A DECISION SUPPORT MODEL FOR THE SELECTION OF BEST VALUE INFORMATION TECHNOLOGY PROCUREMENT METHOD

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SUMMARY: *The procurement of Information Technology (IT) is as important as the use of the technology. Procurement includes two aspects: the selection of the right IT product as well as the selection of the method to procure it. Ineffective IT exploitation and poor procurement practices in construction organizations often create obstacles in reaping the full potential of IT investments. This paper presents a Decision Support Model to assist in the selection of the best procurement method for procuring IT for construction organizations. It uses a value-based framework drawn from value engineering (value matrices) which enables the identification of best value IT procurement methods to procure IT solutions and requirements. The model was developed using object oriented modeling techniques providing greater flexibility in future modification and expansion. It was implemented as a decision support system and tested using real life cases from the construction industry. A forum of experts positively evaluated and verified the concept and the usability of the system. The research was carried out in Sri Lanka using the construction industry as the forum for development of the system. The decision support model creates a knowledge repository for IT procurement in Sri Lanka but introduces a methodology and opens the opportunity to further enhance aspects of IT procurement globally.*

KEYWORDS: *Information Technology Procurement methods, Value Matrices, Decision Support Model*

1. INTRODUCTION

There are numerous methods and research carried out to identify the best Information Technology (IT) solution for an organization (Abbott and Blundell, 2000). There is hardly any research carried out to identify the best method of procuring IT solutions (Cheung et al., 2001). For example if a construction organisation requires an IT system to manage supplies to construction sites there is no clear methodology to decide whether to adopt Off-the shelf IT supplies or Consulting service contracts to procure the required IT system.

The rapid evolution and spread of IT the usage of IT has increased in every category of business. IT can no longer be viewed as an enhancement to traditional business procedures but rather as an innovative agent that enables new and different alternatives to organizing, administrating and operating business enterprises (Ahmad and Russell 1995). With increased usage of IT within the construction industry the quality of documents, communication channels, speed of work and simplicity of access to project information have improved (Rivard, 2000). Lack of effective IT exploitation methods in construction organizations often creates a difficulty in justifying future expansion and use of IT innovations. Unavailability of methods of identifying best IT products, procurement methods, costs and benefits exacerbates this situation. This problem is global and drawbacks are experienced in all types of enterprises (Hochstrasser and Griffiths, 1991; Bruce, 1995). The review of literature on procurement of IT reveals that there is not much research undertaken in this area. An article by the Central Unit of Procurement in the UK (2003) states; “everybody benefits from fast, effective and transparency in procurement”. It reduces supplier’s cost, enables the organizations to fulfill commitments faster and more effectively and gives better value for the client’s money. Therefore, the success of use of IT highly depends on how it is procured and whether it is procured with full knowledge of all costs and benefits. These issues underline the necessity of having a systematic approach and a greater level of guidance for the selection of the best method for procurement of IT.

A survey on the usage of IT in the construction industry of Sri Lanka revealed that there is organization-wide poor utilization of IT (Mettananda, 2004). This demands the introduction of a tool to evaluate and prescribe procurement methods and provide feedback on their probable successes or failures. In most cases, although IT investment achieves business requirements, it may not provide value for money. Simply, it may not increase client satisfaction nor reduce expenditure on procurement methods.

This study aimed to investigate challenges associated with IT procurement and develop a decision support model for construction organizations to assist in the selection of the best IT procurement method which is capable of increasing customer satisfaction whilst removing unnecessary expenditure through the use of value matrices.

Following are the main objectives of this research:

1) Identification of methods of IT procurement and to establish the extent of use of these techniques in the construction industry.
2) Exploitation of IT procurement methods in other sectors with a view to documenting best practices in IT procurement for the benefit of the construction industry.
3) Development of a decision support model for selecting the best value method of procurement to procure IT, incorporating the decision analysis technique of value matrices through an object oriented modeling process.

2. RESEARCH METHODOLOGY

Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision may imply that alternatives are considered and the one that best fits with goals, objectives, desires, values and so on is chosen (Harris, 1980). The general decision making process consists of several steps: Define the problem, Determine requirements, Establish goals, Identify alternatives, Define criteria, Select a decision making tool, Evaluate alternatives against criteria, and Validate solutions against problem statement.

The approaches for decision making based on the number of criteria are distinct. Multi Attribute Decision making methods are used when the number of the criteria and alternatives are finite and the alternatives are explicit. There are various multi attribute decision making methods which can be used for the decision making process:

- Cost benefit analysis – Evaluate the costs and benefits on monetary basis (Rogers, 2001).
- Elementary methods – Evaluate few alternatives and criteria without computational support for single decision maker. There are various methods such as pros and cons analysis, maximum and maxima methods, conjunctive and disjunctive and Lexicographic methods (Linkov et al., 2004).
- Multi Attribute Utility Theory (MAUT) - Evaluate the criteria based on weights which properly reflect the relative importance of the criteria. The basis of MAUT is the use of utility functions which can be applied to transform the raw performance values of the alternatives against diverse criteria that are both factual and judgmental to a common dimensionless scale. There are various methods as Simple Multiattribute Rating Technique (SMART) (Edward and Barrett, 1994), Generalized means and Analytical Hierarchy Process (AHP) (Satty, 1980; Cheung et al., 2001).
- Outranking methods – Most common methods are ELECTRE (Figueira et al., 2004) and PROMETHEE (Brans et.al, 1986; Vincke and Mareschal, 1995)
- Group Decision making (Lai et al., 2002)
- Sensitivity Analysis (Forman and Selly, 2001)

This research uses value matrices which is central to value engineering (Kelly et al., 2004; Shen and Liu 2003, 2004; Sung and Connor 2005; Robert et al., 2005). It provides a value based approach to decision making and uses the concept of MAUT for decision making. A detailed discussion of the use of value matrices is provided in section 5.3.

The research methodology used is indicated in Figure 1 below.

