SELECTION OF SUITABLE PROCUREMENT SYSTEMS IN CONSTRUCTION: A MULTI-CRITERIA DECISION SUPPORT MODEL

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ABSTRACT: The use and development of appropriate procurement systems helps to avoid problems and is the key to the attainment of project specific goals. A systematic and consistent approach for procurement selection is essential to achieve the project success and ensure value for the client's money. This paper presents a decision support model developed, based on Multi Attribute Utility Technique. Four rounds of Delphi survey were conducted to investigate the most significant factors and their level of influence on various procurement systems. The synthesis of the survey outcome revealed that client requirements, project characteristics together with factors from external environment are significantly influencing the procurement selection in Sri Lanka. The special feature of the developed model is the inclusion of a set of exclusive selection criteria at macro level and abundant procurement options. The outcome of the model was tested for its applicability and efficiency with the use of multiple case studies. The model has the potential to assist clients/their consultants and seeks to overcome any inconsistency in the effective decision making process on procurement selection.

Keywords - Construction Procurement, Decision Support Model, Procurement Selection, Selection Criteria, Sri Lanka.

1. INTRODUCTION

The fundamental issue of all procurement systems in construction is the development of framework which clearly establishes the roles, responsibilities and relationships of parties involved in a project. Construction procurement is a key factor which contributes to achieve the overall strategic goals of the client, thus to the 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 has led to the demand for more sophisticated methods of selection being devised (Masterman and Gameson, 1997). In addition, due to the fragmented and complex nature of construction projects, there is no one way of dealing with procurement, as often they are different in scale, complexity and nature. In dealing which procurement systems, there is a need to take into consideration various factors from the projects' internal and external environment in which the project and the industry operate. To establish procurement selection procedures, clients should formalize a set of suitable selection criteria based on their specific needs, objectives, project requirements and external environments.

With an increased awareness in the general benefits of alternative procurement systems, many clients now employ a variety of procurement systems for their projects. 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 project procurement system used in Sri Lanka reveals that the Measure and Pay is the dominant system and usage of alternative procurement system is less sophisticated 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. Government as a major client and regulator neglected the development of alternative procurement methods (Shiyamini et al, 2005). In addition, the practice of procurement selection is rather unstructured and ad hock. There is no systematic and realistic approach used to select a procurement system for a particular project. Therefore, there is a need for the exploration of alternative project delivery systems and the development of model for a realistic selection process. In this background, this paper has attempted to identify and analyze the significant factors influencing the selection of procurement systems in the Sri Lankan construction industry. A decision support model has been developed to assist the clients or their representatives (consultants) in initial decision making for selecting most appropriate procurement systems for any kind of building projects.

2. ALTERNATIVE APPROCHES TO PROCUREMENT SELECTION: LITERATURE REVIEW

The wrong selection of construction procurement approaches usually leads to project failure or general dissatisfaction of the client. Procurement selection therefore has received much attention from researchers in recent past. According to Masterman, (1992), the practice of procurement selection is somewhat unstructured and ad hock. 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 one, ranging from simple rating systems (Franks, 1990) to highly complex systems such as multi-attribute, 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. Whether such an approach is used for the selection is still doubtful. The following, Table 1, summarizes the review of alternative approaches to procurement selection and their basic methodology developed over the past two decades.

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	1998	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.

Table 1. Review of alternative approaches to procurement selection (Continued)

Author	**Year**	**Description of Alternative Approaches**
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 is 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 its relative importance on a client/project profile.
Tucker and Ambrose	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 weight 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 based on client requirements.

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 strongest criticisms was the selection of procurement variables. The other is the utility value developed through opinions of industry experts. In particular 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 include limited number of criteria based on client's requirements and some consider limited number of client's requirements and project characteristics.

- The available procurement systems included in the existing models are limited. Certain models failed to include the variants of main categories of procurement systems. Other models include limited number of variants.

- Some models are conditional and cannot be used by any types of clients (Alhzmi and Mccaffer, 2000).

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

- Some 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).

Against this background, this 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.

3. RESEARCH METHODS

The attempt to develop such a Decision Support Model is based on the review of alternatives approaches developed over the past decade and the current practice of procurement selection in Sri Lankan construction industry. It focuses on the development of a MAUT based selection model that is construction project procurement selection specific. The research methods adopted in this study include Delphi techniques, Multi-Attribute Utility Technique (MAUT), case studies and interviews. The steps involved in carrying out the study, are: (1) Formation of key selection criteria at macro level; (2) Determination of wide range of procurement systems; (3) Collection of utility values for each criteria against each procurement system; and (4) Collection of selection criteria weightings. Steps 1 and 3 were achieved by conducting four rounds of Delphi survey. The Delphi method is a highly formalized method of communication that was designed to extract the maximum amount of unbiased information from a panel of experts (Chan et. al, 2001). Therefore, it was considered that it would be appropriate to adopt the Delphi technique for this purpose. At the completion of the fourth round, utility values for significant factors were received against various procurement options which are commonly used in construction industry. All together 12 types of procurement systems from main four categories, were included in this model. Table 2 summarizes the formats of Delphi survey and the methods of analyzing the data collected from each round of Delphi.

