A Decision Support System for the Selection of Best Procurement System in Construction

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Abstract

The procurement system is a key means through which the client creates pre-conditions for successful achievement of project specific objectives. Wrong selection of procurement system generally leads to project failure and client dissatisfaction. Therefore, a systematic and realistic approach for the selection of the best procurement system is critical to the success of any project to achieve the clients' ultimate goals. As far as Sri Lankan construction industry is concerned, the practice of procurement selection is rather unstructured and ad hoc. Therefore, a realistic and consistent approach is essential to aid the clients in selecting the most appropriate procurement system. This paper presents a Decision Support System developed for the procurement selection based on Multi Attribute Utility Technique. Four rounds of Delphi surveys were carried out to investigate the most significant factors and their level of influence on various construction procurement systems. From the third and fourth round of Delphi, utility values for each factor against various procurement systems were derived. Based on decisive factors and the utility values derived form the survey, a multi-criteria model was developed. The special feature of the model is the inclusion of a set of exclusive selection criteria at macro level and wide range of various procurement options. The outcome of the model was evaluated for its applicability and efficiency with the use of multiple case studies and an expert opinion survey. Finally, the evaluated model was further enhanced to a Decision Support System. The model has the potential to assist the clients/their consultants and it seeks to overcome any inconsistency in the effective decision making process.

Introduction

The construction industry is one of the backbones of the economy of many countries. Industry-wide studies on the performance of the construction industry (NWPC, 1990; Latham, 1994; Egan, 1998) have pointed to some key improvement areas, one of which is the use of an appropriate procurement method. Since the construction procurement determines the overall framework and structure of responsibilities and authorities for participants within the construction process, it is a key factor which contributes to achieve the overall strategic goals of the client and project success. The selection process of procurement systems has become increasingly complex, mainly as a result of the continuing proliferation of alternative methods for procuring building projects, their ever increasing technical complexity and clients' continuing desire for speedy commencement and completion, all of which have led to the demand for more sophisticated methods of selection being devised. In addition, due to fragmented and complex nature of construction projects, there is no fixed metod of dealing with procurement, as often they are different in scale, complexity and nature. In choosing which procurement system to apply, there is a need to take into consideration various factors from the internal and external environment in the operatinal area of the project and industry. A variety of factors have to be taken into account before any practical decisions can be made. Several researchers have strived to develop a systematic approach for procurement system selection (NEDO 1985; Skitmore and Mardson, 1988; Masterman, 1992; Chan et.al., 2001; Cheung et.al., 2001; Luu et.al., 2003). Among the various models, Multi Attribute Utility Technique (MAUT) has received the greatest attention.

The Sri Lankan construction industry has not developed in quite the same way as that of other developing countries during the past decades. The current review of the trends of project procurement systems used in Sri Lanka reveal that the Measure and Pay is the dominant system and usage of alternative procurement system is underprivileged compared to other developing countries. The popularity of Measure and Pay is mainly due to the Government influence on the construction industry of Sri Lanka. As a major client and the regulator, the Government has not taken initiative for the development of alternative procurement methods (Shiyamini et al, 2005). In addition, the practice of procurement selection is rather unstructured and ad hoc. There is no systematic and realistic approach used to select an appropriate system for a particular project. Therefore, identification of significant factors affecting the selection of procurement system and development of model for a realistic selection process is essential to the success of any type of project. In this context, the primary aim of this study on construction procurement was to investigate factors affecting the selection of procurement system and development of Decision Support Model for construction clients/their consultants to assist them in initial decision making on procurement

selection which is capable of increasing client's satisfaction while removing unnecessary influence of individuals involving procurement system selection on behalf of clients.

Research Methodology

The attempt to develop such a Decision Support System is based on the review of alternative approaches developed over the past decade and the current practice of procurement selection in Sri Lankan construction industry. Multi Attribute Utility Techniques (MAUT) were employed for the development of the model which is to be used as a decision making tool for best procurement system selection in construction. The use of MAUT can minimize the subjective elements that tend to predominate in the decision making process and can increase transparency (Shen *et al.*, 1998). In this study, MAUT was used to integrate both priority ratings and the utility values derived from the respective factors. It focuses on the development of a MAUT based selection model that is construction project procurement selection specific. The model was developed using the results derived from four rounds of Delphi survey. Delphi method is a highly formalized method of communication that is designed to extract the maximum amount of unbiased information from a panel of experts (Chan *et.al.*, 2001). Therefore, it was considered appropriate to adopt the Delphi technique which targeted to identify & analyze the decisive factors affecting the selection of procurement systems and attain the utility values for each factor against various procurement systems. The steps involved in carrying out the study were:

(1) determination of key selection criteria at macro level;

(2) determination of wide range of procurement systems;

(3) collection of utility values for each criteria against various procurement systems; and (4) collection of selection criteria weightings. Delphi and MAUT techniques were used to facilitate a more systematic and logical approach in the selection process, hence improving objectivity and reducing subjectivity in decision making.

