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Conceptual Framework for the Development of a Web-Based System for Managing Suppliers' Performance

Zi Qian Li
Department of Built Environment, Universiti Tunku Abdul Rahman, Kuala Lumpur, Malaysia
lizq1@mail2.utar.edu.my

Hai Chen Tan
Department of Built Environment, Universiti Tunku Abdul Rahman, Kuala Lumpur, Malaysia
tanhc@utar.edu.my

Chimay Anumba
Department of Architectural Engineering, The Pennsylvania State University, PA, USA
anumba@engr.psu.edu

Fah Choy Chia
Department of Built Environment, Universiti Tunku Abdul Rahman, Kuala Lumpur, Malaysia
chiafc@utar.edu.my

Abstract
In the construction industry, a project is very often procured by the client 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. Collectively, therefore, the contractors, consultants, subcontractors and material suppliers can all be rightly regarded as "suppliers" as they all are engaged for supplying their skills and knowledge (i.e. service) or materials to their client. Review of existing literatures shows that most of the research are 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 to allow them to clarify and to improve themselves. This paper presents the findings from existing literature on the current practice on the supplier selection and proposes a framework comprising a Web-based system to address the aforementioned shortcomings. It also forms part of an ongoing research that aims to develop a more rounded Web-based supplier's performance management system which facilitates the leveraginge of suppliers' knowledge for the benefit of the ongoing projects.

Keywords
Suppliers, Suppliers' Performance Management, Supplier Selection, Web-based Technology

1. Introduction

In the construction industry, the client or developer who owns a project normally is not directly involved in the construction work of the project. Instead, the client is dependent on the various suppliers to carry out the actual construction work. Suppliers, in the context of this research, are defined to include the contractor, consultants, material suppliers and subcontractors who have contributed their skills and knowledge (i.e. service) and materials into a construction project. As the "supplier" has 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. 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, it is crucial to have an efficient and effective mechanism to manage the performance of suppliers for the purpose of contract awarding and also to facilitate continuous improvement throughout the duration of the project.

This paper begins with a discussion on the importance of managing the performance of suppliers and the existing research in the area. This is followed by a description of a conceptual framework comprising a Web-based system for managing the performance and the selection of suppliers, which is also capable of capturing the useful knowledge from the suppliers and with improved two-way communication among the parties involved. This paper forms part of the initial findings of an ongoing research. Further findings will be presented elsewhere.

2. Importance of Managing Suppliers' Performance

According to Prahinski and Benton (2004), supplier's performance is an operational measure of key competitive success factors of how well a supplier utilises his available resources to achieve the specific goals. The suppliers' performance has direct impacts on the success of a project. Having the right suppliers can significantly reduce the purchasing cost, shorten product development lead time, lead to better product quality and ultimately deliver greater value to the client (Saen, 2007; Ragatz et al, 2002). Conversely, selecting the wrong supplier is enough to deteriorate the whole supply chain's financial and operational position (Araz and Ozkarahan, 2007), which may also lead to delays and poor customer service (Chan and Kumar, 2007). The importance of managing supplier's performance is even more obvious in the local construction industry where a big proportion of construction works normally are subcontracted to other companies.

A systematic approach for managing suppliers can help to build the closeness and long-term relationship between the clients and suppliers. A close-relationship, in turn, is essential to establish trust between clients and suppliers (Male and Mitrovic, 2005). 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). Periodical review of suppliers' performance also enables the identification of their weaknesses that require improvements (Humphreys Li and Chan, 2004). 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.

3. Existing Research

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. These are very often characterised by the use of information and communication technology (ICT). For instance, Arslan et al (2008) have developed a Web-Based Sub-Contractor Evaluation System (WEBSES) that allows sub-contractors to be evaluated online based on a set of combined criteria. 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 their relevant sub-works, helps to speed up the selection process and leads to cost savings during the bidding process.

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, checked, compiled and subsequently disseminated to relevant users in the industry for contractor selection purpose. The evaluators will evaluate and monitor the contractors' performance based on a set of key performance criteria. To reflect the specific requirements of the client or project, the appraisers are allowed to alter the weighting

assigned to each criterion or sub-criterion. Only those with good recent performance and adequate available capacities will be then invited to submit tenders.

