PROJECT PROCUREMENT SYSTEM SELECTION MODEL

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ABSTRACT: In the last two decades, there have been significant changes in the technical and economic conditions prevailing in the construction industry. To overcome the shortcomings of the traditional procurement methods, the construction industry has developed a large number of different procurement systems. A systematic approach for selection of the most appropriate system is now needed. This paper presents the development of the project procurement system selection model (PPSSM), which integrates the techniques of the analytic hierarchy process and Parker's judging alternative technique of value engineering into a multicriteria multiscreening system. A survey was conducted in Saudi Arabia with the aim of testing the PPSSM for effectiveness and efficiency and assisting the governmental agencies to select the most appropriate procurement system for implementation of their projects. For this purpose, a questionnaire was developed. On the basis of the synthesis process of the PPSSM, Saudi public clients selected design and build as the most appropriate procurement system for their projects, with an overall priority of 0.496. The outcome of the study demonstrates the effectiveness of PPSSM in helping the client in the construction industry to choose the procurement system that fulfills the needs of the client and the project requirements.

INTRODUCTION

It has been estimated that the selection of an appropriate procurement method could reduce construction project costs by an average of 5% (*Contractual* 1982). Each project has its own characteristics and requirements, and for the project to be successful, the procurement method must address the technical features of the project alongside the client and contractor needs. The number of different procurement systems in the construction industry has increased over the last decade, and this has resulted in the need to conduct a selection process for any specific project in a disciplined and systematic manner. Various procurement selection methods have been developed to help the client choose the most appropriate procurement system for their specific needs (Ireland 1985; Skitmore and Marden 1988; Masterman 1992). For example, work done by Skitmore and Marden (1988) modified the multiattribute technique of the Building Economic Development Committee (BEDC) (1985) procurement path decision chart and went on to use discriminant analysis to distinguish between the different procurement paths for decision-making purposes. In 1998, the Royal Institution of Chartered Surveyors Quantity Surveyors Division developed an expert system package entitled ELSIE (Ashworth 1988). The ELSIE package includes four linked software modules. The procurement module of this package was a subjective component, which acted as an intelligent adviser for only five procurement options. Bennett and Grice (1990) used the BEDC's *Thinking about building guide* (1985) and Skitmore and Marden's work to tabulate the strengths and weaknesses of the various procurement systems. Mohsini (1993) presented 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) used the 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 choosing an appropriate procurement method. The main difficulties common to these studies are as follows:

- All models seem to ignore some important factors in the selection of the most appropriate procurement systems.
- The available options in the database of a number of the existing models are limited.
- Some of the models are conditional and cannot be used by any client.
- Some of the models require the use of advanced mathematical techniques, which are considered to be time consuming.
- A number of the existing models adopt a primitive approach to the selection process and limit the number of options to be considered.

Against this background the project procurement system selection model (PPSSM) was developed.

PPSSM

In designing the PPSSM, the first step was to construct a framework to be used in evaluating the activities associated with the design and construction of a project in relation to various procurement systems. Fig. 1 presents the framework that concentrates on examining the relationship between different procurement systems with reference to the following six criteria: project characteristics, market attributes, contractor and architect/engineer (A/E) needs, categories of client, client design organization, and the local design and construction regulations. In this framework, ''client needs'' are listed and grouped into four categories: cost, time, quality, and general needs. Procurement systems are classified according to the integration of the design and construction management.

The second step of the PPSSM was the design of a comprehensive methodology to be used in the selection of most appropriate procurement system. The proposed model is an integration of Parker's alternative technique of value engineering (Parker 1985) and analytic hierarchy process (AHP) theory (Saaty 1994). The PPSSM comprises four screening levels. The first three screenings are part of Parker's technique, and the final screening uses Saaty's AHP theory (Fig. 2).

The nature of the procurement system selection requires an effective decision-making technique to systematically evaluate procurement systems against a number of criteria. The developed PPSSM causes the project team to discuss and determine needs from desires, the important from the unimportant, and trade-off from non-trade-off items. The four screening states range from the first rough screening process to the most detailed fourth screening. In each screening stage, potential procurement systems are subjected to evaluation prior to selection for further analysis. Hence, only the most promising systems