Alternative Approaches to Procurement Selection: Literature Review

According to Masterman (1992), the practice of procurement selection is rather unstructured and ad hoc. One of the pertinent questions is that, in reality does the client or his representative use a structured model for procurement selection? Several procurement selection systems have been developed to help the clients to choose the most appropriate procurement systems, ranging from simple rating systems (Franks, 1990) to highly complex systems such as multi-attribute and matrix based systems (Skitmore and Marsden, 1988; Liu, 1994). However, in all of the models there is always a need to input the specific characteristics of client, project and possibly procurement process features that are subjective based on the point of view of the user. Further, it is strategically important to make sure that the selection is done systematically and in a closely controlled manner. Table 1 summarizes the review of alternative approaches to procurement selection and their basic methodology developed over the past two decades.

Among these models, Multi Attribute Utility Technique (MAUT) received the greatest attention. Chang and Ive (2002) discussed some of the inherent problems of using MAUT for procurement selection. One of the strongest criticisms was the selection of procurement variables. The other is the utility value developed through opinions of industry experts. Particularly they are critical about the subjective nature of assigning values to procurement selection parameters to obtain mean utility values. The main difficulties common to these alternative approaches developed during the past two decades could be pointed out as follows;

- All models failed to include some important factors based on main criteria for the selection of most appropriate procurement systems. Some of the models only include limited number of criteria based on client's requirements and certain models consider limited number of client's requirements and project characteristics.

- The available procurement systems included in the existing models are limited. Certain models seem to ignore the variants of the main categories of procurement systems. Some of the other models include limited number of variants of main categories.

- Some models are conditional and cannot be used by any client (Alhzmi and McCaffer, 2000).

- Some of the models require the use of advanced mathematical techniques, which are considered to be time consuming (Alhzmi and Mccaffer, 2000).

- Some of the models require the use of advanced computer packages, which can not be used by all the clients/consultants.

- A number of existing models adopt a primitive approach to the selection process and limit the number of options to be considered (Alhzmi and McCaffer, 2000).

Table 1: Review of alternative approaches to procurement selection

Author	Year	Description of Alternative Approaches
NEDO	1985	Rating system using a client's priority for nine key areas
Skitmore and Marsden	1988	Two systems: a multi-attribute model based on the NEDO model with a rating system and weighting of client priorities; and a discriminate analysis technique utilizing variances in procurement characteristics under certain criteria.
Brandon *et al.*	1988	A computer expert system called ELSIE, which determined suitable procurement systems, based on project characteristics and client requirements.
Franks	1990	Simple rating system based on client's performance requirements.
Singh	1990	Two systems: a multi-attribute model based on the NEDO model with a rating system and weighting of client priorities; and a discriminate analysis technique utilizing variances in procurement characteristics under certain criteria.
Bennett and Grice	1990	System based on the NEDO and Skitmore and Marsden models and allows clients to weight specific criteria multiplied by set utility ratings for the various systems.
Mohsini	1993	A knowledge-based expert system (project acquisition strategy consultant), which starts by establishing the project characteristics and the client's posture towards project control and risk taking
Gordon	1994	Three drivers of project, owner, and market as well as a risk-allocation analysis and a commodity versus service analysis, to guide the clients into using an appropriate procurement method.
Liu	1994	An organizational behaviour-based model utilizing an act-to-outcome process governed by organizational goals, which in turn are subject to moderators, which determine goal/performance relationship.
Chan *et al.*	1994	A model utilizing the Bennett and Grice model, but uses a different procurement category developed for the Australian construction industry.
Love	1996	A systematic first-principle analysis
Love *et al.*	1998	A procurement path decision chart, which allows clients to weight a simple set of criteria based on clients' requirements multiplied by set utility ratings for the various systems.
Dell'Isola *et al.*	1998	Decision matrix-based model that rates the performance of each procurement system for selected issues and their relative importance on a client/project profile.
Ambrose and Tucker	1999	A three-dimensional interaction matrix that provides a procedure to evaluate the appropriateness of a procurement system for a particular project and the needs of the client.
Alhazmi and McCaffer	2000	A Project procurement system selection model which is an integration of Parker's judging alternative technique of Value Engineering and Analytical Hierarchy Process (AHP)
Chan *et al.*	2001	A multi attribute model, which allows clients to weigh a set of exclusive criteria multiplied by set utility ratings for limited number of procurement systems.
Cheung *et al.*	2001	A procurement selection model based on multi-attribute utility technology with the use of Analytical Hierarchy Process (AHP) to determine the importance weightings of the selection criteria basedon client requirements.