Table 2. Formats of Delphi survey and Data analysis

	Round 1	**Round 2**	**Round 3**	**Round 4**
Instrument	Questionnaire 1	Questionnaire 2	Questionnaire 3	Questionnaire 4
Data base for Questionnaire	Literature review	Results from round one	Results of factor analysis carried out for round two results	Results from round three
Purpose	To gather a set of exclusive criteria for construction procurement selection	To identify the level of importance of each selection criteria	To assess the suitability of each factor against various procurement system	To reconsider and reassess the suitability of each factor against various procurement system
Duration	Two weeks	Eight weeks	Four weeks	Five weeks
Number of experts responded	35	35	30	25
Data Analysis		Calculation of: • Percentage of Responses • Weighted mean • Standard deviation • Severity index • Coefficient of variation and • Factor analysis for identified significant factors	Calculation of: • Average utility values • Concordance coefficient (w) & • Related level of significance	Calculation of: • Average utility values • Concordance coefficient (w) • Related significance & • Percentage improvement of utility values and level of significance

Multi Attribute Utility Techniques (MAUT) was employed for the development of models, to be used as a decision making tool for best procurement 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 (selection criteria weighting) and the utility values derived from the respective factors. These two techniques were used to facilitate a more systematic and logical approach in the selection process, hence improving objectivity and reducing subjectivity in decision making. Finally, step 4 was achieved by conducting multiple case studies in actual projects.

4. FORMATION OF KEY SELECTION CRITERIA

A set of exclusive selection criteria at macro level has been established from this study based on the Sri Lankan context. This study has adopted the Delphi technique to establish the set of selection criteria and for obtaining the utility values for each selection criteria against various procurement systems. The Delphi technique has been demonstrated to be powerful and appropriate to achieve these tasks by deriving objective opinions in a rather subjective area. This study has focused on the selection criteria in terms of client requirements, project characteristics and external environment, thus selection criteria has been focused at macro level. The purpose of the factor analysis was to elicit the underlying relationships among the eligible factors affecting the procurement selection and to reduce the factors into a small number of components. The results of factor analysis revealed nine significant factors from client requirements, six factors from project characteristics and five from the external environment. Each factor derived from factor analysis was carried to the final round which was aimed at attaining the utility values for each significant factor against various procurement systems. The Table 3 shows the final set of significant selection criteria and their level of significance derived from Delphi survey.

Table 3. Key selection criteria and their level of significance

	Selection Criteria	Significance level
CLIENT 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 involvement of parties	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

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

5. THE DECISION SUPPORT MODEL

The model presented in this paper is a device for selecting a most appropriate procurement option for various types of projects in construction industry. The model consists of a set of selection criteria, a set of utility values, and a broader categorization of various procurement systems (12 types). The model was designed for construction clients and their consultants/principal advisors, particularly those who use an unrealistic method to select the procurement system and responsible for the selection process. Primarily, this model guides *the selection of an appropriate procurement system which not only considers the requirements of clients and projects but also considers the impact of external environment*. In this way it will be possible to ensure that projects are procured in an efficient and effective way that will lead to added value to the client. This will further facilitate the construction clients in intelligent and informed decision making in available procurement routes for various types of building projects.

5.1 Development of the model

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 the Delphi survey carried out in four rounds. Figure 1 illustrates detailed design of conceptual framework developed for project procurement selection model.