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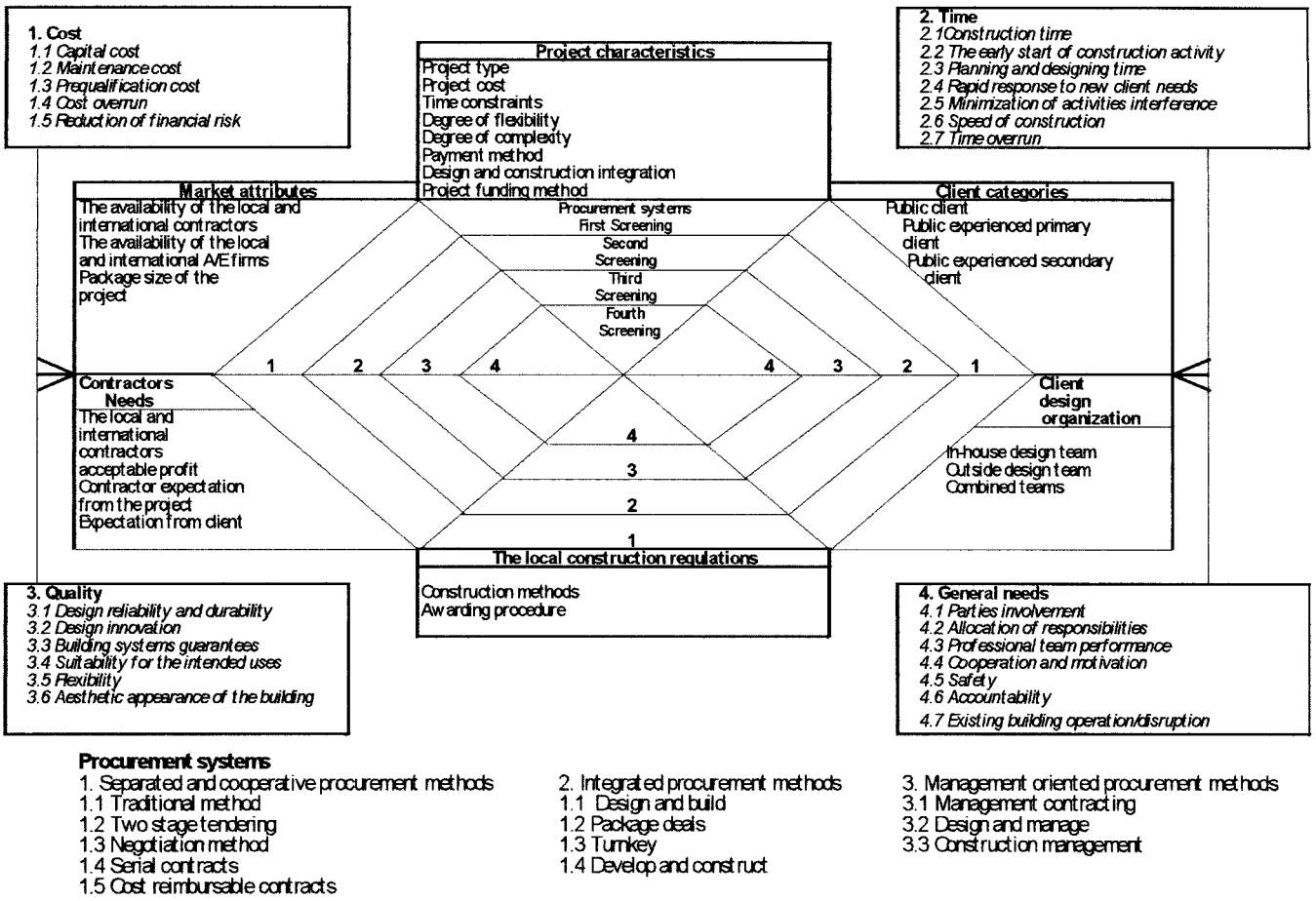

FIG. 1. Project Procurement System and Selection Environment

proceed for further evaluation. The following is an overview of the four screening methods.

First Screening: Feasibility Ranking

The first step is to develop a set of evaluation criteria by which to judge the competing procurement systems for feasibility. The format for use in the first screening process is shown in Fig. 3 for project characteristics criteria only. Similar formats are used for market attributes, contractor and A/E needs, categories of client, client design organization, and the local design and construction regulations.

The second step is to score the above six criteria on a 0–5 basis, with 5 being the score for the highest probability of implementation for the least time, most benefit, and required quality. The lists of procurement systems are placed vertically for evaluation with the respect to these criteria.

In the first screening, it is important that no procurement system should be discarded without being scored. The purpose of the first screening is not to draw a conclusion regarding the optimum solution to be followed, but to create two lists of procurement systems. The first list is for the systems that are not considered to be feasible for the particular project, and the other list is for further review at the subsequent screening.

Second Screening: Evaluation by Comparison

In the second screening, the comparison of feasible procurement systems is made by listing the advantages and disadvantages of each. To conduct a fair and objective comparison, all the good points for each procurement system will be listed as well as the bad points. Based on a review of literature and interviews with different construction industry participants, a list of various procurement systems with their common benefits and drawbacks was prepared as a guide for the comparison. The number of benefits and drawbacks may be equal in number but they will not be equal in strength and importance as perceived by the decision makers. The purpose of the second screening stage is to provide the opportunity to maximize the benefits of each procurement system, while at the same time minimizing the drawbacks. This can be done by modifying the procurement system or finding solutions to overcome the negative factors. For example, if a procurement system has the problem of uncertainty regarding the overall project cost at the inception stage, the client team can overcome this problem simply by agreeing with the contractor that the final cost should not exceed an agreeable guaranteed maximum cost stated in the contract. This will minimize the level of financial risk the client might face at the end of the project. Once the comparison of all the benefits and drawbacks is completed, the listed procurement systems remaining after the first screening can be ranked according to the preferences of the decision makers. The decision maker can eliminate the lowest ranked procurements and the higher ranked systems will go forward for further analysis.

Third Screening: Weighted Evaluation

A weighted evaluation process is used in this model to identify the optimum procurement systems with reference to the factors considered to be most influential in the selection process. This technique is employed to bring more objectivity to subjective decision making. This third screening stage is divided into two stages: the paired comparisons and matrix analysis.