Against this background, the present study has attempted to develop a selection model by which most of the difficulties pertaining to the existing models could be overcome by the end user.

Formation of Procurement Selection Criteria

A set of exclusive selection criteria at macro level has been established from this study based on the Sri Lankan context. Delphi technique was adopted to ascertain the set of selection criteria and the utility values for each selection criteria against a wide range of various procurement systems. Altogether, four rounds of Delphi survey were conducted. The Delphi technique has demonstrated to be powerful and appropriate technique to achieve these tasks by deriving objective opinions in a rather subjective area. The synthesis of the outcomes of the previous studies related to procurement selection seems to neglect some of the significant factors from key selection criteria. Therefore, this study has focused on the selection criteria in terms of client requirements, project characteristics, and external environment, thus ensuring that the selection criteria have been focused at macro level. The results of factor analysis revealed nine significant factors from client requirements,six factors from the project

Table 2: Significant selection criteria and their level of Significance Selection Criteria

	Selection Criteria	Significance level
CLIENTS' REQUIREMENTS	Risk management	0.0000
	Time availability and predictability	0.0000
	Price certainty	0.0000
	Price competition	0.0000
	Accountability	0.0000
	Flexibility for changes	0.0000
	Quality of work	0.0000
	Responsibility and Parties involvement	0.0399
	Familiarity	0.0000
PROJECT CHARACTERISTCIS	Project cost and Funding method	0.0000
	Project complexity	0.0000
	Project type	0.0000
	Time constrains	0.0000
	Degree of flexibility	0.0000
	Payment modality	0.0000
EXTERNAL ENVIRONMENT	Market competition	0.0000
	Economic condition and the fiscal policy	0.0120
	Technology	0.0000
	Socio cultural suitability	0.0210
	Regulatory environment	0.0000

characteristics and five factors from the external environment. Each factor derived from factor analysis was carried to the third and fourth rounds which targeted to attain the utility values for each significant factor against various procurement systems. Table 2 shows the final set of exclusive selection criteria and their level of significance derived from the fourth round of Delphi.

The synthesis of the survey results revealed that all the factors have remarkable influence on the selection process and factors from client requirements and project characteristics significantly influence the selection compared to external environmental factors. Based on the decisive factors identified and utility values derived from the fourth round of Delphi, a Multi Attribute Utility Model was developed and it was enhanced into a Decision Support System.

Decision Support System (DSS)

Main objective of designing such a DSS is to assist a user-friendly environment for intelligent and informed decision making for construction procurement selection. Additionally, the DSS facilitates the following:

- Ensures systematic and consistent approach for procurement selection through the application of relevant research methods
- Assists construction clients in the initial decision on making an appropriate procurement selection for any kind of building project.
- Provides better understanding on selection criteria which influence the procurement selection and various types of traditional as well as alternative construction procurement systems in practice.
- Provides report on ranked list of procurement systems

The model was designed for construction clients and/ or their consultants/principal advisers, particularly those who use an unrealistic method to select the procurement system and are responsible for the selection process. Primarily, this model guides how to select an most favorable procurement system for a particular type of building project. This model not only considers the requirements of clients and project's profile but also the impact of external environment on procurement selection. In this way, it will be possible to ensure that the project is procured in an efficient and effective way that adds value for the client.

Model Development

Development of the model consists of two main phases: Design phase and Development phase. Designing phase of the model was further considered in two processes:

Conceptual designing and Information modeling. Conceptual design demonstrates the principles of the model while information model deals with the contents of the model. Conceptual design illustrates basic concepts behind procurement selection, which is based on secondary data collected through literature and results from Delphi survey carried out in four rounds. Figure 1 illustrates detailed design of conceptual framework for project procurement selection model.

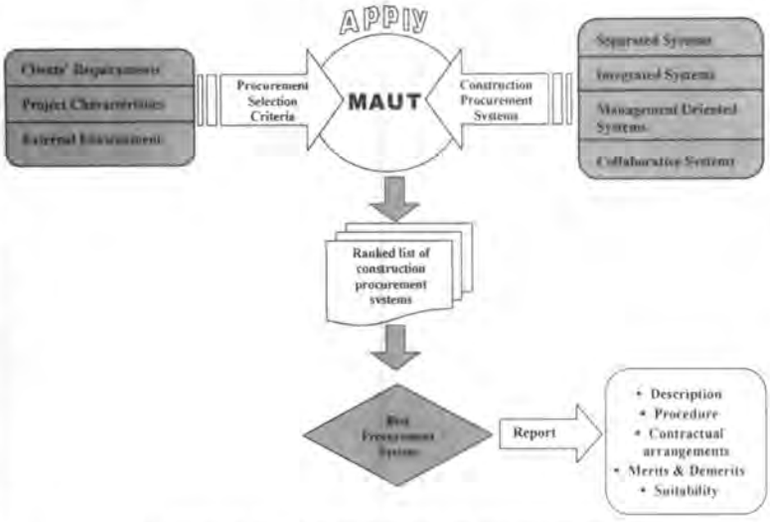


Figure 1: Detailed design of conceptual framework for the model

The steps involved in developing the contents of the model are:

(1) Determination of selection criteria;
(2) Determination of various procurement systems;
(3) Collection of utility values; and
(4) Collection of weightings for each selection criteria.

Step 1 and Step 3 were achieved using Delphi technique and the Step 4 was achieved using interviews with project's client or consultants. The clients' weights determine the relative importance of each criterion on a scale of 1-5. This relative importance score is termed as priority rating. Finally the MAUT was applied to achieve the selection procedure in a systematic and disciplined manner.

The Object Oriented Information Model

Information modeling which is the logical representation of information, simply defines procedures, which must be followed, and data required to achieve user requirements. There are two main techniques of information modeling, viz: Structured approach and Object oriented approach (Ramakrishnan and Johannes, 2004). The object oriented approach was used to develop the information model as it was developed to imitate a more natural way of defining systems than that is offered by the structured approach. This method provides greater flexibility and reusability, furnishing a components based programming framework (Rumbaugh *et al.*, 1991; Booch, 1991). The Unified Modeling Language (Beaumont, 2005; Collins, 2005) standard notations were used to express the content of the information model generated. The object-oriented model developed for the procurement selection is depicted at Figure 2.

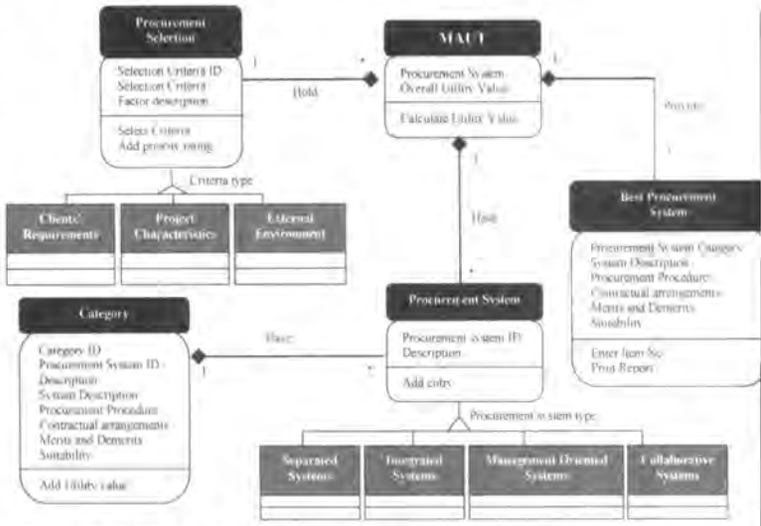


Figure 2: Object oriented model for procurement selection

Object models symbolize the entities and their relationships. Model consists of five classes as follows;

1. **Procurement selection class** (contains *selection criteria ID* and *selection criteria*)
2. **MAUT class** (contains *procurement system ID* and *overall utility value*)
3. **Procurement system class** (contains *procurement system ID* and *description*)
4. **Category class** (contains *category ID, procurement system ID, description, system description, procurement procedure, contractual arrangements, merits & demerits* and *suitability*),
5. **Best procurement system class** (contains *procurement system category, system description, procurement procedure, contractual arrangements, merits & demerits* and *suitability*).

The methods "Add entry", "Add priority rating", "Select criteria", "Add utility value", "Print report" and "Calculate overall utility value" are the tasks or process carried out by the system.

Application of MAUT

MAUT is a methodology that may be used as a tool for measuring objectivity in an otherwise subjective area (Fellows *et al.*, 1983). Procurement system is the overall managerial approach by which a client commissions and obtains a building. MAUT is an attempt to apply a quantitative decision method to the context of construction procurement route selection, so as to provide clear normative advice for improving the quality of clients' decision-making (Skitmore and Marsden, 1988; Chan, 1995; Love *et al.*, 1998; Ambrose and

Tucker, 2000). Therefore, Multi-Attribute Technique was considered to be the foremost technique appropriate for examining the main selection criteria & their variables and the preferences of experts' weights for each system in the most objective way. In this study, MAUT is used to integrate both priority ratings and the utility values derived from the respective factors. An example for the application of MAUT for the project procurement selection is portrayed in Table 3 (A part of the model).

