenges of the emergence of knowledge economy, creating and sustaining a knowledge culture is required where knowledge is valued, created, shared, rewarded and transformed into productive knowledge to create value. It relies to a great extent on the expert's knowledge to develop the end products (Sanchez et al., 2013). This is essential to justify what an organisation produces, what people are employed and what

processes are required so that client's design and construction requirements are fulfilled (Robinson et al., 2005).

3.3   Knowledge Management Processes

Knowledge management (KM) generally deals with the organised attempt and systematic to utilise the knowledge within an organisation to transform the ability of knowledge to share, store and use it to improve performance and to compete (Yang, 2011). There is a plethora of definitions for KM to encapsulate what KM is and how it should be done (Diakoulakis et al., 2004) and this result in the variations of the scope and content (Haggie and Kingston, 2003) but there is not yet a common consensus or agreement on the definition and KM concept despite very much of concern on the subject (Tan et al., 2010). This may due to different perspectives on the concepts and perception of knowledge can lead to different definitions and formulations of knowledge management (Chong, 2005).

KM can be viewed from a process perspective, an outcome perspective, or the combination of these (Al-Ghassani et al., 2006). Knowledge Management (KM) is a managerial activity or a combination of a series of sub-processes (Chen and Mohamed, 2008) which transfers, develops, stores, transmits and applies knowledge, as well as provides the members of the organisation with real data and information to response and make the right decisions in order to accomplish the organisation's goals (Kanagasabapathy et al., 2006). Similarly, KM is defined as is defined as "the framework in which

all processes could be viewed as knowledge-related processes and therefore involving creation, distribution, renewal and application of the knowledge in support of the organisation strategic objectives" (Dow et al., 2008).

Diakoulakis et al. (2004) view KM as an extension of information management (or e-commerce) and traditional data. They further suggest a holistic way to KM as a generic task spreading throughout a knowledge worker's management functions. Lin et al. (2009) regard KM as the combination of management systems, information, communication technologies and organisational mechanisms through which an organisation focuses and fosters individual and group behaviours in terms of generation and assimilation, reuse and capitalisation, transfer and sharing of knowledge to create value for the organisation. In addition, Chong (2005) sees KM as the means of achieving innovation in process and services/products, organisational adaptation and effective decision-making to the market for the creation of business value, to bring about a sustainable environment (Zin and Egbu, 2010), and to generate a competitive advantage to organisations. Salojarvi et al. (2005) define KM in the similar way by seeing KM as the art of value creation by leveraging intangible assets. All the definitions concentrate on the fact that knowledge is a valuable asset that needs to be well managed, which also indirectly substantiate the importance of KM.

3.4 Knowledge Sharing

Knowledge sharing is one of the knowledge management processes (Yesil et al., 2013) and also the main component in KM systems (Yesil et al., 2013). This is because knowledge sharing is every bit important and critical to knowledge management as storing, capturing and distributing ideas, experiences, information and knowledge (Low and Mohammed, 2005).

Knowledge sharing is a process between individuals (Sanchez et al., 2013). It is the process where one unit is acted upon by the experience of another (Willem and Buelens, 2009) or the behaviour of an individual disseminating his or her obtained data, information and knowledge to other colleagues (Wang and Noe, 2010; Wang and Wang, 2012). It is also about making knowledge available to others (Ipe, 2003) from the home base main office to the new venture in the host nation (Geppert and Clark, 2003) to create new knowledge (Sanchez et al., 2013). It is also the process of communication between two or more participants that involving the acquisition and provision of knowledge (Usoro et al., 2007).

Knowledge sharing may involve the network to understand what others know (Nesheim and Gressgard, 2014). It happens via face-to-face communications through networking or written correspondence with other expertises (Pulakos et al., 2003). To disseminate or share knowledge is related to how individuals deliver a right knowledge at the right time to the right person (Larsson and Ohlin, 2002).

Lee and Ahn (2007) see knowledge sharing as the conversion of knowledge into accessible and applicable formats in the knowledge management system where the form that can be understood, absorbed, and used by other individuals. Wang and Noe (2010) note that knowledge sharing takes place when the two central processes happen (i.e. to donate and collect knowledge and then to share the intellectual capital).

3.5   Importance of Knowledge Sharing

Construction industry is characterised by high intensity of knowledge. It is being made up of different professionals, design and construction team, and organisations that provides a range of services for customers, clients and the wider community (Kivrak et al., 2008). Related to this, Egbu and Robinson (2005) note there are knowledge-based elements such as design, cost estimation, risks management, safety issue and etc. in the construction activities. This presents a situation where construction team members have to share knowledge and collaborate to each other to meet the needs of client. The development of knowledge sharing enable fruitful knowledge to be shared among the construction team members. Such practice would help in project management especially for critical task (Lin and Lee, 2012). Carrillo and Chinowsky (2006) contend that new knowledge can be exploited and accumulated from knowledge sharing activity. Egbu and Robinson (2005) emphasise the importance to capture and share knowledge about processes, product and people as knowledge primarily resides in people and not in technology. The importance of knowledge sharing includes:

3.5.1 Facilitating the Access and Sharing of Knowledge across Projects

Knowledge sharing facilitates the transfer of knowledge across a variety of project interface which let the construction firms to seize the chance to exploit and capitalise on various knowledge-based resources (Wang and Noe, 2010) and to improve construction team performance (Al-Ghassani et al., 2004). When knowledge is shared across the projects, the gap between what employees know and what the organisation knows is narrowed (Anumba et al., 2005), collaborative working is then developed (Dent and Montague, 2004) and project's objectives are easier to be met (Al-Ghassani et al., 2004).

The construction organisations will be able to retain the knowledge that would otherwise be lost when team member leaves the group (Egbu, 2004). Furthermore, new knowledge will be created through an incremental positive development of an idea that resulted by the sharing of team members (Carrillo et al., 2004). The shared knowledge will benefit both the knowledge contributors and knowledge acceptors (Bartol and Srivastava, 2002) in term of grabbing the ideas that may not be obtained inside the own organisation (Wasko and Faraj, 2005). The sources of knowledge for any given work group can range from customers to organisational experts to members themselves (Cummings, 2004). When the knowledge base is enriched and accumulated (Egbu, 2004; Anumba et al., 2005), the organisation can record and measure the value of the knowledge that has been shared (Bartol and Srivastava, 2002).

3.5.2 Reduction in Construction Project Costs

The sharing of knowledge not only improves the quality of the services (Hansen, 2002; Paulraj et al., 2008) but also lower the product cost (Anumba et al., 2005). Research shows that knowledge sharing activity is effective in reducing risk and uncertainty (Carrillo et al., 2006), to avoid past mistakes (Anumba et al., 2005; Chen and Mohamed, 2008), to reduce response time (Paulraj et al., 2008) and to control the flow of construction project (Kamara et al., 2005). Risk, waiting time and uncertainty are often related to project cost (Anumba et al., 2005). When the supplier becomes aware of the previous pitfalls, the cost of rectification work is then saved (Fong and Yip, 2006; Chen and Mohamed, 2008). Research shows that lower cost can be achieved for greater product design and operational efficiency if knowledge is shared and managed properly (Cummings, 2004; Paulraj et al., 2008).

3.5.3 Faster Completion of Construction Project

Many construction firms have recognised the benefits of faster completion of project through knowledge sharing activities (Zin and Egbu, 2010). The project-relevant information is shared among the team members where good perspectives and ideas are developed from that (Cummings, 2004). It also reduces project variation (Kamara et al., 2003), enhance co-ordinating and efficiency among the project team members (Modi and Mabert, 2007; Sanchez et al., 2013) and response rapidly to changes (Zin and Egbu, 2010). The project knowledge is not only to be captured 'live' but also to be shared as

soon as possible (Tan et al., 2010). Therefore, the construction team members can learn on the key events and avoid the repetition of similar mistake so that construction project can to be completed early (Egbu, 2004; Anumba et al., 2005; Kamara et al., 2005). When knowledge is shared, the project team will have more time to deal with contingency work (Kamara et al., 2005).

3.5.4   Improvement of Firms' Innovation Capability

Yesil and Dereli (2013) contend that knowledge is the source of innovation. New knowledge is an output of innovation process and hence knowledge is inseparable from that process (Anumba et al., 2005). The management of innovation is basically about the management of knowledge – the sharing, creation, reformulation and linking different types of knowledge (Al-Ghassani et al., 2004). Related to this, Wang and Wang (2012) states that firms' innovation capability is decided by employees' willingness to share knowledge and to learn. Yesil et al. (2013) notes that organisational learning is possible only when the individuals are willing to contribute or share their knowledge.

In the same way, Wang and Wang (2012) contend that knowledge sharing can populate the knowledge repository to improve company innovation capability. As Carrillo et al. (2004) point out, innovation requires "the generation and incorporation of variety in the development of knowledge and making sense of knowledge across a broad spectrum". Knowledge sharing involves the re-conceptualising the problem (Carrillo et al., 2004), scanning

and evaluating the reusable ideas, analysing the ideas in depth (Al-Ghassani et al., 2004) and improving existing working methods (Wang and Wang, 2012). These activities will lead to improvement of firms' innovation capability (Yesil el al., 2013). It is found that innovative organisation is likely to see their own situation better and to gain competitive advantage (Hsu et al., 2007).

3.5.5   Risk Minimisation

Carrillo et al. (2006) point out that knowledge sharing could also be an effective mechanism for mitigating risks. The knowledge is shared to mitigate the impact of risk brought about and also to prevent the happening of accident in project (Anumba et al., 2005). Therefore, construction firms have fewer uncertainties to deal. The clients' need changes often have caused the increase of uncertainty in project. Only knowledge sharing activities can cope with the uncertainty (Kamara et al., 2005). This is because the firms and project teams can gain more time for co-planning to deliver with greater quality (Khalfan et al., 2010), or even to convert the risk into economic value (Ipe, 2003). Ipe (2003) and Kamara et al. (2005) contend that project is much easier to be completed if the risk involved is minimised. This is especially for the more complex and risky projects. The project team can have a better control of the project whereas client will enjoy the better work quality brought about (Carrillo et al., 2004). This would then create win-win situation (Mitton et al., 2007).

3.5.6 Gaining Competitive Advantage

It is evident by the number of research done that knowledge sharing will bring competitive advantages to the company (Kamara et al., 2003; Zin and Egbu, 2010). As Wang and Wang (2012) point out, the competitive construction firm will be more agile and able to deal with the competitive environment. Hsu (2008) and Khalfan et al. (2010) mention that only the competitive firm is able to stand firm and be ahead of their competitors. Al-Ghassani et al. (2004) find that knowledge sharing promotes the development of core competencies or capabilities. In this instance, the unique firm behaviour will differentiate the firm from other competitors (Fang et al., 2010). Lee and Ahn (2007) believe that knowledge sharing not only can deliver competitive advantage to the construction firm but also benefit the whole construction industry.

3.6 Rewards for Knowledge Sharing

As knowledge is very often viewed as a private goods (Wei et al., 2010), rewards therefore have to come together with its sharing (Bock and Kim 2002). Wei et al. (2010) point out that people receive commensurate benefits by exchanging their knowledge through market mechanisms. From the perspective of economic exchange theory, knowledge sharing will occur when its rewards exceed its cost. The extrinsic benefits would encourage the people to build positive attitude towards knowledge sharing (Bock and Kim, 2002). When comes to social exchange theory, it is concerned with intrinsic

rewards (Zafirovski, 2005). As pointed by Cropanzano (2005), "social exchange differs from economic exchange in that social exchange entails unspecified obligations. It tends to engender the feelings of personal obligation, gratitude and trust".

Rewards for knowledge sharing can be regarded as the motivator to stimulate effective acquisition, application and sharing of knowledge to take place (Dent and Montague, 2004). It starts from the contributor and ends when the receiver gets the knowledge. Rewards for knowledge sharing can be in different forms, which include economic rewards, access to knowledge, career advancement and security, enhanced reputation and personal satisfaction (Dent and Montague, 2004).

There are different perspectives on rewards for knowledge sharing and how it should be done (Ipe, 2003). The importance of rewards for knowledge sharing is as follows:

3.6.1 Encouraging Knowledge Sharing among Project Participants

The lack of a transparent and rewards recognition system would demotivate people to contribute and share their knowledge (Chua, 2003; Wang and Noe, 2010). Knowledge is lost due to the time lapse in capturing the knowledge (Hsu, 2008; Tan et al., 2010). It is difficult to share knowledge when knowledge sharing culture is not nurtured (Yao et al., 2007). A firm can record and measure the value of the knowledge plus its' impacts to establish

appropriate rewards for knowledge sharing (Bartol and Srivastava, 2002). Reward is not necessary in terms of money but also in the other forms like promotion, peer acclaim and physical reward (Robinson et al., 2005). Collins et al (2001) contend that these rewards will encourage the employee to improve their performance (Olomolaiye and Egbu, 2006) or even to accomplish an outstanding task (Aretoulis et al., 2009). Another reason for having rewards is to encourage the employees to contribute to company knowledge base (Bartol and Srivastava, 2002) as the knowledge is often resided in the experts' or employees' mind (Sanchez et al., 2013). The need for rewards to promote knowledge sharing is also supported by the work of Dyer and Nobeoka (2000), Earl (2001) and Hall (2001).

3.6.2 Recognising Team Member's Contribution

Establishment of reward for knowledge sharing helps to recognise employee's contribution to the project (Dent and Montague, 2004). For instance, Anumba et al. (2005) find that once employees are awarded for the recognition of their contribution, the construction project will be delivered in smoother way. They may even further improve their performance and work in a trustworthy and willing manner after their contribution to knowledge is recognised (Anumba et al., 2005). According to Wang and Noe (2010), one of the important rewards for knowledge sharing is the recognition of employees' contribution. In Korea, the emphasis on performance-based pay system has been found to contribute to knowledge sharing (Kim and Lee, 2006).

3.7   Summary

The different perspectives and processes of knowledge management (KM) as well as knowledge sharing have been discussed. The following chapter will describe the methods used in this research to achieve the aim and objectives. It also justifies the logic adopted for triangulation or combined approach in this research.

CHAPTER 4

RESEARCH METHODOLOGY

This chapter covers the methodology adopted to achieve the aim and objectives of this research. It reviews some relevant research concepts including: the meaning of research, research strategy and also presents the research design of this research.

4.1   The Meaning of Research

According to the Compact Oxford English Dictionary (2008), a research is "the systematic study of materials and sources in order to establish facts and reach new conclusions." Naoum (2007) notes that "research" may be used interchangeably with other words such as inquiry, study or investigation and research needs to be implied or conducted in a careful, scientific and critical manner. Naoum (2007) asserts that a research project must have aim and objectives, with the ultimate outcome of expanding the knowledge. Research is also viewed as the steps of the process to collect and analyse information in order to enhance the understanding of an issue or topic (Creswell, 2005).

Fellows and Liu (2008) define research in three ways. The first definition of research is a careful search or investigation. They contend that

research can be considered to be a voyage of discovery, where anything is discovered or not. The discovery concerns the process of investigation as well as the technical subject. Even no new knowledge is apparent, the investigation may lend further support for extant theory. Besides that, research is regarding the contribution to new knowledge (Fellows and Liu, 2008). Its emphasis relies on determining facts in order to reach new conclusions and new knowledge. It is concerned with the facts and conclusions which is drawn from the way and how is being proven form the scientific components. A research may be regarded as a learning process as well (Fellows and Liu, 2008). It is the process of acquiring knowledge and understanding. It constitutes the teaching and communication process to stimulate learning (Fellows and Liu, 2008).

According to Creswell (2005), research adds to knowledge. It can expand knowledge, address the gaps in knowledge, replicate knowledge, broaden perspectives and inform a good practice. It can contribute or deepen the existing information and issues. Besides that, it improves practice. The suggestion improvements from research offer the scholars new ideas. It also helps practitioners evaluate approaches in order to determine which results will be useful. To scholars, the research builds the research skills. It helps individuals develop conceptual, writing, organising and presenting skills (Creswell, 2005).

4.2   Research Strategy

Research strategy can be interpreted as "the direction in which the research objectives can be asked and questioned" (Naoum, 2007). Research strategies can be categorised into two types, namely, quantitative research and qualitative research (Naoum, 2007). These two approaches are the major approach to educational research (Creswell, 2005). In the other way, Fellow and Lui (2008) classify research strategies into seven types. These include pure and applied research, quantitative and qualitative research, instrumental research, descriptive research, exploratory research, explanatory research and interpretive research. Research strategy plays an important role to investigate the issue, approaches to the objective, conducting the methods, obtain and analyse the result from the respondents and eventually contribute new research area or deepen the existing knowledge (Creswell, 2005).

4.2.1   Quantitative Research

Quantitative research is 'objective' in nature (Naoum, 2007). It is a type of research "in which the researcher decides what to study, asks specific, narrow questions, collect numeric (numbered) data from participants, analyses these numbers using statistics and conducts the inquiry in an unbiased and objective manner, in order to determine whether the hypothesis or the theory hold true" (Cresswell, 2005). Quantitative data is not an abstract, but they are hard and reliable (Naoum, 2007). Usually, quantitative data are measurements of countable, tangible, sensate features of the world (Naoum, 2007).

According to Fellow and Liu (2008), quantitative approaches tend to seek to gather factual data and relate them to positivism. This approach will "study the relationships between facts and how such relationships and facts accord with theories or the findings of any research previously executed" (Fellow and Liu, 2008). Sometimes, scientific techniques are required to obtain measurements-quantified data. Data analyses will yield the quantified results, whereas the conclusion is derived from evaluation of the results in consideration of the literature and theory (Fellow and Liu, 2008).

Quantitative research "adopt 'scientific method' in which initial investigation of theory, literature derives precise aim and objectives with proposition(s) and hypotheses are to be experimented and tested – refutation and conjecture may be adopted" (Greene and Caracelli, 1997). Naoum (2007) note that quantitative research can be conducted through close ended questionnaire survey, which is less tedious to be conducted and the data collected is easy to be understood.

4.2.2   Qualitative Research

Qualitative research is 'subjective' in nature (Naoum, 2007). It relies on the views of participants where broad and general questions are asked to collect insights and data consisting largely of words or text from participants (Fellow and Liu, 2008). It emphasises meanings, experiences, verbally described and description. As pointed out by Greene and Caracelli (1997), an

exploration of the subject in the qualitative research is "undertaken without prior formulations – the object is to gain understanding and collect information and data such that theories will emerge" (Greene and Caracelli, 1997). Thus, qualitative research is a precursor to quantitative research (Fellow and Liu, 2008).

Qualitative research describes and analyses the words for the themes and then conducts the inquiry in a biased manner or subjective to investigate the beliefs, understandings, opinions, views of people (Creswell, 2005). Fellow and Liu (2008) highlight that the data gathered may be unstructured or will be in the raw form. Consequently, the objectivity of qualitative data often is questioned. A variety of the surroundings external conditions such as environmental variables are probably to impact on the data. This approach is conducted in a more active way if compared to the quantitative studies (Fellow and Liu, 2008).

Naoum (2007) further explains that the information gathered in qualitative research can be categorised into two categories called exploratory and attitudinal. Exploratory research is adopted when the knowledge about the topic is insufficient. It is intertwined with the need for a precise and clear statement of the recognised problem. Attitudinal research is applied to view or evaluate subjectively the perception or opinion of a person towards a particular object. Creswell (2005) asserts that qualitative research is usually conducted in the form of case study or interview. The data collected in this approach are rich and with deep insight. The targeted sites and participants are

identified based on people and places that can best help to enhance the understanding of central phenomenon (Creswell, 2005). Thus the facts collected are more specific, detailed and rich toward the issue (Fellow and Liu, 2008). Fellow and Liu (2008) point out that "analyses of such data tend to be considerably more difficult than with quantitative data, often requiring a lot of filtering, sorting and other 'manipulations' to make them suitable for analytic techniques." Therefore, the final outcome of qualitative research will be throwing up hypotheses and hunches which it can be tested more rigorously by further research in quantitative approach (Naoum, 2007).

4.2.3   Triangulation or Combined Approach

Triangulation is "the use of two or more research methods to investigate the same thing such as experiment and interviews in a case study project" (Fellow and Liu, 2008). It is a "legitimate inquiry approach" (Creswell, 2005). As an example, a postal or other questionnaire to a generalised, "representative sample of respondents would assist the researchers to appreciate the general validity of the findings from the particular case study and would serve to aid understanding of its unique and generally applicable features" (Fellow and Liu, 2008). Creswell (2005) points out that triangulation or combined approach is a good design to use as it builds on the strengths of both quantitative and qualitative data. It is a 'very powerful mix' (Miles and Huberman, 1994) to develop 'a complex' picture of social phenomenon (Greene and Caracelli, 1997). However, Vaivio and Siren (2010)

opine that triangulation research is not limited to the mixing of methods, but also describes the combination of investigators, theories or data sources.

Triangulation or combined approach is adopted in this study as both quantitative and qualitative data are collected through case studies and a survey on the performance of the system. Case study is preferred in examining contemporary events, in this case, to investigate how the Malaysia construction companies manage suppliers' performance and selection of suppliers for new job. Through the case study, details of the related issues and the end-users' requirements for the development of the system are obtained. This approach is suitable as the detailed end-users' requirements for the development of the system required cannot possibly be obtained through quantitative method such as survey. Case study approach allows the direct observation of the related issues being studied and face-to-face interviews with the persons involved in the events.

For the survey, questions were asked during the interviews to obtain the details of the information needed and insights from the interviewees. There is also an element of quantitative research in the evaluation of the system, as quantitative data on what the participants from the industry think about the performance of it on various aspects are collected and analysed. Triangulation or combined approach enables more detailed data to be collected compared to either case study or survey alone. The results of the analysis are then used for the development of the system.

4.3 Research Design

A research design includes the procedure and methodology employed to conduct scientific research or to decide the methodological approach in finding the solutions for the research problem (Fellow and Liu, 2008). Naoum (2007) define research design as an action appraisal for moving from 'here' to 'there', where 'here' can be justified as the initial set of questions to be responded and answered whereby 'there' may be interpreted as some set of conclusion of these questions. A number of major steps may be found between 'here' and 'there' including the relevant data collection and analysis (Creswell, 2005).

