A Decision Support Model for Contractor Selection in a Government Procurement Supply Chain: Evidence from an Emerging Market

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This paper employs the decision support system, such as the Analytical Hierarchical Process (AHP) methodology to model contractor selection problem in a government procurement supply chain. The proposed methodology used a set of criteria for the selection and evaluation of the best contractor. A case study of a government Ministry in Ghana is used to illustrate contractor selection problem. The AHP model is used because it allows different types of contractor capabilities to be examined. The result findings indicate that contractors' experience is the most important followed by manpower resources, financial stability, and relevant equipment for contractors' selection in Ghana.

INTRODUCTION

The motivation for this case study is because the procurement department of a government Ministry in Ghana often performs its contractor selection process arbitrarily. Selecting the most appropriate contractor or core of contractors is imperative to the success of any government construction projects. Thus, because contractors can perform an important role in any construction project, contractor selection constitutes a major decision for public authorities (Anagnostopoulos and Vavatsikos, 2006). In developing countries the imperative in selecting the most appropriate contractor is often taken for granted in construction procurement supply chain. Indeed, selection of contractors in developing countries such as in Ghana is often based on the criterion of least bid amount or cost. This myopic mindset of selecting contractors often in the long run can lead to poor construction performance, cost overruns, project completion delays, abandonment of projects, among others. For example, Anvuur and Kumaraswamy (2006) noted that "the performance of construction in Ghana is poor and many reports have decried the public sector's lack of commercial edge in the exercise of its procurement function." In the developing countries, some of the problems associated with construction industry are cost overruns and repeated delays (e.g., Okpala and Aniekwu, 1988; Werna, 1993; Mansfield *et al.*, 1994). Ogunsemi and Aje (2006) assert that "construction projects in Nigeria are generally characterized by cost and time overrun, substandard work, disputes and abandonment; emanating from several factors of which the wrong choice of contractors is a key factor."

Contractor selection problem represents a typical multi-criteria decision making (MCDM) problem that encompasses both quantitative and qualitative criteria (Sonmez et al., 2002). According to Sonmez et al (2002), when confronted with MCDM problems, “a decision maker may need to provide uncertain, incomplete, or imprecise assessments due to a lack of information, time pressure and/or shortcomings in expertise.” Arguably, one way a decision maker can handle the preceding is to use AHP methodology to a contractor prequalification problem. According to Hutush and Skitmore (1998), “there is a need for a contractor selection technique that is capable of considering multiple criteria.” The AHP is one such technique that permits the treatment of both quantitative and qualitative criteria. Singh and Tiong (2006) contend that contractor selection problem is a complex multi-criteria decision making process which are mostly subjective in nature and difficult to quantify. Saaty’s (1994) AHP is one of the methods based on the initial qualitative assessments that later assumes a quantitative form. However, the AHP is used in this case study because of its simplicity, practicality and appropriateness in selection problems. Meredith and Mantel (2000) noted AHP as a reliable tool for project selection. Thus, the use of AHP methodology is appropriate to construction project contractor selection for the purchasing and procurement supply chain managers in a Ghanaian government Ministry. AHP has been used in contractor selection problems (e.g., Ibrahim et al 2002; Al-Harbi, 2001; Mian and Christine, 1999).

The rest of the paper is structured as follows. Section 2 briefly reviews the contractor selection literature. Section 3 presents the research methodology. Section 4 describes the data collection and analysis. Section 5 discusses the research findings. Finally, section 6 presents the conclusions and managerial implications.