Model evaluation

Next stage was the evaluation of the practical use of the model to ensure the consistency and soundness of the model. Multiple case studies in a sampling of 44 building projects and unstructured interviews with selected clients/consultants from the industry were conducted to test the practical use of the model. These case studies demonstrate how this model could be applied in reality to come up with the best procurement systems for various types of building projects. Altogether, 44 case studies on actual projects were carried out to validate the contents and evaluate the applicability of the model. The results of the model were compared with the actual procurement system adopted to each project selected. The actual procurement systems used for selected projects include thirty seven 'Traditional Measure and Pay', one 'Traditional Lump Sum', five 'Design and Build' and one 'Turn key', suggesting a seemingly dominant use of the Traditional Measure and Pay system. Out of the 44 case studies conducted, there were 31 (70%) matching results and 13 (30%) non-matching results observed. Even though the selection practice of construction procurement is rather unstructured and ad hoc, the results revealed from the model demonstrates that 70 % of the results tally with the procurement system already adopted. Therefore, it can be stated that the applicability of the model is efficient in the Sri Lankan industry.

Development of DSS

DSS development based on evaluated model consisted of three main phases: Database development, System interface development and System testing. These are explained in detail in the following sections.

Database development

A database is a collection of data, which provides meaningful information. It facilitates data integrity, consistency and independence and reduces redundancy. DSS database uses structure of relational model as it provides ability for end users to create and change the records in the database in a user-friendly process (Lonnie and David, 1997). Moreover, many standard software packages facilitate development of relational databases. Relationships among entities of DSS are illustrated in the object oriented model given in Figure 2. There are various software programmes available for database development such as Oracle, Microsoft SQL and IBM™ DB compatible with Java development. Microsoft™ Access 2000 was used for the development of database in this DSS.

System interfaces

System interfaces were developed using Java programming language, which incorporates certain features such as polymorphism and inheritance, illustrated at object oriented framework for procurement selection. Java development environment offers certain

Table 3: Illustration for the use of Multi Attribute Utility Model

	SELECTION CRITERIA	Client's Priority rating	Utility values										
			Separated			Integrated					Management Oriented		Collaborative	
			M & P	LS	PC	D & B	PD	TK	D & C	PFI	CM	MC	Part	JV
	Clients' Requirements													
1	Risk Management	5	62.83	81.74	55.06	77.83	69.57	81.43	57.83	57.17	61.09	63.48	71.30	69.57
			314.15*	408.7	275.3	389.15	347.85	407.15	289.15	285.85	305.45	317.40	356.50	347.85
2	Time Availability & Predictability	5	58.83	60.00	65.00	82.17	81.30	84.13	61.96	54.35	63.09	63.50	57.78	56.52
			294.15	300.00	325.00	410.85	406.50	420.65	309.8	271.75	315.45	317.50	288.90	282.60
3	Price Certainty	5	66.41	95.43	43.70	82.83	76.71	86.96	58.48	54.35	60.43	58.57	50.57	52.74
			332.05	477.15	218.50	414.15	383.55	434.80	292.40	271.75	302.15	292.85	252.85	263.70
4	Price Competition	3	93.26	82.83	69.57	64.57	62.35	51.74	49.45	42.96	64.13	59.57	42.61	58.04
			279.78	248.49	208.71	193.71	187.05	155.22	148.35	128.88	192.39	178.71	127.83	174.12
5	Accountability	2	89.13	76.30	84.57	57.17	56.52	51.09	57.7	54.48	72.98	70.13	69.78	70.26
			178.26	152.6	169.14	114.34	113.04	102.18	115.4	108.96	145.96	140.26	139.56	140.52
6	Flexibility for Changes	4	95.43	38.70	78.70	51.96	50.87	38.48	56.3	51.30	71.70	68.48	70.22	66.04
			381.72	154.80	314.80	207.84	203.48	153.92	225.20	205.20	286.80	273.92	280.88	264.16
7	Quality of Work	5	77.61	72.17	67.00	67.78	64.57	59.70	62.74	57.57	78.35	78.35	75.82	76.30
			388.05	360.85	335.00	338.90	322.85	298.50	313.70	287.85	391.75	391.75	379.10	381.50
8	Responsibility & Parties Involvement	5	67.87	70.13	60.43	72.09	67.39	74.35	68.91	68.08	70.57	69.74	69.35	71.09
			339.35	350.65	302.15	360.45	336.95	371.75	344.55	340.4	352.85	348.7	346.75	355.45
9	Familiarity	3	97.83	90.00	73.17	72.61	57.61	59.13	54.83	47.10	43.04	42.09	33.48	36.74
			293.49	270.00	219.51	217.83	172.83	177.39	164.49	141.3	129.12	126.27	100.44	110.22

M & P – Measure & Pay, LS –Lump sum, PC – Prime Cost, D & B – Design & Build, PD – Package Deal, TK – Turnkey, D & C – Design & Construct, PFI – Private Finance Initiative, CM – Construction Management, MC – Management Contracting, Part – Partnering, JV – Joint Ventures

* utility value

benefits for this kind of purposes such as faster development, reusability, increased quality, modular architecture, better mapping of problem domain and client/ server applications (Adhikari, 1995; Taylor, 1990).