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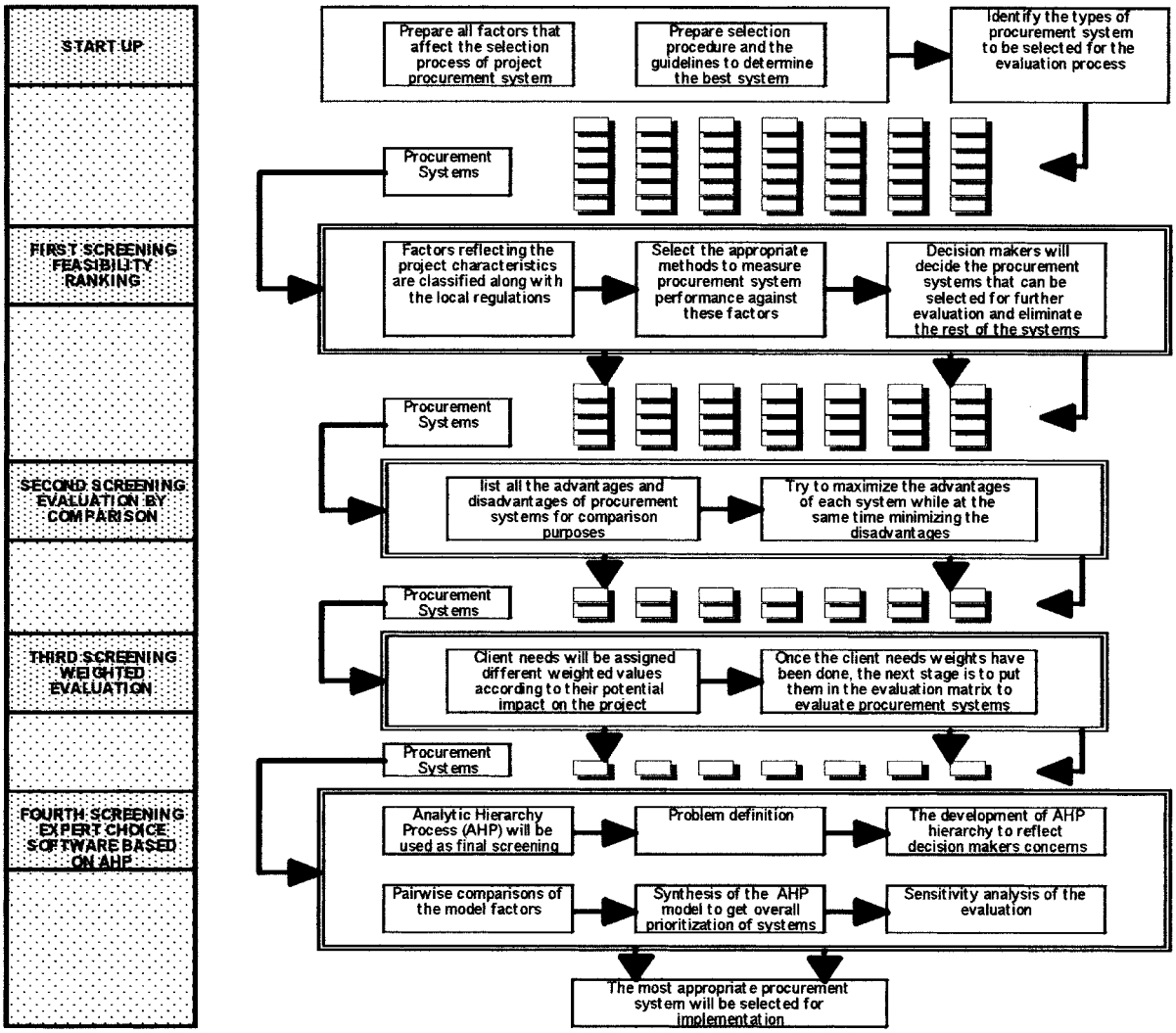

FIG. 2. Multicriteria/Multiscreening PPSSM

Paired Comparisons

In judging procurement systems, the client's needs must be assigned differing weighted values representing their potential impact on a project or the importance assigned to them by the decision makers. The technique used to place the weights of importance to be assigned to each criterion is called paired comparison. This was performed by comparing one need to only one other need at a time. During this process, it can be determined which need is of greater importance as well as the magnitude of the difference in importance.

Evaluation Matrix

At the end of the paired comparison, the weights of the client's needs are established. The next task is to use the client's needs and their weights in evaluating the procurement systems surviving the first two screenings. It is assumed that all of the procurement systems that have survived meet the client's basic needs.

Fourth Screening: AHP

Dyer and Forman (1991) provide a general description of the use of AHP developed by Saaty. The application of AHP for PPSSM involves four major steps: problem hierarchy, pairwise comparisons, construction of overall priorities rating with AHP (synthesis), and evaluation of the consistency of judgment.

In this final screening, the computerized decision support software, namely *Expert Choice version 9.0*, was used to structure the PPSSM based on the theory of AHP. The procedures involved in PPSSM utilize several levels to derive its objective solution. The selection of the most appropriate procurement system is the goal of the decision makers, and this is located at level 0 of the model to serve as the goal node. Factors affecting the procurement system selection, which had been classified into six categories, were inserted in level 1 of the model to serve as the main criteria. In addition to these categories, client needs were inserted in level 1 because these are considered to be important factors in the selection process. Levels 2 and 3 of the model define subcriteria nodes for categories in level 1. Levels 1, 2, and 3 of the hierarchy consisted of a total of 7, 27, and 83 nodes, respectively. Finally, the alternative solutions or courses of action (procurement systems) occupied level 4 to serve as the choice available for the decision makers in the last screening stage.

PPSSM TESTING

This section reviews the results of the survey conducted in Saudi Arabia to achieve the following goals: (1) Test the effectiveness of the proposed PPSSM in procurement selection; and (2) assist the public clients in Saudi Arabia to choose the right procurement system for their projects.

A questionnaire was developed to collect the data needed for the model operation to test its efficiency and effectiveness

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PROCUREMENT SYSTEM SELECTION MODEL	FEASIBILITY RANKING	SHEET NO. 1

SCALE OF ASSESSMENT (1)

4- Extremely appropriate
3- very appropriate
2- Moderately appropriate
1- inappropriate
0- Extremely inappropriate

PROCUREMENT SELECTION CRITERIA (2)

1. PROJECT CHARACTERISTICS

Procurement systems	Project types	Offices	Residential	Project size	Large size project	Normal size project	Project cost	High cost project	Medium cost project	Low cost project	Degree of flexibility	Flexible scope of work project	Fixed scope of work project	Degree of complexity	Highly specialized technology needed	Normal technology needed	Time constraints	Crucial	Important	Not important	Payment methods	Lump-sum	Fixed fee	Percentage fee	Unit price	Design/ construction integration	Highly needed	Not needed	Project funding methods	Government funded projects	Private funded projects
1. Separated and cooperative procurement methods																															
1.1 Traditional method																															
1.2 Two stage tendering																															
1.3 Negotiation method																															
1.4 Continuity contracts																															
1.5 Serial contracts																															
1.6 Cost reimbursable contracts																															
2. Integrated procurement methods																															
2.1 Design and build																															
2.2 Package deals																															
2.3 Turnkey																															
2.4 Develop and construct																															
3. Management oriented procurement methods																															
3.1 Management contracting																															
3.2 Construction management																															
3.3 Design and manage																															

