Research Journal of Applied Sciences, Engineering and Technology 4(4): 316-321, 2012
ISSN: 2040-7467

Submitted: August 08, 2011 Accepted: September 25, 2011 Published: February 15, 2012

PROMA-A Decision Support System to Determine Appropriate Procurement Method

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Abstract: The aim of this study was to develop computer application software using the weighted sum model equation to assist construction industry practitioners in making analytical decision about building procurement options. A survey of construction industry practitioners in Nigeria was conducted to prioritize the selection criteria and determine the utility factors for the procurement options against selection criteria. The results were used to populate the software. The program uses clients' consultants', contractors' or the combined utility factors for cost categories to recommend an appropriate procurement method for a particular type of building. This makes the program better than earlier works which ignored the effect of cost categories on procurement options' performance.

Key words: Multi-attribute, Nigeria, procurement method, selection criteria, weighted sum, utility factors

INTRODUCTION

Proliferation of procurement methods after Latham's and Banwill's reports meant clients have the responsibility to choose the most appropriate method for their building projects. This has become imperative because the client is faced with various options to procure his project. The problem is not the several options available to the client but appropriateness of the option he chooses for his project based on project objectives and the options' ability to meet such objectives. As noted by Kumaraswamy and Dissanayaka (2001) decisions to use any of the available options to procure construction services are often subjective. The challenge of appropriateness is more pronounced in developing countries but worse in most commonwealth developing countries which mostly structure their construction industries after the British system. As observed by Wells (1986), the traditional contracting method has been more or less preserved and used as first choice procurement method for projects in these countries. This is done without any apparent recognition of/or adjustment for the local situation or needs (Gidado, 1996).

In Nigeria, the public client believes because of the civil service structure, it is only the traditional contracting, i.e., Design-Bid-Build (DBB) is appropriate while the private client thinks it is only the design – build is appropriate for his projects. This is so because in the Nigerian construction industry, the client and consultants do not have specific procedure in choosing their procurement method to implement their projects. They base it mostly on familiarity with a particular procurement method. It is against this background that a framework to systematically guide clients in the Nigerian construction industry is urgently required. This Okpala (2000) suggested will completely overhaul the existing construction industry's framework and make it competitive to survive the present Nigerian ailing economy. Hence the aim of research work was to develop an Information and Communication Technology (ICT) enabled decision support system to determine the appropriateness of various procurement method options for a particular building project.

Approaches to selection of appropriate procurement method: NEDO (1985) suggested that clients could rate the different procurement methods that emerged after Emerson's and Banwill's reports using client's priority rating of the selection criteria. Since then many researchers have developed different approaches to building project procurement selection. The approaches have varied from the NEDO's simple rating system to more complex multi-attribute, the analytical hierarchical process and matrix-based techniques. Ng *et al*. (2002) observed that these approaches were proposed to overcome identified weaknesses of the selection practices.

The simple rating and knowledge based expert systems: The NEDO (1985) procurement path decision charts listed eight key areas of client's possible priorities or needs which must be considered and then matched with the characteristics of the various procurement systems available. By this technique the client simple rates the procurement system available against client's priorities and then eliminates those procurement systems whose characteristics are incompatible with the client's needs.

Masterman (1992) contends that though the technique is useful as a guide to eliminate unsuitable procurement methods, it is insufficiently sophisticated to enable a final decision to be taken as to the appropriate procurement method. In Franks (1990) work, the procurement systems were rated based on their ability to satisfy seven client criteria using a rating scale of 1-5. As Masterman (1992) noted, this technique is flawed with subjectively.

Knowledge-based procurement decision support systems have been proposed. These procurement decisions support systems utilize computer - based expert system to select the most appropriate procurement method. One of such was the "ELSIE" developed by the RICS Quantity Surveyors Division in 1988 on behalf of the UK construction industry to demonstrate the potential of such systems (Brandon, 1990). The "ELSIE" expert system consists of four modules: financial budget, procurement, time and development appraisal. The procurement module contains a consensus view of about twelve quantity surveyors practitioners. This consensus view was used to form the knowledge base of the expert system to provide recommendations on the most appropriate procurement method via a software program. According to Love *et al.* (1998) the software program poses series of questions to relate the timing, quality, design, cost parameters and the project peculiarities. Then upon evaluation of the information supplied by the user, the system recommends (ranked in order of suitability) some procurement methods, indicating also the extent those methods will satisfy the client requirements.