CONTRACTOR SELECTION PROCESS

Successful completion of either a private sector or government projects depends on the proper selection of the most appropriate contractor or set of core contractors. However, to achieve the right prequalification and bid evaluation process purchasing or procurement supply chain managers must determine the requisite attributes. Hatush and Skitmore (1997) suggest that “prequalification and bid evaluation processes requires the development of necessary and sufficient criteria.” Success of any government projects depends on the selection of core contractors. Contractor prequalification process which entails array of decision attributes has been discussed in the literature (e.g., Zedan and Skitmore 1994; Moselhi and Martinelli, 1993; Ng, 1992; Merna and Smith, 1990; Russell, 1988; Hatush and Skitmore, 1997). For example, some of the criteria considered in contractor selection problem are bid amount, managerial capability, organizational structure, technical competence, relevancy of experience, depth of organization, financial stability, current workload, health and safety records, reputation, past performance, key personnel availability, and relevant experience on comparable construction (Holt et al., 1994; Russell et al., 1990; Hatush and Skitmore, 1998, 1997; Hunt et al., 1996; Moselhi and Martimelli, 1993; Merna and Smith, 1990; Anagnostopoulos and Vavatsikos, 2006).

RESEARCH METHODOLOGY

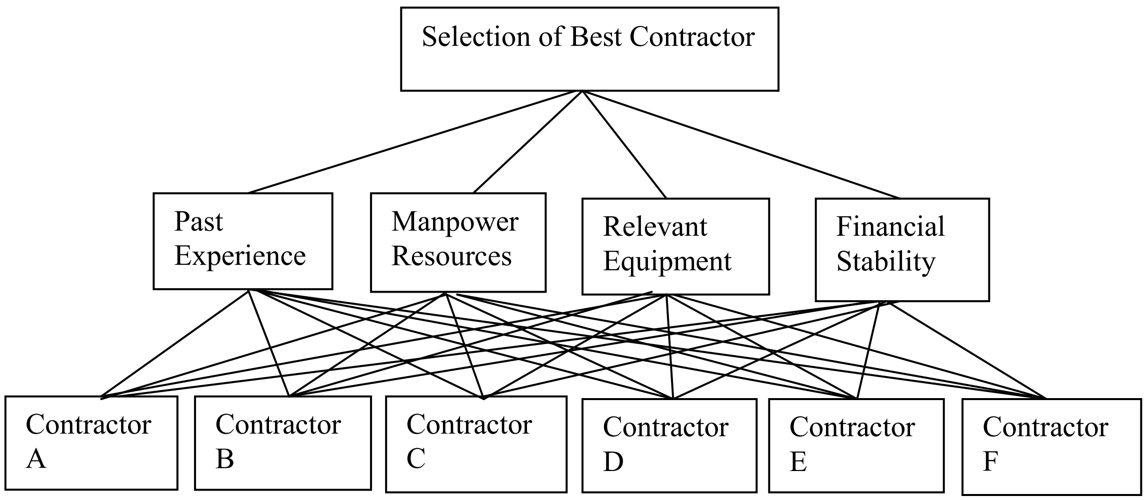
A decision-making environment entails multiple criteria called MCDM. Contractor selection problem represents a typical MCDM problem that entails multiple criteria that can be both qualitative and quantitative. An example of MCDM selected to model contractor selection is AHP developed by Saaty (1980). It is chosen because it allows decision-makers to model a complex problem in a hierarchical structure showing the relationships of the overall goal, objectives, and alternatives. Following Saaty (1980), the hierarchy structure of contractor selection for a government construction procurement project is shown in Figure 1.

1. Define an unstructured problem and determine the overall goal. The overall goal is to select the best contractor.

2. Build the hierarchy from the top through the intermediate levels to the lowest level which usually contains the list of alternatives. The major decision criteria occupy the second level of the hierarchy. The

decision maker defines the criteria that will be used to judge the alternative options. The defined decision criteria are contractor's experience, availability of manpower (key personnel), relevant equipment, and financial stability. The alternative contractors considered by the procurement supply chain managers are contractors A, B, C, D, E, and F.