There are also attempts to use computing technology such as Case-Based Reasoning (CBR), Mathematical Programming, Analytical Hierarchy Process (AHP), Analytic Network Process (ANP) and Fuzzy Set Theory (FST) to assist in the selection of the best supplier. This list is not exhaustive and only a few main ones are discussed in this paper. Mathematical Programming optimises the interactions and trade-offs among different factors of interest by considering constraints and different issues (Sanayei, Mousavi and Yazdankhah, 2010). Ng (2008) develops a weighted linear program to address the multi-criteria supplier selection problem based on MP. The user is required to rank the criteria's importance in a sequence rather than specifying the exact weight values. The scores of the suppliers are then compared to identify the most suitable supplier.

AHP is a theory of measurement through pair-wise comparisons that relies on the judgements of experts to derive priority scales (Saaty, 2008). It is a robust technique that allows managers to determine preferences of criteria for selection purposes, quantify those preferences, and then aggregate them (Sarkis and Talluri, 2002). 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 elements at an upper level is used to compare the elements at the level immediately below with respect to it to weigh the priorities. The process of weighing is continued until the final priorities of the alternatives at the bottom most level is obtained (Saaty, 2008). Hou and Su (2006) develop a Web Services-Oriented Multi-Possibility Supplier Selection (WMPSS) system based on AHP to help manufactures to identify suitable suppliers for the components, materials and services required for product design. Other similar research based on AHP are Xia and Wu (2007) and Liu and Hai (2005).

Analytic Network Process is a generalised and less sophisticated version of AHP (Sarkis and Talluri, 2002). The main is difference is that AHP only considers one-way hierarchical relationships among the factors, whereas ANP considers also the many possible relationships among the groups of factors or those within them (Saaty, 2001). Bayazit's supplier selection model (2006) based on ANP allows both qualitative and quantitative criteria to be incorporated in the selection of suppliers. Choy and Lee (2002) introduce a generic model using the CBR technique to deal with the supplier selection problem. It functions by capturing past experience and the past cases of the supplier and then matches the aforementioned attributes to the existing problem. FST is also used to quantify some qualitative criteria for the purpose of the evaluation and selection of suppliers (Amin and Razmi, 2009).

4. Shortcomings of Current Practice

The current approaches are mainly focused on utilising the information on suppliers' performance for 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 for decision makers in real situations shielded from the suppliers (Seydel, 2005). There is no mechanism available to integrate suppliers into the system that manages their performance. Without this, the suppliers do not have an opportunity to clarify and defend themselves should the information that is used for the evaluation is inaccurate or out-dated. In addition, the selection and evaluation of suppliers' performance appear to concentrate more on that prior to their appointment rather than throughout the course of a project. The better approach is to capture the performance of the suppliers for all the projects awarded to them continuously, which will be 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.

Kamara et al (2003) point out 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. This may enable the client and other project

team members to benefit from the enriched knowledge about the development and construction 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 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 the system.

Li et al's (2006) research reveals that a Web-based system can lead to the more logical and efficient organisation, storage and retrieval of the data on project performance. Therefore, it is envisaged that a Web-based system that can provide access to the users from different organisations at geographically dispersed locations for managing suppliers' performance can be a good option to address the aforementioned issues and requirements. Furthermore, a Web-based system also allows custom designed modules for capturing suppliers' knowledge and improving the communication between the client and suppliers to be incorporated easily. The details of a conceptual framework for managing supplier's performance are introduced in the following sections.

5. Web-based Supplier's Performance Management System – Conceptual Framework

The core of the conceptual framework is a custom designed 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, as depicted in Figure 1. The framework can be designed to function as a standalone system, or can be part of a larger system such as the Capri.net methodology designed for the "live' capture and reuse of project knowledge (Tan et al, 2010). The latter will allow the benefits brought about through reusing the knowledge captured to be fully harnessed, which is facilitated by the synergy of the two systems.