Mohsini and Botros (1990) developed a similar knowledge-based expert system known as Project Acquisition Strategy Consultant (PASCON). This system is driven by a backward-chaining reasoning process to reach conclusions deduced from the input data and rules in the knowledge base. The expert system both generates and evaluates alternative procurement methods unlike other works which consider few generic ones. PASCON consist of three modules, in the first module, the system identifies the project's requirements and constraints under three sub-goals of project characteristics, type of construction documents to be used and the risk factor. Module two identifies those project procurement strategies that are best fitted with the projects characteristics and constraints and are most likely to satisfy the owner's objectives (Mohsini and Botros, 1990). The client assigns a certainty factor to either time or cost to indicate the relative importance of the two objectives. Module three displays the procurement method(s) selected after the earlier operations and then recommend the appropriate participants describing their roles and responsibilities. It also recommends the most appropriate method of awards and compensation. As Mohsini and Botros (1990) noted, some of the procurement methods generated based on the project requirements and constraints and probably selected by the system might make very little sense from a practical point of view.

At the core of Kumaraswamy and Dissanayaka (2001) knowledge - based decision support system is three levels. These were designed to capture and incorporate any casual relationships linking project performance levels (Client criteria) against three sets of independent variables in turn. These variables are:

- Project-specific internal conditions such as project complexities.
- Procurement options such as fixed price lump sum etc.
- External conditions such as skilled labour availability in the project location

At the end of various interactions between these independent variables and the project expected performance levels, the system recommends compatible procurement options based on the systems knowledge – based rules.

The Analytical Hierarchy Process approach (AHP): Cheung *et al*. (2001) applied the analytical hierarchy technique to assist clients in determining the importance weightings for eight selection criteria that include speed, certainty, quality level etc. A pair wise comparison matrix was developed using a scale of importance of between '1' (equal importance), '3' (weak importance of one over another), '7' (very strong and demonstrated importance) and '9' (absolute importance). In addition utility factors were assigned by experts against each criterion for each procurement method considered. The choice of an appropriate procurement method was based on the highest utility value derived from the procurement methods taking into account the relative importance of the selection criteria.

The AHP model of Alkhalil (2002) was developed based on selection criteria grouped under project characteristics, owner's needs and owner's priority. These three broad selection criteria are further broken down into hierarchy of four levels from large elements to small elements. For example, he subdivided the project characteristics into elements of scope, clarity, schedules, contract price and complexity. While contract price itself was divided into elements of lump sum and cost plus. In the Alkhalil (2002) model, each of the elements in a level of a hierarchy was compared pair wise with other elements of same level with respect to a criterion at higher levels. By this, the client determines the relative importance of each of the elements in the hierarchy in relative to other elements at the same level. Through this aggregation process one of the alternative procurement methods considered is selected based on the alternatives that attained the highest priority value.

The Multi-attribute Utility Approach (MAUA): In MAUA decision makers assess the value of possible outcomes based on utility i.e, relative desirability of each possible outcome (Fellows *et al*., 1983). It is similar to the expected utility theory that dictates that choice x is better than y, if and only if the expected monetary utility coming from x is larger than that of y as in the games of theory (Chang and Ive, 2002). However, in the MAUA, the decision maker is faced with a multi-attribute pay off decision tree theory rather than a single - attribute pay off (monetary unit) decision tree of the betting game. The MAUA is developed where the expected utility of choice j is determined by:

$$Uj = \sum_{i=xi}^{n} wij\, xi \quad \text{(Chang and Ive, 2002)} \qquad (1)$$

where xi is the value given to the attribute i of a utility function decided by the decision maker's subjective evaluation and wij are the utility coefficients relating attributes to options (Chang and Ive, 2002). Fellows *et al.* (1983) opined that, the MAUA could be used as a tool to measure objectivity in an otherwise subjective area of management. The MAUA is regarded as the foremost technique appropriate for examining the criteria of clients and the preferences of expert's weight for each procurement method in the most objective way (Love *et al* 1998).