FIGURE 1
STRUCTURE OF GOVERNMENT CONSTRUCTION PROCUREMENT PROJECT



3. Construction of pairwise comparison matrix. Build a set of pairwise comparison matrices for each level of the hierarchy and then conduct all the pairwise comparisons. The pairwise comparison matrix A, where element a_{ij} of the matrix is the relative importance of i^{th} factor with respect to j^{th} factor, can be determined as follows:

$$A = [a_{ij}] \tag{1}$$

Where the entry in row *i* and column *j* of A (a_{ij}) indicates how much more important objective (criteria) *i* is than objective j. Each entry in matrix A is positive ($a_{ij} > 0$) and reciprocal (($a_{ij} = 1/a_{ji}$) for all $i, j = 1, 2, 3,\ldots n$). "Importance" is measured on an integer-valued 1-9 scale for pairwise comparisons. It allows the transformation of qualitative judgments and/or intangible attributes into preference weights (level of importance) or numerical values. The pairwise comparisons are accomplished in terms of which element dominates or influences the order. According to Saaty, a value of 1 between two criteria indicates that both equally influence the affected node, while a value of 9 indicates that the influence of one criterion is extremely more important than the other.

4. n(n – 1)/ judgments are needed to develop a set of matrices in step #3. Reciprocals are assigned in each pairwise comparison automatically.

5. Utilizing the hierarchical synthesis to weight the eigenvectors according to the weights of the criteria. The total is for all weighted eigenvectors corresponding to those in the next lower level of the hierarchy.

6. After completing all the pair-wise comparisons, the consistency can be evaluated using the eigenvalue (λ_{max}), to derive the consistent index (CI). Specifically, Saaty (1990) recommended that the maximum eigenvalue, λ_{max}, can be determined as

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij} \, W_j/W_i, \tag{2}$$

Where λ_{max} is the principal or maximum eigenvalue of positive real values in judgment matrix, W_j is the weight of j^{th} factor, and W_i is the weight of i^{th} factor.

7. Consistency Test. Each pairwise comparison which has several decision elements for CI measures the entire consistency judgment for each comparison matrix and the hierarchy structure. Thus, CI and consistency ratio (CR) are used to determine the consistency of the comparison matrix. A matrix is assumed to be consistent if and only if $a_{ij} * a_{jk} = a_{jk}\ \forall_{i\,jk}$ (for all *i, j, and k).* Specifically, CI for each matrix order *n* is determined by using (3).

$$CI = (\lambda_{max} - n)/n - 1 \qquad (3)$$

Where n is the matrix size or the number of items that are being compared in the matrix.
Based on (2), the consistency ratio (CR) in (4) can be determined as below:

$$CR = CI/RI = [(\lambda_{max} - n)/n - 1]/RI \qquad (4)$$

CR is acceptable, if its value is less than or equal to 0.10. However, if it is greater than 0.10, the judgment matrix will be considered inconsistent. To rectify the judgment matrix that is inconsistent, decision-makers' judgments should be reviewed and improved.

Data Collection and Analysis

Relational data were derived with the aid of questionnaire administered on purchasing and procurement managers within a Ghanaian Ministry to determine the order of importance of the contractor selection criteria. Prequalification evaluation scores for six contractors were obtained based on past experience, financial soundness, relevant equipment, and manpower resources criteria. Essentially, from the hierarchy tree, a questionnaire was developed to enable pairwise comparisons between all the criteria at each level in the hierarchy. The pairwise comparison process elicits qualitative judgments that indicate the strength of the purchasing and procurement purchasing managers' preference in a specific comparison according to Saaty's 1-9 scale. Indeed, they were requested to respond to several pairwise comparisons where two categories at a time were compared with respect to the goal. The result of the survey questionnaire technique was then used as input for the AHP. The matrix of pairwise comparisons of the criteria or attributes given by the chemical firm in the case study is shown in Table 1. The judgments are entered utilizing the Saaty's pairwise comparison preference scale explained in no. 3. The data collected were analyzed with the aid of AHP using Expert Choice Software 11.5.