The research design is depicted in Figure 4.1. Firstly, the scope and area of this research is explored and narrowed down. It is followed by the study on the relevant areas to identify the gap in research. Then, the title of the research is determined together with the formation of aim and objectives. Next, the relevant studies and research which are related to this research are collected for review. According Naoum (2007), literature review serves two purposes:

- It looks for the systematic reading of previously unpublished and published information pertaining to the area of investigation; and
- To provide insights on how to design the study more effectively.

```
                    ┌─────────────────────┐
                    │    Initiate study   │
                    │    on the field     │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Identify a research │
                    │      problem        │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Determine the       │
                    │ research topic      │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Develop aim and     │
                    │ objectives          │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Review the          │
                    │ literatures         │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Identification of   │
                    │ construction company│
                    │ for interview,      │
                    │ selection of        │
                    │ respondents         │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Development of a    │
                    │ framework and       │
                    │ prototype           │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Evaluation of the   │
                    │ prototype and       │
                    │ analysis of the     │
                    │ result              │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Refinement of the   │
                    │ prototype system    │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Reporting findings  │
                    │ (results,           │
                    │ discussion,         │
                    │ conclusions)        │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Recommendation for  │
                    │ further research    │
                    └─────────────────────┘
```

Figure 4.1: Research Design of This Research

Identification of suitable construction firms for detailed case studies is carried out after literature review stage. Use is made of a number of semi-structured interviews with key industry personnel from Malaysia construction companies to obtain detailed information as to the supplier selection process, which includes also the criteria used for supplier selection. The shortcomings on current practice and the end users' requirements on leveraging ICT to better manage supplier and facilitate knowledge sharing are identified as well. Open ended questions are asked during the interviews with some probing on a list of topics and the respondents' views are recorded. The result is then reported in detailed case studies presented in subsequent chapter. Semi structured interview is chosen because it can ensure the richness of data collected and is not as restrictive as the structured interview.

Analysis of the information obtained from the industry is conducted to identify the areas and processes that can be better managed with the aid of IT-based information system. It is followed by the development of a framework and prototype Web-based application for managing the performance of suppliers. This involves the detailed study on how the functionalities required to be incorporated into the system and also the specified format for representing the framework. Subsequently, the framework is encapsulated into a Web-based system using the latest Web-based technology.

This is followed by the testing and evaluation of the prototype system. For convenience and also to enhance the construction players' understanding of the system, the prototype application is first demonstrated to the

participants from the construction companies interviewed before and only the evaluation is then conducted. Later, the evaluation results are analysed so that improvements can be made to refine the system.

The data collected for this research are categorised to primary and secondary data. Primary data is the direct data collection which is obtained in the first hand. There are few methods of obtaining primary data such as survey approach, case study approach and problem-solving approach (Naoum, 2007). Alternatively, secondary data is collected by adopting the desk study approach and sought from other sources. It can be either in a statistical or descriptive format (Naoum, 2007). Both primary and secondary data have advantages. The primary data obtained is more reliable, authentic and objective. The advantage of primary data is that the operationalisation of the theoretical constructs, the design of research and the strategy of data collection can be specified to the research question, which ensures that the study is coherent, and logical (Hox and Boeije, 2005). They further explain that the in fact information actually helps to address the problem (Hox and Boeije, 2005). Conversely, collecting data from secondary data saves time and cost if compared to primary data. It acts as a useful comparative tool to compare the new data with the existing data as to produce higher quality works (Hox and Boeije, 2005).

4.4　Summary

The relevant research concepts and research design are presented in this chapter. It includes the discussions on the selection of a suitable method for this research. Triangulation or combined approach is adopted in this research as both quantitative and qualitative data are collected through case studies and a survey on the performance of the system. The next chapter presents the finding from the case studies and the methodology for managing suppliers' performance and knowledge sharing. It identifies the shortcomings and the room for improvements on current practice.

CHAPTER 5

DEVELOPMENT OF THE SYSTEM

As mentioned in Chapter 4, case studies are conducted to explore and obtain deeper insights into the current approaches in the construction industry for supplier selection, the way of managing suppliers' performance, identify shortcomings of current practice, and lastly derive the requirements on how to leverage ICT for managing suppliers' performance as well as knowledge sharing. This chapter presents the findings and analysis of the case studies, and the development of the system for managing suppliers' performance.

5.1   Background of Case Studies Company

Twelve case studies are undertaken, which involve semi-structured interviews with fifteen representatives from twelve companies whose positions range from Contract Manager to Project Manager to ensure that a comprehensive view is obtained. The twelve case study companies are registered on the main board of Bursa Saham Stock Exchange Malaysia. Background information on the companies is presented in Table 5.1. The business nature of these companies is either contractor or developer. This helps to prevent bias and ensure that both main contractor's and developer's perspectives on the relevant issues are obtained for the development of the system for managing suppliers' performance.

Table 5.1: Background of Case Study Companies

Company	Position of Interviewee	Company Background	Revenue in The Year 2012 (RM)
A	Assistant Contract Manager	Construction and Engineering Contractor	565M
B	Assistant Contract Manager	Building Construction and Civil Engineering Contractor	208M
C	Project Manager, Assistant Contract Manager	Infrastructure and Property Developer	3087M
D	Senior Contract Executive	Building Contractor	39M
E	Project Manager	Diversified Contractor	5336M
F	Project Manager	Property and Infrastructure Developers	1283M
G	Assistant Contract Manager	Building Contractor	1560M
H	Contract Manager	Diversified Contractor	20195M
I	Contract Manager	Property Developer	993M
J	Assistant Contract Manager	Property Developer	2526M
K	Project Manager, Project Executive	Property Construction Developer	3849M
L	Contract Executive	Property Developer	799M

5.2   Findings from the Case Studies

The findings from the case studies represent the collective views of the companies involved in the areas investigated, where significant overlaps of information are observed. However, the findings from three companies are reported as independent case studies as the companies have developed custom-designed computer applications to manage their suppliers' performance. These

companies are Company E, Company H and Company K. As the practice of the rest of the companies is very much similar, characterized by the use of readily available computer applications for suppliers' management, the results are therefore presented together as a case.

5.2.1   Company E

Company E is one of Malaysia's leading conglomerates and is listed on the Main Market of Bursa Malaysia Securities Berhad (Bursa Securities). It is also registered as a Class A contractor with Contractor Service Centre Malaysia (PKK) and G7 (i.e. the highest grade possible) contractor with Construction Industry Development Board Malaysia (CIDB). Its service include property development, construction, infrastructure concessions and plantations, manufacturing and quarrying. The company's revenue reached RM 5.33 billion in the year 2012. A growing presence is established in neighbouring developing markets with operations spanning presently ten countries, with its core business in Malaysia, India, Indonesia, United Arab Emirates, and China.

5.2.1.1   Current Approach for the Selection of Suppliers

There are certain rules and procedures that need to be followed for the selection of suppliers in Company E due to the ISO certification obtained. For the subcontract jobs that worth more than RM 50,000, the project director has to nominate at least three subcontractors for the selection process. If the

subcontract job is worth more than RM 200,000, the project director needs to obtain clearance from the Tender and Contracts Department on the short listed subcontractor and to request the Tender and Contracts Department to nominate subcontractors for bidding purpose. Besides that, the department needs to participate in reviewing on the tender document. If there are any insufficient documents and errors, the supplier is required to take necessary actions or furnish the details. Tender and Contracts Department will use designated standard form to prepare the tender evaluation report and recommend the supplier for the job. The criteria used for selection include past experience (track record), management and staff, financial capabilities, plant and equipment, quality and record on health and safety.

5.2.1.2 The Ways of Managing Suppliers' Performance

Company E uses custom-designed computer application to manage the subcontractors' performance as depicted in Figure 5.1. The system is mainly for project manager, project director and other executives to monitor the on-going construction projects. Contract particulars, project personnel, executive summary, progress report, financial status, appendices, summary information, generate report and other relevant information are included in the system so that the latest project's issue and progress can be known instantly. The system can be used to control the project's risks and work progress as monthly progress reports, work progress photo, variation work, quality control and assurance report, plant and equipment record can be found within the system. Not only that, monthly project expenses and progress claim report as depicted

in Figure 5.2 and 5.3 can be retrieved from the system to control the cost. The evaluation of subcontractors' performance will be done manually and later to be scanned to the system. The subcontractors' performance will be evaluated in term of the completion on time, compliance to requirement, commitment and response to site instructions, ability to solve problem, technical knowledge, cooperation and timely submission of reports. Corrective Action Request (CAR) review meeting is held quarterly to review the incomplete works as well as discussing the area where subcontractors should improve.
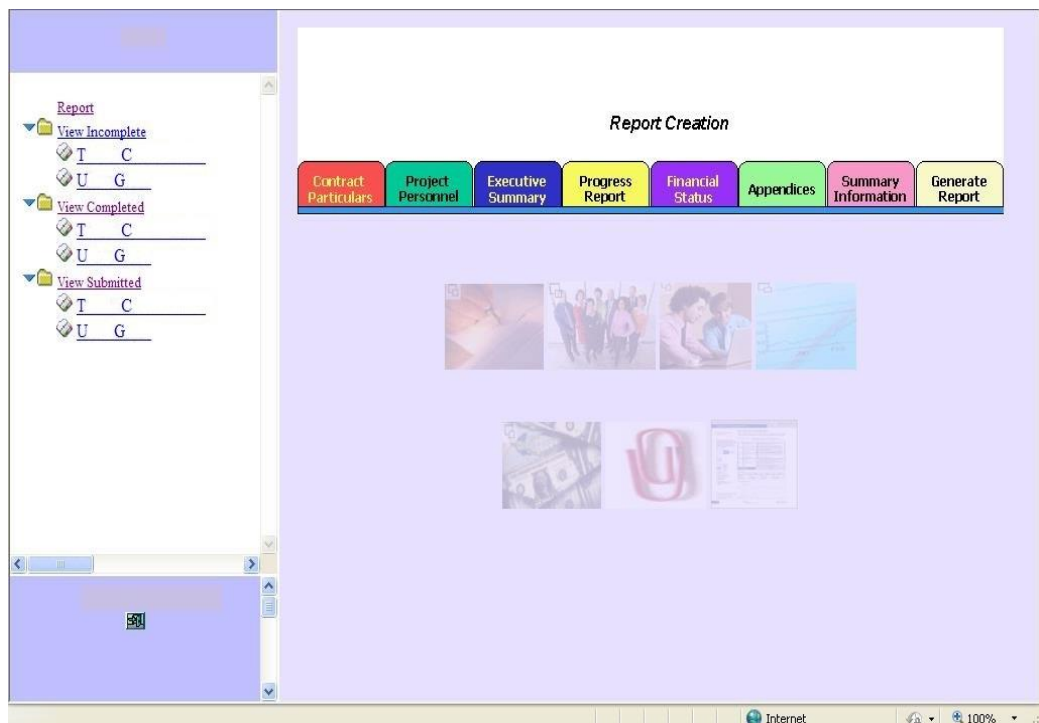
Figure 5.1: Details of a Construction Project
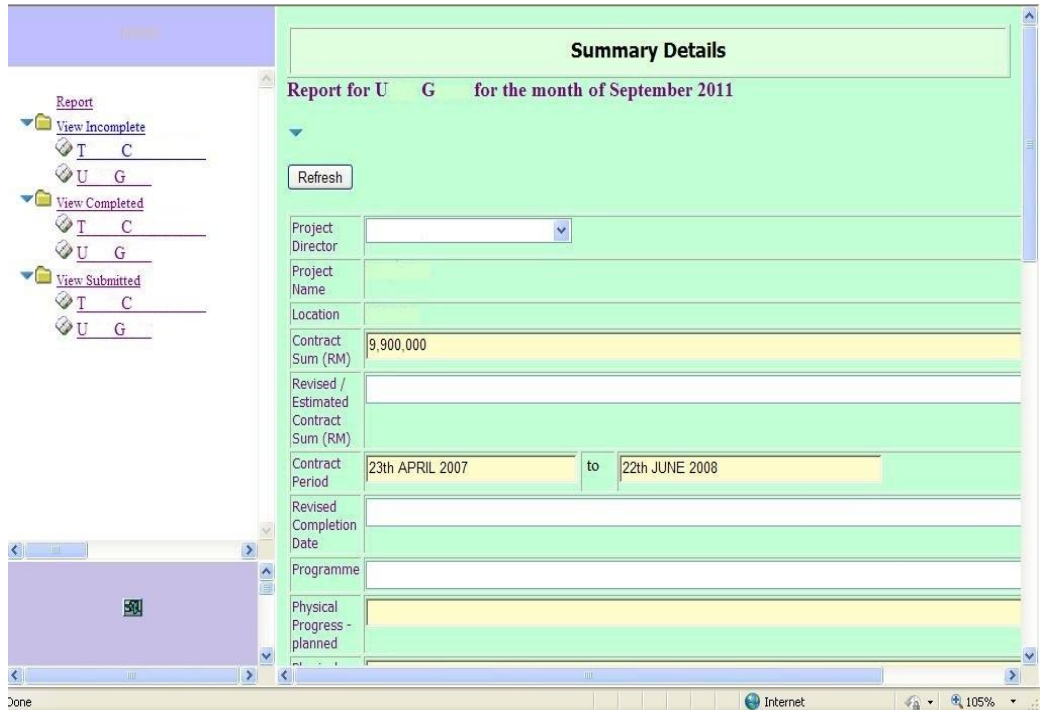
Figure 5.2: Monthly Project Expenses' Details
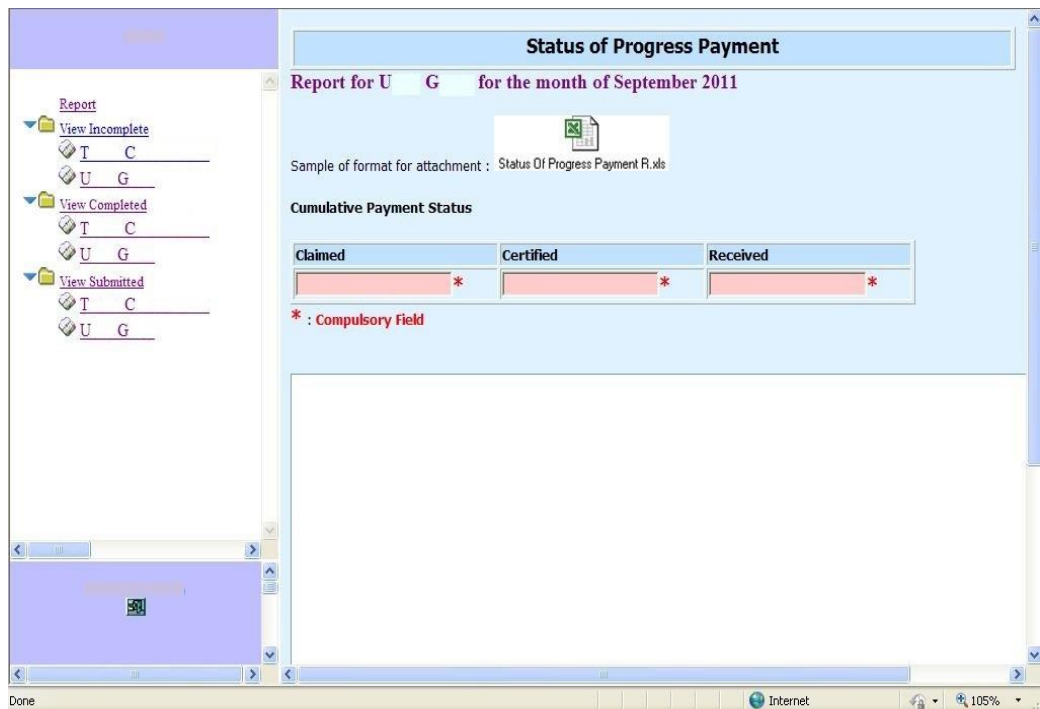
Figure 5.3: Status of Progress Payment

5.2.2   Company H

Company H is a diversified group of companies that involves in variety fields. Its' businesses mainly focus on the management and ownership of regulated utilities and other relevant infrastructural assets. It is a "Class A" Malaysian turnkey contractor and has registered as a G7 contractor with Construction Industry Development Board Malaysia (CIDB). Company H was the first Asian non-Japanese company that is to be listed on the Tokyo Stock Exchange. In the year 2012, the company's revenue was RM 20 billion. Company H was the largest non-government linked company in the year 2010's "MB 100 Survey" of Malaysia's largest listed companies.

5.2.2.1   Current Approach for the Selection of Suppliers

As one of the largest construction firms in Malaysia, Company H has a standard procedure for supplier selection. The subcontractors are required to submit relevant forms such as Form 24 (Return of Allotment of Shares), Form 9 (Companies Commission of Malaysia) and Form 49 (Return Giving Particulars in Register of Directors, Manager and Secretaries etc.) and company profile. Prequalification process is carried out to determine the suitability of subcontractor. Later, the qualified subcontractors will go through the tender process. A list of criteria that comprises past project performance, financial strength, manpower strength, equipment and assets available and quality system certification are used for selection and comparison purpose.

The supplier who has been awarded the subcontractor work will be registered in the company database and his performance for the job will be evaluated.

5.2.2.2 The Ways of Managing Suppliers' Performance

Custom designed computer application as depicted in Figure 5.4 is used in Company H for managing the suppliers' performance. The management of the company is granted full access to the system meanwhile the employees have restricted access that is only sufficient to manage their own projects and subcontractors. Project particulars, project variation, parties involved, supplier's status and other relevant information (such as monthly progress claim, record on project cast flow, addendum, memo, meeting record) can be viewed from the system. This information is vital for problem solving and to ensure that the actual work progress is in line with the proposed schedule. The subcontractors' performance is evaluated once they have finished their s work. The project manager will use the subcontractor evaluation form to evaluate the respective subcontractor and then scans it to the system. The evaluation result will determine the supplier status, i.e. to be retained as preferred subcontractor or removed from the list. Company H uses the conformance to specification, delivery efficiency, response to immediate request, problem solving capabilities, co-operation and support and supplier's attitude as the criteria to evaluate the subcontractor's performance.

Figure 5.4: Company H's Integrated Information System

5.2.3   Company K

Company K supplies fully-integrated construction services, particular specialise in building and civil engineering, mechanical and electrical engineering, geotechnical solutions and logistics services. It is registered as G7, i.e. the highest grade contractor, with Construction Industry Development Board Malaysia (CIDB). Company K has ventured into the markets of India, Singapore, the Middle East and the Caribbean. Its revenue was RM 3.84 billion in 2012.

5.2.3.1   Current Approach for the Selection of Suppliers

The subcontractors who would like to tender for the subcontracting work for a project will have to undergo the pre-qualification assessment. The criteria used for the purpose include the supplier's technical expertise, financial standing, past project performance and registration with authority. After being shortlisted, the technical bid assessment is conducted to analyse the costing, technical aspect and method statements of the bid. Tender interview will be conducted later to clarify if there is any query. The most competitive tender will be recommended by the tender committee to the board of management for final decision. All of the subcontractors who work with Company K are classified into three categories, namely registered, conditionally approved or fully approved supplier.

5.2.3.2   The Ways of Managing Suppliers' Performance

Company K has a custom designed computer application as depicted in Figure 5.5 for managing the suppliers' performance. Performance evaluation is carried out on all the team members who are involved in the project. The evaluation is initiated by the person in charge (PIC) of the respective project from Supply Chain Department (SCM). They will start evaluating the team member such as main contractor, subcontractor, architect, quantity surveyor or even themselves. After that, Project Management (PM) Department and also the Profit Centre Manager (PCM) will perform the evaluation again. Finally, the result of the evaluation is sent to the Head of Department of SCM for

compilation. The various parties involved can then view their respective records (including that of the past projects) via a custom designed computer application. Two main criteria are used for the suppliers' performance evaluation (i.e. quality and time) as depicted in Figure 5.7. There are sub-criteria under the two main criteria. For instance, 60 per cent of the weightage (as depicted in Figure 5.6) is apportioned to the sub-criterion quality to examine suppliers' workmanship, which cover end product quality, attendance of the training on quality control, construction method and compliance to company quality standard; whereas 40 per cent is assigned to "time" which includes completion of time, supplier's attitude, etc. The underperforming suppliers will be sent a reminder to improve their performance. The evaluation of project team members' performance is carried out every six months.
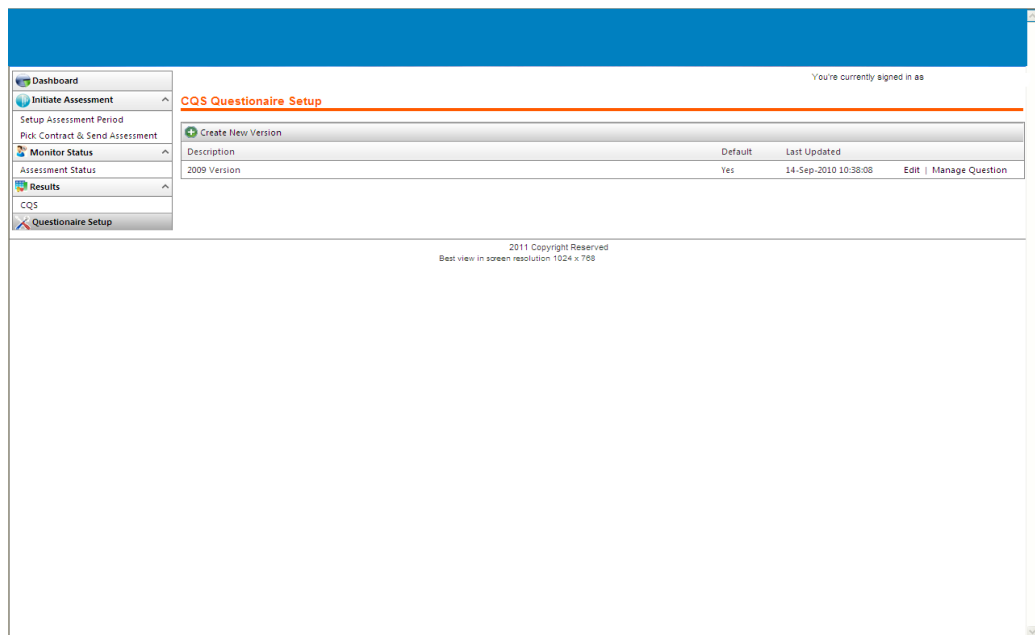
Figure 5.5: Screen Shot Showing the page for Setting up Evaluations