There are four user interfaces including main and sub menu that work with DSS, details of which are discussed below:

1. Main menu
2. Construction procurement selection criteria and the priority level entry form
3. Ranked list of procurement systems
4. Report on selected procurement system

Main menu

This is the pathway to the DSS. It consists of five main menus and certain main menus possess some sub menus. Main menu of DSS comprises certain components as depicted in Figure 3.



Figure 3: Main Menu of the DSS

This illustrates five options:

- **About :** Provides introduction to DSS and its special features
- **Help** : Guides the end user, how to use the model
- **Selection:** This is the main component of DSS, which enables the end user to consider important selection factors at macro level and to give the priority rating according to the client's specific requirements, project characteristics and influence of external environment.

- **Ranked list**: Provides a ranked list of procurement systems, which assists the end user in initial decision making to select appropriate procurement options for his/her project.
- **Cost :** Provides understanding of true cost saving in each procurement option
- **Exit:** Allows exit from the system.

Construction procurement selection criteria and the priority level entry form

This form (Figure 4) facilitates the end user to provide inputs to the system. This form is used to consider the selection criteria and enter priority ratings for individual projects. The main components of the input screen are clearly explained below.

A. Considers key selection criteria
eg.: Client's requirements, Project characteristics, External Environment
B. Determines the factors which influence the selection of procurement for the particular project.
C. Provides description for each selection factor
D. Assigns priority rating to each factor (weightings 1-5)

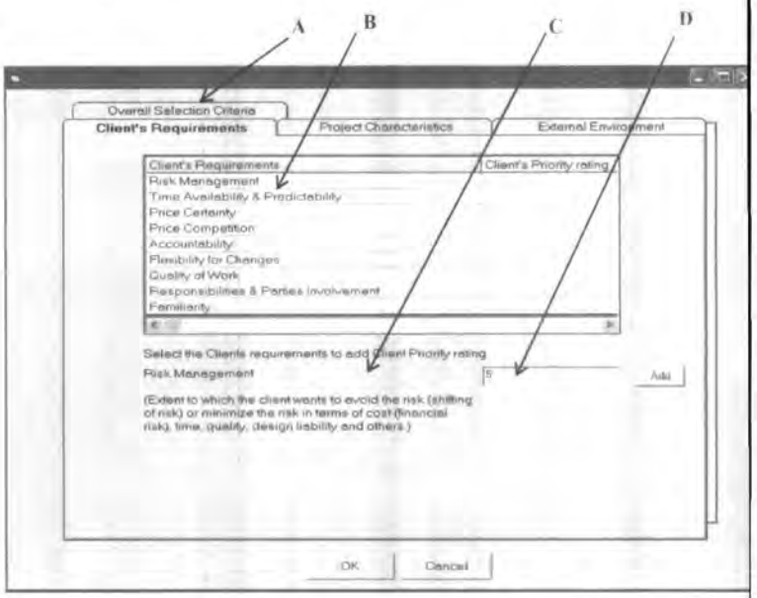


Figure 4: Priority level entry form

Ranked list of procurement systems

This form (Figure 5) provides ranked list of best procurement systems for given project.

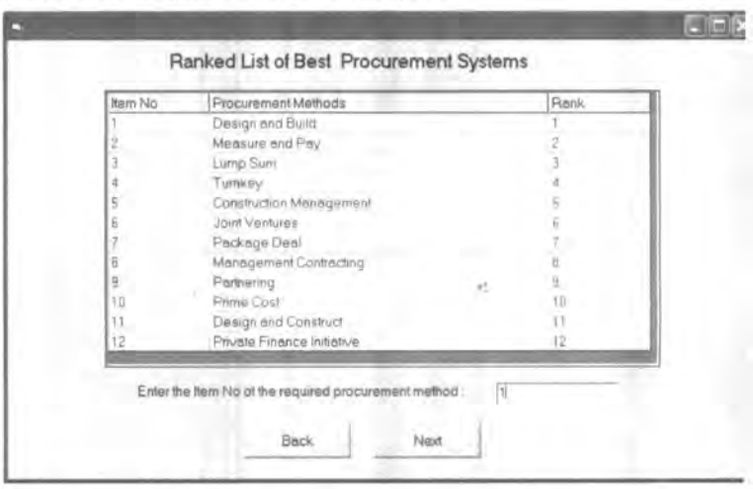


Figure 5: Ranked list of procurement systems

This facilitates the selection of an appropriate procurement system from the ranked list of procurement options. The end user gets the idea of suitable procurement system according to their order of frequency.