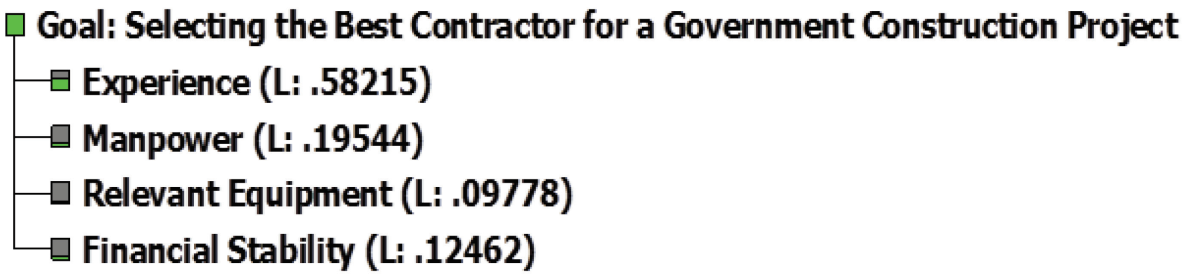
TABLE 1
PAIRWISE COMPARISON MATRIX WITH RESPECT TO GOAL

Goal	Past Experience	Manpower Resources	Relevant Equipment	Financial Stability
Past Experience	1	3	5	6
Manpower Resources	1/3	1	3	1
Relevant Equipment	1/5	1/3	1	1
Financial Stability	1/6	1	1	1

EMPIRICAL RESULTS

The pairwise comparison of the major criteria priority shown in Figure 1 indicate that experience is the most preferred criterion for selecting a contractor with a priority of 0.582 followed by manpower (availability key personnel (0.1954), financial stability/soundness (0.125), and relevant equipment (0.098).

FIGURE 2
MAJOR CRITERIA PRIORITY WITH RESPECT TO GOAL



Composite Priority with Respect to Alternative Contractor

Table 2 reports the composite priority with respect to alternative contractors. According the result findings, the most appropriate contractor to select is contractor C followed by A and B contractors.