Questions
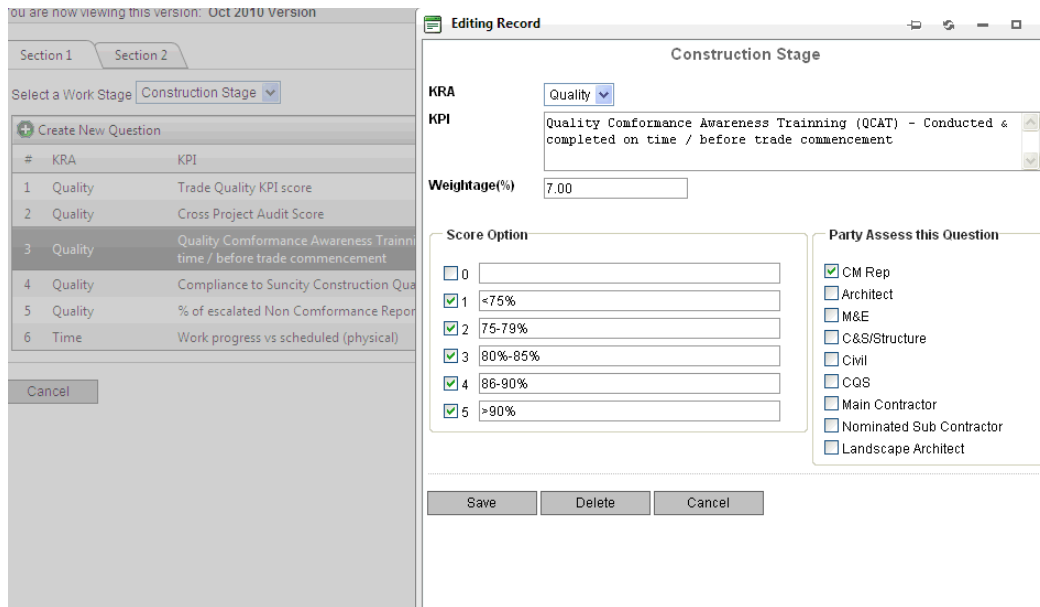
Figure 5.6: The Evaluation of Work Executed or Service Provided
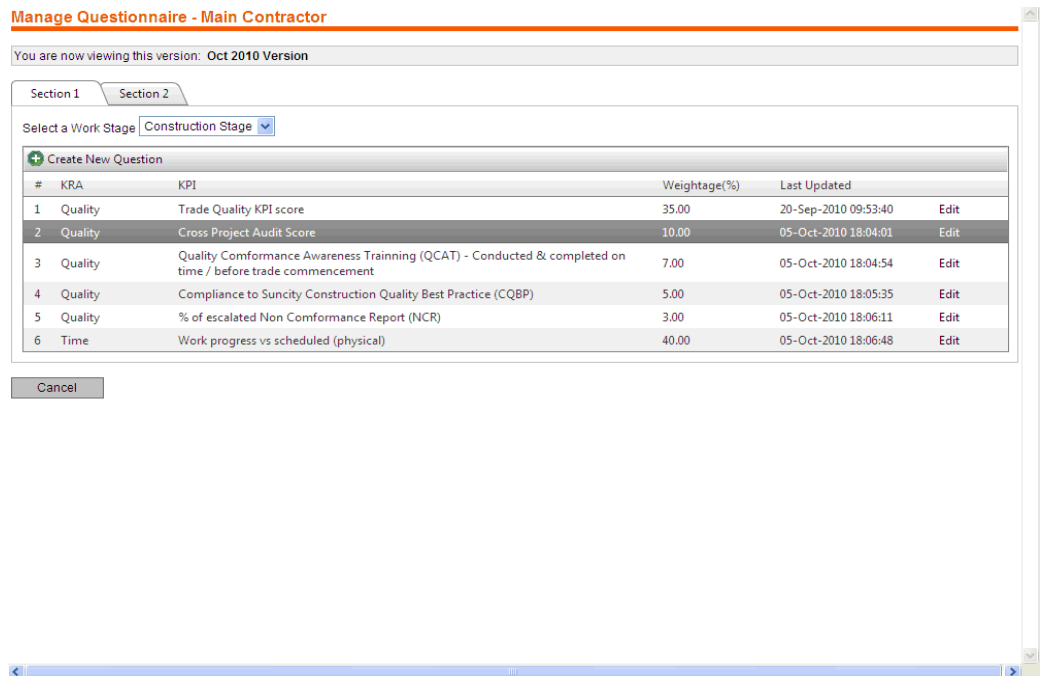
Figure 5.7: The Evaluation Criteria and Weightage

5.2.4   Other Companies

The findings about the practice of the other construction companies involved in the study are reported in the following sections. The business natures of the companies are diverse, which include civil engineering work, building work, and special trades. Despite the notable annual turnover, there is a lack of IT support in these companies for managing suppliers' performance.

5.2.4.1   Current Approach for the Selection of Suppliers

Suppliers are required to undergo prequalification process prior to tendering for the subcontracting work. The suppliers need to submit the company portfolio and other relevant documents to the contractor or developer. After that, the contractor or developer will study the documents and then shortlist the qualified suppliers. Three to five prequalified suppliers are normally invited for tendering. This is followed by tender submission, tender interview and tender comparison. Only one supplier is recommended by the tender committee with the consent of contract manager or the head of department to the Board of Directors. After a discussion with the tender committee / contract manager, the Board of Directors will decide and award the subcontracting work to the most suitable supplier. The general criteria used to select subcontractor by the companies include tender price, subcontractors' past performance, current workload, technical capability, financial strength, plant and equipment, management and staff. Printed forms and spread sheets

are used during the supplier selection process. No custom-designed or off-the-shelf IT-based systems are used to assist in the selection of suppliers.

5.2.4.2 The Ways of Managing Suppliers' Performance

The current practice by the construction companies to manage the supplier performance includes meeting, daily site supervision, progress report, and subcontractor/supplier performance evaluation. The criteria used to evaluate suppliers' performance include completion on time, suppliers' conformant to work, suppliers' attitude / behaviour, planning and problem solving capabilities and cooperation with project team. Suppliers' performance evaluation is conducted at six months to twelve months interval. The construction companies are not leveraging much on ICT or custom designed computer applications for the better management of suppliers' performance. Existing available computer software (e.g. Microsoft Office) is used merely for preparing the paperwork, keeping record and comparing the difference between the actual work progresses and the planned progress.

5.3 Discussion

The case studies reveal that the construction companies have their own in-house criteria for the selection of suppliers as this is dependent on the type of tasks, nature of project, unique requirements of clients, and other factors. It is impossible to adopt a once size fits all criteria for the purpose. Table 5.3 shows the different criteria for the selection and evaluation of suppliers'

performance used by the case study companies. Figure 5.8 illustrates the general process for the supplier selection and performance evaluation that is practiced by the contractor and developer firms in Malaysia.

It was observed that the use of ICT by the Malaysia construction companies for the selection of suppliers and the monitoring of their performance is still very low. The reasons are stated in Table 5.2.

Table 5.2: Reasons of the Low Usage of ICT in Supplier Selection and

Performance Evaluation

Reasons of the low usage of ICT by the Malaysia construction companies for the selection of suppliers and managing their performance	Companies concerned
- Construction firms are not willing to allocate sufficient fund to develop custom designed computer application for the better management of suppliers' performance;	C, F, G
- Smaller construction firms do not have the resources for the development of the system. They give priority to expanding the company rather than developing custom designed computer application;	A, B, D, I, L
- The employees are reluctant to change and resist the use of new system. Adoption of a custom designed computer application can be time consuming. Learning curve is long especially for the employees who are less IT literate;	B, D, K, L
- Negative past experience with custom-designed computer application. Some companies are of the opinion that the functions of the custom designed computer application may not be comprehensive enough and often fail to provide all the functions needed. There are instances where some of the minor but important details or features are left out by the programmer;	A, E, G, J, H
- Some companies are keen to follow the conventional way of using printed forms and spread sheets for the management of suppliers' performance and supplier selection as many of their suppliers have insufficient knowledge in using ICT.	C, F, H, I, J

Table 5.3: Criteria for Supplier Selection and Performance Evaluation

Company	Criteria for Supplier Selection	Criteria for the Evaluation of Suppliers' Performance
E	- Tender price - Past project performance - Management and staff - Financial standing - Plant and equipment - Record on health and safety	- Completion on time - Compliance to requirement - Commitment and response to site instructions - Proactive and effective solutions to issues / problems - Technical knowledge - Cooperation with project team - Timely submission of reports
H	- Tender price - Past project performance - Financial strength - Manpower strength - Equipment assets strength - Quality system certification	- Conformance to specification - Delivery efficiency - Response to immediate request - Problem solving capabilities - Co-operation and support to project team - Supplier's attitude
K	- Tender price - Technical capability - Financial competitiveness - Past project performance - Registration with authority / professional bodies - Manpower availability	60% of the weightage is apportioned to work quality. These cover: - Construction method - Attendance of the training on quality control - End product quality - Compliance to company standard 40% of the weightage is given to time related criteria such as completion on time.
Others Companies	- Tender price - Past project performance - Current workload - Technical capability - Financial strength - Plant and equipment - Management and staff - Record on health and safety	- Completion on time - Workmanship / work quality - Suppliers' attitude / behaviour - Planning and problem solving capabilities - Cooperation with project team

```
                    ┌─────────────────────┐
                    │  Calling for tender  │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │  Supplier to submit  │
                    │ company profile and  │
                    │ relevant documents for│
                    │   pre-qualification  │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Elimination of suppliers│
                    │ with poor track record │
                    │ and insufficient capacity│
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Pre-qualified suppliers to│
                    │ collect tender document │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Supplier to submit tender│
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │   Tender interview   │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │   Tender comparison  │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Recommendation of the│
                    │ most suitable supplier by│
                    │ the Tender Committee or│
                    │ Contract Executive with│
                    │ the consent of Contract│
                    │  Manager / HOD       │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Board of Director /  │
                    │ management to make   │
                    │      decision        │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Subcontracting work is│
                    │ awarded to the supplier│
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Managing suppliers'  │
                    │    Performance       │
                    └─────────────────────┘
                        │           │
               ┌────────┘           └────────┐
               ▼                             ▼
    ┌─────────────────┐          ┌─────────────────┐
    │   Suppliers'    │          │ Meeting, daily site│
    │  performance    │          │ supervision, work │
    │  evaluation     │          │ progress report  │
    └─────────────────┘          └─────────────────┘
               │                             │
               └────────┐        ┌───────────┘
                        ▼        ▼
                    ┌─────────────────────┐
                    │  Project Completion  │
                    └─────────────────────┘
```

Figure 5.8: The Flowchart Showing the Current Practice for the Supplier

Selection and the Management of Suppliers' Performance in Typical

Local Construction Firms

5.3.1 Shortcomings of Current Approach for the Selection of Suppliers and the Management of Their Performance

It was observed that some of the custom designed computer applications used by the case study companies for the selection and management of suppliers' performance are not comprehensive in terms of the features. For instance, the application used by Company E and Company H still requires the users to scan and then upload the relevant documents (such as project monthly report or claims) to the system. This is not only time consuming but also inconvenient.

Besides that, none of the the custom designed computer applications used by the case study companies facilitate two-way communication. The suggestions or opinions given by other evaluators to improve the supplier's' performance are shielded from the knowledge of the subcontractors. There is no mechanism give credit or award the respective supplier for the outstanding performance.

The case studies reveal that knowledge sharing is neither prevailing nor practiced by most of the case study companies. There is no mechanism or feature available for the capture of the knowledge of suppliers on how improvements can be made to existing/on-going project. This may result in the loss of opportunity to reuse the valuable knowledge of the suppliers.

It was found that only Company K provides reward for knowledge sharing. The employees of Company K are entitled to reward or work promotion once the knowledge contributed is validated by the management. However, this is not extended to include the suppliers. The management will evaluate the benefits brought about by the knowledge before giving the credits to the respective employees. On the other hand, Company E and Company H conduct Post Project Review (PPR) after the end of a project. The awareness of knowledge sharing by the rest of construction companies is still very low most likely because it is still a relatively new concept to them.

5.3.2 Requirements for the Development of the System

The main requirement for the development of the methodology is to ease the management of supplier performance and the supplier selection, provide better transparency and leverage on the knowledge of the suppliers. The Web-based system must also address the shortcomings found on the current practice. For example, the current practices are the black-box models where the actual facts used by the decision makers to make up their mind are shielded from the suppliers. For the supplier selection, pre-determined criteria are incorporated to the system for the ease of user to select supplier. However, the criteria are still customisable in order to provide some flexibility to the users. The criteria for selection may subject to changes from time to time as necessary to cope with the requirements of the respective construction firms.

The Web-based system shall facilitate the management of the suppliers' performance. Many research have reported the importance of managing suppliers' performance. The historical data on the performance and profile of the suppliers need to be captured by the system as these help to reveal the reliability of the suppliers and also them to enhance their performance. For continuous improvement purpose, the system needs to allow the suppliers to access their own performance records so that they can improve themselves based on the feedback given and the result of the evaluation. All the better, the suppliers are allowed to communicate with their client on their performance.

Another feature that needs to be incorporated into the system is to capture the suppliers' knowledge on how the existing project can be further improved. The supplier is allowed to contribute and access knowledge shared by others in the system at any time without having to meet face-to-face with others for the purpose. The value and impacts of the knowledge shared need to be evaluated before the credits are given to the suppliers. Knowledge contribution may be considered as one of the criteria for supplier selection in order to encourage knowledge sharing.

There are some additional requirements that need to be considered as it may alter the design of the system. The additional requirements include:

a) Cost: The methodology used for the management of suppliers' performance and knowledge sharing should not incur significant

additional cost to the companies. The system should be capable of running on the existing ICT systems and platforms.

b) Workload: The methodology developed should not create significant additional workload to members of staff in view of their existing heavy workload. It would be better if the methodology could be integrated into existing job functions and help alleviate the existing heavy workload. It is observed that this is the key to minimising rejection and securing acceptance from the users.

c) Ease of use: The system developed needs to be user friendly and only minimum training is required to use it.

d) Reliable and comprehensive: The system developed should be stable and able to perform all the relevant functions. The system must be secure and is not accessible to the unauthorised users.

e) Representation of knowledge: The knowledge captured tends to be represented and organised in a logical and simple to understand way. Related to this, Tan et al. (2010) developed a system called Capri.net for the 'live' capture and reuse of project knowledge. The format used by the Capri.net system to represent knowledge covers the followings:

i) Background information on the project: These include project title, project title, project location, project sector, type of project, start and completion dates, duration, companies involved and date on which the knowledge is captured.

ii) Abstract: This is a short description of the knowledge captured.

iii) Details: This is the detailed explanation of the knowledge so as to facilitate others to understand better and hence sharing that knowledge. Video clips, photographs and diagrams can also be used to help explain the details about the knowledge, or to capture the tacit knowledge.

iv) Conditions for reuse: This spells out the condition(s) for reusing a particular knowledge entry.

v) Reference: This contains the reference to other relevant knowledge captured in the system, project documents, publications (e.g. books and reports), websites, where further details may be obtained. A hyperlink to Web pages showing the contact details of the author to aid the transfer of tacit knowledge is also provided here.

However, there are some additional data fields required for the representation of knowledge, i.e.:

i) Subject: This is a short title or description of the knowledge contributed;

ii) Impacts: This spells out how much the knowledge contributed can help in reducing the cost and time, or how it affects the performance of the suppliers. This requires verification by someone who is expert in that area.

Simply put, the design of the methodology must reflect the fact that the project team members are often pressed for time and not always collocated. The system must be user friendly as to avoid the creation of burden to the participants.

5.4 Methodology for Managing Suppliers' Performance and Knowledge Sharing

A methodology for supplier selection, managing supplier performance and facilitate knowledge sharing in construction project has been developed based on the findings from the case studies and literature review. The methodology comprises:

- A Web-based information system - This is where all the knowledge captured from a project and also the suppliers' relevant information are stored. The information system will run in the project extranet environment where only designated users from organisations collaborating in a project can gain access into the system.
- Experts - This is a role, normally charged to the experts or very experienced personnel, to verify and to rate the knowledge contributed.
- Project Administrators (PA) - This is a role, normally charged to a project manager, project director, director or other designated person, to select the most suitable supplier for a project/work and to evaluate their performance.

- System Administrators (SA) - This is a role, normally assigned to Information Technology Specialist or other designated persons. They can add new project, insert project details, add new suppliers or users, and assign role to various users. They can update the details and delete the existing suppliers or projects as instructed. They are granted for full access into the system to make sure system works well.

The proposed methodology is designed to allow two ways communication (client and suppliers), provide better transparency and capture the knowledge contributed by suppliers once it is created or identified. Users need to enter the knowledge identified in the specified format. The knowledge contributed needs to go through a validation process to verify its accuracy. All the knowledge contributed are stored in the system. Besides that, the methodology is meant to ease the supplier selection process and monitoring of the suppliers' performance throughout the course of a project. The senior management of a construction company (e.g. main contractor or developer) is often located at the head office and hence detached from the daily operation directly at the site level. Only designated users (i.e. Project Administrators) are allowed to participate in the supplier selection and performance evaluation. The details on how the PE, SA and information system interact with each other are depicted in Figure 5.9.
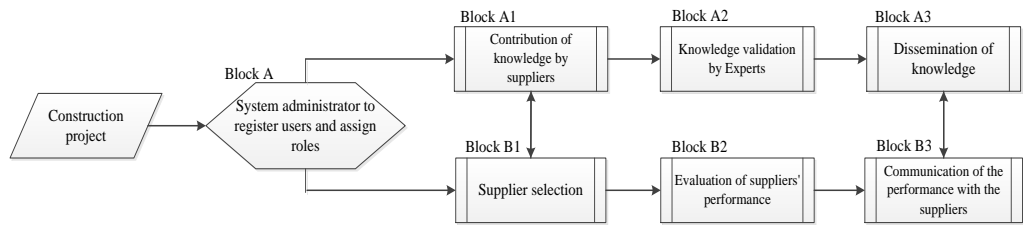
Figure 5.9: Methodology for the Selection of Suppliers and the Management Their Performance

5.4.1 Block A: System Administrators to Register Users

The System Administrators first need to register the users (i.e. log in username, password, and email) either as consultant supplier, Experts or Project Administrators (PA) and enter details of the project (e.g. project title, duration, location and construction team members) into the system. The different user groups would mean having different accessible level to the web page. For instance, project details (e.g. project title, duration, location and construction team members) can only be inserted and edited by System Administrators. System Administrators are granted full access to the system and are responsible for ensure the project information entered are correct.

5.4.2 Block A1: Contribution of Knowledge by Suppliers

All the suppliers involved in the project will be assigned a log-in name and password to access the system. This allows them to update their particulars and to enter their knowledge once knowledge is created or

identified, or at any time which is convenient to them. Photographs, diagrams and documents can be uploaded to the system to provide more details about the knowledge and to facilitate reuse.

5.4.3 Block A2: Knowledge Validation by Experts

Validation is essentially the review of the knowledge captured to ensure the accuracy of knowledge entered and to recognise the contribution by supplier. To validate the knowledge contributed, the Experts or the very experienced personnel will evaluate the time and cost saving brought about, and then to rate and comment on the contributed knowledge. In order to reduce the risk of "gaming", where rating given can be biased one way or another and offensive comment may be given, the users will be notified that such actions are unacceptable and they may be barred from using the system consequently.

5.4.4 Block A3: Dissemination of Knowledge

To facilitate sharing of reusable project knowledge, knowledge contributed will be made available for access through the Web-based system once it is submitted. The users can have an overview of all the knowledge captured and to access the full details. The details of the captured knowledge include the information of the project background, knowledge subject and details, knowledge contributor, relevant documents, verification status and the rating given. All the users are allowed to give constructive comment and to

rate the knowledge submitted; however, the final and conclusive rating will be given by the Experts. To nurture knowledge sharing culture, knowledge contribution is made one of the criteria for supplier selection.

5.4.5 Block B1: Supplier Selection

This process is about selecting the most suitable supplier for a project/task during bidding process. All the suppliers will be requested to complete and update their company profile at predetermined intervals. For the purpose, the shortlisted suppliers' company profile, past project performance, technical capability, financial strength, project in hand can be accessed and compared. Knowledge contribution score will be taken into consideration to encourage knowledge sharing. The Project Administrators can evaluate suppliers in a systematic way, which may lead to time, cost and paper saving. All the supplier's information and relevant document are recorded in the system.

5.4.6 Block B2: Evaluation of Suppliers' Performance

Different types of suppliers are involved in a typical project, which logically requires different set of criteria for selection and performance evaluation purpose. Therefore, these sets of criteria must be customisable based on individual company's requirements. Due to time constraint, however, only the criteria for the selection of sub-contractors are formulated and incorporated into the prototype application as proof of concept for the purpose

of this research. For the evaluation of the respective supplier's performance, it will be only carried out after the project/work is finished. The criteria used include whether or not the project/work is completed on time and within budget, as well as the workmanship. PA can provide some suggestions as to how the suppliers can improve their performance. The result of the project performance evaluation will be accessible to the suppliers also to facilitate transparent and fair evaluation. With the aid of web-based system, the supplier performance evaluation can be carried out in fast and convenient manner.

5.4.7 Block B3: Communication of the Performance with the Suppliers

Having good communication may foster learning, develop greater confidence in one another, and display cooperative and trusting behaviours that are crucial to success. Yet, there is no a mechanism is available in current approaches to feedback to the suppliers their performance. Hence, the methodology is developed in such a way that it allows the suppliers to access their own performance records. This also allows the suppliers the opportunity to clarify or defend themselves should the information that is used for the evaluation is inaccurate, or the issues that have given them a low score have been addressed albeit yet to be updated in the system.

5.5   Summary

The case studies reveal that there is a need for a Web-based database with modules for the capture of information on the suppliers' performance across projects, selection of suppliers based on a set of criteria and the sharing of reusable project knowledge by the suppliers. Therefore, a methodology for managing suppliers' performance and knowledge sharing has been introduced and encapsulated into a prototype system called MySuppliers.net. Chapter 6 presents the details of the automation of the system. The result of the evaluation of the system and the suggestions for improvement are also reported in detail in the next chapter.

CHAPTER 6

OPERATION OF THE SYSTEM

Chapter six covers the system architecture, development, operation, testing and evaluation of the prototype MySuppliers.net application. Acceptance Test is conducted to test the compliance of the requirements for the design of the software. Evaluation of the prototype application is subsequently undertaken with the involvement of practitioners in the industry. Based on the findings of the evaluation, the prototype application is then further refined.