As applied to construction management it involves four steps (Chang and Ive, 2002):

- Identification of priority variables (i.e., criteria)
- Fixing the utility factors by experts relating achievement of priority variables as outcomes to procurement routes.
- Determination of relative importance attached to each criterion
- Summing up the weighted priority variable of each procurement route and choosing the one with highest score.

Chan (1995), Love *et al.* (1998) and Ambrose and Tucker (2000) all used the idea of MAUA to develop models to aid practitioners select the most appropriate procurement system. Out of the multi-criteria decision methods, the multi-attribute utility approach was considered in this work for its relatively simple application.

RESEARCH METHODOLOGY

The database needed to populate PROMA was captured through a questionnaire survey administered on clients, consultants and contractors in Lagos and Abuja, Nigeria in 2006. Client (public and private), consultants were asked to identify the selection criteria necessary to choose a procurement method. The selection criteria were, speed, cost certainty, time certainty, price competition, quality, risk avoidance (in the event of time slippage) and risk avoidance (in the event of cost slippage). The respondents were asked also to prioritize these selection criteria based on the type of building and cost.

The project types were residential, offices and commercial buildings. The cost was categorized into N10 million (Naira) - N100 million (Naira), N101 million (Naira) - N500 million (Naira) and above N500 million (Naira). Respondents were asked to prioritize the selection criteria using a 5- point scale; 1- "not important", to 5- "very important". The reliability of the five - point Likert scale was tested using Cronbach α of the SPSS package at 5% significant level. Also Kendall's coefficient of concordance test was used to determine the degrees of agreement of rankings within groups.

In addition, clients, consultants and contractors were asked to indicate the performance of procurement methods against the selection criteria. A rating of 1- meaning, low suitability in achieving a selection criterion and 10 - meaning, very high suitability in achieving a selection criterion by a procurement method based on cost categories was used. The procurement methods rated were those common in Nigeria, such as design - bid-build, design-build system, management contracting, direct labour system and Build - Own - Operate - Transfer (BOOT). It should be noted that, the results of the prioritization by the clients were published in Ojo (2009a) while the bench-mark performance of the procurement options against selection criterion were published in Ojo (2009b).

PROMA - development tool: A computer application software known as "PROMA" was written to assist construction industry's practitioners in making analytical decision about building procurement options. It uses the weighted sum model equation as in equation 1which is coded using the C^{++} programme language. For its operation, it uses data stored in an external database file that is created and accessed using the SQLite embedded database engine.

The system: The database used is composed of five different modules:

- **Selection criteria:** contains the names of the different selection criteria
- **Respondents:** contains the names of different classes of respondents
- **Project cost:** contains the description of the various project cost
- **Procurement method:** contains the names of the different procurement methods
- **Full data set:** contains the values specific to each class of respondents and project cost required for calculating the weighted sum

Fig. 1: Weighted Sum interface (the various headers have been maximized for better viewing)

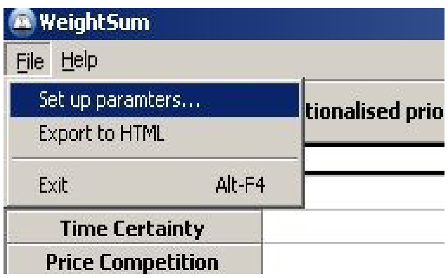


Fig. 2: Starting the parameter setup wizard

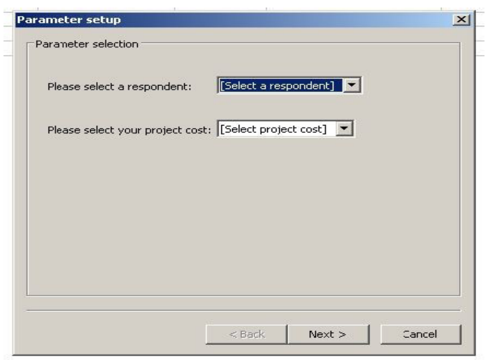


Fig. 3: The parameter setup wizard first page

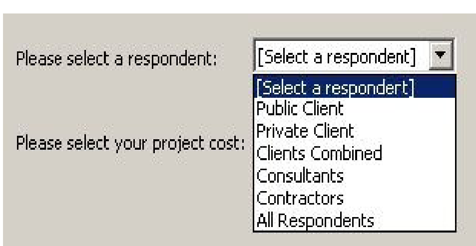


Fig. 4: Respondents selection

when the program launches the user is presented with this interface as in Fig. 1 which contains seven different criteria that the user is expected to assign importance to:

Fig. 5: Project cost selection

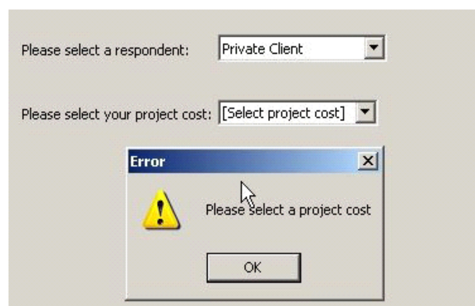


Fig. 6: Result of an invalid selection

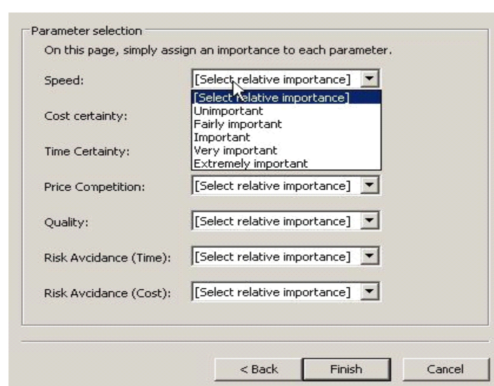
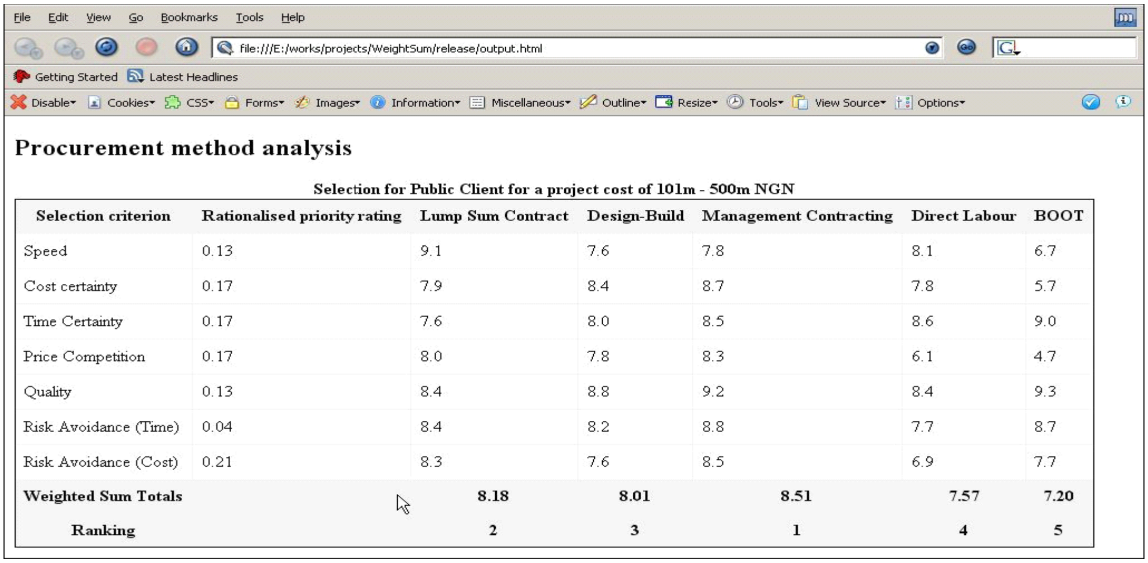