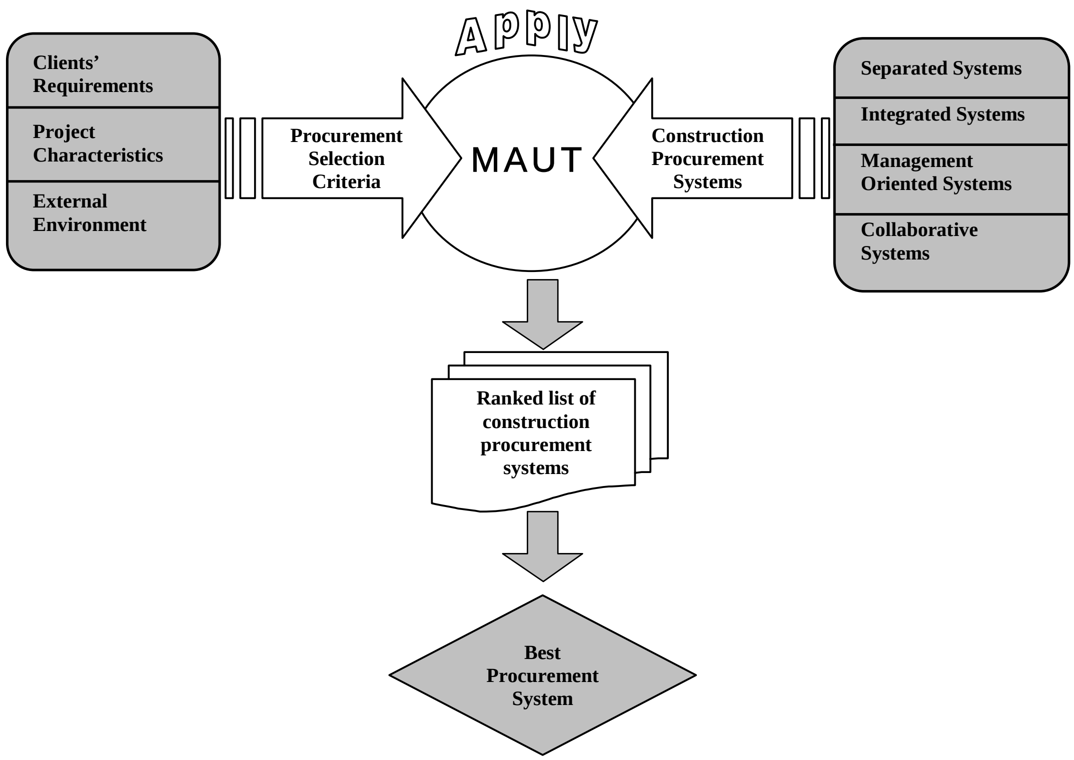

Fig. 1. Detailed design of conceptual framework for procurement selection model

5.2 Use of the model

The model developed in this study can be used by following the steps listed below.

Step 1 : The end user considers all priority factors and gives the relative importance for each factor in the table on a scale of 1 to 5, where 1 represent 'least significant' and 5 represent 'most significant'. The prioritization exercise enables the end users to specify their requirements according to the characteristics of the project and influence of external environment.

Step 2**:** Each priority rating is taken in turn and multiplied by each of the utility values in the table and the results are entered into the appropriate columns, respected to each procurement options. These are compared to all factors and procurement options.

Step 3**:** The overall utility value of each of the resulted columns, under each procurement options, are calculated, and ranked in descending order. The best procurement option will have the highest overall utility value.

An illustration for the use of a model is shown in Figure 2. This particular illustration demonstrates the outcome of a model applied to Club building. With respect to the model outcome, the model proposed Design and Build as the appropriate procurement system for this Club building. Thus, the developed model was subject to evaluation by similar kind of multiple project scenarios.

5.3 Model evaluation

The evaluation process is targeted to check the practical use of the model and to ensure the consistency and soundness of the model. Multiple case studies with the sample 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 in 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 includes thirty-seven 'Traditional measure and pay', one 'Traditional lump sum', five 'Design and build' and one 'Turn key' (one number), suggesting a dominant use of the traditional measure and pay system. Out of the 44 case studies conducted, 31 (70%) matched results and 13 (30%) non-matched results observed. Even though the selection practice of construction procurement is rather unstructured and ad hoc, the results revealed from the model shows that 70% of the results tally with the procurement system already adopted. Therefore, it can be stated that the applicability of the model is relevant to the Sri Lankan industry.

	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	71.3	69.57
			314.15	408.7	275.3	389.15	347.85	407.15	289.15	285.85	305.45	317.4	356.5	347.85
2	Time Availability & Predictability	5	58.83	60	65	82.17	81.3	84.13	61.96	54.35	63.09	63.5	57.78	56.52
			294.15	300	325	410.85	406.5	420.65	309.8	271.75	315.45	317.5	288.9	282.6
3	Price Certainty	5	66.41	95.43	43.7	82.83	76.71	86.96	58.48	54.35	60.43	58.57	50.57	52.74
			332.05	477.15	218.5	414.15	383.55	434.8	292.4	271.75	302.15	292.85	252.85	263.7
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	76.3	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	38.7	78.7	51.96	50.87	38.48	56.3	51.3	71.7	68.48	70.22	66.04
			381.72	154.8	314.8	207.84	203.48	153.92	225.2	205.2	286.8	273.92	280.88	264.16
7	Quality of Work	5	77.61	72.17	67	67.78	64.57	59.7	62.74	57.57	78.35	78.35	75.82	76.3
			388.05	360.85	335	338.9	322.85	298.5	313.7	287.85	391.75	391.75	379.1	381.5
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	73.17	72.61	57.61	59.13	54.83	47.1	43.04	42.09	33.48	36.74
			293.49	270	219.51	217.83	172.83	177.39	164.49	141.3	129.12	126.27	100.44	110.22