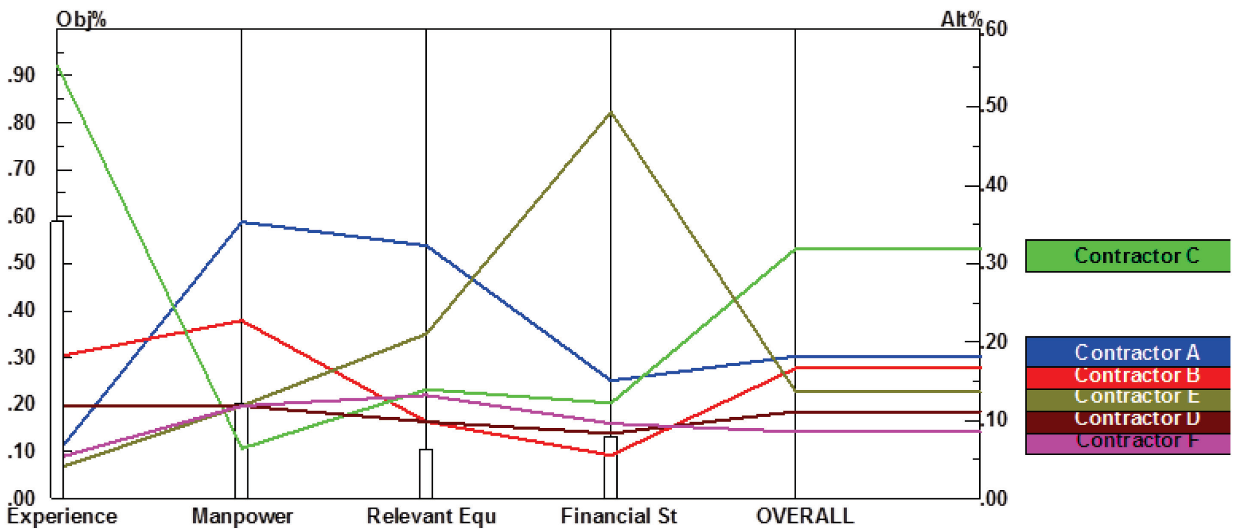
TABLE 5
OVERALL PRIORITY WITH RESPECT TO ALTERNATIVE CONTRACTOR

Alternative Contractor	Criteria (CR: 0.05 < 0.10)				Overall Priority
	Experience 0.58215	Manpower 0.19544	Relevant Equip 0.09778	Financial Stab 0.12462	
Contractor A	0.05837	0.35509	0.32269	0.15053	0.18156
Contractor B	0.18145	0.22726	0.09820	0.05534	0.16679
Contractor C	0.55222	0.06413	0.13904	0.12175	0.31920
Contractor D	0.11761	0.11851	0.09820	0.08316	0.11110
Contractor E	0.03861	0.11851	0.21012	0.49341	0.13618
Contractor F	0.05174	0.11851	0.13176	0.09581	0.08518
CR	0.06<0.10	0.01<0.10	0.03<0.10	0.02<0.10	

Sensitivity Analysis on the Priority Weights of Criteria

Saaty's AHP method provides an opportunity to investigate the sensitivity of decision criteria with the aid of Expert Choice Software. If group of decision makers believe that a criterion might be more or less important than originally indicated, they can drag that criterion's bar to the right (increase) or left (decrease) and then observe the impact on alternatives. The objective of sensitivity (SA) of contractor in a government Ministry is to determine how the small changes (perturbation) in input parameters will impact the ranking of the alternative suppliers. Because of limitation of space we investigated few sensitivity analysis of the impact of changing priority of the criteria on the alternative contractors' ranking. For performance sensitivity analysis (Figure 3), the alternative contractor ranking is as follows: contractor C, contractor A, Contractor B, contractor E, contractor D, and contractor F.

FIGURE 3
PERFORMANCE SENSITIVITY ANALYSIS (PSA)



Increasing (decreasing) relevance equipment priority from 0.10 (Figure 3) to 0.25 (0.05) (Figure 4 scenario 1) did not change the contractors' ranking (insensitive or stable). For financial stability, increasing the priority from 0.15 (Figure 3) to 0.25 (Figure 4) changed contractors' ranking (sensitive), while decreasing the priority from 0.15 to 0.5 did not change contractors' ranking (insensitive). Similarly, increasing manpower resources from 0.20 (Figure 3) to 0.30 (Figure 5) remained stable. Even when it was decreased from 0.20 to 0.10, contractors' ranking remained stable.