FIG. 3. Feasibility Ranking

and was distributed to the governmental agencies concerned. In all, 40 governmental agencies in Saudi Arabia engaged in design and construction projects were served with the questionnaire. Experts from 30 agencies were selected to participate in the second part of the questionnaire. The second part was to establish the data to be incorporated in the PPSSM, in particular, those related to the client's needs and the prioritization of procurement systems. These 30 were selected as they represented the mainstream of construction activity in Saudi Arabia. The following is a summary of the survey results of the four screening stages of the PPSSM.

First Screening: Feasibility Ranking

A set of evaluation criteria was developed to judge the different procurement systems for feasibility. A specific format was designed that vertically includes the procurement systems and horizontally includes the major parameters that affect the selection process, as shown in Fig. 3. The respondents were asked to evaluate the performance of different procurement systems with respect to the listed parameters with the aid of a numerical 1–5 point scale representing extremely inappropriate to extremely appropriate.

For the traditional method, the final outcome of the results indicated that 3 respondents selected the moderately appropriate choice, whereas 7 and 20 respondents selected the inappropriate and extremely inappropriate choices, respectively. The mean was equal to 1.42 and the agreement index (AI) was equal to 28% as the lowest AI of all procurement systems. This procurement system therefore falls into the inappropriate range.

For design and build, the survey indicated that 17, 10, and 3 respondents selected extremely appropriate, very appropriate, and moderately appropriate choices, respectively, whereas no respondents ticked the inappropriate or extremely inappropriate choices. The mean was equal to 4.47 and the AI was equal to 89% as the highest AI of all procurement systems. This procurement system falls into the extremely appropriate range.

In summary, the results of the first screening indicated very clearly that five systems fall into the inappropriate range and as a result these systems will be eliminated from subsequent analysis. These procurement systems are: traditional method, two stage tendering, continuity contracts, serial contracts and cost-reimbursable contracts. The remaining eight procurement systems that fall into the appropriate range will proceed to the next level of screening. Of these, design and build, design and manage, construction management and management contracting were all rated extremely appropriate. Package deals and develop and construct achieved very appropriate while negotiation and turnkey methods only reached moderately appropriate. Table 1 presents the results of the screening showing the respondents' ratings with respect to the above systems.

Second Screening: Evaluation by Comparison

In the second screening, the comparison of procurement systems is made by listing the advantages and disadvantages of each. The purpose of evaluation by comparison is to provide for the client team the opportunity to maximize the benefits of each system and at the same time to minimize the number of drawbacks. Based on interviews with the public client rep-

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resentatives, negotiation method and turnkey are considered inappropriate for further analysis. The major reasons for the elimination of these two procurement systems are shown next.

Drawbacks of the negotiation method are as follows:

- The cost is higher compared to other methods.
- There is doubt whether the contractors can maintain performance.
- The government purchasing provision and projects execution regulations require public projects to be open to all qualified competitors.

Drawbacks of turnkey are as follows:

- Experience suggests that the application of this method does not help the client to achieve all his needs, because little attention is given to the formulation of a precise brief prior to the construction process.
- The client requires a higher degree of project control.
- The existing public regulations use this procurement system for limited projects.

Based on the comparison of all the benefits and drawbacks of the second screening, negotiated method and turnkey will be eliminated from further analysis, and the remaining procurement systems will be considered in the third screening.

Third Screening: Weighted Evaluation

The weighted evaluation process is used at this phase of the model to identify the optimum procurement systems with reference to the criteria considered to be influential in the selection process. The two stages of the weighted evaluation, the criteria weighting process (paired comparisons) and matrix evaluation for the survey, are considered below.

Analysis of Paired Comparisons

The first step was a detailed survey to establish the list of all client's needs that are important in the final selection of procurement systems. At this stage, no attempt was made to judge these needs because later those needs that are not valuable will eventually drop out as a result of receiving little weight. A comprehensive list of the client's needs is developed in four major categories: cost, time, quality, and general needs, each with minor subneeds. All of the procurement systems were evaluated against these client needs. Paired comparisons were carried out on the basis of the survey conducted in Saudi Arabia.

The second step was to determine the importance of each need to the evaluation team. Each of the needs was assigned a letter and these are used to compare A against B, A against C, and so on, as the client needs scoring matrix is filled in. When selecting between two criteria, the degree of importance of the selection can also be indicated. The preference or importance of one criterion decision over another can be major (3), medium (2), minor (1), or none (0). Starting with capital cost (criterion A), the team compared it to maintenance cost (criterion B). This comparison was made to find out how each function related to the selection process of procurement systems, so that the team might determine which one was of the greatest importance. Having compiled and fully understood the pertinent data, the experts were able to make a knowledgeable decision. When the decision makers finalized their evaluation, the key letter corresponding to the criterion having the greater importance was placed in the AB square of the matrix. In this paired comparison, it was determined that capital cost (criterion A) and maintenance cost (criterion B) were both equally important. Once the decision had been formulated, the mag-