Report on selected procurement system

This form provides on screen or printed form of report on selected procurement system. The report consists of the following;

- Description for the system
- Procedures associated with the respective systems
- Contractual arrangements of the system (Relationship between parties involved)
- Merits and demerits of the system
- List of suitable projects which can be procured through the selected procurement system (Examples from industry practice)

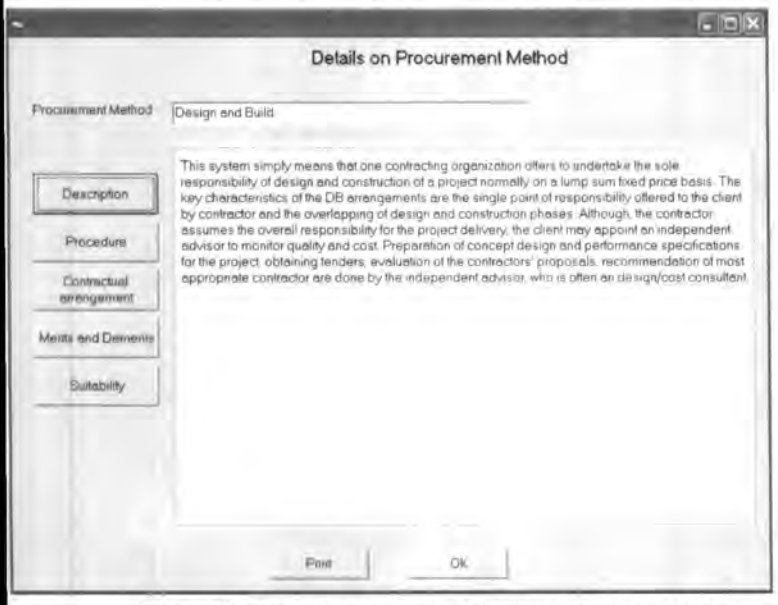


Figure 6: Report on selected procurement method - Description

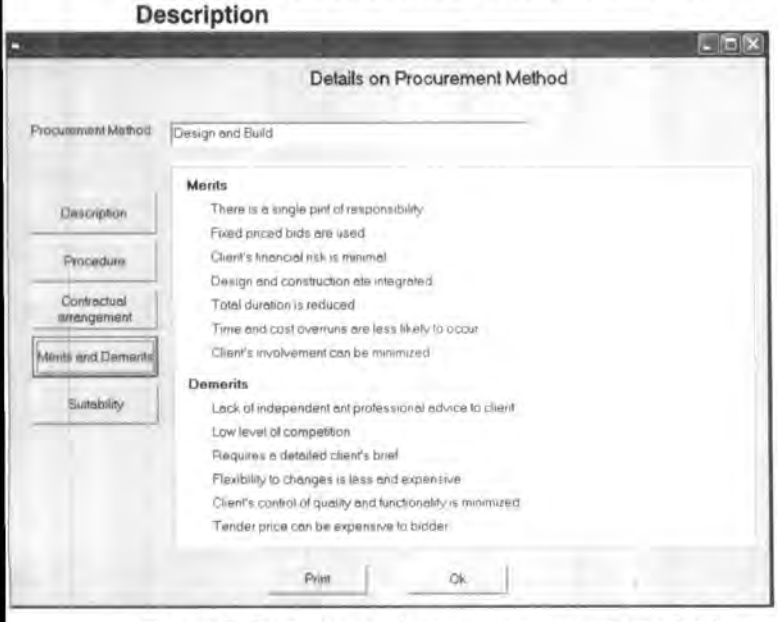


Figure 7: Report on selected procurement method – Merits and Demerits

The main objective of this report is to provide more information on the selected procurement method, in particular to the clients who lack knowledge in alternative procurement systems. Above Figure 6 and Figure 7 illustrate details on the *'Design and Build'* procurement system. They depict the description of the system and merits & demerits of such system respectively.

System testing

The purpose of the system testing is to validate the accuracy and applicability of the developed system. The DSS prototype was tested in two stages by using sample data and actual data. In the first stage, it was tested by using hypothetical cases to validate the development process. Then the model was tested with actual scenarios developed by results extracted from the industry-based case studies to verify accuracy. If the DSS to be implemented as an industry software, it should be developed further by the use of same software programmes or any other to make it a fully functional software. Since at present it is a prototype in which most interfaces are saddled with default outputs.