6.1   System Architecture of Prototype Application

To automate the methodology for supplier selection and managing suppliers' performance, a prototype application which consists of a Web-based database is developed. The system architecture of the prototype application is shown in Figure 6.1. The system runs in a project extranet environment which is only accessible to designated users from collaborating organisations – in this case, the suppliers and the designated staff of the client organisation. The database is the core of the system where all the important information about the suppliers and the knowledge shared are stored. The application logic/code helps to reduce potential workload of users in the supplier selection, and the

submission or sharing of knowledge. A standard Web browser is used to interact with the system.
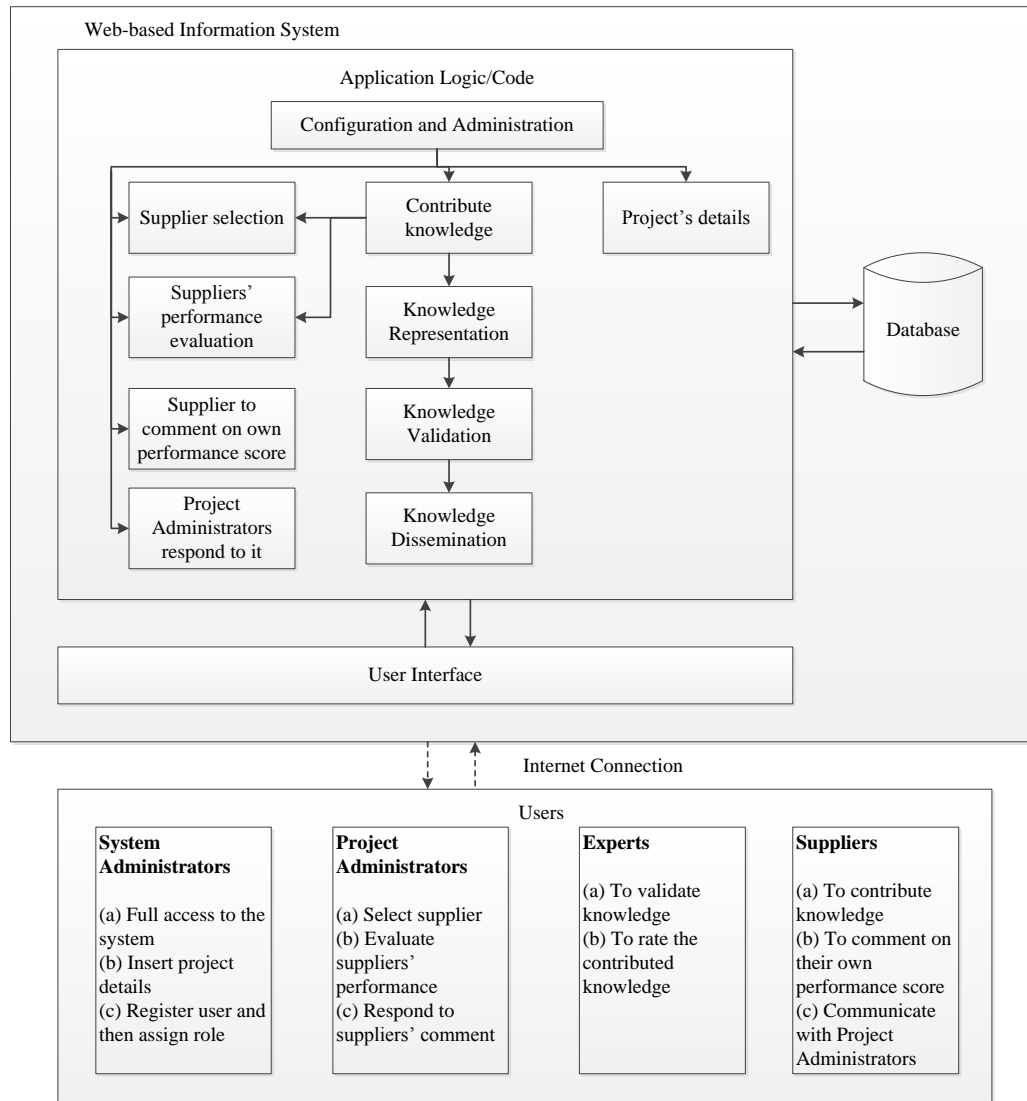
Figure 6.1: System Architecture of the Methodology for Supplier Selection, Managing Suppliers' Performance and Knowledge Sharing in Construction Project

6.2 Selection of Development Environment

The selection of a suitable development environment for the Web-based information system impacts on the speed of development, and the cost of developing and running the end product. ASP.NET 4.0 and Microsoft^TM SQL Server Express 2008 combination is selected for the development of the Web-based information system. This combination is one of the latest Web-based database development technologies offered by Microsoft ^TM. An integrated development environment (i.e. Microsoft Visual Web Developer 2010 Express for the development of ASP.NET 4.0 application) is freely available from Microsoft ^TM. In addition, Microsoft Visual Web Developer 2010 Express also comes with a free Microsoft ^TM SQL Server Express 2008. Microsoft Visual Web Developer offers the following advantages:

(a) Associated codes for the controls can be generated automatically by Microsoft Visual Web Developer. Creation of various controls such as login, logout and forgotten password on a Web Page can easily be done with a drag and drop feature. This can reduce the development time.

(b) It comes with a built-in security system. Different end-user roles with different access authentications can be created easily without the need of creating complicated program codes.

(c) The fully integrated development environment allows the management of the database, development of the program codes

and the program debugging to be done through Microsoft Visual Web Developer.

6.3   User Interface and Program Codes Development

User interface design is critical in the development of the Web-based information system. This is because it affects the user-friendliness of the system and also impinges on the design of the database structure. Microsoft^{TM} Visio is used to design the draft mock-up user interfaces. Microsoft^{TM} Visio allows mock-up user interfaces to be created quickly without needing the associated program code to be completed so that it can save time for the progress of the prototype development. Conversely, ASP.NET 4.0 requires some of the codes completed in order to have the features or functions visible and working.

6.3.1   Supplier Selection

Challenge: The design of the supplier selection user interface and associated functions must be geared towards minimising the need for re-entering supplier's information. This is critical in order to reduce the creation of additional workload to the users. A dropdown list and a textbox are to be created for the user to select the shortlisted suppliers and to enter the quoted price. The user interface enables the users to compare the selected supplier's information simultaneously. Related to this, the program codes must be written in such the way to allow the function/features to happen.

Solution: Three list views are created on the user interface to let the user to choose the suppliers (See Figure 6.2). The list views menu is linked to the suppliers' information in the database (See Figure 6.3). Therefore, the user can avoid the need for re-entering the suppliers' information for the purpose. A link is provided to change the page to "edit mode" so that the user can select other suppliers and update the tender price accordingly. The newly selected supplier's detail and his tender price are displayed after the 'update' button is clicked (See Figure 6.4). Then, the user can continue with the comparison of suppliers' information so that capable and suitable supplier is selected.

Figure 6.2: List View Menu and Textboxes Are Provided for the User to Choose Supplier and Insert the Tender Price

My Supplier Management System (MySuppliers).Net

Home | Index Page | Consultants | Suppliers | Supplier Selection | Construction Projects | Knowledge Sharing | My Account

Selection of Supplier for New Work Package, STEP 2 OUT OF 2

Project Title:	Proposed 25 Storey Office Building On Lot 6854, Jalan Dato Abdullah Tahir, Johor Bahru, Johor.

Project Amount: RM 50,000,000.00
Project Location: Johor Bahru, Johor
Project Start Date: 1/2/2008
Project Completion Date: 31/1/2010

Work Package: Reinforcement
Budgeted Sum for Work Package: RM1,000,000.00
Work Package Start Date: 15/4/2008
Work Package End Date: 31/8/2012

Supplier's Company Name:	Glencome Civil Engineering	Manhattan Construction Ltd	Blue Diamond M Ct Limited

Click Here To Select Other Suppliers / Edit Tender Price

Tender Price:	RM999,000.00	RM989,898.00	RM988,988.00

Last 5 Past Project Performance's Score:

Glencome Civil Engineering

Project Title	Completion Date	Work Package	Performance Score	
Proposed Construction And Completion Of Factory and Office on Lot PT 3243, Tanjung Malim, Perak.	31/12/2013	Drainage	4.0	Click for Others
Proposed Design, Construction & Completion of 548 Units (5 Blocks) Government Apartment at Parcel 17rk2 in Precinct 17, Putrajaya Using Industrialized Building System (IBS) Technology	1/1/2013	Ceiling Finishes	6.7	Click for Others
Proposed Design, Construction & Completion of 548 Units (5 Blocks) Government Apartment at Parcel 17rk2 in Precinct 17, Putrajaya Using Industrialized Building System (IBS) Technology	1/1/2013	Drainage	5.3	Click for Others
Proposed Design, Construction & Completion of 548 Units (5 Blocks) Government Apartment at Parcel 17rk2 in Precinct 17, Putrajaya Using Industrialized Building System (IBS) Technology	1/1/2013	Brick/Blockwork	3.3	Click for Others
Proposed 25 Storey Office Building On Lot 6854, Jalan Dato Abdullah Tahir, Johor Bahru, Johor.	31/1/2010	Control Instrumentation System	3.3	Click for Others

Manhattan Construction Ltd

Project Title	Completion Date	Work package	Performance Score	
Proposed Development Of Infrastructure Works For Phase 1A, Bandar Enstek, Mukim Labu, Daerah Seremban, Negeri Sembilan.	30/4/2014	Bored Pile	2.3	Click for Others
Proposed Construction And Completion Of Factory and Office on Lot PT 3243, Tanjung Malim, Perak.	31/12/2013	Steel Pile	2.7	Click for Others
Proposed Design, Construction & Completion of 548 Units (5 Blocks) Government Apartment at Parcel 17rk2 in Precinct 17, Putrajaya Using Industrialized Building System (IBS) Technology	1/1/2013	Light Fitting	5.7	Click for Others
Proposed 25 Storey Office Building On Lot 6854, Jalan Dato Abdullah Tahir, Johor.	31/1/2010	Ceiling Finishes	3.3	Click for Others
Proposed 25 Storey Office Building On Lot 6854, Jalan Dato Abdullah Tahir, Johor.	31/1/2010	Brick/Blockwork	2.3	Click for Others

Blue Diamond M Ct Limited

Project Title	Completion Date	Work Package	Performance Score	
Proposed Development Of Infrastructure Works For Phase 1A, Bandar Enstek, Mukim Labu, Daerah Seremban, Negeri Sembilan.	30/4/2014	Heating Ventilation and Air Conditioning	7.7	Click for Others
Proposed Construction And Completion Of 124 Units Grow Homes At Pt 10C Kota Bayuemas On Lot 49, 4520 And 1154, Sungai Sedu, Klang, Selangor.	30/4/2014	Bored Pile	6.3	Click for Others
Proposed Construction And Completion Of Factory and Office on Lot PT 3243, Tanjung Malim, Perak.	31/12/2013	Reinforcement	2.3	Click for Others
Proposed Design, Construction & Completion of 548 Units (5 Blocks) Government Apartment at Parcel 17rk2 in Precinct 17, Putrajaya Using Industrialized Building System (IBS) Technology	1/1/2013	Glazing and Cladding	5.7	Click for Others
Proposed 25 Storey Office Building On Lot 6854, Jalan Dato Abdullah Tahir, Johor Bahru, Johor.	31/1/2010	Heating Ventilation and Air Conditioning	4.7	Click for Others

Technical Capability:

Description	Model Capacity	Market Value
Rigid Backhoe	580C	RM40,000.00
Concrete Mixers	168CM	RM50,000.00

Description	Model Capacity	Market Value
Loader	LC233	RM80,000.00
Articulated Hauler	AH402	RM100,000.00
Dump Truck	DT675	RM100,000.00

Description	Model Capacity	Market Value
Pile-driving machine – Onbekend Bohler	TCD 222	RM155,000.00
Asphalt Planer	CI PR1050	RM400,000.00

Financial Strength

(a) Bank Facilities:

	Glencome	Manhattan	Blue Diamond
Overdraft (O/D):	RM400,000.00	RM3,000,000.00	RM800,000.00
Letter of Credit (L/C):	RM400,000.00	RM2,500,000.00	RM750,000.00
Trust Receipt (T/R):	RM400,000.00	RM2,000,000.00	RM700,000.00
Banker's Acceptance (B/A):	RM400,000.00	RM1,500,000.00	RM650,000.00
Bank Guarantee (B/G):	RM400,000.00	RM1,000,000.00	RM600,000.00
Total Bank Facilities:	RM2,000,000.00	RM10,000,000.00	RM3,500,000.00

(b) Credit Facilities:

Name	Credit Term	Credit Limit
Hong Leong Bank	36 months	RM2,000,000.00
RHB Bank	30 months	RM1,000,000.00
Total Credit Facilities:		RM3,000,000.00

Name	Credit Term	Credit Limit
Public Bank	36 months	RM5,000,000.00
Maybank	24 months	RM5,000,000.00
Total Credit Facilities:		RM10,000,000.00

Name	Credit Term	Credit Limit
CIMB Bank	18 months	RM400,000.00
Lee Wah Bank	24 months	RM500,000.00
Total Credit Facilities:		RM900,000.00

Total Financial Capabilities: RM5,000,000.00 | RM20,000,000.00 | RM4,400,000.00

Management and Staff:

(a) Directors:

Directors' Name	Directors' Qualification or Experience
Esme Cullen	BSc in 3E
Alice Cullen	MSc in Psychology

Directors' Name	Directors' Qualification or Experience
Liu Bei	MSc in Construction Management
Guan Yu	BSc in Quantity Surveying
Zhang Fei	Diploma in Building

Directors' Name	Directors' Qualification or Experience
Jacob Black	MBA
Carlisle Cullen	BSc of Marketing

(b) Principal Officers:

Name	Designation
Antioch Peverell	Pre Contract Manager
Fred Weasley	Company Secretary

Name	Designation
Zhao Yun	Project Director
Ma Zhao	Account Manager

Name	Designation
William Petersen	Project Director
Marg Helgenberger	Purchasing Manager

Project In Hand:

Nature of Work	Value
Construction And Completion Of Earthwork, Civil And Structural Works For Gunung Mas Mill, Johor.	RM11,203,065.00
Proposed Construction And Completion Of One Unit Bin Centre,Pump House, Nursery Store And Nursery Shades At Tissue Culture Laoratory, Kota Tinggi.	RM500,000.00

Nature of Work	Value
Refurbishment of Essential Residential Housing, Maintenance Building & Gate House Complex Etc.	RM500,000.00
Upgrading facilities of Ware House & Allied buildings at Palwal.	RM550,000.00

Nature of Work	Value
Proposed main building and ancillary works for proposed factory on lot PTD 45344 & PTD 65034, Mukim Senai, Daerah KulaiJaya, Johor.	RM4,500,000.00
Construction and completion of 1 Unit 2 x 9m tonnes FFB hopper field ramp at Sg Gemas Estate Gemas, Negeri Sembilan.	RM309,000.00

Relationship: Approved | Approved | Preferred

Total Knowledge Contribution Score:
25 Star(s) — Click for Details | 9 Star(s) — Click for Details | 7 Star(s) — Click for Details

Ranking: 1 | 1 | 1

Remark: Not Yet Verified

Work Package Is Awarded To: Glencome Civil Engineering — With Price of RM _____

Submit Cancel

Figure 6.3: Suppliers' Relevant Details

Figure 6.4: User Interface for Selecting Suppliers for Comparison

6.3.2 Evaluate Suppliers' Performance

Challenge: There is a need to evaluate suppliers' performance upon the completion of subcontracting work so that their performance is known. A list that shows all the subcontract work packages and the details (i.e. work scope, supplier involved and result of evaluation) needs to be represented clearly.

Solution: A dropdown list is created on the page so that the project administrators can choose the project. Once the project is chosen, a list that shows all the subcontract work packages of that project is tabulated accordingly (See Figure 6.5). The performance score of the supplier is marked as 'Not Yet Evaluated' if the relevant supplier's performance is not yet evaluated. A hyperlink called 'Evaluate Performance' is created to direct the

112

project administrators to evaluate the suppliers' performance once a supplier has finished his work (See Figure 6.6). The criteria used for supplier's performance evaluation include whether or not the project/work is completed on time and within budget, as well as the workmanship. The supplier's performance score is displayed in the list after the project administrators finishes the evaluation process (See Figure 6.5).

Figure 6.5: A List That Shows the Details of Subcontract Work Packages

Figure 6.6: Supplier's Performance Evaluation Page

6.3.3 Validate Knowledge

Challenge: Rating-based validation mechanism is built into the system to validate new knowledge. The mechanism to validate knowledge shall not to be visible on the page anymore once the knowledge is validated. A mechanism for managing the users' comments and ratings for a knowledge item is required. Furthermore, the Experts should be provided with an additional function for validating and deleting a rejected knowledge item from the system.

Solution: There is a 'Verify It Now' button at the middle of the page, which is only visible to the Experts (See Figure 6.7). The design of the button is to redirect the Experts to the 'Knowledge Verification Page' (See Figure

6.8). The Experts will verify the financial and cost impacts brought about and comment on the knowledge contributed. Subsequently, the Experts can rate the knowledge. In the user interface for representing the details of a knowledge item (i.e. the 'Knowledge Details Page'), a text box and a dropdown list are provided for collecting users' comments and ratings for the knowledge contributed (See Figure 6.7). Program code is written to make the aforementioned 'Verify It Now' button invisible (see Figure 6.9) when the knowledge has been verified. In addition, the 'delete' button on the 'Knowledge List' page is only visible by the Experts.

Figure 6.7: 'Knowledge Details Page' and the Verify Knowledge Button

(Only Visible to the Experts)

115

Figure 6.8: Knowledge Verification Page (Accessible by Experts Only)

Figure 6.9: 'Verify Knowledge Button' Becomes Invisible When the

Knowledge Has Been Verified

6.3.4 Suppliers to Comment on Their Own Performance Score

Challenge: Suppliers are able to view their own performance score and directly comment on it should the rating given to them is not reflecting the actual situation. Another challenge is to highlight the latest comments entered on their performance score for ease of reference.

Solution: There are two buttons on the 'Home Page', namely 'My Company's Current Projects' and 'Past Subcontracting Works' Score' buttons. Supplier can view the relevant details of their current subcontracting work by clicking 'My Company's Current Projects' button. Once the project administrators have evaluated the suppliers' performance, the data of current subcontracting work will be automatically transferred to 'Past Subcontracting Works' Score Page'.

6.3.5 Project Administrators' Response to Comment

Challenge: The function for the project administrators to reply to the comment of the suppliers needs to be simple, easy to use and can be tracked. This is critical in order to reduce the time taken for the project administrators to look for the comment as there might be a lot of suppliers in the system.

Solution: A page is created for displaying the latest comments (from the project administrators and suppliers), which is only accessible by the project administrators. There are hyperlinks that lead the project administrator

to the details of the comment given to allow him to respond to the comment. There is also a dropdown menu on the lower part of the page to allow the project administrators to trace back of the earlier comments (See Figure 6.10).

Figure 6.10: Screen Shot of the 'Respond to Comment Page'

6.4   Database Design

The Web-based information system comprises two Microsoft™ SQL Server 2008 databases, namely membership database and the main database. The membership database contains the information about the roles, identity and authentication of users. It plays an important role in the security of the system. It helps to ensure that only the user with the correct username, password and authentication can access the stipulated sections of the system.

The main database stores all the details pertaining to the suppliers, project details and project knowledge contributed. In the database, each of the tables stores only one type of information and is linked to others through relationships. This type of database structure (i.e. a normalised relational database) ensures that a non-primary key data is only stored in one table in a database. This helps to reduce the potential of data update and deletion anomalies.

6.5   Operation of the Prototype Application

This section describes the operation of the prototype application with the aid of relevant screen shots.

6.5.1   Logging In

When the system is first accessed, the Login Page is displayed (see Figure 6.11). All the hyperlinks found on that page (except the 'Forgot Password?' link) will not function before the identity of the user is verified. The users can log into the system by entering their user name and password. In case they forget their password, they can click on the 'Forgot Password?' link. This will bring up the 'Forgot Password Page' where the user will be requested to provide their login name (see Figure 6.12). The password will then be sent to the user's registered email address in the system.
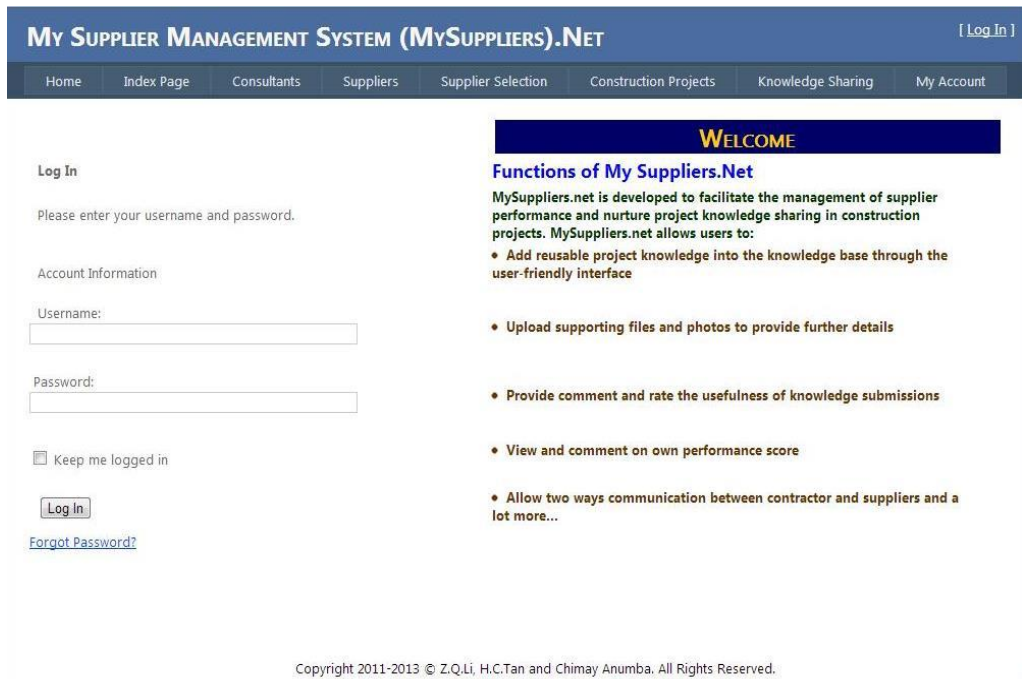
Figure 6.11: Login Page

Figure 6.12: Screen Shot of the 'Forgot Password Page'

6.5.2 Browsing the Home Page

After successfully logging into the system, the user will be redirected to the 'Home Page' (see Figure 6.13). When any of the buttons, namely that for 'edit company profile', 'company current project', 'past performance score', 'company contributed knowledge', 'to contribute new knowledge', and 'the latest contributed knowledge', is clicked it will execute and lead the users to the respective function. There is a panel for "System Administrators" only (which includes also Project Administrators and Experts) for them to perform the functions as shown.

Figure 6.13: Screen Shot of the Home Page

6.5.3   Edit Company's Profile

When the ordinary users click the 'My Company's Profile / Edit Profile' button, this will lead them to a page which shows the company's basic information. If the 'More Details' button on the page is clicked, it will lead the user to the page that shows the additional information of the company (i.e. types of work involved, financial capabilities, quality assurance system and etc.). There are four buttons at the bottom of the page, namely, 'Edit This Page', 'Edit Other Info', 'Next Page' and 'Previous Page' (see Figure 6.15). Each of the buttons will direct the user to the respective function of the system. The 'To Edit' button (see Figure 6.14) is designed for the user to edit the company's information via the textboxes or drop down lists provided (see Figure 6.16). The user can click on the 'Update' Button if the information on that page is edited. This will redirect the user back to the read-only page where company's information is shown.