5.1. Web-based Database

Web-based platform is preferred for the development of the system for its ability to provide simultaneous access to the users at anytime across geographical boundaries and organisations. The system can be designed to function like a private network that is only accessible by authorised users, who can be physically located in different organisations, to provide a centralised and reliable means for managing the suppliers' performance information. Information, such as suppliers' profile and their products or services, can be stored in the Web-based database for future use.

The development of the system based on the Web-based platform also means that there is no installation of software application required in the individual user's computer. What required are the access to the Internet and a Web browser, which indirectly also addresses the potential cross operating system compatibility problem. In addition, the requirements of the computing facility used to access the system are not as demanding as most of the computing operations are performed by the server. This suggests that the existing mobile computing devices (e.g. smart phone and tablet PC) should have the necessary computing power for the purpose. All these will then translate to lower system implementation cost, if compared to the conventional non Web-based solutions. This is critical as cost is known to be one of the most crucial issues concerning the implementation of such systems (Tan et al, 2010).

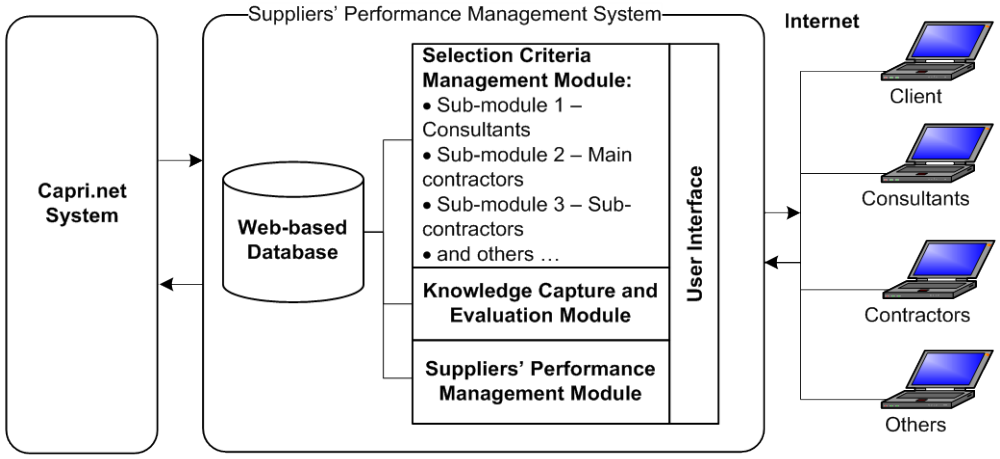

Figure 1: Conceptual Framework of a Web-based Suppliers' Performance Management System

5.2. Selection Criteria Management Module

This module contains the program logics and criteria used for the evaluation and selection of suppliers. Related to this, a number of criteria for the purpose have been identified from existing literatures, which are very much different from the conventional approach that focuses mainly on the speed and price (Ting and Cho, 2008). Dickson's (1966) research conducted in 1960s is among the initial research done in the area which is widely cited. 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 to1990 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. 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. Subsequently, Watt et al (2009) conduct 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. There are some criteria identified by Cheraghi et al (2004) as important which are not given similar emphasis by Watt et al (2009).

There are also other relevant criteria, which 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) propose a universal model for contractor prequalification based on the practice of public project owners in six countries. 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). However, there is a possibility that if the public project owners from other regions or countries are involved the result might show some differences.

Therefore, as revealed by the existing literatures the selection criteria might be different for different industries, companies or types of projects. Occasionally, these criteria might be even different for the same type of project of the same company but at different times. Furthermore, different sets of criteria are likely to be needed for the evaluation of different types of suppliers, such as the material suppliers and

subcontractors. This is depicted in Figure 1. Simply put, the selection criteria are rather fluid and subject to changes from time to time as necessary to cope with the requirements of individual project. Therefore, instead of attempting to propose a set of "one size fits all" criteria with fixed and predefined weight, it is envisaged that flexibility should be built into the module for the management of the criteria. This is to allow the management to define the criteria and assign weight to them at ease to suit the unique requirements of different projects. The preset criteria, other than the "innovation / knowledge contribution", are only for the reference of the individual user or company which can be adapted as appropriate. However, for the purpose of this study the system to be developed will mainly cater for the selection of subcontractors even though there is a possibility to extend the functions to cover that of other suppliers.