TABLE 1. Statistical Summary of First Screening

Procurement systems (1)	Results (2)	ASSESSMENT SCALE: Extremely Appropriate, Frequency (3)	% (4)	Very Appropriate, Frequency (5)	% (6)	Moderately Appropriate, Frequency (7)	% (8)	Inappropriate, Frequency (9)	% (10)	Extremely Inappropriate, Frequency (11)	% (12)	Statistical summary: Mean (13)	Standard deviation (14)	AI (%) (15)	Variance (16)	Median (17)	Mode (18)	Ranking (19)
1. Separated and cooperative procurement methods																		
1.1 Traditional method	Inappropriate	0	0.00	0	0.00	3	10.00	7	23.33	20	66.67	1.42	0.6	28.42	0.40	1.00	1.01	13
1.2 Two stage tendering	Inappropriate	0	0.00	2	6.67	3	10.00	8	26.67	17	56.67	1.64	0.86	32.65	0.78	1.00	1.08	12
1.3 Negotiation method	Appropriate	0	0.00	3	10.00	9	30.00	17	56.67	1	3.33	2.50	49.35	54.67	0.46	1.90	2.28	7
1.4 Continuity contracts	Inappropriate	0	0.00	0	0.00	3	10.00	14	46.67	13	43.33	1.66	0.62	33.35	0.41	1.00	1.59	11
1.5 Serial contracts	Inappropriate	0	0.00	0	0.00	5	16.67	12	40.00	13	43.33	1.72	0.70	34.35	0.51	1.00	1.39	10
1.6 Cost reimbursable contracts	Inappropriate	0	0.00	0	0.00	4	13.33	14	46.67	12	40.00	1.75	0.68	34.97	0.48	1.00	1.59	9
2. Integrated procurement methods																		
2.1 Design and build	Appropriate	17	56.67	10	33.33	3	10.00	0	0.00	0	0.00	4.47	0.64	89.34	0.43	3.32	4.83	1
2.2 Package deals	Appropriate	0	0.00	16	18.00	9	30.00	5	16.67	0	0.00	3.39	0.72	67.41	0.54	2.15	3.88	5
2.3 Turnkey	Appropriate	0	0.00	0	0.00	15	50.00	10	33.33	5	16.67	2.38	0.69	47.3	0.49	1.12	2.75	8
2.4 Develop and construct	Appropriate	0	0.00	16	18.00	9	30.00	5	16.67	0	0.00	3.36	0.73	67.35	0.55	2.09	3.83	6
3. Management oriented procurement methods																		
3.1 Management contracting	Appropriate	13	43.33	11	36.67	6	20.00	0	0.00	0	0.00	4.20	0.76	84.03	0.60	3.04	4.59	4
3.2 Construction management	Appropriate	13	43.33	12	40.00	5	16.67	0	0.00	0	0.00	4.27	0.73	85.44	0.55	3.07	4.67	3
3.3 Design and manage	Appropriate	16	53.33	9	30.00	5	16.67	0	0.00	0	0.00	4.37	0.72	87.39	0.54	3.13	4.81	2

Note: Feasibility ranking of first screening: 5 = extremely appropriate ($80 < AI \leq 100$), 4 = very appropriate ($60 < AI \leq 80$), 3 = moderately appropriate ($40 < AI \leq 60$), 2 = inappropriate ($20 < AI \leq 40$), 1 = extremely inappropriate ($0 < AI \leq 20$).

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nitude of the difference in importance was also rationalized. Based on the above comparison of capital cost (criterion A) and maintenance cost (criterion B), the decision makers decided that there was no preference in importance; therefore a notation A/B was recorded in the AB square of the matrix. The comparison of capital cost (criterion A) with respect to other client's needs criteria was continued (i.e., the comparison of criterion A to criteria C–Y, one at a time). As each comparison was made, the relevant key letters and weighting were recorded.

The next step was to perform the paired comparison of maintenance cost (criterion B) with respect to each below it in the evaluation matrix (i.e., the comparisons of criterion B to criteria C–Y, one at a time). Again, as each weighted comparison was made, the key letters and weighting were determined and recorded in the appropriate square of the second row in the matrix.

Continuing with the comparison weighting evaluation, each criterion (C–Y) was individually compared to every other criterion, one at a time. The scoring matrix was finalized as shown in Fig. 4.

The third step, following completion of the comparative evaluations, is to total the raw scores of each criterion by summing the assigned letters in the matrix. For example, referring to the scoring matrix of the client needs criteria, it can be noted that key letter A was placed in the matrix 24 times and had a total of 117. In the same way for each key letter, the weight factors are added and recorded in the raw score.

The fourth step is to adjust the raw scores to an assigned weight if desired. The raw scores were converted to a scale of 1–10 with 10 assigned to the criterion with the highest raw score and the other criteria adjusted accordingly as illustrated in Table 2.

TABLE 2. Adjusted Raw Scores of Assigned Weight

Client criteria (1)	Raw score (2)	Assigned score (3)	Rank (4)
1. Total cost of the project	117	5	1
1.1 Capital cost (A)	43	10	1
1.2 Maintenance cost (B)	15	3	6
1.3 Prequalification cost (C)	13	3	6
1.4 Cost overrun (D)	22	5	5
1.5 Reduction of financial risk (E)	24	6	4
2. Time	99	3	4
2.1 Construction time (F)	24	6	4
2.2 The early start of construction activity (G)	2	1	8
2.3 Planning and designing time (H)	3	1	8
2.4 Rapid response to new client needs (I)	34	8	3
2.5 Minimization of activities interference (J)	6	1	8
2.6 Speed of construction (K)	5	1	8
2.7 Time overrun (L)	25	6	4
3. Quality	121	5	2
3.1 Design reliability and durability (M)	39	9	2
3.2 Design innovation (N)	8	2	7
3.3 Building systems guarantees (O)	10	2	7
3.4 Suitability for the intended uses (P)	42	10	1
3.5 Flexibility (Q)	9	2	7
3.6 Aesthetic appearance of the building (R)	13	3	6
4. General needs	112	4	3
4.1 Parties involvement (S)	11	3	6
4.2 Allocation of responsibilities (T)	13	3	6
4.3 Professional team performance (U)	8	2	7
4.4 Cooperation and motivation (V)	33	8	3
4.5 Safety (W)	36	8	3
4.6 Accountability (X)	4	1	8
4.7 Existing building operation/disruption caused (Y)	7	2	7