Evaluation of DSS: review of expert opinion survey

The objective of the expert opinion survey was to verify the acceptability and efficiency of the model and DSS through experts' opinion. The survey was conducted among industry experts who posses experience in procurement and those who are familiar with IT applications. Information was elicited through semi structured interviews, demonstrations, and discussions as such methods provide openness to an interviewee (clients/consultants/principal advisers) to express genuine opinion, feeling at ease. Table 4 presents the review of the results of expert opinion survey.

Table 4: Review of expert opinion survey

DSS for Construction Procurement Selection	
Criteria	**Expert opinion**
General view	• Since the procurement selection practice is rather un-structured and ad hoc, development of a systematic and consistent model is well appreciated • It will assist building clients in initial decision making • It is construction procurement specific, therefore, will perform its superior function to industry practice. • The 'help' menu of the system assists clients who are not experienced in IT, how to use this system
Shortcomings	• Clients who are not familiar with IT may face difficulties in making use of this model. • It does not give any indication on cost aspects of procurement systems.
Suggestions	• Model should be flexible enough to include the further selection criteria and new procurement options to keep up with new developments in procurement. • Improve prototype to fully functional software.
Application of Research Methodology	
Delphi	• Delphi is suitable techniques to achieve the defined objectives of the author.
MAUT	• Since procurement system is overall managerial approach, MAUT is a relevant tool to make rather subjective matters of management into objective matters.

The author in consideration of certain views expressed by such experts makes following comments.

- Model will be updated at regular time intervals to keep it up-to-date to overcome tendencies of is olation.

- Although public sectors organizations cannot adopt this model due to policies imposed on procurement by the government, still it can be used as a base to improve or modify procurement polices.

- Model was designed, evaluated and developed based on results obtained by surveys and case studies conducted in actual construction projects. Therefore, it is more suitable for construction clients or their consultants/principal advisors.

- Although development of model to fully functional software is not within the scope of this research, enhancing the model up to that extent will provide more benefits to construction industry.

- The cost aspects of selected procurement system are not within the scope of the research due to time limitations.

Limitations of DSS

This DSS is subjected to following constraints and limitations:

1. Model contents restricted to nineteen selection criteria and twelve types of procurement systems, which were identified through the comprehensive Delphi survey conducted among experts in construction industry.

2. Model development and evaluation is restricted to buildings projects.

3. Model development is restricted to a scaleable prototype, which is only used for demonstration purposes of a real system. Therefore, most interfaces are saddle with default outputs.

4. Model provides reports on best procurement systems, but there is no flexibility for a user to query reports, as they would prefer.

5. The cost aspects of the selected procurement systems have not been incorporated in this model.

Conclusions

A Systematic and realistic approach for the selection of most suitable procurement system is critical to the success of any project, thus to achieve the clients' ultimate goals. This study has adopted the Delphi technique together with MAUT to develop a multiple decisive factor model for the selection of best procurement system in construction. These two techniques were used to facilitate a more systematic and consistent approach in the selection process, hence improving objectivity and reducing subjectivity in decision making. The Delphi technique was used to derive the utility values for each factor against various procurement systems. The special feature of this model is the inclusion of a set of selection criteria at macro level. The final selection model consists of a set of selection criteria in terms of clients' requirements, project characteristics & external environment, a set of utility values for each selection criteria and a broader categorization of procurement systems. This is useful for the construction clients and their consultants who often involve in procurement selection by the quickest and ad hoc methods without being fully aware of the factors and various procurements options. As envisaged, the model will make clients and their consultants/principal advisers aware of the needs to take into account multiple factors and various procurement options before selecting a procurement option and a set of selection criteria at macro level is specifically defined to achieve that. The application of the model seeks to overcome any inconsistency in the effective decision making process due to the influence of individuals and other external factors and has the potential to assist the clients/consultants. The implementation of this model to aid procurement selection is advocated to place the clients in best possible position to select correct method of procurement for their projects at a particular circumstance.

Finally, the evaluated model was successfully enhanced into a Decision Support System (DSS) which allows users to make intelligent and informed decisions on selection of procurement routes for various building projects. DSS development herein is restricted to a scaleable prototype, which is only used for demonstration purposes of a real system. Evaluated model was enhanced to DSS with integration of new technology in two development phases which includes database and interfaces development. The expert opinion survey, which targeted to validate the model, revealed that the DSS provides assistance in initial decision-making on project procurement selection to all types of building clients of the construction industry. Since this DSS is a prototype, most interfaces are saddled with default outputs. DSS can be effectively used by the industry clients only through further development of a fully functional system.

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