Fig. 7: Importance values to assign to selection criteria

- Speed
- Cost certainty
- Time certainty



Procurement method analysis

Selection for Public Client for a project cost of 101m - 500m NGN

Selection criterion	Rationalised priority rating	Lump Sum Contract	Design-Build	Management Contracting	Direct Labour	BOOT
Speed	0.13	9.1	7.6	7.8	8.1	6.7
Cost certainty	0.17	7.9	8.4	8.7	7.8	5.7
Time Certainty	0.17	7.6	8.0	8.5	8.6	9.0
Price Competition	0.17	8.0	7.8	8.3	6.1	4.7
Quality	0.13	8.4	8.8	9.2	8.4	9.3
Risk Avoidance (Time)	0.04	8.4	8.2	8.8	7.7	8.7
Risk Avoidance (Cost)	0.21	8.3	7.6	8.5	6.9	7.7
Weighted Sum Totals		**8.18**	**8.01**	**8.51**	**7.57**	**7.20**
Ranking		**2**	**3**	**1**	**4**	**5**

Fig. 8: The exported HTML document in a web browser

- Price competition
- Quality
- Risk avoidance (time)
- Risk avoidance (cost)

The name of each of those criteria is stored in the database in the selection criteria table. This database can be modified independently of the program and it will make use of any changes in the database.

Also there are five different procurement methods already stored in the database:

- Lump sum contracts
- Design-build
- Management contracting
- Direct labour system
- BOOT

To begin using the program, the user selects set-up parameter from the file menu as in Fig. 2.

This action starts the parameter set-up wizard which enables the user to enter the various parameters for his particular requirement. This is displayed in Fig. 3.

The user is requested to enter what kind of respondent utility factors he wishes to use as in Fig. 4.

Then after, the user is requested to select the estimated cost of project in millions of Naira as in Fig. 5.

It is important to note that, it is not possible to select the first items in each of the combo boxes in the wizard as there will be an error message, should the user try to proceed with an invalid selection as shown in Fig. 6.

Once the respondent and project cost are recognized as valid values, the user can then progress to the next page as displayed in Fig. 7.

Table 1: Sample priority rating

Criterion	Rationalized priority rating
Speed	3÷26 = 0.12
Cost certainty	2÷26 = 0.07
Time certainty	5÷26 = 0.19
Price competition	4÷26 = 0.15
Quality	5÷26 = 0.19
Risk avoidance (Time)	4÷26 = 0.15
Risk avoidance (Cost)	3÷26 = 0.12

For each of the aforementioned selection criteria, the user is requested to attach an importance value for each criterion. It was decided to use descriptive rather than numeric importance values because the descriptions are easier to decipher. However, each importance value is converted to a number between 1 and 5 with “Unimportant” having a value of 1 and “extremely important” having a value of 5. These values are converted to rationalized priority ratings used for the weighted sum calculations. The rationalized priority ratings are computed thus: each criterion numeric equivalent is divided by the sum of all importance attached to a criterion. For example, if a user selected value as “important” (3), “fairly important” (2), “extremely important” (5), “very important” (4), “extremely important” (3), in that order, the sum of the equivalent would be 3+2+5+4+5+4+3 = 26.

The rationalized priority rating for each criterion is calculated as in Table 1. After this, the user clicks “Finish” to populate the table with the utility factors data retrieved from the database for each class of respondents. This is then multiplied by the criterion’s rationalized priority rating and added to a running total. For example, for a user who chose public client’s utility factors and project cost of N101 million - N500 million for a rationalized priority rating of Fig. 8.

The weighted sum for lump sum contracts is calculated thus:

$$(0.13\times9.1) + (0.17\times7.9) + (0.17\times7.6) + (0.17\times8.0) + (0.13\times8.4) + (0.04\times8.4) + (0.21\times8.3) = 8.18$$

This is calculated for all procurement options as in Fig. 8 and rankings are assigned, the "best in class" is ranked 1 and "least in class" as 5. Once the parameter set up is completed the user can export it as a Hypertext Markup Language (HTML) document for printing by selecting File - export to HTML

CONCLUSION

PROMA utilizes seven selection criteria identified in the Nigerian context as influencing the choice of a procurement method and the weighted sum model. Also it uses the benchmark performance derived from the respondents' rankings of suitability of procurement options on each selection criterion. Hence, the user has the option of using the clients', consultants', contractors' utility factors or the combined utility factors. The utility factors of PROMA were for cost categories. This approach makes PROMA better and cost specific than earlier works which ignored the effect of cost category on procurement options' performance. PROMA after consultation recommends the procurement options in the order of appropriateness. But it depends on the user to accept the most appropriate depending on the reasonableness of the recommended procurement option to the user's organizational structure.

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