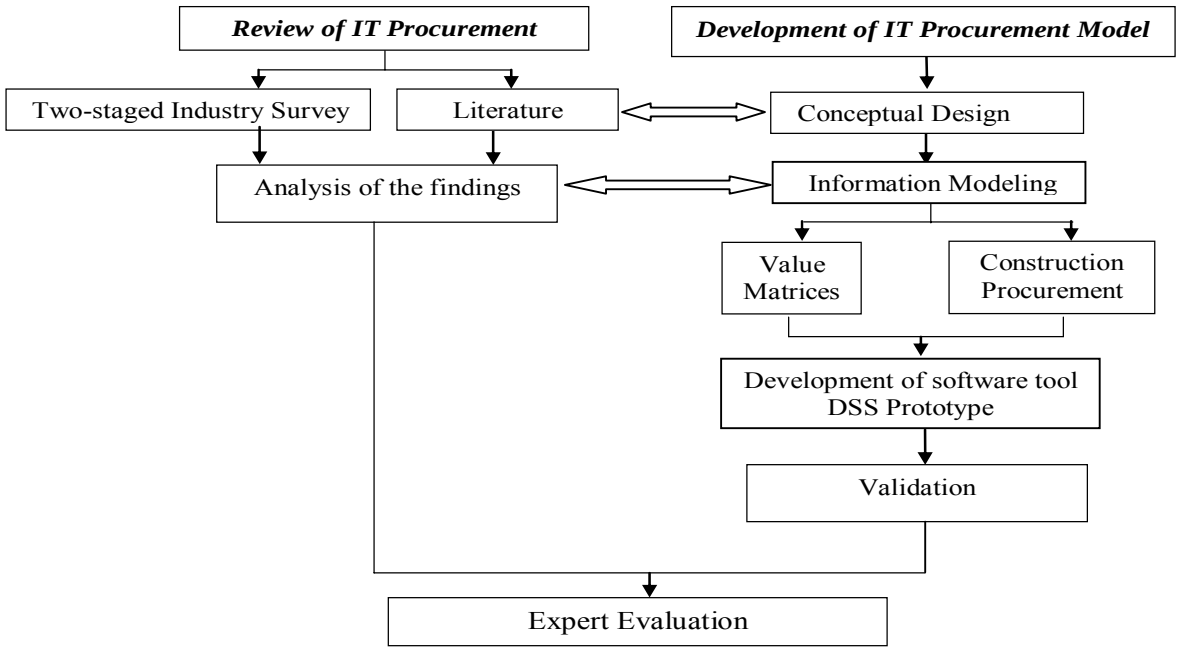

Figure 1Research Methodology

A detailed literature review was carried out to identify available methods of IT procurement. This was followed up by a two staged detailed survey of construction organizations and IT Service Providers to establish the current status of IT procurement within the industry and to identify methods and practices of IT procurement in usage. Based on the knowledge gathered a conceptual model was developed using object oriented modelling techniques and value matrices allowing the users to make an intelligent and informed decision on the procurement route. The model was tested and validated with the use of real life IT procurement cases obtained from the industry. The model, DSS and the research project was then evaluated using a forum of domain experts. Each stage of the methodology is explained in detail in the forthcoming sections exploring the results obtained at each stage.

3. REVIEW OF PROCUREMENT OF IT

Performance of IT is measured by the extent to which it actually contributes to achieving an organization's goals (Caldeira and Ward, 2002). Literature reveals that selection of a suitable methodology for IT procurement continues to be topical, and only a few advanced studies exist (Cheung et al., 2001). World Bank Report (2001), defined IT procurement as a common term used to designate all procurement activity that deal with computing and communications technologies regardless of whether they are hardware, software, supply or service components. The Department of Finance, California (2002) goes a step beyond to define IT procurement as any contract, interagency agreement or purchase estimate to conduct any activity listed below, or any combination of these activities. The activities classified as IT procurement include: IT facility preparation, operation maintenance, development and implementation or changes to application systems, documentation of systems and procedures, project appraisal or assessment, performance measurement, employment of personnel in support of or directly related to any of the above activities. This is a wider and comprehensive definition covering all aspects of IT Procurement.

There are examples of application of management techniques such as cash flow forecasting, life cycle costing and investment appraisal for the evaluation of IT investments (Drabble and Jenkins, 2001; Thomassian, 1999; Abbott and Blundell, 2000) and articles on IT relating to budgeting, developing IT strategies, measuring benefits and procurement strategies (www.microsoft.com; www.itcpb.org.uk; www.oracle.com). However, there is no evidence for the availability of a standard guide for selection of IT procurement method in general or one that is specifically applicable for construction organizations. The following sections provide a discussion of several important factors related to IT procurement (Perera and Karunasena, 2004).

3.1 Reasons for failures of IT procurement

Thomassian (1999) states that traditional procurement practices fail in large IT projects. The main causes for failures of IT procurement can be summarized as follows (Table 1):

Table 1: Reasons for failures of IT procurement (Central Unit of Procurement, 2003)

Failures	Reasons
Design & definition failures	Arise due to uncertainty of required outputs and non-relation with organization's end goals.
Decision making failures	Arise due to poor decision making on procurement process and unclearness of direction of project.
Project discipline failures	Arise due to weakness of arrangement to identify and evaluate risks.
Supplier Management failures	Arise due to less understanding of supplier commercial imperative, insufficient transparency of management information
People failures	Arise due to poor communication between project team and end users.

Table 1 clearly indicates that poor decision-making on procurement as one of the key factors that adversely affects the success of IT projects.

3.2 Factors for successful IT procurement

Successful IT procurement depends on many factors. Figure 2 identifies ten factors that are required for successful IT procurement (Ken, 2003).

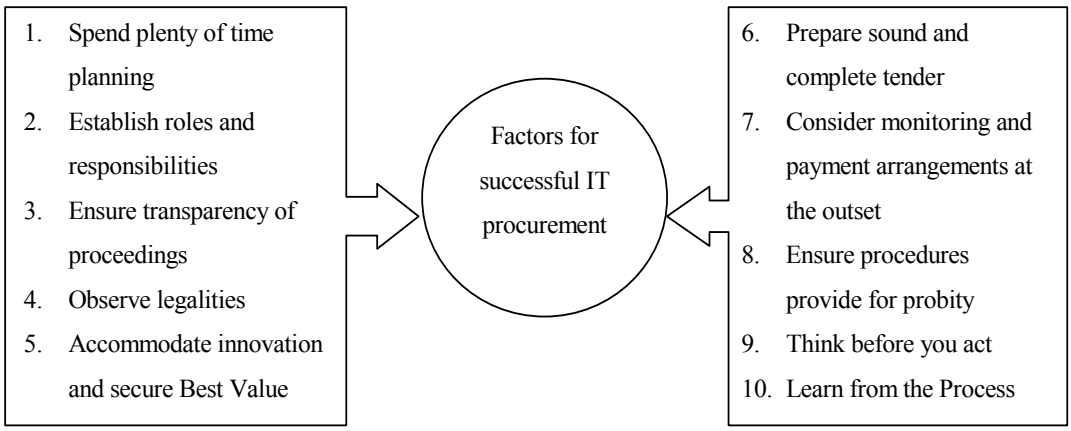

Figure 2: Factors for successful procurement

These factors were considered in the development of the decision support model described herein.