Figure 6.14: Screen Shot of the Page Showing Company's Basic Information

Figure 6.15: Screen Shot that Displays the Company's Relevant Information

COMPANY BASIC INFORMATION
Name of Company: IJM Corporate Berhad

Address of Company: Not Available

City: Not Available

State: Federal Territory of Kuala Lumpur

Telephone No: Not Available

Fax No: Not Available

Form of Business Organisation 1:   Not Available

Form of Business Organisation 2:   Not Available

Business Registration No: Not Available

Registration No With CIDB: Not Available

Company Website: Not Available

Contact Person: Not Available

Designation of Contact Person: Not Available

Contact Person Email 1:   Not Available

Contact Person Email 2:   Not Available

Contact Person No: Not Available

About Company: Not Available

History of Company/ Company Achievement: Not Available

Update Cancel

▶ Next Page   Edit Page 1 of 19

Figure 6.16: Screen Shot of the 'Editing Company's Basic Information Page'

6.5.4 To View Supplier Company's Current Projects

If the suppliers want to view their company's current project, they can just click on the image button called 'My Company's Current Projects' on the 'Home Page' (see Figure 6.13). When the 'My Company's Current Projects' image button is clicked, it will link the users to the page where all the company's current projects' details, such as project title, project amount, project start date, project completion date, project location, client's name, last edited by and last edited date are revealed (see Figure 6.17). The 'To Update' hyperlink (see Figure 6.17) allows the project administrators to edit or update any project's details (see Figure 6.18). Additional details about the relevant

project will be displayed when the users click on the project title name (see Figure 6.19). The hyperlinks that show the construction team members' name (see Figure 6.19), when clicked, will display more details about them (see Figure 6.20).

Figure 6.17: Screen Shot of the Page Showing All the Companies' Current Projects

Figure 6.18: Screen Shot of the Page for Editing Project's Details

Figure 6.19: Screen Shot of Page Showing the Details of a Project

Company Name:	Trust Design Ar Sdn Bhd
Nature of Business:	Architect
Others:	Not Available
Address of Company:	6, Floor 1, Wisma Ricardo, Jalan Aladin, Seremban, Negeri Sembilan.
City:	Seremban
State:	Negeri Sembilan
Telephone No:	06-4541160
Fax No:	06-4541000
Registration With Authority/ Profesional Body	Persatuan Arkitek Malaysia
Form of Business Organisation:	Partnership
Company WebSite:	Not Available
Contact Person:	Siti Nurhaliza
Contact Person Email:	sitinur@msn.com
About Company:	We are registered architect with Persatuan Arkitek Malaysia. The company was subsequently reincorporated as an unlimited company under the name of Fauza and Liew Sdn in 1996. To move in line with the prevailing market and planned business development, the company was restructured and renamed as Trust Design Ar Sdn Bhd in December 1999. Our services include the architectural design, interior design and related design to the building.
History of Company/ Company Achievement:	As a company, we have seen much change over the past 10 years. We have grown in terms of our capacity from 4 key personnel which consist of its two founding members Ar. Fauza Amin and Ar. Liew Teck Yau and Senior Architect Paul Lau and Emma Bueno as the Director to approximately 80 employees with offices in Negeri Sembilan, Penang, Kota Kinabalu, Kuching and two other operation offices in Bintulu and Sandakan. We are also planning to open our latest office in Johor within the first quarter of 2014.
Last Edited Date:	3/12/2012

Back to Consultant List

Figure 6.20: Screen Shot of the Page Showing the Details of the

Construction Team Member

6.5.5   Past Subcontracting Works' Score

If the supplier would like to view their past subcontracting works'
score in the system, s/he can click on the 'Past Subcontracting Works' Score'
button (see Figure 6.13). This 'Past Subcontracting Works' Score' page (see
Figure 6.21) comprises a table that shows past project titles, the work
packages involved, awarded price, work package start date, work package
completion date, score and comment given, evaluation by whom, evaluation
date and a hyperlink that allows for responding the comment or score given.
When the user clicks on the project title hyperlink, it will show the particular
project's details (See Figure 6.22). If the users want to respond to the score

127

given or to defend themselves should the comment given is not fair, they just need to click the 'Respond to the score given' hyperlink. It will then redirect them to the page that allows them to leave comment (See Figure 6.23). Below the past subcontracting works' performance score, there is a list of the latest comments on the performance score. If the user would like to know more about the comments given, the user can click on the 'Click for Details' hyperlink. This will lead to the page where they can communicate with contractor regarding their performance score (See Figure 6.23). This feature provides an opportunity to the suppliers to clarify or defend themselves should the information that is used for the evaluation is inaccurate, or the issues that have given them a low score have been addressed albeit yet to be updated in the system.

Figure 6.21: Screen Shot of Page Showing the Past Subcontracting Works' Score

Figure 6.22: Screen Shot of the Page Showing the Project's Details

Figure 6.23: Screen Shot of the Page that Allows the Supplier to

Communicate with Contractor on His Performance Score

129

6.5.6 My Company's Knowledge Contributed

Knowledge contributed by the user's company is accessible through the button names 'My Company's Knowledge Contributed' at the home page (see Figure 6.13). All the knowledge that is contributed by the user's company will be shown together with the rating given (see Figure 6.24). The hyperlink that shows the knowledge topic will lead to the page where the detail of knowledge is shown (see Figure 6.25).

Figure 6.24: Screen Shot of the List of Knowledge Contributed by a Supplier with the Rating Given to the Knowledge

Figure 6.25: Screen Shot of Showing the Details of 'Knowledge Page'

6.5.7   Contribute New Knowledge

The 'Contribute New Knowledge' button (see Figure 6.13) will direct
the user to the page where the user can contribute new knowledge (see Figure
6.26). The page is characterised by two dropdown menus which allow the user
to choose the project and the stages that the knowledge is relevant to. The
relevant project's details and participants are shown when the project title is
selected from the dropdown menu. There are three textboxes with three

watermark sentences for the user to fill in the knowledge topic, knowledge details and knowledge impact. The watermark sentences are meant to guide the user on the type of information required. Three file upload functions are provided for uploading relevant documents, photos, files, images or data to provide more details about the knowledge and improve the opportunity for reuse. After providing all the details, the user can click on the 'Add Knowledge' button to add knowledge into the system.
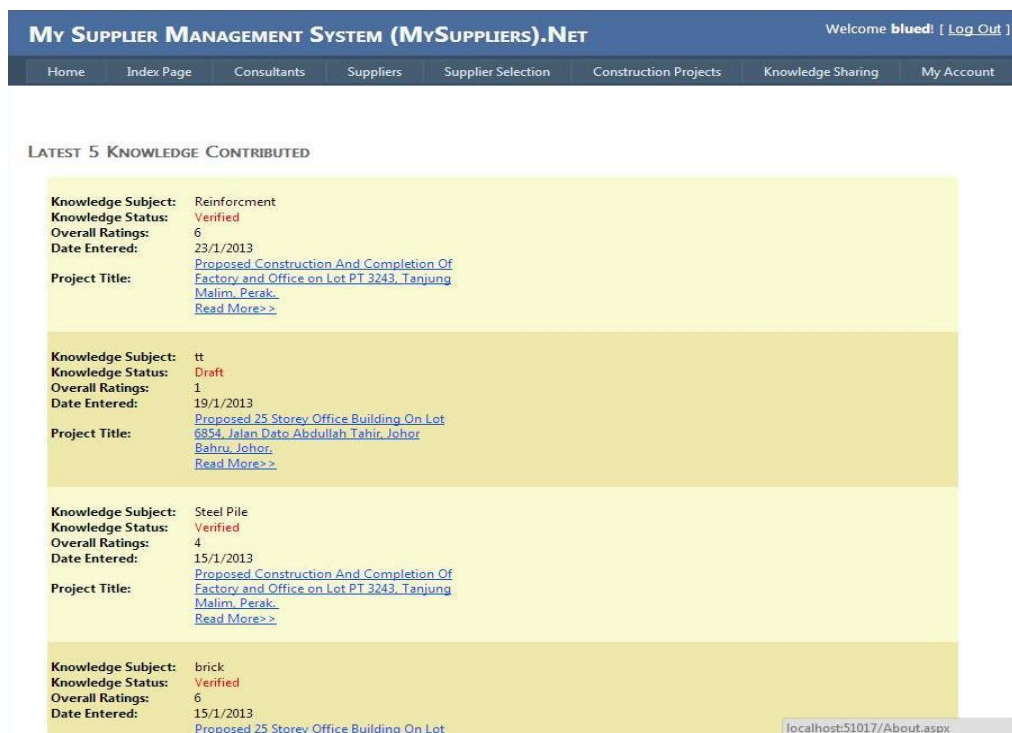
Figure 6.26: Screen Shot of the 'Add Knowledge Page'

6.5.8 Latest Knowledge Contributed

If the user would like to have a complete view of the latest list of knowledge contributed, s/he can click the 'Latest Contributed Knowledge' link on the 'Home Page' (see Figure 6.13). This will lead the user to the page that shows the most up to date list of the knowledge contributed (see Figure 6.27). The knowledge subject, knowledge status, overall ratings, date entered and title of project from which is captured are provided. If the user would like to know more about a particular knowledge item, the user can click on the 'Read More' hyperlink. This will lead the user to the 'Knowledge Details Page' where all the details of the knowledge item are revealed (see Figure 6.25).

Figure 6.27: Screen Shot of the 'Latest Knowledge Contributed Page'

6.6   Roles Assigned to the Users

There are different roles that the users can be assigned to in the system. Users with different roles will have different access levels in the system, which is depicted in Table 6.1.

6.6.1   Ordinary Users

There are two types of Ordinary Users in the system, namely Suppliers and Consultants. Both of them have the same access rights to the system. The 'Suppliers' group is usually assigned to contractors, subcontractors, nominated subcontractors, nominated suppliers, material suppliers or other designated person; whereas the 'Consultants' group includes the quantity surveyors, architects, civil and structural engineers, mechanical and electrical engineers and other consultants. The ordinary users can view or edit their own company profile, view current projects involved, retrieve the past performance score, comment on the past performance score, contact other suppliers or consultants, share new knowledge, view all the contributed knowledge and also comment on the knowledge shared in the system.

6.6.2   Experts

This is a role, normally charged to a contract manager, director or other designated experienced person, to manage the knowledge base, to verify and to rate the knowledge contributed (i.e., the development of project knowledge

files for a project). The default status for any knowledge contributed is set as "draft". The Experts will go through the details of the knowledge and then validate it. The perceived benefit brought about by the knowledge, i.e. in terms of time and cost saving, will be verified too. If the Experts would like the knowledge contributed to be revised before it is validated, he may leave a comment on how the knowledge can be enhanced for the action of the originator.

6.6.3 Project Administrators

This is a role, normally charged to a project manager, project director, director or other designated person, to select the most suitable supplier and then award sub-contracting work to the supplier. Evaluation on the respective supplier performance will be carried by the Project Administrators after the work is finished. Project Administrators can provide some suggestions as to how the suppliers can improve their performance.

6.6.4 System Administrators

This is a role, normally assigned to Information Technology Specialist or equivalent, to add new project, add or edit project details, add new suppliers and assign role to them. Log in username, password, and email are required for new supplier registration. The System Administrators will then register the new user as an Ordinary Users, Experts or Project Administrators as instructed. To add new project, the System Administrators would need to enter the details

of the project (e.g. project title, duration, location and construction team members). They can delete the existing projects or suppliers as instructed. They are granted full access to the system to make any authorised amendment. They are responsible to ensure that the Web-based system is functioning properly.

Table 6.1: Roles Available in the System

Roles / Accessibility	Ordinary Users	Experts	Project Administrators	System Administrators
Contribute Knowledge	√	√	√	√
View Suppliers' List or Knowledge List	√	√	√	√
Comment on Knowledge Contributed	√	√	√	√
Validate Knowledge		√		√
Selection of Supplier for Subcontracting Work			√	√
Evaluation of Suppliers' Performance			√	√
Comment on Supplier's Performance Score	√		√	√
Add or Edit or Delete Supplier / Project				√

6.7 Testing and Evaluation of the System

Software testing is defined as the execution of a program against test cases with the aim of detecting faults (Glenford et al., 2012). It serves as one

136

of the most effective apparatus for software reliability improvement and assurance (Cai et al., 2007). The testing techniques are defined in accordance to the artefact used to derive test cases, such as white-box testing, black-box testing, model-based testing and fault-based testing (Lemos et al., 2013). An important classification of the tests available is the black-box and white box dichotomy (Lemos et al., 2011). Black-box technique is also called 'functional' or 'specification based' testing that derives test cases from the description or specification of a program (Lemos et al., 2013). White-box testing or 'structural' derives the test cases from the implementations (Bartolini et al., 2011).

For software evaluation, it is the formal evaluations of work items of a software product with the intended purposes of finding defects efficiently and effectively in the development process (Xue and Ma, 2009). This process ensures that a higher quality software product is shipped to the testers and ultimately to the users (Lemos et al., 2011). Some overlaps of the functions of software testing and software evaluation in the literatures are observed. For instance, Choudhary and Kumar (2011) define testing as any activity aimed at evaluating the capability of a system. Testing helps evaluate the various aspects of the software to reduce the expected cost of software failure over the products' life (Xue and Ma, 2009). For the purpose of this research and to avoid confusion, testing is perceived as an examination of the functionalities of the software to ensure that it is free from error. Evaluation is regarded as the subsequent process conducted to obtain external views from the users on whether the software has catered for its design requirements and also to

identify further refinements needed for the software. The details of the testing and evaluation undertaken are described in the following sections.

6.7.1 Prototype Testing

The selection of tests to be conducted depends on the aspects of the software to be tested. Sometimes, it will be restricted by time and resource constraints. Due to time constraints, the extensive tests such as life-cycle testing (Choudhary and Kumar, 2011), hierarchical approach testing, i.e. top down testing or bottom up testing (Noss, 1990) which involves a series of different tests at different development levels of software, are considered inappropriate. In this regard, a Statement Test is preferred as it is simple, less complicated and more relevant for the purpose of the evaluation. The test is conducted to ensure that all the sub-tasks attributed to a function work in the way they are supposed to do.

6.7.2 Statement Test

This is the acceptance tests on the requirements (i.e. statements) for the design of software (Ricca et al., 2009). Each of the requirements comprises an input action to be performed on the software application and an expected output of the input. In order to pass the test, the real output must match with the expected output. The details of the requirements of the prototype application that were tested are depicted in Table 6.2.

Table 6.2: Test Results of the Statement Test

Input	Expected Output	Result
Log into the system using individual user name and password	• Login succeeded	Achieved
Log out from the system	• Log out succeeded	Achieved
Add project details into the system (Project Administrators only)	• Project details added into system	Achieved
	• Index page updated	Achieved
Edit project details (Project Administrators only)	• Project details edited	Achieved
	• Index page updated	Achieved
Add new user (System Administrators only)	• New user added	Achieved
Add personal details into the system	• Personal details added into system	Achieved
Edit personal details	• Personal details edited	Achieved
Supplier Selection		
Add project title, work package, budgeted sum of work package, choose three suppliers and insert their tender price for selection purpose	• Details of the project and work package, the respective tender price and the chosen three suppliers' details are shown	Achieved
To choose others suppliers and insert their tender price	• The suppliers' details are changed accordingly	Achieved
	• The tender price is updated accordingly	Achieved
Click on the relevant hyperlink to access the project details	• Project's details displayed	Achieved
Click on the relevant hyperlink to access the supplier past performance score	• The list of all of the past performance score that belong to the particular supplier displayed	Achieved
Click on the relevant hyperlink to access the supplier's knowledge contribution score	• The list of all of the knowledge contributed by the particular supplier displayed	Achieved

Table 6.2 continued: Test Results of the Statement Test

Click on the submit button to award subcontracting work package to a supplier	• Awarded subcontracting work list for the project is displayed	Achieved
	• The awarded subcontracting work package, supplier and awarded sum are tally with the decision made during supplier selection	Achieved
Evaluation of suppliers' performance		
Delete a subcontracting work package (System Administrators only)	• Subcontracting work package removed from the system	Achieved
		Achieved
	• Awarded subcontracting work list for the project is updated	
Click on the relevant hyperlink to access the project details	• Project's details displayed	Achieved
Click on the relevant hyperlink to access the supplier's basic information	• Supplier's basic information displayed	Achieved
Click on the relevant hyperlink to evaluate the supplier's performance	• These information are displayed about the supplier that is to be evaluated: project titles, subcontracting work, awarded sum, start date and end date are displayed	Achieved
	• The result of evaluation displays "Not Yet Evaluated" prior to evaluation	Achieved
Add rating for the performance of supplier	• Rating added	Achieved
	• Average rating calculated automatically	Achieved
Add comment about the performance of supplier	• Comment added	Achieved
	• Details of the user who submitted the comment captured	Achieved

Table 6.2 continued: Test Results of the Statement Test

Communication with suppliers on their performance score		
Click on the relevant hyperlink to access the content of communication	• Content of communication displayed	Achieved
	• The relevant subcontracting work's details and supplier's performance score displayed	Achieved
Click on the relevant hyperlink to access the supplier's basic information	• Supplier's basic information displayed	Achieved
Click on the relevant hyperlink to access the project details	• Project's details displayed	Achieved
Add comment on the supplier's performance score	• Comment added	Achieved
	• Date and user who submitted the comment captured	Achieved
	• The list that shows the latest 5 comment updated	Achieved
Knowledge Sharing		
Add a knowledge item, where the knowledge should be tagged as 'draft' before it is validated by Experts	• Knowledge details added into system	Achieved
	• Knowledge contributed is tagged as 'draft' before it is validated by Experts	Achieved
	• Details of the author captured automatically	Achieved
	• Date of entering knowledge inserted automatically	Achieved
	• List of knowledge page and Index page updated	Achieved
Add file attachment for knowledge item	• File is attached and its download link displayed	Achieved

Table 6.2 continued: Test Results of the Statement Test

Access to knowledge		
Click to access the index page	• The knowledge subject, knowledge status, overall ratings, date of the latest five knowledge items added displayed • Hyperlink items to access the relevant project and knowledge item details displayed	Achieved Achieved
Click the hyperlink to access a knowledge item	• Details of knowledge, and the associated author and project details returned	Achieved
Click to access relevant hyperlink to access the project's details	• Project details displayed	Achieved
Click to access relevant documents through the hyperlinks	• The files are either to be downloaded or opened	Achieved
Click the 'View Other Knowledge' button to access the list of all knowledge contributed	• The list of all knowledge contributed displayed	Achieved
Delete a knowledge item (Experts only)	• Knowledge removed from the system • List of knowledge page and Index page updated	Achieved Achieved
Click the 'View Total Knowledge Contribution Score' button to access the list of all accumulated knowledge contribution score	• The list of all accumulated knowledge contribution score displayed	Achieved
Click the hyperlink to access the list of knowledge contributed by the respective author	• The name of the author, supplier's company name and the list of knowledge contributed by the respective author are displayed	Achieved
Click the hyperlink to access the supplier's basic details	• Supplier's basic information displayed	Achieved

Table 6.2 continued: Test Results of the Statement Test

Knowledge Validation		
Add comment about a knowledge item	• Comment added	Achieved
	• Details of the user who submitted the comment captured	Achieved
Add rating for a knowledge	• Rating added	Achieved
Access the knowledge validation function/control (Expert)	• The knowledge validation function/control is made visible to the Expert only	Achieved
Change the status of the knowledge from 'draft' to 'validated' (Expert only)	• Knowledge status changed	Achieved
	• Index page and list of knowledge page updated	Achieved
Change the status of the knowledge from 'draft' to 'to be revised' (Expert only)	• Knowledge status changed	Achieved
	• Index page and list of knowledge page updated	Achieved
Finalise rating for a knowledge (Expert only)	• Rating added	Achieved
	• Index page and list of knowledge page updated	Achieved
Add comment about a knowledge item (Expert only)	• Comment added	Achieved
	• Details of the user who submitted the comment captured	Achieved

6.7.3   Prototype Evaluation

This section describes the evaluation and associated results of the prototype application developed. The most useful features of the prototype application identified and the participants' suggestions for improvements are also presented.

6.7.3.1 Evaluation Procedures

The evaluations are conducted to identify the level at which the system has addressed the end-users' requirements identified from the case studies conducted. To ensure consistency, the evaluations involve only participants from the case study companies.

Most of the evaluations are conducted on one-to one basis. The evaluation starts with a brief introduction of the concept of using ICT for selecting supplier, evaluating suppliers' performance, enabling two-way communication between contractor and suppliers and also facilitating knowledge sharing. This is followed by the demonstration of the various features and the operation of the prototype application. Subsequently, the participants are allowed to try out the prototype application. Guidance is provided to the participants whenever necessary. An evaluation form (see Appendix A) is then given to the participants to complete. The details of the evaluation form are presented in the next section.

6.7.3.2 Evaluation Form Design

An evaluation form is designed to evaluate the performance of the prototype application and to identify the area for improvements. The evaluation form comprises three main sections. Section A consists of 16 questions about the prototype application. The questions are further grouped into four subsections:

- Section 1 – Function for the selection of supplier

- Section 2 – Function for the evaluation of suppliers' performance

- Section 3 – Function to facilitate two-way communication between the suppliers and the contractor

- Section 4 – Function for knowledge sharing

The participants are requested to provide their answers to the questions using a rating scale from 1 (very poor) to 5 (excellent). Section B provides an opportunity for participants to specify the most favourable features and to put forward their suggestions for improvements for the prototype application. Section C covers the background information about the participant.

6.7.4   Evaluation Results

The prototype application scored an overall average of 3.8 out of 5.0 in the evaluation. The result shows that number of ratings 4 and 5 are about three times of that of ratings 1 and 2 (see Table 6.3). Hence, the result is positive. The average ratings of the various sections are also presented in subsequent sections.

6.7.4.1   Selection of Supplier

The participants found that the prototype application can help in the selection of suppliers. An average rating of 3.70 is given to this feature. However, the participants noted that there is a need to further enhance the

feature and function provided in the system. These include attaching files on specification, detailed breakdown, method statement and bill of quantity for comparison purpose. A satisfactory average rating of 3.5 was received on the default criteria for the selection of supplier. The participants pointed out the need to allow the criteria to be customised based on individual company's requirements. The participants were satisfied with the prototype application's ability in terms of providing the detailed information to facilitate the selection of the right supplier for the right job. This is evident by the average rating of 3.8 given by the participants. The participants recognised that the system does present well the suppliers' relevant information for selection purpose by giving an average scoring of 3.7. Further to this, they recommended the use of graph to show the suppliers' strength for each of the criteria.