Evaluation Matrix

The first step in the evaluation matrix is to evaluate each procurement system for each criterion given. The scoring system for the evaluation matrix assigned 1–5 points on a scale of poor to excellent, where 1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent. To achieve this, 30 public agencies were consulted to establish the appropriate evaluation of each procurement system with respect to each criterion. For example, when design and build was evaluated against capital cost, 17 selected excellent and 13 selected very good, whereas no respondent ticked the remaining choices. The mean was equal to 4.57 and the AI was 91.33. Based on this survey, it can be demonstrated that design and build performs excellently (E) with respect to capital cost. The process of evalua-

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
A	A/B	A-3	A-3	A-2	A-1	A-1	A-2	A-1	A-3	A-2	A-1	A/M	A-3	A-3	A/P	A-2	A-3	A-2	A-2	A-2	A-2	A/W	A-3	A-2
	B	B-2	D-1	E-2	B-1	B-1	B-1	I-2	B-2	B/K	B-1	M-1	B-1	B/O	P-2	B-1	B-1	B-1	B-1	B-1	B/V	W-2	B-1	B/Y
		C	D-1	E-2	F-2	C-1	H-1	I-3	J-1	C/K	L-2	M-2	N-2	O-1	P-2	C-3	R-3	C-3	T-1	C-1	V-2	M-3	C-3	C-3
			D	D/E	D/F	D-1	D-1	I-2	D-2	D-2	D-2	M-2	D-1	D-1	D/P	D-1	D-2	D-1	D-1	D-1	D/V	W-1	D-2	D-2
				E	E-1	E-2	E-1	I-1	E-1	E-2	E-2	M-2	E/O	E-1	P-1	E-1	E-1	E-1	E-1	E-2	E-1	W-2	E-2	E-1
					F	F-2	F-2	F-2	F-2	F-3	L-1	M-3	F-1	F/O	P-2	F-2	F-3	F-2	F-1	F-1	F/V	W-2	F-3	Y-1
						G	G-1	I-2	J-2	K-1	L-2	M-3	N-1	O-1	P-3	Q-1	R-1	S-1	T-1	G-1	V-2	W-2	X-2	Y-1
							H	I-3	H-2	K-1	L-2	M-3	N-1	O-1	P-3	Q-1	R-1	S-1	T-1	U-1	V-2	W-2	X-1	Y-2
								I	I-2	I-2	I-1	I/M	I-2	I-2	I/P	I-3	I-2	I-1	I-1	I-1	I/V	I/W	I-2	I-2
									J	J-1	L-2	M-2	J/N	O-2	P-2	J/Q	R-1	S-1	J-2	U-1	V-2	W-2	J/X	Y-1
										K	L-1	M-2	K/N	O-1	P-2	K/Q	R-1	S-1	T-2	K/U	V-2	W-2	K-2	K-1
											L	M-2	L-2	L-2	P-1	L-2	L-2	L-1	L-1	L-1	V-2	W-1	L-2	L-2
												M	M-3	M-2	M/P	M-2	M-2	M-1	M-1	M-1	M/V	M/W	M-2	M-3
													N	N/O	P-2	N/Q	R-1	S-1	T-2	U-2	V-3	W-2	N-2	N-2
														O	P-2	O-1	O/R	S-1	O-1	U-1	V-2	W-2	O-1	O-1
															P	P-3	P-2	P-3	P-2	P-3	P-2	P/W	P-3	P-2
																Q	R-1	S-1	Q-2	Q-2	V-3	W-1	Q-2	Q-1
																	R	S-1	T-2	R-1	V-3	W-2	R-2	R-1
																		S	T-1	S-2	V-2	W-3	S-1	S/Y
																			T	T-2	V-2	W-1	T-1	T/Y
																				U	V-2	W-2	U-3	Y-2
																					V	W-1	V-3	V-1
																						W	W-3	W-3
																							X	X-1
																								Y

HOW IMPORTANT
3 Major preference
2 Medium preference
1 Minor preference
0 No preference

FIG. 4. Scoring Matrix

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tion of each procurement system with respect to each criterion continues until the preferences of all procurement systems with respect to each of the client's needs have been established.

The second step is to multiply the ranking of each with the weighting of each criterion and enter the result in the space provided (Fig. 5).

The third step, after all the procurement systems have been evaluated, is to rank them according to their total score. Package deals and develop and construct ranked fifth and sixth, respectively, and were eliminated because their mean values fall into the fair range.

The remaining procurement systems with means falling into the good, very good, and excellent ranges were considered in the final screening (Table 3).

Fourth Screening: AHP

The final screening uses the computerized model. The following is a summary of the major steps of the fourth screening for the study conducted in Saudi Arabia.

Entering Pairwise Comparisons

The development of the PPSSM includes all the attributes reflecting the goal and the concerns of the public client in relation to an appropriate procurement strategy. At each level pairwise comparisons are conducted for each category with the ones in the adjacent upper level, and the ratings are entered into a comparison matrix. The preference of the public clients for a particular procurement system was judged with respect to each model factor, and the numerical matrix mode was used as the default. On the basis of decision makers' perceptions, the priorities among the criterion items in the hierarchy are established by using pairwise comparisons. For example, when judging the relative preference of factors located in level 1 with respect to the goal, a rating of 1 is assigned in the comparison with market attributes and contractor and A/E firms needs. This indicates their relative importance at the top level (i.e., they are perceived to be equally important to the public clients). In comparing project characteristics with categories of client with respect to the goal, the former is perceived to have weak importance over the latter and a rating of 3 is assigned. Similarly, in comparing market attributes with local design and construction regulations with respect to the goal, the latter is deemed to have very strong importance over the former, and a rating of 7 is assigned. A number in italics indicates that an inverse relationship exists between the two criteria being compared. Following the same procedure, the remaining pairwise comparison matrices among the nodes in the hierarchy can be established. Table 4 presents the start of pair comparison of level 0 with level 1. Similar pair comparison tables exist for the model nodes.