3.3 Methods for IT Procurement

Options for IT procurement are mainly categorized as Straightforward and Complex (Figure 3).

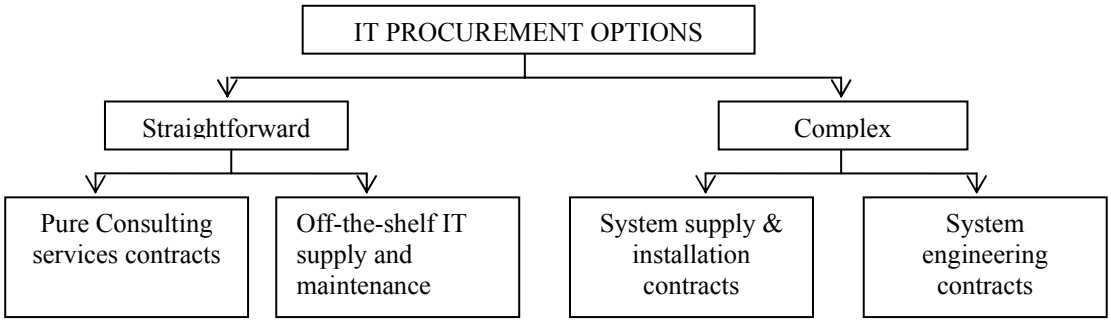

Figure 3 IT Procurement Systems (World Bank Report, 2001)

These are further subdivided in to four other categories:

1) Consulting services contracts - Consultants are expected to provide intellectual services according to the highest professional standards. E.g.: Procurement plan for an Information System.
2) Off-the-shelf IT supplies and maintenance contracts - The purchaser who defines required product and services specifications assumes the technical risk.
3) System supply and installation contracts - Supplier assumes responsibility for the design, supply, and installation of facility defined by the purchaser mainly in terms of performance specifications.
4) System engineering contracts - Combination of aspects of engineering contracts, consulting services and supply of products.

Each of these procurement options entails various payment methods such as cash purchase, hire/leasing, 'risk and reward' and arrangement with an Application Services Provider (ASP). These procurement methods and the payment options were incorporated in the detailed IT procurement method selection model and are referred to as IT Procurement Methods in this paper. The next section describes the survey of the construction industry carried out to identify the use of IT procurement methods in industry.

4. SURVEY OF THE CONSTRUCTION INDSUTRY

A detailed survey of industry was conducted to establish current status of use of procurement methods to procure IT. The survey also served as a method to establish the need for greater guidance in IT procurement for construction organizations. A two staged structured interview format was used for the conduct of the survey.

1. Stage 1: survey of 80 construction organisations
2. Stage 2: survey of 20 IT service providers

Construction organizations in Sri Lanka are primarily represented by construction contractors and consultants. Construction contractors in Sri Lanka are classified in to 7 grades (M1 to M7), where M1 represents the largest organisations and M7 represents the smallest. The survey sample size was restricted to 100 organizations comprising of 20 consultant organizations, 60 contracting organizations (selected from among M1, M2, M3 grades and foreign contractors) and 20 IT providers. The survey sample included over 90% of representatives of contractors and 20 largest consultancy practices. This included all the large-scale construction organizations. These are the organizations capable of significant investments in IT. The survey was carried out by visiting the organizations and requesting the person responsible for IT procurement to fill the survey responses within an interview session. This way the researchers managed to achieve a 100% response rate. The following section highlights the main findings of the survey.

4.1 IT Procurement Methods used in Industry

The survey related to current practices in IT procurement in construction organizations revealed the following (Perera and Karunasena, 2004):

- 97% of organizations consider IT as a strategy to improve organizational performance.
- 75% of organizations hardly adhere to any rules and regulations for procurement of IT. Only 10% of government organizations even adhere to the "Guidelines on Government Tender Procedure 1997" for procurement of material and equipment including IT.
- Only 3% had licensed software. This is in fact violation of international copyright laws.
- 20% of organizations adopted a strategic plan for development of IT within their organizations.
- Common methods used for IT procurement were: Consulting services, Off-the-shelf IT supply and maintenance, Systems supply & installation and Systems Engineering. These options were used with different methods of payment: direct purchase, hire or leasing.
- Although organizations were conscious of the value of investments, there is no evidence of use of value engineering techniques to evaluate IT procurement.

In addition, the survey also revealed some factors within the IT sector that contribute to the problems associated with IT procurement:

- Unavailability of adequate resources (finance and technical) to invest on IT.
- Poor standard of after sales services provided by the IT providers.

- Difficulty of identifying the best IT products and systems in the open market, and inability to assess suitability of such products for the organization.
- Poor regulation of the IT sector and non-availability of industry standards, independent information and customer protection.

The major causes of concern in procurement of IT were the poor levels of knowledge of professionals, unavailability of a guide for procurement system selection and the difficulty of identifying best IT products. All these factors underline the need for greater guidance for IT procurement to assist professionals in the construction industry. This research addressed some of these issues through the development of a model for selecting the best valued method of IT procurement.

5. THE DECISION SUPPORT MODEL

The main function of the model is to facilitate its users in intelligent and informed decision making on available procurement methods to procure IT. This approach was adopted as various companies have various IT requirements based on size, activities and nature of their business. The IT solutions identified should relate with the business and consequently play a part in and be integrated with construction activities. The model is designed for senior management, particularly those without adequate knowledge of IT procurement but responsible for procurement of IT. It provides a ranked list of best-value procurement methods with details of procedures and associated merits and demerits of each procurement method.

Development of the DSS for selecting the IT procurement method consisted of phases for design and implementation. The Design Phase was again considered in two stages as conceptual modeling and information modeling. The conceptual model illustrates the principles of the IT procurement model while information model deals with the contents of it. The model was evaluated for its contents to ensure its accuracy and validity of data through industry based case studies. The evaluated model was then implemented as a DSS. It was tested with actual data for its accuracy and workability. Finally, an expert evaluation was conducted to verify the validity of the research and the model.

5.1 The Conceptual model for Best Value IT Procurement Method Selection

The conceptual model illustrated in Figure 4 was based on secondary data collected through literature and information extracted from experiences of domain experts. Variables such as IT procurement requirements and IT procurement options (methods) were identified through literature review and further evaluated through the findings of industry survey.