Fig. 2. Illustration of 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
	Project Characteristics													
1	Project Cost & Funding method	2	63.04	90.13	59.57	78.04	71.76	82.78	54.35	56.13	63.26	59.78	60.77	63.91
			126.08	180.26	119.14	156.08	143.52	165.56	108.7	112.26	126.52	119.56	121.54	127.82
2	Project Complexity	2	66.47	55.87	61.83	67	63.04	50.6	74	68.2	81.35	78.04	74.73	81.87
			132.94	111.74	123.66	134	126.08	101.2	148	136.4	162.7	156.08	149.46	163.74
3	Project Size	2	75.9	66.3	65.65	72.83	63.91	58.7	75.13	60.65	76.26	75.39	68.61	70.78
			151.8	132.6	131.3	145.66	127.82	117.4	150.26	121.3	152.52	150.78	137.22	141.56
4	Time Constrains	3	49.78	61.96	79.13	83.04	77.87	75.65	70.65	66.7	66.52	62.7	60.78	64.78
			149.34	185.88	237.39	249.12	233.61	226.95	211.95	200.1	199.56	188.1	182.34	194.34
5	Degree of Flexibility	2	89.35	50.39	73.91	54.74	49.13	42.77	56.74	46.3	69.13	69.35	73	66.26
			178.7	100.78	147.82	109.48	98.26	85.54	113.48	92.6	138.26	138.7	146	132.52
	External Environment													
1	Market condition	5	73.61	68.87	59.13	77.00	68.39	70.78	67.20	65.64	59.78	58.83	54.57	57.61
			368.05	344.35	295.65	385	341.95	353.9	336	328.2	298.9	294.15	272.85	288.05
2	Economic condition	5	55.57	69.13	55.78	69.09	53.88	55.57	56.87	66.51	64.57	63.92	71.56	73.04
			277.85	345.65	278.9	345.45	269.4	277.85	284.35	332.55	322.85	319.6	357.8	365.2
3	Technological aspects	4	53.91	53.48	47.83	78.04	63.17	71.87	64.43	65.75	62.83	61.39	73.04	74.78
			215.64	213.92	191.32	312.16	252.68	287.48	257.72	263	251.32	245.56	292.16	299.12
4	Socio cultural suitability	2	54.65	53.70	61.87	50.22	49.13	49.04	45.00	58.61	59.57	60.04	59.30	61.43
			109.3	107.4	123.74	100.44	98.26	98.08	90	117.22	119.14	120.08	118.6	122.86
5	Regulatory Environment	2	54.35	52.91	51.39	59.57	59.35	62.35	64.57	69.91	66.74	63.70	65.66	68.04
			108.7	105.82	102.78	119.14	118.7	124.7	129.14	139.82	133.48	127.4	131.32	136.08
Overall Utility			**4619**	**4552**	**4120**	**4704**	**4284**	**4360**	**4033**	**3885**	**4327**	**4247**	**4182**	**4291**
Overall Ranking			**2**	**3**	**10**	**1**	**7**	**4**	**11**	**12**	**5**	**8**	**9**	**6**
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														

Fig. 3. Illustration of the use of Multi Attribute Utility Model

6. CONCLUSION

This study has found the significant factors affecting the selection of procurement systems to be the requirements and characteristics of the client, together with project characteristics and external environment. This demonstrates that selection of procurement system should address the factors at macro level and consider all macro level factors in the selection process, will ultimately lead to the success of the project and assure the value for money construction clients. In addition, it is essential that the selection is carried out logically, methodically and in a well disciplined manner by the client or his consultant/principal adviser.

Selection of most suitable procurement systems is a difficult task, since each project is owned by individual clients/bodies with different requirements and possesses unique characteristics. However, 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 decision support model for the selection of suitable 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 and external environment, a set of utility values for each selection criteria and a broader categorization of procurement options. This is useful for constriction clients and their consultants/principal advisors as they often make procurement selection by the quickest and ad hoc methods without being fully aware of the factors and various procurements options. As envisaged, the model is to make clients 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/his consultants. The implementation of this model to aid procurement selection is advocated to place the client in best possible position to select correct method of procurement for his project at a particular circumstance.

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