6.7.4.2 Evaluation of Supplier's Performance

The system's function for evaluating suppliers' performance was given a good average rating of 3.7 by the participants. The second question (i.e. Question 2.2 in Table 6.3) on how well does the default criteria help in the evaluation of suppliers' performance received an average rating of 3.5, which is satisfactory. They saw the need to allow more criteria for assessing suppliers' performance to be added and files to be attached for the same purpose. The additional information which covers the project's details and work scope, the total amount of projects awarded to the suppliers are well presented to facilitate suppliers' performance evaluation, where an average rating of 3.8 was given by participants. The function for evaluating suppliers'

performance was perceived as very easy to use with a very high average rating of 4.0.

6.7.4.3   Communication with Suppliers on Their Performance Score

The participants were satisfied with the features that allow the suppliers to view and respond to the contractor's comments on them by giving the average rating of 3.8. The prototype application was also recognised as effective in facilitating two-way communication between contractor and suppliers on the latter's performance, where an average rating of 3.9 was given by the participants. Related to this, the function for suppliers to communicate with contractor was regarded as easy to use with a high average rating of 4.1 given.

6.7.4.4   Knowledge Sharing

The system is well developed for facilitating knowledge sharing where an average rating of 3.9 was given by participants. The participants noted that the list of shared knowledge is efficient in providing the users an overall view of all the captured and shared knowledge in the system by giving an average rating of 3.8. The template used to represent the knowledge contributed received a high average of 3.9. This shows that the participants were satisfied with the template used to represent knowledge. The participants found that the mechanism is capable for calculating the suppliers' score for the knowledge contributed. An average rating of 3.7 is given to this feature. The question on

the knowledge validation mechanism of the prototype application receives a

high average rating of 4.0. This reveals that the participants were confident

that the adopted mechanism can help to ensure the accuracy and correctness of

the shared knowledge.

Table 6.3: Rating of Key Features of the Prototype Application

Sections		Average rating (out of 5)	Total number of Ratings 1 and 2 (Not agree)	Total number of Ratings 4 and 5 (Agree)
No	**Section 1: Selection of Supplier**			
1.1	How well does the system help in the selection of supplier?	3.7	4	13
1.2	How well does the default criteria help in the selection of supplier?	3.5	5	12
1.3	How well does the extra information (i.e. the links to additional information such as knowledge contribution score, project details, and supplier's miscellaneous details) facilitate the selection of the right supplier for the right job?	3.8	4	12
1.4	How well does the system in representing the suppliers' relevant information for selection purpose?	3.7	4	12
	Average:	3.7	-	-
	Section 2: Evaluation of the Supplier's Performance			
2.1	How well does the system's evaluation function in evaluating supplier's performance?	3.7	4	11
2.2	How well does the default criteria (completion on time, completion on cost and workmanship) help in the evaluation of supplier's performance?	3.5	6	11
2.3	How well does the additional information presented (e.g. the information that shows project and work scope, and the total sum of projects awarded) in facilitating supplier's performance evaluation?	3.8	4	12
2.4	How easy is the system to use for evaluating suppliers' performance?	4.0	3	14
	Average:	3.8	-	-
	Section 3: Communication with suppliers on their performance score			
3.1	How useful is the feature that allows the suppliers to view and respond to the contractor's comments on them?	3.8	3	13
3.2	How well does the system in facilitating two-way communication between the contractor and suppliers on the latter's performance?	3.9	3	14
3.3	How easy is the system to use for suppliers to communicate with contractors?	4.1	2	14
	Average:	3.9	-	-

Table 6.3 continued: Rating of Key Features of the Prototype Application

_____

No	Section 4: Knowledge Sharing			
4.1	How well does the system help in facilitating knowledge sharing?	3.9	3	12
4.2	How well is the list of shared knowledge in providing an overall view of all the knowledge captured in the system?	3.8	4	12
4.3	How well does the template represent the knowledge contributed?	3.9	3	14
4.4	How well is the mechanism for calculating the supplier's score for the knowledge contributed?	3.7	2	13
4.5	How well is the knowledge validation mechanism in ensuring the correctness of knowledge contributed?	4.0	2	15
	Average:	3.9	-	-
	Overall Average:	3.8	-	-

_____

6.7.5 Suggestions for Improvement

The participants describe the prototype application as: 'easy to use', 'user friendly', it leads to the 'ease of communication between contractors and suppliers', 'encourage knowledge sharing to benefit project and improve suppliers performance', 'suppliers' relevant details can be compared within a page', 'easy for contractor to continuously manage suppliers' performance', it provides 'systematic tabulation of awarded suppliers' list for conducting performance evaluation', 'suppliers are able to view their performance score' and 'a good platform to facilitate two-way communication between suppliers and contractors'. They further pointed out that it is a good initiative to develop a system that records down suppliers' related particulars and also facilitate supplier selection and performance evaluation. Other comment includes 'suppliers' performance can always be improved with the aid of the system as their performance is monitored continuously'. This proves that the methodology has addressed the critical end-users' requirements that

significant additional workload is not desired and system is easy to use for the management of suppliers' performance and knowledge sharing in construction project. However, some suggestions for improvement are also received. These include:

(a) Customisable criteria for the selection and performance evaluation purposes based on individual company's requirements.

(b) Allow files to be attached (e.g. bills of quantity and specification) for comparing suppliers' tender.

(c) Allow relevant suppliers' list to be shown only based on the type of subcontracting work.

(d) Graphs can be used to illustrate the suppliers' company performance instead of using text or numbers.

(e) Create a mechanism to allow search function to locate a particular supplier or knowledge.

(f) Require a more comprehensive knowledge validation mechanism to verify the knowledge contributed and also to prevent the duplication or plagiarism of knowledge shared.

(g) To define clearly the rules for contributing knowledge such as the time frame for submission, the targeted audience (i.e. for general sharing or for those involved in a particular project), and the disclaimer to indemnify the author of a knowledge item against the legal consequences of misuse.

A suggestion to automatically send out email notification when knowledge is contributed had been incorporated into the prototype application. The notification shall be sent out too when suppliers have commented on their own performance score. Suggestions (a), (b), (c), (d), (e) and (f) entail extensive development in order to deliver the desired features and are hence not incorporated into this version of the prototype. Suggestion (g) might be essential for knowledge capture activities involving different organisations, but this is better drafted by legal professionals.

Some suggestions are related to the future development of the prototype application. The participant suggested that the prototype application can be further designed to enable the system to automatically make the decision based on the predetermined criteria. This suggestion has been carefully considered and would be further explored in the future as appropriate.

6.8   Summary

The operation of the prototype application is explained and depicted with the aid of relevant screen shots. Acceptance Test has been conducted to make sure the requirements/statements are complied with in the design of the system. Furthermore, the prototype application was evaluated by the practitioners in the industry. The evaluation result reveals that the system has addressed the important requirements of the end-users. The system is regarded as effective based on the result, which is 3.8 out of 5.0. The prototype application is then further refined based on the suggestions given. However,

some of the suggestions entail further work and addition time, and hence are not considered. The next chapter covers the conclusions of this research, the limitations of this research and further work that can be made to this system.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

This chapter concludes the research in the management of suppliers' performance in construction. It presents the shortcomings of current practices on managing suppliers' performance and explains the need of a methodology for managing the supplier selection process, monitoring their performance and capturing their knowledge. The chapter also covers the main user requirements for the development of the methodology. Lastly, it summaries with the areas that researchers and practitioners can look into, and recommends further work that can enhance the methodology introduced in this research.

7.1 Summary

This research aims to develop a methodology that provides an efficient means for selecting the most suitable suppliers and managing their performance. The methodology or system must facilitate convenient and secured access through the Internet and help to leverage the suppliers' knowledge for the benefit of the on-going projects. The objectives of this research are achieved through the study of the existing practice of the Malaysia construction industry in managing suppliers to identify the areas that information and communication technology (ICT) may contribute to better management of the whole process. It is followed by the development of a

Web-based system for better managing the performance records and the knowledge about suppliers that will improve the existing mechanism for the selection of suppliers. It is followed by the evaluation of the Web-based system with the involvement of the case study companies.

A number of research that look into the selection of suppliers in the construction industry have been initiated or conducted. However, these research are mainly focused on capturing the information on suppliers' performance to facilitate better supplier selection process. There is no evidence that mechanisms are available to feedback to the suppliers their performance as recorded in the system to improve themselves. The importance of such mechanisms is apparent as without it the supplier does not have an opportunity to clarify and defend themselves should the information that was used for the evaluation be inaccurate or if he has in fact addressed the issues that gave him a low score (and these improvements have not yet been reflected in the records). Another feature that can also be incorporated is one that is able to capture the knowledge of suppliers on how improvements can be made to an existing/on-going project. This may form part and parcel of the criteria for evaluating the performance of supplier as appropriate. Clearly, there is an apparent need for a system that is capable of performing the functions for the purpose of contract award, managing suppliers' performance and to facilitate knowledge sharing.

In the context of this research, "supplier" is to include contractors, consultants, subcontractors and material suppliers as they all are engaged for

supplying their skills and knowledge (i.e. service) or materials to the project. Research shows that it is important to manage suppliers' performance as it can facilitate the informed decision making on the selection of the most suitable suppliers. It prevents suppliers with poor track record and insufficient capacity to be selected, which may in turn lead to the success of a project and also the reduction of project risk. These will lead to the improvement of a company's competitiveness ultimately. Clients also enjoy the benefits brought about as they will be satisfied with the end product quality.

Various criteria have been introduced for supplier evaluation and selection. From the existing literatures, it is revealed that cost, performance, delivery, supplier related profile and innovation are the criteria frequently used for the selection of suppliers in construction industry. Although many research have discussed the importance of innovation or knowledge contribution, it is often overlooked as one of the selection criteria. The sub-criteria of supplier related profile include technical capability, service, financial strength, management, capacity, reputation and relationship. However, the criteria for selection may subject to changes from time to time as necessary to cope with the requirements of the respective construction firms. In a nutshell, there is no consensus observed on the criteria for supplier selection as different companies have their own set of in-house criteria for suppliers' selection.

A plethora of methods for supplier selection, characterised by the use of information and communication technology, are found in the existing literatures to help the decision makers to select the right supplier for the right

job. These include Web-Based Sub-Contractor Evaluation System (WEBSES), e-Reporting system, Mathematical Programming (MP), Multi-Attribute Decision Making (MADM), Case-Based Reasoning (CBR) and Fuzzy Set Theory (FST). Among these methods, only WEBSES and e-Reporting System attempt to use web-based concept for the supplier selection and evaluation, where suppliers are evaluated online based on a set of combined criteria. However, those approaches are black-box models where the logics adopted are shielded from the suppliers. It is aggravated by the less interactive as they do not facilitate two-way communication between the client and suppliers. Not to mention to give credit to the supplier of his outstanding performance in the project.

Existing literatures show that the most fundamental distinction of knowledge are tacit and explicit. As many research have investigated how knowledge should be managed and reused, it results in a plethora of definitions for Knowledge Management. There is a need to implement knowledge sharing in construction project. This is to capture the created knowledge before it is lost and also to minimise risk in the project. Moreover, it helps to improve firms' innovation capability and lead to a more successful construction project. The impacts or potential benefits brought about by the shared knowledge, e.g. in terms of time and cost saving, are evaluated before giving reward of knowledge to the respective contributor (i.e. the supplier). The reward of knowledge can be in different forms (e.g. incentive, career advancement and security or economic rewards) as this is decided by the individual company's policy.

Triangulation or combined approach is adopted in this study as both quantitative and qualitative data are collected. These cover the detailed end-users' requirements for the development of the system required (qualitative data) and what the participants from the industry think about the performance of the system developed (quantitative data). Twelve semi-structured interviews were conducted with fifteen representatives from large construction firms in Malaysia to explore the current approaches for supplier selection, the way of managing suppliers' performance, and also to identify the end-users' requirements on the methodology for managing suppliers' performance and knowledge sharing. Most of the local construction companies are found to use spread sheet and printed files containing the details about the suppliers for the purpose of selection and performance evaluation. They are unaware of the benefits brought about by ICT as there is a lack of IT support in the related matter. The ICT is merely used for handling paperwork and keeping record of files.

The case studies revealed that only three interviewed construction firms have developed custom design computer application, but it is not comprehensive in term of features. The systems do not capture the historical data on the performance of the suppliers for the selection purpose. This information is critical to reveal the reliability of the suppliers and also to allow them to improve their performance. In addition, the custom design computer application still requires the users to scan and then upload the relevant documents (such as project monthly report or claims) to the system. This is not only time consuming but also inconvenient. For the better management of

suppliers' performance, the end-user requirements for the development of the methodology for supplier selection, managing suppliers' performance and facilitate knowledge sharing in construction project are identified from the interviews. These include:

- The methodology must ease the selection process where the contractor / developer can select the most suitable suppliers efficiently. It avoids the over-dependence on price as the criterion;

- The methodology shall facilitate the management of the suppliers' performance. The suppliers' performance is captured throughout the course of a project and allows them to access their own performance records to improve themselves;

- The methodology must be able to capture the suppliers' knowledge on how the existing project can be further improved. The supplier can contribute and access others contributed knowledge at any time any placewhich is convenient to them. The value and impacts of the knowledge shared will be evaluated before giving the credits to the suppliers;

- The methodology used for the management of suppliers' performance and knowledge sharing should not impose extra workload and additional cost to the companies;

- The system developed needs to be user friendly and only minimum training is required to use it;

- The system developed should be stable and able to perform all the relevant functions;

- The system must be secure and is not accessible to the unauthorised users; and

- The knowledge captured must be well organised and represented in a logical, simple and easy to understand way.

The system that consists of a Web-based database was developed to store the relevant information with software modules for managing the criteria for supplier selection, knowledge capture and evaluation, and managing suppliers' performance across projects. The system mainly comprises of four modules, i.e. for supplier selection, evaluation of supplier's performance, communication with suppliers on their performance score and knowledge sharing.

For the supplier selection, all the suppliers will be requested to complete and update their company profile at predetermined intervals. For the purpose, the shortlisted suppliers' company profile, past project performance, technical capability, financial strength, project in hand can be accessed and compared simultaneously. To nurture knowledge sharing culture, knowledge contribution is made one of the criteria for supplier selection. The criteria for the selection and evaluation are customisable to provided desired flexibility to the users. The evaluation of the respective supplier's performance is only carried out after the project/work is finished. This system allows the suppliers to access their own performance records and then to communicate with contractor on their performance score should the result of evaluation is lower than the expectation or the comment given is inadequate.

To facilitate sharing and reuse of project knowledge, knowledge contributed will be made available for access through the Web-based system once it is validated by Experts. The knowledge can be on how to save time and cost, or improving the progress of a project or the performance of suppliers. Photographs, diagrams and documents can be uploaded to the system to provide more details about the knowledge, with the aim to improve the opportunity for reuse. The users can have an overview of all the knowledge captured and to access the full details. Not only that, the user even can give constructive comment and to rate the knowledge submitted. However, the final and conclusive rating will be determined by personnel who are expert in the field. This process, i.e. validation, is essentially the review of the knowledge captured to ensure the accuracy of knowledge entered. The impacts or potential benefits brought about by the knowledge, e.g. in terms of time and cost saving, will be weighted accordingly to the credits of the contributor (i.e. the supplier).

System evaluation was carried out to further improve the features and design of the system. Evaluation of the system conducted involved the participants from the construction companies interviewed before. Positive feedbacks were received with an overall score of 3.8 out of 5.0. The evaluation result reveals that the system has addressed the important requirements of the end-users. The suggestions for improvement given entail further development in order to deliver the desired features and are hence not incorporated into this version of the prototype. These include cater the need to select and manage the performance of different suppliers with different sets of criteria.

7.2   Conclusions

A number of findings pertaining to this research are concluded. These include:

a) Selection of supplier is critical as it ensures the right supplier is selected for the right job. Suppliers' performance has to be managed throughout the course of project. The benefits brought about for managing suppliers' performance may include project cost reduction, decreased production development lead time, reduction of risk, better end product quality and customer satisfaction, prevention of the deterioration of supply chain, and improved company competitiveness which will in turn lead to a more successful project.

b) The existing research on suppliers' performance management appear to focus on the use of advanced ICT to aid the selection of suppliers based on some predetermined criteria, and do not capture other useful information about the suppliers that may help ensure a better decision to be made. Not only that, the supplier's ability to contribute knowledge and propose better alternative solutions is very often overlooked in the existing research.

c) It is important to have a mechanism to capture and share the knowledge created in construction projects. This helps to facilitate the access and sharing of knowledge across projects and allows improvement to the companies' innovation capability. The shared

knowledge is critical for risk minimisation and bringing competitive advantage to the companies. The impacts or potential benefits brought about by the knowledge are evaluated before crediting to the respective contributor (i.e. supplier). Reward of sharing can be in different forms to recognise suppliers' knowledge contribution and to promote knowledge sharing.

d) Different construction companies have their own set of in-house criteria for the selection of suppliers as this is dependent on the nature of project, unique requirements of clients and other factors. It was observed that most of the construction companies still depend on paper-based forms instead of custom-designed computer applications for the selection of suppliers and the management of their performance. The reasons include insufficient funding and resources, employees' attitude (e.g. reluctant to change, resistance to the use of new system and negative past experience with custom-designed computer application).

e) Knowledge Management is neither prevailing nor practiced by most of the case study companies. They are unaware of the benefits brought about by KM. This is likely because that KM is considered as a relatively new management tool in the Malaysian construction industry. They should begin to implement knowledge management system (i.e. knowledge sharing within the construction project) in the organisation to better leverage on their knowledge to enhance their competitiveness.

f) There are some improvements that can be made to the current practice of the construction companies in managing suppliers' performance and their knowledge. In this regard, a Web-based information system is a very suitable platform that allows custom-designed modules for capturing suppliers' knowledge and managing their performance. It can help to drive for modernisation in management approach of local construction companies to improve the efficiency and their performance.

g) Web-based platform is preferred for the development of a system to manage suppliers' performance for its ability to provide simultaneous access to the users at any time across geographical boundaries and organisations. The system can be made accessible only by authorised users to provide a centralised and reliable means for managing the suppliers' performance information.

h) The Web-based suppliers' performance management system will facilitate:

i) The capture of the information on the performance of, and knowledge about, suppliers in a Web-based system to prevent information loss. It is a secure database. Suppliers can contribute their knowledge into the system at any time any place which is convenient to them. This helps to capture the knowledge contributed in the most-timely way before the details are forgotten or the expertise has left the project team. This is also a place where the project team can learn from the

captured knowledge to avoid unnecessary mistakes before a new project is started.

ii) Fast retrieval of information and knowledge represented in a user friendly format to facilitate reuse. The system is designed in the way that every user can use it without undergoing any training. The knowledge shared are organised and represented in a systematic and logical way. The user can easily locate the information and knowledge in the system. There are also the detailed explanations of the knowledge shared with the aid of uploaded documents to provide more details about the knowledge, with the aim to improve the opportunity for reuse.

iii) Informed decision making on the selection of the most suitable suppliers based on the records captured in the system. This system avoids relying on the price quoted by the suppliers as the sole decision making criterion. Many research show that the lowest price tender may not be the cheapest as the tenders may have resorted to submitting a series of well-managed claims to make up for the loss, or may abandon the project when it turns up to be unprofitable. Other factors such as the capacity, financial strength and stability, past experience, expertise, availability of resource and also the ability to provide innovative solutions are emphasised during the selection of supplier.

iv) Prevention of suppliers with poor track record and insufficient capacity to be selected due to inefficient information

management. The suppliers' particular and relevant information are saved in the Web-based suppliers' performance management system once the supplier has been registered into the system. The suppliers will be requested to complete and update their company profile. This avoids inconvenience (e.g. files lose problem, human error and avoid traveling to another destination for obtaining the relevant documents). The user can trace suppliers' past performance easily as their performance on past project is captured and evaluated to the system.

v) Enhancement of performance and ultimately more successful projects due to the time and money saved by avoiding the potential problems caused by poor supplier. Clients always look for suppliers who can supply a service or material at lower cost and also can perform. Only capable supplier is engaged for the subcontracting work package. The supplier is allowed to access their own performance record to improve themselves. The potential problem due to the poor performance of supplier is avoided (e.g. unsatisfactory end product quality, extension of time for the incomplete work, bankruptcy and etc.).

vi) Provision of useful first-hand information for the senior management on the performance and issues at site or project level. There is a lack of the methodology in current practice to allow individuals to provide useful information as to the

performance and other related issues at any place and any time which is convenient to them. The Web-based suppliers' performance management system addressed these limitations and enables the senior management without going to the real site to obtain the latest information at any time and any place.

vii) Continuous improvement to the project at different stages by allowing suppliers to share their knowledge as to how improvements can be made. The Web-based suppliers' performance management system enables suppliers' performance evaluation to be conducted. The results of the evaluation can be used as a bench mark for continuous improvement in the other project. This system also eases the supplier to share their knowledge as to how improvements can be made to the project once the knowledge is created or identified. The impacts or potential benefits brought about by the knowledge, e.g. in terms of time and cost saving, will be weighted accordingly to the credits of the supplier.

i) Evaluation of the Web-based system involved the participants from the case study companies. Evaluations were conducted on the modules of the system for which the participants' suggestions for improvement were obtained. Positive feedbacks were received with an overall average of 3.8 out of 5.0. The evaluation result reflects that the methodology has addressed the important end-users' requirements. Some of the suggestions for improvement

entail significant additional work and are hence not incorporated into this version of the prototype. Further studies may involve the development of an improved version of this prototype application where all the participants' suggestions are incorporated.

7.3 Further Work

A number of existing and additional features are suggested to be improved and incorporated into the system for the prototype application. These are:

- Improvement of the existing supplier comparison functions in the system. It is suggested that more interactive and graphical means should be adopted to show the relevant information about the suppliers' for comparison purpose.

- Improvement of the membership control to restrict the access of sensitive knowledge. The sensitive and important knowledge shall not be accessible by the companies that are not involved in the project from which the knowledge is captured from. This advanced function is not available in this version of the prototype.

- Development of a mechanism for recording the users who have accessed the knowledge item.

- Development of a mechanism to validate knowledge based on users' comment.

The areas for further research are as follows:

- Development of a Web-based system to manage the performance of consultants, contractors, subcontractors and material suppliers. The system can be designed in line with the company's internal quality management procedures with a set of customisable criteria. Some of the companies' practice of performing the selection using spreadsheet and information transferred from printed files containing the details about the suppliers is not only susceptible to human error but also inefficient. In today's highly competitive world, there is a need to develop an effective and more robust mechanism or system for managing suppliers' performance.