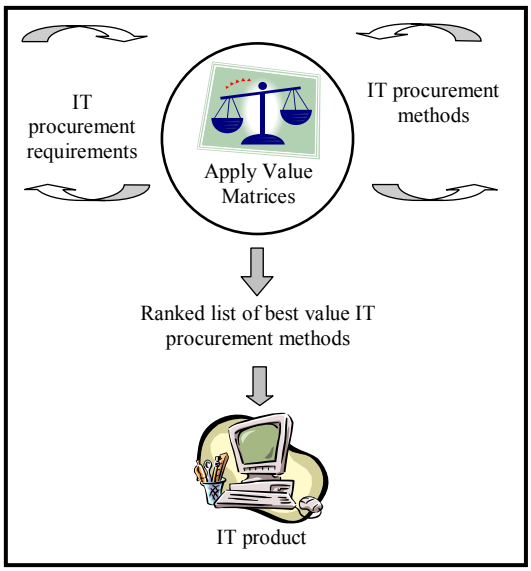

Figure 4: The Conceptual Model for IT procurement

The model assumes that IT solutions already identified have satisfied functional, financial and technical requirements of an organization. Requirements are diverse and difficult to define, highly sensitive to changing

business objectives, organizational politics, and capacity of end users and are subject to rapid technological changes over time.

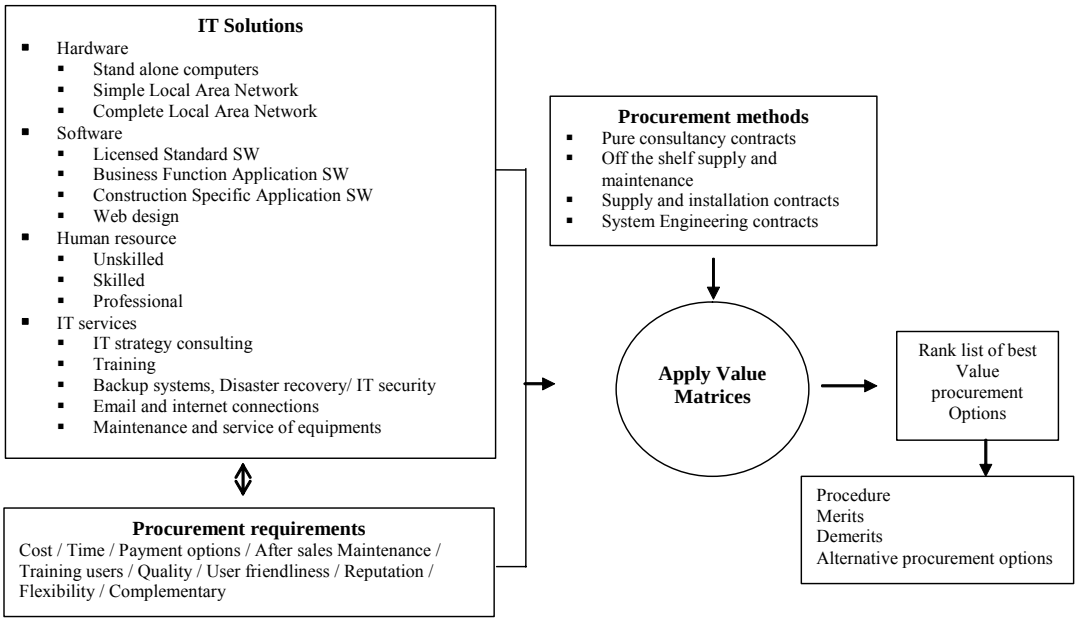

Figure 5: The Detailed Design of the Conceptual Model

Figure 5 illustrates the detailed design of the conceptual model for IT procurement. IT requirements are the inputs for the model while a ranked list of best value procurement options are the output of the model. In addition the model knowledge base consists of all available procurement and payment options procurement procedures, their merits and demerits and alternative procurement options. The model uses value matrices to match and compare competing alternatives to identify the best-value procurement routes relevant to the identified IT solution and the requirements of the organisation. It initially weighs evaluated criteria according to their relative importance (set by the user) and then scores alternatives based on weighted criteria to determine those that are optimal. IT procurement requirements are scored against procurement options to determine the ranked list of best-value procurement options for the identified IT solutions. An example of application of value matrices to identify IT procurement route is illustrated in section 5.3.

The construction industry inherits mature and refined procurement methods. The model provides an opportunity to use the wealth of experience gained from building procurement as alternative methods for adoption for IT procurement. This will enable to devise new procurement methods for IT procurement. There are various theoretical models developed for selection of procurement methods for construction by various researchers (Kumarswamy and Dissanayaka 1996; Skitmore and Marsden 1988; Love et al., 1998; Cheung et al., 2001). These models can be adopted to provide alternative options as a further development of this IT procurement model. The conversion of this conceptual model to a workable object oriented information model is explained in detail in the next section.

5.2 The Object Oriented Information model

Information modeling is the logical representation of information identified at pervious stages. Simply, it 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. The object oriented approach was used to develop the information model as it was developed to mimic 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 (ULM) standard notations were used to express the content of the information model generated (Coad et al., 1999; Collins, 2005).

The object-oriented model for IT procurement is illustrated below in Figure 6.