FIGURE 4
SCENARIO 1 PSA WITH RESPECT RELEVANT EQUIPMENT

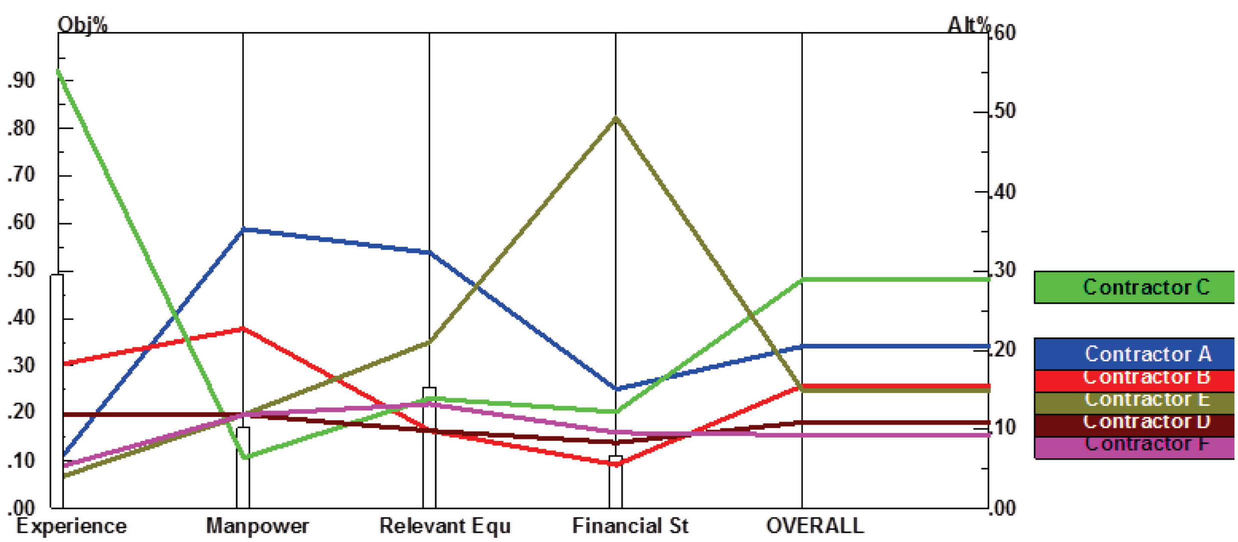
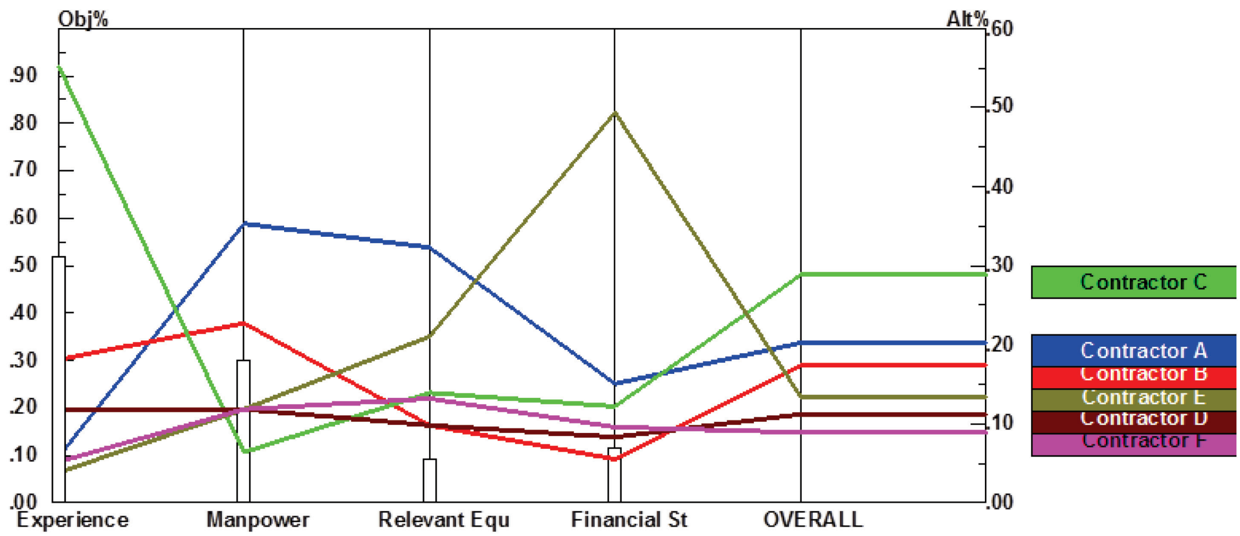


FIGURE 5
SCENARIO 2 PSA WITH RESPECT TO FINANCIAL STABILITY



Conclusions and Managerial Implications

This paper discusses a multi-criteria decision support system for the selection of the most suitable contractor. Essentially, it examines the criteria used by the purchasing and Procurement Department of a government Ministry in Ghana to prequalify contractors. For this case study, contractor selection criteria considered include experience, financial stability/soundness, available manpower resources, and relevant equipment criteria. Contractor selection represents one of the premier functions of purchasing and procurement supply chain managers within any government. The proposed multi-criteria decision making such as AHP is an important approach for contractor selection. For construction procurement supply chain managers in both private and public sectors, selecting the right contractor is imperative in the successful deliver of construction projects. However, selecting the most appropriate contractor for construction project can be a daunting challenge for any private or public client. Contractor Selection represents a crucial decision which can affect the progress and success of any government construction project.

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