- Explore the integration of the suppliers' performance management system with the existing information systems of an organisation (e.g. subcontractor relationship database, project database and technical information databases). This may require the development of a middleware application to synchronise and update the relevant information in other information systems with that in the suppliers' performance management system. This can help to enhance the richness of the contents in different information systems for better decision making.

- Development of a Web-based system for the clients or developers to automate the supplier selection process. The software agents are capable of analysing the relevant tender documents, coordinating tender interviews and advising on the award of the tender. The

criteria for the selection of suppliers can be amended on case by case basis.

- Development of a more comprehensive mechanism for rewarding the users who have contributed knowledge that has positive impacts on a project. This may also be link to the staff appraisal system as appropriate.

7.4   Limitation of the Research

The fifteen construction companies interviewed were mainly developer and contractor. Other professionals in the industry, such as architects and engineers, were not targeted as their companies' operations are not involved in the selection of suppliers and the management of the suppliers' performance. In addition, only the function for the selection of subcontractors and management of their performance by the contractor has been developed as proof of concept. The fully developed system should also allow the client or developer to manage and select their consultants, main contractors and material suppliers, but such functions have not been developed in this version of prototype due to time constraint.

Different types of suppliers are involved in a typical project, which logically requires different set of criteria for the selection and performance evaluation purpose. Therefore, these criteria must be customisable based on individual company's requirements. Due to time constraint, however, only the criteria for the selection of sub-contractors are formulated and incorporated

into the prototype application as proof of concept for the purpose of this research. It is suggested that more interactive and graphical means, instead of the use of texts or numbers, should be adopted to show the performance of the suppliers. However, as additional time, work and cost are required to address this suggestion the feature cannot be introduced into this prototype.

It is also recognised that more time is needed to fully evaluate the prototype application with the cooperation of construction companies. More participants and projects are to be involved in the evaluation as this is essential to improve the functions of the system. More constructive suggestions for improvements can be gathered from the personal experience of using the prototype application. However, this is difficult to be achieved in this project due to time constraint. The effectiveness of the prototype system in the management of suppliers' performance and their knowledge contribution is positive, based on the result of the evaluation. It is recognised that, however, a full test or evaluation using real projects will be able to better confirm the system's effectiveness.

7.5   Concluding Remarks

The importance of supplier selection, managing suppliers' performance and knowledge sharing/contribution in construction projects, and facilitating two-way communication between supplier and contractor are evident through this research. The shortcomings of current practice in supplier selection and management of their performance, and end-user requirements for the

development of the methodology for the better management of suppliers'
performance and knowledge sharing in construction project were identified
from the case studies conducted. These findings led to the development of the
aforementioned methodology. Subsequently, it was encapsulated in a Web-
based prototype application. Web-based platform was chosen for its ability to
provide simultaneous access to the users at any time across geographical
boundaries and organisations. The prototype application can encourage the
sharing of knowledge among the suppliers whilst enabling more informed
decision making on the selection of suppliers based on the information
captured, which may in turn lead to the success of a project.

LIST OF REFERENCES

Abdul-Rahman, H. and Wang, C., 2010. Preliminary approach to improve knowledge management in engineering management. *Scientific Research and Essays*, 5(15), pp. 1950-1964.

Akarte, M., Surendra, N., Ravi, B. and Rangaraj, N., 2001. Web based casting supplier evaluation using analytical hierarchy process. *Journal of the Operational Research Society*, 52(5), pp. 511-522.

Al-Ghassani, A.M., Anumba, C.J., Carrillo, P.M. and Kamara, J.M., 2006. Prototype system for knowledge problem definition. *Journal of Construction Engineering and Management*, 132(5), pp. 516-524.

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J. and Carrillo, P.M., 2004. An Innovative Approach to Identifying Knowledge Management Problems. *Journal of Engineering, Construction and Architectural Management*, 11(5), pp. 349-357.

Al-Ghassani, A.M., Robinson, H.S., Carrillo, P.M. and Anumba, C.J., 2002. A framework for selecting knowledge management tools. *Proceedings of the 3rd European conference on knowledge management (ECKM)*, 24-25 September 2002, Trinity College Dublin, Ireland, pp. 37-48.

Amin, S. H. and Razmi, J., 2009. An integrated fuzzy model for supplier management: A case study of ISP selection and evaluation. *Expert Systems with Applications*, 36(4), pp. 8639-8648.

Amjad, A.K. and Charles, S.L., 2003. Recent legal developments in the United Arab Emirates and highlights from Bahrain, Egypt, Iran, Kuwait, Oman, Pakistan, Qatar and Saudi Arabia. 21(1), pp. 1-13.

Anand, G., Ward, P.T. and Tatikonda, M.V., 2010. Role of explicit and tacit knowledge in Six Sigma projects: An empirical examination of differential project success. *Journal of Operations Management*, 28(4), pp. 303-315.

Anumba, C.J., Egbu, C.O., and Carrillo, P.M., 2005. Chapter 13: Concluding Notes. In: Anumba, C.J., Egbu, C.O., and Carrillo, P.M. (eds.). *Knowledge Management in Construction.* Oxford: Blackwell, pp. 213-216.

Araz, C. and Ozkarahan, I., 2007. Supplier evaluation and management system for strategic sourcing based on a new multi criteria sorting procedure. *International Journal of Production Economics*, 106(2), pp. 585-606.

Aretoulis, G. N., Kalfakakou, G. P. and Striagka, F. Z., 2009. Construction material supplier selection under multiple criteria. *Operational Research,* 10(2), pp. 209-230.

Arslan, G., Kivrak, S., Birgonul, M. and Dikmen, I., 2008. Improving sub-contractor selection process in construction projects: Web-based sub-contractor evaluation system (WEBSES). *Automation in Construction*, 17(4), pp. 480-488.

Barla, S.B., 2003. A case study of supplier selection for lean supply by using a mathematical model. *Logistics Information Management,* 16(6), pp. 451–459.

Bartol, K. M. and Srivastava, A., 2002. Encouraging Knowledge Sharing: The Role of Organizational Reward Systems. *Journal of Leadership & Organizational Studies*, 9(1), pp. 64-76.

Bartolini, C., Bertolino, A., Elbaum, S. and Marchetti, E., 2011. Bringing white-box testing to Service Oriented Architectures through a Service Oriented Approach. *Journal of Systems and Software*, 84(4), pp. 655–668.

Bayazit, O., 2006. Use of analytic network process in vendor selection decisions. *Benchmarking: An International Journal*, 13(5), pp. 566-579.

Bevilacqua, M., Ciarapica, F. and Giacchetta, G., 2006. A fuzzy-QFD approach to supplier selection. *Journal of Purchasing and Supply Management*, 12(1), pp. 14-27.

Bock, G. W. and Kim, Y., 2002. Breaking the myths of rewards: An exploratory study of attitudes about knowledge sharing. *Information Resources Management Journal*, 15(2), pp. 14-21.

Bottani, E. and Rizzi, A., 2008. An adapted multi-criteria approach to suppliers and products selection - An application oriented to lead-time reduction. *International Journal of Production Economics*, 111(2), pp. 763-781.

Bourdreau, A. and Couillard, G., 1999. System integration and knowledge management. *Information Systems Management,* 16(4), pp. 24-32.

Cai, K.Y., Dong, Z. and Liu, K., 2008. Software testing processes as a linear dynamic system. *Information Sciences*, 178(6), pp. 1558–1597.

Carrillo, P. and Chinowsky, P., 2006. Exploiting Knowledge Management: The Engineering and Construction Perspective. *Journal of Management in Engineering*, 22(1), pp. 1-10.

Carrillo, P., Anumba, C. J. and Kamara, J., 2000. Knowledge Management Strategy for Construction: Key I.T. and Contextual Issues. *Proceedings of Construction Information Technology (CIT 2000)*, 28-30 June 2000, Reykjavik, Iceland, pp. 155-165.

Carrillo, P., Robinson, H., Anumba, C. and Bouchlaghem, N., 2006. *A Knowledge Transfer Framework: the PFI context. Construction Management and Economics*, 24(10), pp. 1045-1056.

Carrillo, P.M., Robinson, H.S., Al-Ghassani, A.M. and Anumba, C.J., 2004. Knowledge management in UK construction: strategies, resources and barriers. *Project Management Journal*, 35(1), pp. 46-56.

Chan, F. and Kumar, N., 2007. Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega*, 35(4), pp. 417-431.

Chan, F., 2003. Performance Measurement in a Supply Chain. *The International Journal of Advanced Manufacturing Technology*, 21(7), pp. 534-548.

Charnes, A., Cooper, W. W. and Rhodes, E., 1978. Measuring the efficiency of decision-making units. *European Journal of Operational Research 2*, pp. 429-444.

Chassiakos, A. and Sakellaropoulos, S., 2008. A web-based system for managing construction information. *Advances in Engineering Software*, 39(11), pp. 865-876.

Chen, C., Lin, C. and Huang, S., 2006. A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics*, 102(2), pp. 289-301.

Chen, L. and Mohamed, S., 2008. Impact of the internal business environment on knowledge management within construction organisations. *Construction Innovation: Information, Process, Management*, 8(1), pp. 61-81.

Chen, P.S. and Wu, M.T., 2013. A modified failure mode and effects analysis method for supplier selection problems in the supply chain risk environment: A case study. *Computers & Industrial Engineering*, 66(4), pp. 634–642.

Cheng, E.D.L. and Li, H., 2004. Contractor selection using the analytic network process. *Construction Management and Economics*, 22, pp. 1021-1032.

Cheraghi, S. H., Dadashzadeh, M. and Subramanian, M., 2004. Critical success factors for supplier selection: An update. *Journal of Applied Business Research*, 20(2), pp. 91-108

Chong, S.C., 2005. Critical factors in the successful implementation of knowledge management. *Journal of Knowledge Management Practice*, 13(3), pp. 230 - 256.

Chou, J.-S., Pham, A.-D. and Wang, H., 2013. Bidding strategy to support decision-making by integrating fuzzy AHP and regression-based simulation. *Automation in Construction*, 35, pp. 517–527.

Choudhary, D. and Kumar, V., 2011. Software Testing. *Journal of Computational Simulation and Modeling*, 1(1), pp. 1-9.

Choy, K. and Lee, W., 2002. A generic tool for the selection and management of supplier relationships in an outsourced manufacturing environment: the application of case based reasoning. *Logistics Information Management*, 15(4), pp. 235-253.

Choy, K., Lee, W. and Lo, V., 2003. Design of a case based intelligent supplier relationship management system - the integration of supplier rating system and product coding system. *Expert Systems with Applications*, 25(1), pp. 87-100.

Choy, K., Lee, W., Lau, H. and Choy, L., 2005. A knowledge-based supplier intelligence retrieval system for outsource manufacturing. *Knowledge-Based Systems*, 18(1), pp. 1-17.

Chua, A., 2003. Knowledge sharing: a game people play. *Aslib Proceedings*, 55(3), pp. 117-129.

Collins, C. J., Smith, K. G., and Stevens, C. K. (2001). Human Resource Practices Knowledge-Creation Capability and Performance in High Technology Firms. In: *Center for Advanced Human Resource Studies Working Paper Series.* Ithaca, NY: Center for Advanced Human Resource Studies, Cornell University, pp. 1-36.

Compact Oxford English dictionary of current English., 2008. 3rd ed., rev. ed. New York: Oxford University Press.

Cook, W. and Seiford, L., 2009. Data envelopment analysis (DEA) – Thirty years on. *European Journal of Operational Research*, 192(1), pp. 1-17.

Creswell, J., 2005. *Educational research : planning, conducting, and evaluating quantitative and qualitative research,* 2nd ed. Upper Saddle River N.J.: Merrill.

Cropanzano, R., 2005. Social Exchange Theory: An Interdisciplinary Review. *Journal of Management*, 31(6), pp. 874–900.

Cummings, J. N., 2004. Work groups, structural diversity and knowledge sharing in a global organization. *Management Science*, 50(3), pp. 352-364.

Dainty, A.R.J. and Brooke, R.J., 2004. Towards improved construction waste minimisation: improved supply chain integration. *Structural Survey*, 22(1), pp. 20–29.

Danese, P., 2013. Supplier integration and company performance: A configurational view. *Omega*, 41(6), pp. 1029-1041.

Davenport, T.H. and Prusak, L., 2000. *Working Knowledge: How Organizations Manage What They Know.* Boston, Massachusetts: Harvard Business School Press.

Demirtas, E. and Ustun, O., 2008. An integrated multiobjective decision making process for supplier selection and order allocation. *Omega*, 36(1), pp. 76-90.

Dent, R.J. and Montague, K.N., 2004. *Benchmarking knowledge management practice in construction.* London: CIRIA, Classic House.

Diakoulakis, I. E., Georgopoulos, N. B., Koulouriotis, D. E. and Emiris, D. M., 2004. Towards a holistic knowledge management model. *Journal of Knowledge Management*, 8(1), pp. 32-46.

Dickson, W.G., 1966. An analysis of vendor selection systems and decisions. *Journal of Purchasing,* 2, pp. 5-20.

Dow, R., Pallaschke, S., Merri, M., Montagnon, E., Schabe, M., Belingheri, M. and Bucher, M., 2008. Overview of the knowledge management system in ESA/ESOC. *Acta Astronautica*, 63(1-4), pp. 448-457.

Dowlatshahi, S., 2000. Developing a theory of reverse logistics. *Interfaces*, 30(3), pp. 143-155.

Dyer, J. H. and Nobeoka, K., 2000. Creating and managing a high-performance knowledge-sharing network: The Toyota case. *Strategic Management Journal*, 21(3), pp. 345-367.

Earl, M., 2001. Knowledge management strategies: Towards a taxonomy. *Journal of Management Information Systems*, 18, pp. 215-233.

Egbu, C.O., 2004. Managing Knowledge and Intellectual Capital for Improved Organisational Innovations in the Construction Industry: an Examination of Critical Success Factor. *Engineering, Construction and Architectural Management (ECAM) Journal*, 11(5), pp. 301-315.

Egbu, C.O., and Robinson, H.S., 2005. Chapter 3: Construction as a Knowledge-Based Industry. In: Anumba, C.J., Egbu, C.O., and Carrillo, P.M. (eds.). *Knowledge Management in Construction.* Oxford: Blackwell, pp. 31-49.

Egbu, C.O., Anumba, C.J., and Carrillo, P.M., 2005. Chapter 1: Introduction. In: Anumba, C.J., Egbu, C.O., and Carrillo, P.M. (eds.). *Knowledge Management in Construction.* Oxford: Blackwell, pp. 1-9.

Elinwa, A. U. and Joshua, M., 2001. Time Overrun Factors in Nigerian Construction Industry. *Journal of Construction Engineering and Management*, 127(5), pp. 419-425.

Fagerstrom, B. and Jackson, M., 2002. Efficient collaboration between main and sub-suppliers. *Computers in Industry*, 49(1), pp. 25-35.

Falagario, M., Fabio, S., Nicola, C. and Roberto, P., 2012. Using a DEA-cross efficiency approach in public procurement tenders. *European Journal of Operational Research*, 218(2), pp. 523–529.

Fang, Y., Jiang, F., Makino, S. and Beamish, P. W., 2010. Multinational firm knowledge, use of expatriates, and foreign subsidiary performance. *Journal of Management Studies*, 47(1), pp. 27-54.

Fellows, R. and Liu, A., 2008. *Research methods for construction,* 3rd ed. Oxford: Wiley-Blackwell.

Ferris, G., Perrewe, P., Ranft, A., Zinko, R., Stoner, J., Brouer, R. and Laird, M., 2007. Human resources reputation and effectiveness. *Human Resource Management Review*, 17, pp. 117-130.

Florezlopez, R., 2007. Strategic supplier selection in the added-value perspective: A CI approach. *Information Sciences*, 177(5), pp. 1169-1179.

Fong, P. S. and Yip, J. C., 2006. An Investigative Study of the Application of Lessons Learned Systems in Construction Projects. *Journal for Education in the Built Environment*, 1, pp. 27-38.

Fredendall, L., and Hill, E., 2001. Chapter 1: History and Introduction. In: *Basics of supply chain management*. Boca Raton, Florida, Alexandria Va.: St. Lucie Press, APICS, pp. 1-10.

Gadde, L. and Snehota, I., 2000. Making the Most of Supplier Relationships. *Industrial Marketing Management*, 29(4), pp. 305-316.

Galup, S.D., Dattero, R. and Hicks, R.C., 2002. Knowledge management systems: an architecture for active and passive knowledge. *Information Resource Management Journal*, 15(1), pp. 7-22.

Garfamy, R.M., 2006. A data envelopment analysis approach based on total cost of ownership for supplier selection. *Journal of Enterprise Information Management*, 19(6), pp. 662–678.

Gencer, C. and Gurpinar, D., 2007. Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modelling*, 31(11), pp. 2475-2486.

Geppert, M. and Clark, E., 2003. Knowledge and learning in transnational ventures: an actor centred approach. *Management Decision*, 41(5), pp. 433-442.

Ghodsypour, S. and O' Brien, C., 2001. The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint. *International Journal of Production Economics*, 73(1), pp. 15-27.

Glenford, J.M., Sandler, C. and Tom, B., 2012. *The art of software testing.* Hoboken, N.J: John Wiley & Sons.

Goldman, A., 1967. A Causal Theory of Knowing. *The Journal of Philosophy*, 64(12), pp. 357-372.

Greene, J.C. and Caracelli, V.J., 1997. *Advances in mixed-method evaluation: the challenges and benefits of integrating diverse paradigms*. San Francisco: Jossey-Bass.

Guo, X., Yuan, Z. and Tian, B., 2009. Supplier selection based on hierarchical potential support vector machine. *Expert Systems with Applications*, 36(3), pp. 6978-6985.

Guo, Y., Hu, J. and Peng, Y., 2012. A CBR system for injection mould design based on ontology: A case study. *Computer-Aided Design*, 44(6), pp. 496–508.

Haggie, K. and Kingston, J., 2003. Choosing Your Knowledge Management Strategy. *Journal of Knowledge Management Practice*, 3(4), pp. 1-23.

Hall, H., 2001. Input-friendliness: Motivating knowledge sharing across intranets. *Journal of Information Science*, 27(3), pp. 139-146.

Hammami, R., Temponi, C. and Frein, Y., 2014. A scenario-based stochastic model for supplier selection in global context with multiple buyers, currency fluctuation uncertainties, and price discounts. *European Journal of Operational Research*, 233(1), pp. 159–170.

Hansen, M. T., 2002. Knowledge network: Explaining effective knowledge sharing in multiunit companies. *Organization Science*, 13(3), pp. 232−248.

Ho, W., Xu, X. and Dey, P. K., 2010. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, 202(1), pp. 16-24.

Hou, J. and Su, D., 2006. Integration of Web Services technology with business models within the total product design process for supplier selection. *Computers in Industry*, 57(8-9), pp. 797-808.

Hox, J.J. and Boeije, H.R., 2005. Data Collection, Primary vs. Secondary. *Encyclopedia of Social Measurement*, 1, pp. 593-599.

Hsu, I., 2008. Knowledge sharing practices as a facilitating factor for improving organizational performance through human capital: A preliminary test. *Expert Systems with Applications*, 35(3), pp. 1316-1326.

Hsu, M., Ju, T., Yen, C. and Chang, C., 2007. Knowledge sharing behavior in virtual communities: The relationship between trust, self-efficacy, and outcome expectations. *International Journal of Human-Computer Studies*, 65(2), pp. 153-169.

Huang, S. and Keskar, H., 2007. Comprehensive and configurable metrics for supplier selection. *International Journal of Production Economics*, 105(2), pp. 510-523.

Humphreys, P., Huang, G., Cadden, T. and Mcivor, R., 2007. Integrating design metrics within the early supplier selection process. *Journal of Purchasing and Supply Management*, 13(1), pp. 42-52.

Humphreys, P., McIvor, R. and Chan, F., 2004. Using case-based reasoning to evaluate supplier environmental management performance. *Expert Systems with Applications*, 25(2), pp. 141－153.

Hwang, H.J., 2005. Modeling Virtual Network Collaboration in Supply Chain Management. In: Gervasi, O., Gavrilova, M.L., Kumar, V., Laganà, A., Lee, H.P., Mun, Y., Taniar, D., Tan, C.J.K. (eds.). *Computational Science and Its Applications – ICCSA 2005*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 304–313.

International Labour Organisation., 2001, *Recruitment practices pose problems for construction industry* [Online]. Available at: http://www.ilo.org/global/about-the-ilo/press-and-media-centre/press-releases/WCMS_007879/lang--en/index.htm [Accessed: 14 February 2013].

Ipe, M., 2003. Knowledge Sharing in Organizations: A Conceptual Framework. *Human Resource Development Review*, 2(4), pp. 337-359.

Kahraman, C., Cebeci, U. and Ulukan, Z., 2003. Multi-criteria supplier selection using fuzzy AHP. *Logistics Information Management*, 16(6), pp. 382-394.

Kaklauskas, A., Zavadskas, E.K. and Trinkunas, V., 2007. A multiple criterion decision support on-line system for construction. *Engineering Applications of Artificial Intelligence*, 20, pp. 163-175.

Kalpic, B. and Bernus, P., 2006. Business process modeling through the knowledge management perspective. *Journal of Knowledge Management*, 10(3), pp. 40-56.

Kamara, J.M., Anumba, C. J., Carrillo, P. M. and Bouchlaghem, N., 2003. Conceptual framework for live capture and reuse of project knowledge. *CIBW078 International Conference on Information and Technology for Construction*, 23-25 April 2003, Waiheke Island, New Zealand, pp. 178–185.

Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2005). Chapter 7: Cross-Porject Knowledge Management, In: Anumba, C.J., Egbu, C.O., and Carrillo, P.M. (eds.). *Knowledge Management in Construction.* Oxford: Blackwell, pp. 65-82.

Kanagasabapathy, K.A., Radhakrishnan, R. and Balasubramanian, S., 2006. Empirical investigation of critical success factor and knowledge management structure for successful implementation of knowledge management system − a case study in process industry.

Katsikeas, C., Paparoidamis, N. and Katsikea, E., 2004. Supply source selection criteria: The impact of supplier performance on distributor performance. *Industrial Marketing Management*, 33(8), pp. 755-764.

Kerzner, H, 2009. *Project management: a systems approach to planning, scheduling, and controlling*, 10th ed. Hoboken, N.J: John Wiley & Sons.

Khalfan, M.M.A. and McDermott, P., 2007. Integrated Supply Chain − An Example from the UK Construction Industry. *The construction and building research conference of the Royal Institution of Chartered Surveyors (COBRA) 2007*, 6-7 September 2007, College of Architecture, Georgia Institute of Technology, Atlanta USA. United Kingdom: RICS.