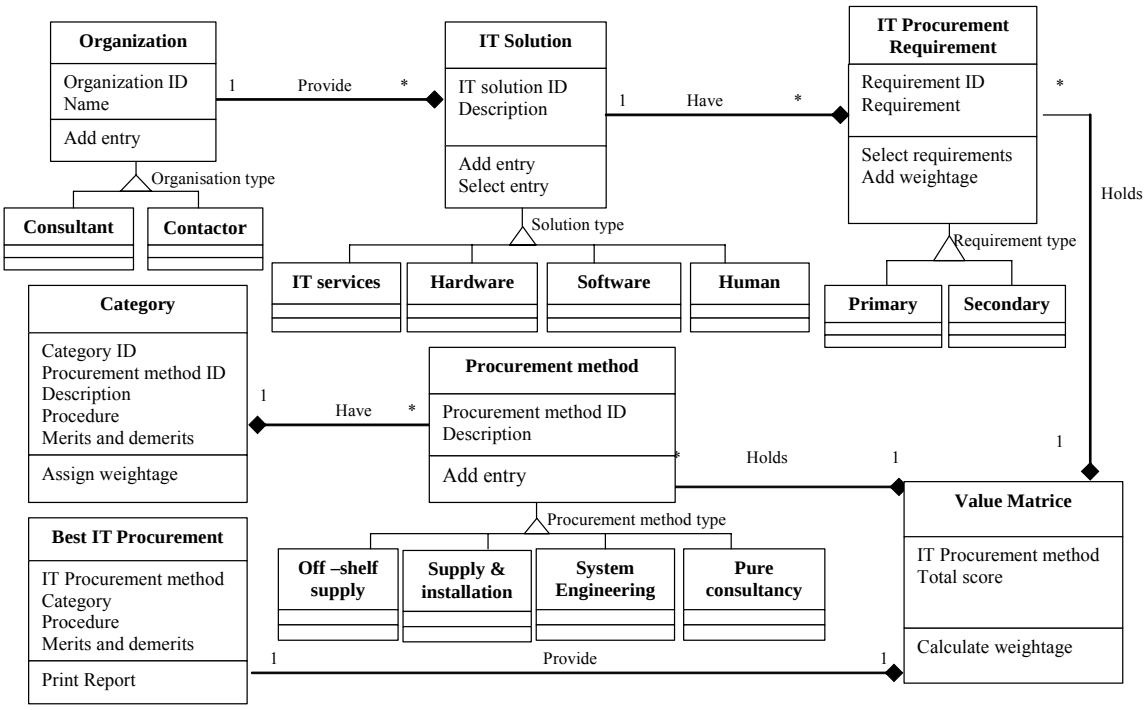

Figure 6: Object oriented model for IT procurement

The object model represents entities and their relationships. It consists of seven classes as:

1) Organization class [containing organization. Identity (ID) and name fields],
2) IT solution class (containing IT solution ID and description),
3) IT procurement requirement classes (containing requirement ID and requirement),
4) Procurement method class (containing procurement method ID and description),
5) Category classes (which contains category ID, procurement ID, description, procedure and merits and demerits),
6) Value matrices class (containing IT procurement ID and total score),
7) Best value IT procurement class (which contains procurement description, category, procedure and merits and demerits) and their relationships.

The methods “Add Entry”, “Select Entry”, “Print Report” and “Calculate Weightage” are the tasks carried out by the system. The inheritance (labeled “organization type”, “solution type” etc.) shows the categories or types that belong to each class.

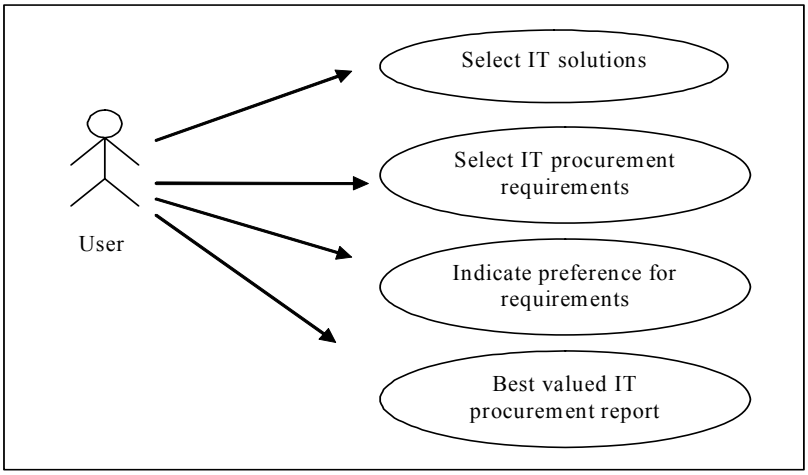

Figure 7: Use-case diagram

Figure 7 illustrates the use-case diagram for the IT procurement model as a part of UML set of diagrams. It represents four important functions of the model from a user's perspective:

1) Select IT solutions,
2) Input IT procurement requirements,
3) Indicate weight factor for each requirement and
4) A report on best value IT procurement options obtained by user.

5.3 Use of Value Matrices

A value matrix is a tool that can be used to analyze complex situations when decision-making becomes hard and laborious task because of multiple variables and varying degree of influences by different factors. This method requires weighing of evaluation criteria according to their relative importance and scoring alternatives on the basis of weighted criteria to determine those that are optimal.

This method is similar MAUT, which is a multi attribute decision-making method that evaluates the criteria based on weights reflecting the relative importance of the criteria. The basis of MAUT is the use of utility functions, which can be applied to transform the raw performance values of the alternatives against diverse criteria both factual and judgmental to a common dimensionless scale. There are various methods that are based on this theory: Simple Multi Attribute Rating Technique (SMART), Generalized Means and Analytical Hierarchy Process (AHP).

In value matrices weighting of evaluation criteria is more similar to that of AHP where pair wise comparisons are carried out to determine the relative importance of scores for each of the criteria on each subjective (judgmental) criterion. With the weightings determined by the pair wise comparison and after further normalization, alternatives are evaluated again in pair wise comparison based on relative performance to identify the list of best procurement options. Moreover the basic concept behind value matrices is more similar to MAUT where the functional aspect of the process is given high consideration.

However, value matrix is a better tool when compared to AHP to achieve the best value in such situations. The value process has more than 50 years of use and refinement which is proven to work for similar situations and has worldwide acceptance. It contains safeguards to avoid failures. These include: functional approach in generating concept understanding, job plan that includes all the phases of good decision making, verification procedures to ensure that the pertinent client needs are evaluated and met, a decision structure during concept comparisons and a result that has an appropriate feedback requirement.

The DSS consists of fifteen IT solutions that belong to all categories of IT such as: standalone computers, simple Local Area Network (LAN), complete LAN, licensed standard software, construction specific application software, business function application software, web design, unskilled, skilled, professionals, IT strategy consulting, training, backup systems/ disaster recovery/ IT security, emails and internet connection and maintenance and services of equipments.

An example of a value matrix for a selected IT solution (purchasing stand-alone computers) is illustrated below.

Table 2 Weighting used for IT Procurement requirements

	Procurement Requirement	**Weightage**	**Code**
1.	Time	10	T
2.	Cost	10	C
3.	Payment options	7	PO
4.	After sales services	9	AS
5.	Maintenance	9	M
6.	Quality	10	Q
7.	Reputation	8	R
8.	Flexibility	5	F
9.	Complementary	3	CO

The weightings used here are defined by the user, based on relative importance, organisational requirements and priorities. Therefore these can change from one procurement to another and from organisation to organisation.

Application of points based on the level of satisfaction of procurement requirements (Table 2) are given below (Table 3).