CLIENT NEEDS		1. Cost	1.1 Capital cost	1.2 Maintenance cost	1.3 Prequalification cost	1.4 Cost overrun	1.5 Reduction of financial risk	2. Time	2.1 Construction time	2.2 The early start of construction activity	2.3 Planning and designing time	2.4 Rapid response to new client needs	2.5 Minimization of activities inference	2.6 Speed of construction	2.7 Time overrun	3. Quality	3.1 Design reliability and durability	3.2 Design innovation	3.3 Building systems guarantees	3.4 Suitability for the intended uses	3.5 Flexibility	3.6 Aesthetic appearance of the building	4. General needs	4.1 Parties involvement	4.2 Allocation of responsibilities	4.3 Professional team performance	4.4 Cooperation and motivation	4.5 Safety	4.6 Accountability	4.7 Existing building operation/disruption	TOTAL
Procurement systems	W T	ASSIGNED VALUE																													
		5	10	3	3	5	6	3	6	1	1	8	1	1	6	5	9	2	2	10	2	3	4	3	3	2	8	8	1	2	
1.1 Design and build	5		E	E	E	E	E		E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E	E	E	E	E	Rank
	4		VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG	1
	3		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G		G	G	G	G	G	G	G	
	2		F	F	F	F	F		F	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	F	
	1		P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P	P	P	P	P	
Appropriate	Sub.T		50	12	15	25	30		30	4	4	40	5	4	30		36	18	18	50	8	12		15	12	10	32	40	4	10	514
2.2 Package deals	5		E	E	E	E	E		E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E	E	E	E	E	Rank
	4		VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG	5
	3		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G		G	G	G	G	G	G	G	
	2		F	F	F	F	F		F	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	F	
	1		P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P	P	P	P	P	
Inappropriate	Sub.T		20	3	3	5	6		6	2	2	8	2	1	6		9	2	2	10	4	3		3	6	2	8	16	1	2	132
2.4 Develop and construct	5		E	E	E	E	E		E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E	E	E	E	E	Rank
	4		VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG	6
	3		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G		G	G	G	G	G	G	G	
	2		F	F	F	F	F		F	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	F	
	1		P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P	P	P	P	P	
Inappropriate	Sub.T		10	3	3	5	6		12	1	1	8	1	2	6		9	2	2	20	2	3		3	6	2	8	8	1	2	126
3.1 Management contracting	5		E	E	E	E	E		E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E	E	E	E	E	Rank
	4		VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG	4
	3		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G		G	G	G	G	G	G	G	
	2		F	F	F	F	F		F	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	F	
	1		P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P	P	P	P	P	
Appropriate	Sub.T		40	12	9	15	18		24	3	3	32	3	4	24		36	6	6	40	6	9		12	12	6	24	24	4	8	380
3.2 Construction management	5		E	E	E	E	E		E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E	E	E	E	E	Rank
	4		VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG	3
	3		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G		G	G	G	G	G	G	G	
	2		F	F	F	F	F		F	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	F	
	1		P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P	P	P	P	P	
Appropriate	Sub.T		40	12	9	20	24		24	4	4	24	4	4	24		36	6	6	40	6	9		12	12	8	24	24	8	8	392
3.3 Design and manage	5		E	E	E	E	E		E	E	E	E	E	E	E		E	E	E	E	E	E		E	E	E	E	E	E	E	Rank
	4		VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG		VG	VG	VG	VG	VG	VG	VG	2
	3		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G		G	G	G	G	G	G	G	
	2		F	F	F	F	F		F	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	F	
	1		P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P	P	P	P	P	
Appropriate	Sub.T		40	12	12	20	24		30	4	4	8	4	4	24		36	12	12	40	8	12		12	12	8	32	32	4	8	414

Key: E Excellent; VG Very Good; G Good; F Fair; P Poor; WT Weighted total; Sub.T Sub-Total

FIG. 5. Evaluation Matrix

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TABLE 3. Statistical Summary of Third Screening

Procurement systems (1)	Results (2)	Excellent Frequency (3)	Excellent % (4)	Very Good Frequency (5)	Very Good % (6)	Good Frequency (7)	Good % (8)	Fair Frequency (9)	Fair % (10)	Poor Frequency (11)	Poor % (12)	Mean (13)	Standard deviation (14)	AI (%) (15)	Variance (16)	Median (17)	Mode (18)	Ranking (19)
2. Integrated procurement methods																		
2.1 Design and build	Appropriate	16	53.33	12	40.00	2	6.67	0	0.00	0	0.00	4.46	0.59	89.15	0.38	3.56	4.72	1.00
2.2 Package deals	Inappropriate	0	0.00	0	0.00	0	0.00	10	33.33	20	66.67	1.35	0.46	26.72	0.21	1.00	1.20	5.00
2.4 Develop and construct	Inappropriate	0	0.00	0	0.00	0	0.00	9	30.00	21	70.00	1.31	0.44	28.24	0.20	1.00	1.20	6.00
3. Management oriented procurement methods																		
3.2 Management contracting	Appropriate	1	3.33	12	40.00	17	56.67	0	0.00	0	0.00	3.45	0.51	68.96	0.28	3.00	3.32	4.00
3.2 Construction management	Appropriate	1	3.33	15	50.00	14	46.67	0	0.00	0	0.00	3.57	0.49	71.12	0.25	3.00	3.60	3.00
3.3 Design and manage	Appropriate	8	26.67	21	70.00	1	3.33	0	0.00	0	0.00	4.25	0.46	85.01	0.22	3.84	4.04	2.00

Note: Scoring system for third screening of evaluation matrix: 5 = excellent ($80 < AI \leq 100$), 4 = very good ($60 < AI \leq 80$), 3 = good ($40 < AI \leq 60$), 2 = fair ($20 < AI \leq 40$), 1 = poor ($0 < AI \leq 20$).