Khalfan, M.M.A., Kashyap, M., Li, X.G. and Abbott, C., 2010. Knowledge management in construction supply chain integration. *Int. J. Networking and Virtual Organisations*, 7(2/3), pp. 207-221.

Kim, S. and Lee, H., 2006. The impact of organizational context and information technology on employee knowledge-sharing capabilities. *Public Administration Review*, 66(3), pp. 370−385.

Kivrak, S., Arslan, G., Dikmen, I. and Birgonul, M. T., 2008. Capturing Knowledge in Construction Projects: Knowledge Platform for Contractors. *Journal of Management in Engineering*, 24(2), pp. 87-95.

Kokangul, A. and Susuz, Z., 2009. Integrated analytical hierarch process and mathematical programming to supplier selection problem with quantity discount. *Applied Mathematical Modelling*, 33(3), pp. 1417-1429.

Kumar, M., Vrat, P. and Shankar, R., 2004. A fuzzy goal programming approach for vendor selection problem in a supply chain. *Computers & Industrial Engineering*, 46(1), pp. 69-85.

Kuo, R., Wang, Y. and Tien, F., 2010. Integration of artificial neural network and MADA methods for green supplier selection. *Journal of Cleaner Production*, 18(12), pp. 1161-1170.

Lambert, D. and Cooper, M., 2000. Issues in Supply Chain Management. *Industrial Marketing Management*, 29(1), pp. 65-83.

Larsson, K. J. and Ohlin, L., 2002. *Implementing A Knowledge Sharing Initiative – Principles For Success.* Master's Thesis, Linkoping Institute of Technology, Sweden.

Lee, A.L. and Fariza Hanum, M.N., 2008. Application of knowledge management in Malaysia Banks – A preliminary study. *Proceedings of Knowledge Management International Conference 2008*, 10-12 June 2008, Universiti Utara Malaysia, Malaysia, pp. 396-401.

Lee, D. and Ahn, J., 2007. Reward systems for intra-organizational knowledge sharing. *European Journal of Operational Research*, 180(2), pp. 938-956.

Lee, E., Ha, S. and Kim, S., 2001. Supplier selection and management system considering relationships in supply chain management. *IEEE Transactions on Engineering Management*, 48(3), pp. 307-318.

Lemos, O.A.L., Ferrari, F.C., Eler, M.M., Maldonado, J.C. and Masiero, P.C., 2011. Evaluation Studies of Software Testing Research. *The 25th Brazilian Symposium on Software Engineering*, 28-30 September 2011, Sao Paulo, Brazil.

Lemos, O.A.L., Ferrari, F.C., Eler, M.M., Maldonado, J.C. and Masiero, P.C., 2013. Evaluation studies of software testing research in Brazil and in the world: A survey of two premier software engineering conferences. *The Journal of Systems and Software*, 86(4), pp. 951-969.

Li, J., Moselhi, O. and Alkass, S., 2006. Internet-based database management system for project control. *Engineering, Construction and Architectural Management*, 13(3), pp. 242-253.

Li, M. and Gao, F., 2003. Why Nonaka highlights tacit knowledge: a critical review. *Journal of Knowledge Management*, 7(4), pp. 6-14.

Li, Q., 2013. A novel Likert scale based on fuzzy sets theory. *Expert Systems with Applications*, 40(5), pp. 1609–1618.

Liao, C. and Kao, H., 2010. Supplier selection model using Taguchi loss function, analytical hierarchy process and multi-choice goal programming. *Computers & Industrial Engineering*, 58(4), pp. 571-577.

Lin, M. J., Hung, S. and Chen, C., 2009. Fostering the determinants of knowledge sharing in professional virtual communities. *Computers in Human Behavior*, 25(4), pp. 929-939.

Lin, Y.-C. and Lee, H.-Y., 2012. Developing project communities of practice-based knowledge management system in construction. *Automation in Construction*, 22, pp. 422–432.

Liu, F. and Hai, H., 2005. The voting analytic hierarchy process method for selecting supplier. *International Journal of Production Economics*, 97(3), pp. 308-317.

Liu, J., Ding, F.Y. and Lall, V., 2000. Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. *Supply Chain Management: An International Journal,* 5(3), pp. 143–150.

Low, S.W. and Mohammed, A.K., 2005. The development of knowledge sharing culture in construction industry. *Proceedings of the 4th Micra Conference*, 4-5 May 2005, University of Malaya, Kuala Lumpur.

Luo, X., Wu, C., Rosenberg, D. and Barnes, D., 2009. Supplier selection in agile supply chains: An information-processing model and an illustration. *Journal of Purchasing and Supply Management*, 15(4), pp. 249-262.

Mafakheri, F., Breton, M. and Ghoniem, A., 2011. Supplier selection-order allocation: A two-stage multiple criteria dynamic programming approach. *International Journal of Production Economics*, 132(1), pp. 52–57.

Mahdi, I.M., Riley, M.J., Fereig, A.M. and Alex. A.P., 2002. A multi-criteria approach to contractor selection. *Engineering, Construction and Architectural Management*, 9(1), pp. 29-37.

Male, S. and Mitrovic, D., 2005. The project value chain: models for procuring supply chains in construction. *The Queensland University of Technology Research Week International Conference*, 4-5 July 2005, Brisbane, Australia.

Miles, M. B. and Huberman, A. M., 1994. *Qualitative data analysis: An expanded sourcebook.* Thousand Oaks, CA: Sage.

Mitton, C., Adair, C.E., Mckenzie, E., Patten, S.B. and Perry, B.W., 2007. Knowledge transfer and exchange: review and synthesis of the literature. *The Milbank Quarterly*, 85(4), pp. 729-768.

Modi, S. and Mabert, V., 2007. Supplier development: Improving supplier performance through knowledge transfer. *Journal of Operations Management*, 25(1), pp. 42-64.

Naoum, S., 2007. *Dissertation research and writing for construction students,* 2nd ed. Oxford: Butterworth-Heinemann.

Nesheim, T. and Gressgård, L.J., 2014. Knowledge sharing in a complex organization: Antecedents and safety effects. *Safety Science*, 62, pp. 28–36.

Ng, S. and Skitmore, R., 1999. Client and consultant perspectives of prequalification criteria. *Building and Environment*, 34(5), pp. 607-621.

Ng, S., Palaneeswaran, E. and Kumaraswamy, M., 2002. A dynamic e-Reporting system for contractor's performance appraisal. *Advances in Engineering Software*, 33(6), pp. 339-349.

Ng, S., Tang, Z. and Palaneeswaran, E., 2009. Factors contributing to the success of equipment-intensive subcontractors in construction. *International Journal of Project Management*, 27(7), pp. 736–744.

Ng, W., 2008. An efficient and simple model for multiple criteria supplier selection problem. *European Journal of Operational Research*, 186(3), pp. 1059-1067.

Noss, R.F., 1990. Indicators for Monitoring Biodiversity: A Hierarchical Approach. *Conservation Biology*, 4(4), pp. 355-364.

Noulmanee, A., Wachirathamrojn, J., Tantichattanont, P. and Sittivijan, P., 1999, *Internal causes of delays in highway construction projects in Thailand* [Online]. Available at: www.ait.c1et.com [Accessed: 14 February 2013].

Olomolaiye, A. and Egbu, C., 2006. Linking Human Resource Management and Knowledge Management for Performance Improvements: A Case Study Approach. *The construction and building research conference of the Royal Institution of Chartered Surveyors (COBRA) 2006,* 7-8 September 2006, University College London. London: RICS.

Ozgen, D., Onut, S., Gulsun, B., Tuzkaya, U. and Tuzkaya, G., 2008. A two-phase possibilistic linear programming methodology for multi-objective supplier evaluation and order allocation problems. *Information Sciences*, 178(2), pp. 485-500.

Palaneeswaran, E. and Kumaraswamy, M., 2001. Recent advances and proposed improvements in contractor prequalification methodologies. *Building and Environment*, 36(1), pp. 73-87.

Parmigiani, A., Klassen, R.D. and Russo, M. V., 2011. Efficiency meets accountability: Performance implications of supply chain configuration, control, and capabilities. *Journal of Operations Management*, 29(3), pp. 212–223.

Paulraj, A., Lado, A. A. and Chen, I.J., 2008. Inter-organizational communication as a relational competency: Antecedents and performance outcomes in collaborative buyer-supplier relationships. *Journal of Operations Management*, 26(1), pp. 45–64.

Perçin, S., 2006. An application of the integrated AHP-PGP model in supplier selection. *Measuring Business Excellence*, 10(4), pp. 34-49.

Pi, W. and Low, C., 2005. Supplier evaluation and selection using Taguchi loss functions. *The International Journal of Advanced Manufacturing Technology,* 26(1-2), pp. 155-160.

Pinto, J., 2010. *Project management: achieving competitive advantage,* 2nd ed. Upper Saddle River N.J.: Pearson.

Pulakos, E. D., Dorsey, D. W. and Borman, W. C., 2003. Hiring for knowledge-based competition. In: Susan, E.J., Michael, A.H., and Angelo, S.D. (eds.). *Managing knowledge for sustained competitive advantage: Designing strategies for effective human resource management*. San Francisco: Jossey-Bass, pp. 155−176.

Quintas, P., 2005. Chapter 2: The Nature and Dimensions of Knowledge Management. In: Anumba, C.J., Egbu, C.O., & Carrillo, P.M. (eds.). *Knowledge Management in Construction*. Oxford: Blackwell, pp. 10-30.

Randeree, E., 2006. Knowledge management: securing the future. *Journal of Knowledge Management*, 10(4), pp. 145-156.

Rennie, M., 1999. Accounting for knowledge asset: Do we need a new financial statement? *International Journal of Technology Management*, 18(5/6/7/8), pp. 648-659.

Ribeiro, F.L., 2003. Using CBR to improve knowledge intensive business processes in the construction supply chains. *Proceedings of the RICS Foundation Construction and Building Research Conference (COBRA) 2003*, 1-2 September 2003, University of Wolverhampton, United Kingdom. London: RICS.

Ricca, F., Torchiano, M., Di Penta, M., Ceccato, M. and Tonella, P., 2009. Using acceptance tests as a support for clarifying requirements: A series of experiments. *Information and Software Technology*, 51(2), pp. 270–283.

Robinson, H. S., Carrillo, P. M., Anumba, C. J. and Al-Ghassani, A. M., 2005. Knowledge management practices in large construction organisations. *Engineering, Construction and Architectural Management*, 12(5), pp. 431-445.

Robinson, H.S., Carrillo, P.M., Anumba, C.J. and Al-Ghassani, A.M., 2004. Developing a business care for knowledge management: the IMPaKT approach. *Construction Management and Economies,* 22, pp. 733-743.

Ruiztorres, A. and Mahmoodi, F., 2006. A supplier allocation model considering delivery failure, maintenance and supplier cycle costs. *International Journal of Production Economics*, 103(2), pp. 755-766.

Saaty, T. L., 2008. Decision making with the analytic hierarchy process. *Int. J. Services Sciences*, 1(1), pp. 83-98.

Saen, R., 2007. Suppliers selection in the presence of both cardinal and ordinal data. *European Journal of Operational Research*, 183(2), pp. 741-747.

Salojarvi, S., Furu, P. and Sveiby, K.E., 2005. Knowledge Management and growth in Finnish SMEs. *Journal of Knowledge Management*, 9(2), pp. 103-122.

Sambasivan, M. and Yau, W.S., 2007. Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, 25, pp. 517 -526.

Sanayei, A., Farid Mousavi, S. and Yazdankhah, A., 2010. Group decision making process for supplier selection with VIKOR under fuzzy environment. *Expert Systems with Applications*, 37(1), pp. 24-30.

Sanayei, A., Faridmousavi, S., Abdi, M. and Mohaghar, A., 2008. An integrated group decision-making process for supplier selection and order allocation using multi-attribute utility theory and linear programming. *Journal of the Franklin Institute*, 345(7), pp. 731-747.

Sanchez, J.H., Sanchez, Y.H., Collado-Ruiz, D. and Cebrian-Tarrason, D., 2013. Knowledge Creating and Sharing Corporate Culture Framework. *Procedia - Social and Behavioral Sciences*, 74, pp. 251–260.

Sarkar, A. and Mohapatra, P., 2006. Evaluation of supplier capability and performance: A method for supply base reduction. *Journal of Purchasing and Supply Management*, 12(3), pp. 148-163.

Sarkis, J. and Talluri, S., 2002. A Model for Strategic Supplier Selection. *The Journal of Supply Chain Management: A Global Review of Purchasing and Supply*, pp. 18-28.

Schiele, H., 2006. How to distinguish innovative suppliers? Identifying innovative suppliers as new task for purchasing. *Industrial Marketing Management*, 35(8), pp. 925–935.

Seydel, J., 2005. Supporting the paradigm shift in vendor selection: Multicriteria methods for sole-sourcing. *Managerial Finance,* 31(3), pp. 49–66.

Stewart, T.A., 1997. *Intellectual Capital: The New Wealth of Organisations.* New York: Doubleday.

Sturges, J.L., Egbu, C. and Bates, M.B., 1999. Innovation in Construction. *Proceedings of the 2nd international conference on construction industry development and 1st conferences of CIB TG 2-9 on construction in developing countries,* 27-29 October 1999, The School of Building and Real Estate, NUS Singapore, pp. 305-313.

Suh, T. and Houston, M. B., 2010. Distinguishing supplier reputation from trust in buyer–supplier relationships. *Industrial Marketing Management*, 39(5), pp. 744-751.

Talluri, S. and Narasimhan, R., 2004. Vendor evaluation with performance variability: A max–min approach. *European Journal of Operational Research*, 146(3), pp. 543-552.

Talluri, S., 2002. A buyer–seller game model for selection and negotiation of purchasing bids. *European Journal of Operational Research*, 143(1), pp. 171-180.

Talluri, S., Vickery, S.K. and Narayanan, S., 2008. Optimisation models for buyer–supplier negotiations. *International Journal of Physical Distribution and Logistics Management*, 38(7), pp. 551–561.

Tan, H. C., Anumba, C., Carrillo, P., Bouchlaghem, D., Kamara, J. and Udeaja, C., 2010. *Capture and reuse of project knowledge in construction*. Chichester U.K.: Wiley-Blackwell.

Tan, K., 2001. A framework of supply chain management literature. *European Journal of Purchasing & Supply Management*, 7(1), pp. 39-48.

Tarofder, A.K. and Haque, A., 2007. Exploring critical factors for supplier selection in telecommunication industry in Malaysia. *Asian Journal of Marketing,* 1(1), pp. 1-13.

Ting, S. and Cho, D. I., 2008. An integrated approach for supplier selection and purchasing decisions. *Supply Chain Management: An International Journal*, 13(2), pp. 116-127.

Ting, S., 2004. A multi-objective approach to supplier selection and purchasing decision in the supply chain. *Multi Criteria Decision Making 2004*, 6-11 August 2004, Whistler, BC Canada.

Topcu, Y.I., 2004. A decision model proposal for construction selection in Turkey. *Building and Environment*, 39, pp. 469-481.

Tracey, M. and Tan, C. L., 2001. Empirical Analysis of Supplier Selection and Involvement, Customer Satisfaction and Firm Performance. *Supply Chain Management: An International Journal*, 6(4), pp. 174-188.

Usoro, A., Sharratt, M.W., Tsui, E. and Shekhar, S., 2007. Trust as an antecedent to knowledge sharing in virtual communities of practice. *Knowledge Management Research & Practice*, 5(3), pp. 199–212.

Vaivio, J. and Siren, A., 2010. Insights into method triangulation and "paradigms" in interpretive management accounting research. *Management Accounting Research*, 21(2), pp. 130-141.

Vandervalk, W. and Wynstra, F., 2005. Supplier involvement in new product development in the food industry. *Industrial Marketing Management*, 34(7), pp. 681-694.

Vinodh, S., Anesh Ramiya, R. and Gautham, S.G., 2011. Application of fuzzy analytic network process for supplier selection in a manufacturing organisation. *Expert Systems with Applications*, 38(1), pp. 272–280.

Wadhwa, V. and Ravindran, A., 2007. Vendor selection in outsourcing. *Computers & Operations Research*, 34(12), pp. 3725-3737.

Wang, G., Huang, S. H. and Dismukes, J. P., 2004. Product-driven supply chain selection using integrated multi-criteria decision-making methodology. *International Journal of Production Economics*, 91(1), pp. 1-15.

Wang, J., Cheng, C. and Huang, K., 2009. Fuzzy hierarchical TOPSIS for supplier selection. *Applied Soft Computing*, 9(1), pp. 377-386.

Wang, S. and Noe, R. A., 2010. Knowledge sharing: A review and directions for future research. *Human Resource Management Review*, 20(2), pp. 115-131.

Wang, Z. and Wang, N., 2012. Knowledge sharing, innovation and firm performance. *Expert Systems with Applications*, 39(10), pp. 8899–8908.

Wang, T. and Yang, Y., 2009. A fuzzy model for supplier selection in quantity discount environments. *Expert Systems with Applications*, 36(10), pp. 12179-12187.

Wasko, M. M. and Faraj, S., 2005. Why Should I Share? Examining Social Capital and Knowledge Contribution in Electronic Networks of Practice. *MIS Quarterly*, 29(1), pp. 35-57.

Watt, D., Kayis, B. and Willey, K., 2009. Identifying key factors in the evaluation of tenders for projects and services. *International Journal of Project Management*, 27(3), pp. 250-260.

Weber, C.A., Current, J.R. and Desai, A., 2000. An optimisation approach to determining the number of vendors to employ. *Supply Chain Management: An International Journal,* 5(2), pp. 90–98.

Wei, J.C., Liu, Lu. and Francesco, C.A., 2010. A cognitive model of intra-organizational knowledge-sharing motivations in the view of cross-culture. *International Journal of Information Management*, 30(3), pp. 220-230.

Willem, A. and Buelens, M., 2009. Knowledge sharing in inter-unit cooperative episodes: The impact of organizational structure dimensions. *International Journal of Information Management*, 29(2), pp. 151-160.

Wu, Z., Choi, T. Y. and Rungtusanatham, M. J., 2010. Supplier–supplier relationships in buyer–supplier–supplier triads: Implications for supplier performance. *Journal of Operations Management*, 28(2), pp. 115-123.

Wu, D.D., Yidong, Zhang., Dexiang, Wud. and David L, Olson., 2010. Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach. *European Journal of Operational Research*, 200(3), pp. 774–787.

Xia, W. and Wu, Z., 2007. Supplier selection with multiple criteria in volume discount environments. *Omega*, 35(5), pp. 494-504.

Xue, X., Wang, Y., Shen, Q. and Yu, X., 2007. Coordination mechanisms for construction supply chain management in the Internet environment. *International Journal of Project Management*, 25(2), pp. 150-157.

Yang, D., 2011. The Effect of Knowledge Management on Product Innovation - Evidence from the Chinese Software Outsourcing Vendors. *iBusiness*, 3, pp. 16-22.

Yao, L. J., Kam, T. H. Y. and Chan, S. H., 2007. Knowledge sharing in Asian public administration sector: The case of Hong Kong. *Journal of Enterprise Information*, 20(1), pp. 51-69.

Yesil, S. and Dereli, S.F., 2013. An Empirical Investigation of the Organisational Justice, Knowledge Sharing and Innovation Capability. *Procedia - Social and Behavioral Sciences*, 75, pp. 199–208.

Yeşil, S., Koska, A. & Büyükbeşe, T., 2013. Knowledge Sharing Process, Innovation Capability and Innovation Performance: An Empirical Study. *Procedia - Social and Behavioral Sciences*, 75, pp.217–225.

Yucel, A. and Guneri, A.F., 2011. A weighted additive fuzzy programming approach for multi-criteria supplier selection. *Expert Systems with Applications*, 38(5), pp. 6281–6286.

Yue, X. and Ma, H., 2009. The Study of Software Reliability Evaluation and Testing Method. *Third International Symposium on Intelligent Information Technology Application,* 21-22 November 2009, Nanchang, China.

Zafirovski, M., 2005. Social Exchange Theory under Scrutiny: A Positive Critique of its Economic-Behaviorist Formulations. *Electronic Journal of Sociology*, pp. 1–40.

Zin, M.I.N. and Egbu, C., 2010. Readiness of organisations to implement a knowledge management strategy: a construction industry overview. *Proceedings of 26th Annual ARCOM Conference,* 6-8 September 2010, Leeds, UK. United Kingdom: Association of Researchers in Construction Management, pp. 789-798.

APPENDIX A

Evaluation of MySupplier.Net System

Sections		Please tick as appropriate. 1 is the lowest and 5 is the highest				
No	Section 1: Selection of Supplier	1	2	3	4	5
1.1	How well does the system help in the selection of supplier?					
1.2	How well does the default criteria help in the selection of supplier?					
1.3	How well does the extra information (i.e. the links to additional information such as knowledge contribution score, project details, and supplier's miscellaneous details) facilitate the selection of the right supplier for the right job?					
1.4	How well does the system in representing the suppliers' relevant information for selection purpose?					
	Section 2: Evaluation of Supplier's Performance					
2.1	How well does the system's evaluation function in evaluating supplier's performance?					
2.2	How well does the default criteria (completion on time, completion on cost and workmanship) help in the evaluation of supplier's performance?					
2.3	How well does the additional information presented (e.g. the information that shows project and work scope, and the total sum of projects awarded) in facilitating supplier's performance evaluation?					
2.4	How easy is the system to use for evaluating suppliers' performance?					
	Section 3: Communication with suppliers on their performance score					
3.1	How useful is the feature that allows the suppliers to view and respond to the contractor's comments on them?					
3.2	How well does the system in facilitating two ways communication between contractor and suppliers on the latter's performance?					
3.3	How easy is the system to use for suppliers to communicate with contractors?					

193

Continued: Evaluation of MySupplier.Net System

No	Section 4: Knowledge Sharing	1	2	3	4	5
	Sections	Please tick as appropriate. 1 is the lowest and 5 is the highest				
4.1	How well does the system help in facilitating knowledge sharing?					
4.2	How well is the list of shared knowledge in providing an overall view of all the knowledge captured in the system?					
4.3	How well does the template represent the knowledge contributed?					
4.4	How well is the mechanism for calculating the supplier's score for the knowledge contributed?					
4.5	How well does the knowledge validation mechanism in ensuring the correctness of knowledge contributed?					

What do you like about the system?

_____

_____

_____

_____

Suggestions for improvement (i.e. how to improve the Web-based Suppliers' Performance Management System):

_____

_____

_____

_____

Name   : _____

Company   : _____

Designation   : _____

Year(s) of Experience in Construction Industry: _____

Contact Number : _____

Email   : _____

Thank you very much and have a nice day.