Table 3 Degree of Satisfaction Points Scale

Level of Satisfaction	**Points**
Non-satisfied	0
Poor	1
Average	3
Good	4
Complete satisfaction	5

Table 4: Alternative analysis matrices

Procurement Option	Code	**T**	**C**	**PO**	**AS**	**M**	**Q**	**R**	**F**	**CO**	**Total**	**Rank**
P1	Weighting	**10**	**10**	**6**	**10**	**10**	**10**	**8**	**5**	**3**		
	Scale	5	3	1	3	3	3	3	5	1		
P2	**Score**	50	30	6	30	30	30	24	25	3	228	3
	Scale	5	3	3	3	3	3	3	3	3		
P3	**Score**	50	30	18	30	30	30	24	15	9	236	2
	Scale	5	5	5	5	5	5	5	1	3		
	Score	50	50	30	50	50	50	40	5	9	334	1

Alternative procurement options P1, P2 and P3 are analysed in

Table 4 where;

P1 – Direct purchase (Off the shelf supply and maintenance contracts)

P2 – Through nomination (Off the shelf supply and maintenance) contracts)

P3 – Calling quotation (Off the shelf supply and maintenance contracts)

The above example illustrates the use of value matrices for an identified IT solution for purchasing stand-alone computers. Initially, a weight is assigned to each IT procurement requirement according to its relative importance (code denotes shortened form for IT procurement requirements). In this example cost, time, quality, maintenance, and after sales services were considered as critical factors by the user and thus a higher weight.

In

Table 4;

Score= Weighting x Scale and Total = ∑Score

Using the alternative analysis matrix weighted IT procurement requirements are scored against alternative IT procurement options identified to determine a ranked list of best value procurement options for the IT solutions identified. Application of scale points for each alternative is based on the state of satisfaction of procurement requirements among selected alternatives where zero represents non-satisfaction and 5 points represents full satisfaction. Solution P3 with the highest Total marks is ranked the best option for procurement (Rank 1).

5.4 Summary of Domain Knowledge

The summary of knowledge content of the information model is illustrated at Table 5. It classifies IT solutions in to four IT product categories (Hardware, Software, Human resources and IT services) and identifies typical procurement requirements for each IT solution. It then ranks the IT procurement methods that suit each type of IT solution and provides a list of best value IT procurement options. This knowledge base is used to provide information for the value matrices process described before.

Table 5: Summary of model

IT category	IT solutions	IT procurement requirements	Ranked list of best value IT procurement options
Hardware	Standalone computers	Cost, Time, Payment options, After sales, Maintenance, Quality, User friendliness, Reputation, Flexibility, Complementary	Off the shelf supply contracts: 1) Calling quotation 2) Through nomination 3) Direct purchasing
	Simple Local Area Network (LAN)	Same	Supply and installation contracts: 1) Calling quotation 2) Open tendering 3) Through nomination
	Complete Local Area Network (LAN)	Same	Supply and installation contracts: 1) Open tendering 2) Calling quotation 3) Through nomination
Software	Licensed Standard Software	Cost, Time, Payment options, After sales, Maintenance, Training users, Quality, User friendliness, Reputation, Flexibility,	Off the shelf supply contracts: 1) Through Agents 2) Through original manufactures
	Business Function Application Software	Same	Off the shelf supply contracts: 1) Open tendering 2) Bespoke development 3) Through agents 4) Original manufacturer 5) Calling quotation 6) Through nomination
	Construction Specific Application Software	Cost, Time, Payment options, After sales services, Maintenance, Training users, Quality, User friendliness, Reputation, Flexibility, Complementary	Off the shelf supply contracts: 1) Bespoke development 2) Open tendering 3) Through agents 4) Original manufacturer 5) Calling quotation 6) Through nomination
	Web design	Same	Supply and installation contracts: 1) Calling quotation 2) Open tendering 3) Through nomination
Human resource	Unskilled	Experience, Educational qualifications, Professional qualifications, Time, personality	Through nomination 1) Through Agents 2) Paper advertisement

IT category	IT solutions	IT procurement requirements	Ranked list of best value IT procurement options
	Skilled	Same	Paper advertisement 1) Through Agents 2) Through nomination
	Professional	Same	Paper advertisement 1) Through Agents 2) Through nomination
IT Services	IT strategy consulting	Cost, Time, Payment options, Quality, Reputation, Flexibility Complementary	Pure consultancy contracts; 1) Calling quotation 2) Open tendering 3) Through nomination
	Training	Same	Off the shelf supply contracts: 1) Calling quotations 2) Through Agents 3) Open tendering 4) Through nomination
	Backup, Disaster recovery/ IT security	Cost, Time, Payment options, After sales, Maintenance, Training users, Quality, User friendliness, Reputation, Flexibility, Complementary	System supply contracts: 1) Open tendering 2) Calling quotations 3) Through nomination
	Email and internet connections	Same	Off the shelf supply contracts: 1) Calling quotations 2) Open tendering 3) Through nomination
	Maintenance and service of equipments	Same	Off the shelf supply contracts: 1) Open tendering 2) Calling quotations 3) Through nomination

5.5 Decision Support System Development

DSS development based on the model created consisted of three main phases: Database development, system interface development and system testing. The databases use a relational model as it provides the ability for the end users to create and change records in the database in a user-friendly manner. Microsoft Access 2000™ was used to create the relational databases. Relationships among entities of the DSS were illustrated at object model in section 5.2.

System interfaces were developed using Java programming language (Net Beans IDE 3.6), which incorporates certain features such as polymorphism and inheritance, illustrated at object model for IT procurement. Java development environment offers benefits such as faster development, reusability, increased quality, modular architecture, better mapping of problem domain and client/ server applications (Adhikari, 1995; Taylor, 1990).

The framework of system interfaces of the DSS consists of four key sectors as illustrated in Figure 8.

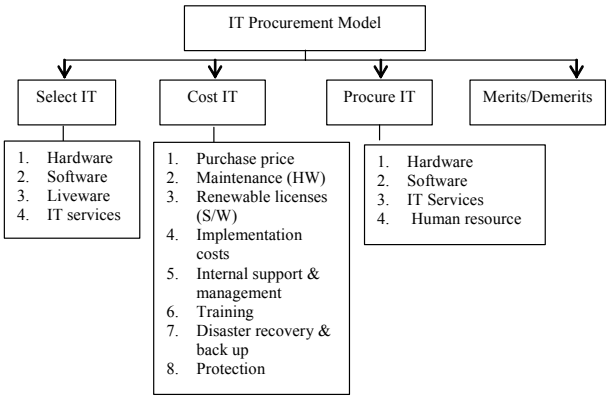

Figure 8: The framework of IT procurement model

These sectors are briefly explained below.

- Select IT - Procurement of IT can be spilt into Hardware, software, Human Resource (liveware) and IT services (Table 5). This provides details of some of the important factors that should be considered during the selection of each.
- Cost IT - In any procurement approach it is necessary to understand the true cost of IT requirements. This section provides a detailed explanation of each component associated with the true cost of IT.
- Procure IT - This section of the model provides details of methods for IT procurement that can be used by different organizations according to their requirements.
- Merits/demerits - This section provides a detailed account of merits and demerits of the selected procurement option.