5.3. Knowledge Capture and Evaluation Module

The importance of capturing suppliers' knowledge is obvious since they are the one who carry out the actual construction work and hence in the best position to shed useful insights on how the existing project can be further improved. Therefore, a mechanism can be incorporated into the system to capture these insights and leverage on their knowledge. The value and impacts of the knowledge shared on the project may also form part and parcel of the criteria for evaluating the performance of the suppliers, which allows them to be rewarded accordingly as appropriate. The mechanism for knowledge capture can also be extended to cover the evaluation of the impacts of the knowledge shared. In lieu of tangible rewards, as an alternative, the participation of the suppliers in contributing their knowledge can entitle them to access to the collective knowledge captured in the system for their own benefit.

To fully exploit the benefits brought about by the knowledge shared, the system can be further integrated with the Capri.net system. Capri.net system is specifically developed for cross organisational and cross project capture, sharing and reuse of knowledge. It has some built-in functions to enable new knowledge created in a project to be shared as soon as possible once it is discovered. This will allow the knowledge shared by the suppliers to be reused and harnessed in the earliest opportunity before such opportunity diminishes.

5.4. Suppliers' Performance Management Module

The current approaches are not interactive as they do not facilitate two-way communication between the client and suppliers. In most of the cases, the suppliers do not have the access to the information about their own performance and criteria used to evaluate them. Therefore, suppliers may lose the opportunity to learn from their mistakes which have led to low rating and from the comments given by the client due to the lack of access to the system. It is also possible that a supplier might have addressed the issues that give him a low score but these improvements have not been reflected in the records. There is also the potential issue of inaccurate data entry and outdated information being recorded in the system. Clearly, in order to address these issues and for continuous improvement purpose a feedback mechanism has to be built into the system for managing suppliers' performance. In addition, the historical data on the performance and profile of the suppliers should be captured by the system as these help to reveal the reliability of the suppliers.

6. Discussion

The advancements in ICT, particularly the Web-based technology, have revolutionised various aspects of the management of construction projects. A Web-based system for managing suppliers' performance, for instance, can offer large and secure storage of relevant data on suppliers' performance, fast retrieval and analysis of the data to compare suppliers' performance to determine their suitability for a project, and the access to the information across geographical locations. Some of these are either impossible to be achieved, or entail a lot of manual inputs from the staff, without the aid of ICT. The maturity of relevant technology has further led to the lowering of implementation cost for such systems, which makes them even more appealing.

This research aims to look into how ICT can help to improve the management of suppliers' performance and also leveraging on their knowledge. The development of the system, however, entails further research to be conducted to identify the specific requirements of the construction organisations as well as to keep the changes to their existing practice in managing suppliers' performance to the minimum. The Web-based suppliers' performance management system proposed will facilitate:

a) Capture of the information on the performance of, and knowledge about, suppliers in a central database to prevent data loss;
b) Fast retrieval of information represented in a user-friendly format;
c) Informed decision making on the selection of the most suitable suppliers based on systematic records captured in the central database;
d) Prevention of suppliers with poor track record and insufficient capacity to be selected due to inefficient information management;
e) Enhancement of performance and ultimately more successful projects due to the time and money saved by avoiding all the potential problems caused by a poor supplier; and
f) Continuous improvement to the project at different stages by allowing suppliers to share their knowledge as to how improvements can be made.

7. Conclusions

This paper proposes a conceptual Web-based framework for managing the selection and performance of suppliers in the construction industry. It attempts to address some of the shortcomings of existing approaches such as the lack of communication on the information pertaining to the performance of suppliers to enable them to improve themselves and a mechanism to leverage on the valuable knowledge of the suppliers. It mainly consists of a Web-based database 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. Further research is needed to identify the precise requirements for the development of the system and the other technical details particularly on how it can be integrated with the methodology for "live' capture and reuse of project knowledge (i.e. Capri.net).

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