Synthesis of Model Results

When all judgments throughout the model are established, the next step is to perform synthesis from the model global goal. The synthesis process converts all the local priorities into global weights of the alternatives. As a result, design and build gained a priority of 0.496 as the highest score among the four procurement systems with an overall consistency index of 0.06. The consistency index helps the decision makers to identify the degree of inconsistency of their judgments. Generally, a consistency index <0.10 is acceptable. Design and manage, construction management, and management contracting ranked second, third, and fourth, respectively, with priorities of 0.258, 0.140, and 0.106.

On the basis of the data entered for the pairwise comparison matrices, the overall priorities of model's main criteria were determined as follows:

- project characteristics—25.1
- market attributes—3.7
- contractor and A/E needs—4.1
- categories of clients—9.5
- client design organization—9.0
- local design and construction regulations—14.7
- client's needs—34.0

From the synthesis of the model results, client's needs and project characteristics are considered to be the most important criteria influencing the procurement selection process.

Sensitivity Analysis and Managerial Judgments

In any problem that involves an optimum decision, it is desirable to see the impact of rating changes in the comparison matrices on the final outcomes. In such an environment, different individuals with different experience levels will have different perceptions in placing preferences and priorities on the factors. The software's five graphical sensitivity modes (dynamic, performance, gradient, 2D, and difference) were used to investigate the sensitivity of the procurement systems to changes in priority of the main criteria in level 1 of the model. The design team can adjust the horizontal bar for any criterion and the length of procurement system bars will change dramatically in response to changes in the system priorities. At the end of the fourth screening, the decision maker will be in a position to decide the most appropriate procurement system to be adopted. This decision will be based on the pairwise comparisons undertaken within Expert Choice and exploration of the sensitivity of judgments. Using the dynamic mode, when the model's main criteria are changed to 2.6, 4.28, 1.8, 2.7, 1.9, 46.6, and 1.6, the priority of the four procurement systems changed to 0.292, 0.296, 0.183, and 0.229, respectively. The ranking of the procurement systems changes dramatically due to change in the criteria priorities. The new ranking of the four procurement systems is, in a descending order: design and manage, design and build, management contracting, and construction management (Fig. 6).

In this final fourth screening of the PPSSM, the decision analysis is performed with AHP and Expert Choice. The following is a brief review:

- The PPSSM hierarchy model has been constructed to include the goal, criteria and subcriteria affecting the procurement selection, client's needs, and the feasible procurement systems surviving from the previous three screening stages.
- The pairwise comparison technique is used to establish the weights of the model elements, examine the inconsistency ratios, and revise judgments.

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TABLE 4. Node: (0) Start of Pair Comparison of Level 0 with Level 1

Procurement selection criteria (1)	Market attributes (2)	Contractor and A/E firms needs (3)	Categories of client (4)	Client design team (5)	Local design and construction regulations (6)	Client needs (7)
Project characteristics	5	5	3	5	2	*2*
Market attributes		1	*3*	*3*	*7*	*6*
Contractor and A/E firms needs			*2*	*2*	*6*	*6*
Categories of client				1	1	*6*
Client design team					1	*4*
Local design and construction regulations						*3*

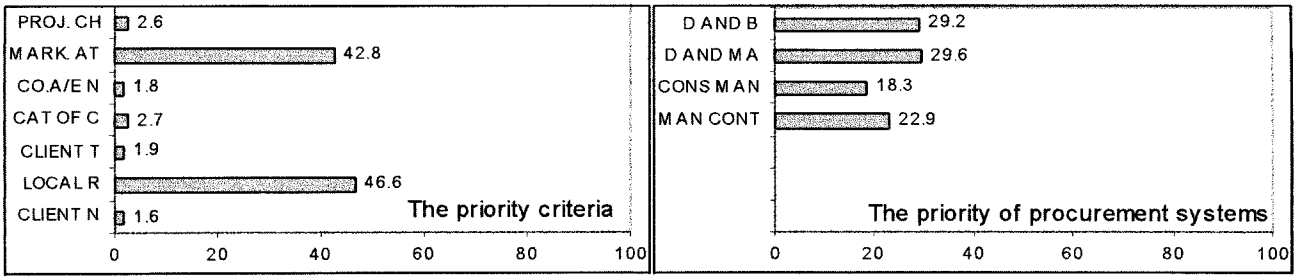

FIG. 6. Procurement System Priorities Variability due to Model Criteria Changes

- From the model goal, the priorities of all the model elements are investigated to determine the dominant criteria that affect the procurement selection process and to identify those of less importance. Also, the overall consistency ratio is examined. This process is called synthesis.
- The sensitivity analysis is performed to determine the sensitivity of the priorities of the procurement systems to change in criteria weights.

The final screening acts as an effective tool to solve the problem of procurement selection where a decision analysis with multiple criteria is performed. The procurement system selection process involves a mixture of qualitative and quantitative criteria and includes a series of subjective judgments by a number of experts.

CONCLUSIONS

The PPSSM has the potential to assist the client in the construction industry in procurement system selection. PPSSM is an integration of Parker's judging alternative technique of value engineering and AHP and consists of feasibility ranking, evaluation by comparison, weighted evaluation, and AHP.

The outcome of the survey indicated that public clients in Saudi Arabia selected design and build as the most appropriate procurement system for their projects. The results of the survey also indicated that PPSSM seems to provide accessible and useful guidance. This approach involves the use of simple pairwise comparisons of the model elements, which requires the use of basic statistical calculations performed by such packages as Excel and Statistical Analysis System. PPSSM is suitable for use by busy clients and consultants because it was considered to be ''user friendly.''

APPENDIX. REFERENCES

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