The system interface was developed using this framework. The form given below (Figure 9) facilitates the input of procurement requirements to the DSS.

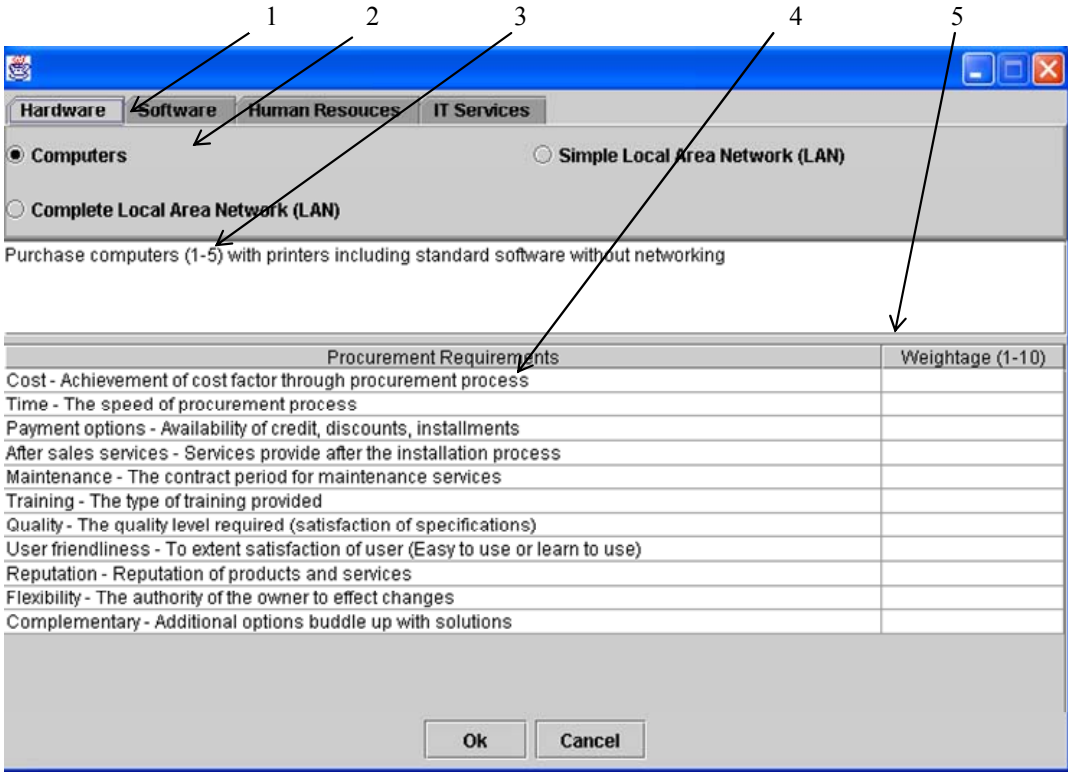

Figure 9 IT procurement requirements entry form

The main parts of the input screen are explained below.

1) Select IT category
2) E.g.: Hardware, Software, Human resource and IT services
3) Select IT solutions identified under each category
4) Hardware - Purchase computers, network design and implementations
5) Software - Standard licensed software, business function software, construction specific software and web development
6) Human resource - Unskilled, skilled and professional
7) IT services - IT strategy consulting, training, backups/ disaster recovery / IT security, maintenance and servicing and email and Internet connections.
8) Provides descriptions of selected IT solution.
9) Provides a detailed account of IT procurement requirements to consider.
10) Place preferred weightage for selected IT procurement requirements (Rank 1-10).

This form (Figure 10) provides ranked list of best value IT procurement options for identified IT solutions.

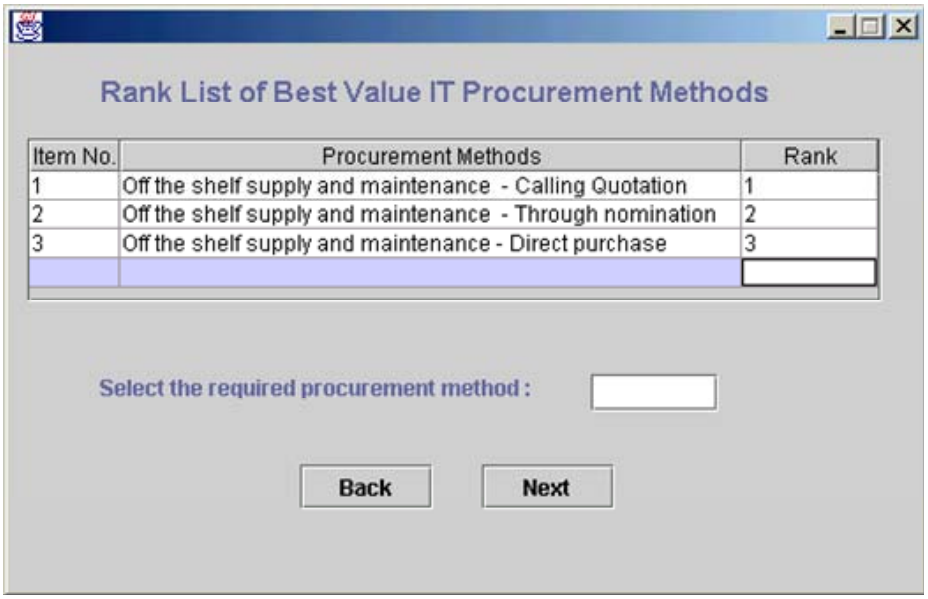

Figure 10: Ranked list of IT procurement methods

This facilitates selection of a preferred IT procurement method from the ranked list of procurement options by entering the relevant "Item NO".

This form (Figure 11) provides on screen information or facility to print reports of a selected procurement method. It includes details such as procurement procedure and its merits and demerits.

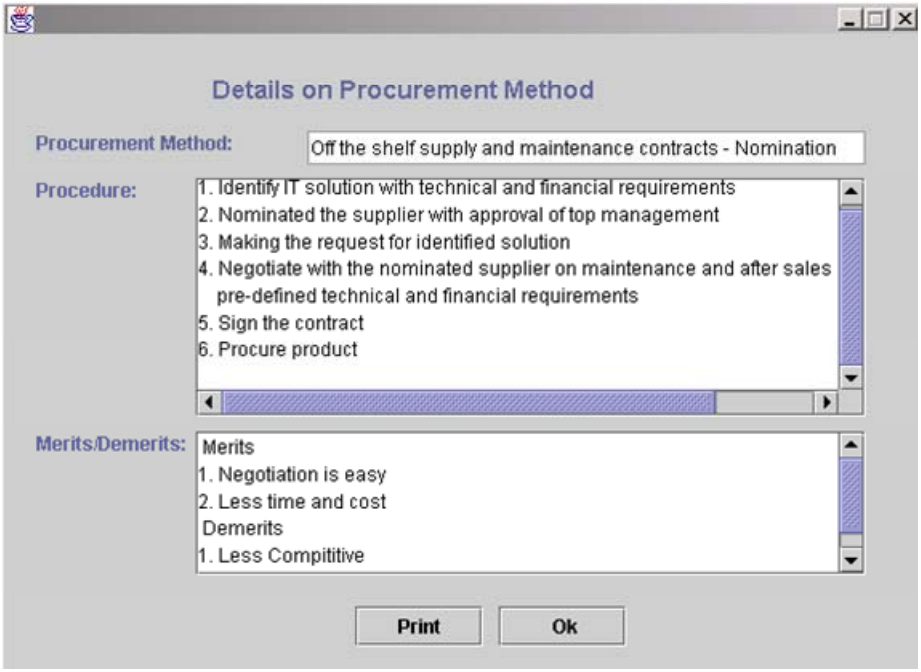

Figure 11: Reports on IT procurement methods

The main objective of this report is to provide more information on selected procurement method. Above figure illustrates procurement details regarding off the shelf supply and maintenance contracts (nomination). It depicts procedure in steps and merits and demerits of the method.

5.6 Model Validation and Expert Evaluation

The DSS model was first validated using thirty industry case studies. It was then followed up by an expert evaluation using a forum of five industry experts on IT and value engineering.

5.6.1 Results of model validation

Model validation was aimed at verifying contents of the model with industry practice. Thirty case studies were carried out using large-scale construction and non-construction organizations within the Colombo metropolitan area. Model derived results for 15 types of IT procurement were compared with the actual procurements occurred. The results indicated the existence of considerable variations in the selection of best-value IT procurement options compared with the industry practice. The following summarizes the comparison.

Out of fifteen IT solutions procured, only seven IT solutions (stand-alone computers, simple LAN, standard licensed software, web design, unskilled, skilled and professionals) represent similar results to the model derived best-value IT procurement options. However, order of ranking of best-value procurement options differs in most cases except in purchasing stand-alone computers and standard licensed software. The rest of the IT solutions represent completely different results. This is significant as it means that industry has not been using best value procurement options. The assignment of weights for IT procurement requirements was almost similar to the model assigned values except for two requirements: time and maintenance.

The model validation exercise shows clearly that model performance was different to the industry practice. Where differences exist, further evaluation through industry experts proved that model performance was acceptable over industry practice. The verification and expert evaluation process is explained in detail in the next section.

5.6.2 Results of expert evaluation

Expert evaluation was carried out as a series of semi-structured interviews, demonstrations and discussions; as such methods provide openness to an interviewee to express genuine opinion, feeling at ease. All opinions expressed by the experts were subjected to a three staged knowledge elicitation analysis process: (1) Transcript writing, (2) Abstracting and (3) Extracting. The extracted responses were tabulated to develop a frame for

analysis and consistency checking using Microsoft Access™. The Standard Package for Social Science™ (SPSS) and MS Excel™ software packages were used for statistical analysis and reporting on data. It concluded that the model assists the initial decision making process and is specifically useful for less IT literate personal to procure IT for construction organizations.

The summary of the expert evaluation is provided in Table 6.

Table 6: Summary of expert evaluation

Category	Description	Expert opinion
IT procurement model (DSS)	General view	-Model will assist less IT literate personal in construction organizations. -At present it is specific to the construction industry. -Performs is superior to industry practice.
	Shortcomings	-Facilitates only basic concepts of IT procurement. -Model should be updated to keep up with new developments in procurement. -Unavailability of system-help and tips (more a developmental issue).
	Suggestions	-Research should be expanded to other industries. -Should be flexible to accommodate future expansions. -Need to expand details of demerits of IT procurement methods. -Improve prototype to fully functional software.
Value engineering application		-Technique of value engineering (value matrices) was approved as a suitable method.
Whole research	General view	-Provides a clear guide on IT procurement for less-IT literate personnel. -Very useful.
	Shortcomings	-Inability of adopting the model in public sector organizations due to availability of government procurement procedure.
	Suggestions	-Expand guide to accommodate identification of best IT solutions and evaluation of bids. -Incorporate new techniques to identify best value IT solutions. -Conduct a standing forum to periodically obtain information from selected organizations.

The views expressed by the experts were considered in detail in the final phase of modification of the DSS. Following are some of the responses to the expert opinion.

- Model can be updated from time to time to incorporate new knowledge in procurement. This is a problem common to most DSS.
- Although public sectors organizations cannot directly adopt this model due to policies imposed on procurement by the government, it can still be used as a base to improve procurement polices or to verify decision making.
- Model was designed, evaluated and developed based on results obtained by literature, surveys and case studies obtained from construction organizations. Therefore, model is more suitable for construction organizations. However, the methodology and the conceptual model will be valid for implementation in any other industry or for any other country.
- Development of the model to fully functional software is not an issue of this research. It may require the collaboration with a software developer to form a knowledge transfer partnership.
- Extension of the research to other industries and new areas and conduct of a standing forum were not considered due to time and resource restrictions.

5.7 Benefits and Special Features of the Decision Support System

Following are the key features and benefits of the IT procurement method selection model and the DSS:

1) It creates a knowledge base on IT procurement methods that includes all aspects of procurement and facilitates best value IT procurement method selection.
2) It provides awareness of factors to consider in the selection of IT procurement methods including procurement requirements with standard definitions for each IT solution included in the system.

3) It provides a clear overview of best-value procurement options including procedures, merits and demerits. It encourages users to properly adhere to the standards in IT procurement.
4) It provides a methodology for selecting a procurement system and support in decision making while creating a knowledge repository for procurement of IT.
5) It provides an understanding of true cost of IT and assures the best value, cost savings and better performance in the procurement process. Systematic IT procurement will encourage greater investment in IT.

5.8 Limitations of IT procurement model

Following are some of the limitations of both the model and the research. These limitations were identified, understood and appropriate measures were taken to mitigate their effects where possible. Some are related to time and resources while others are practical obstacles beyond the control of the researchers.

1) Comprehensive industry survey was geographically limited to Sri Lanka.
2) Practical difficulties of testing the model in real time case studies, due to commercial considerations and unwillingness of companies to devote time on such an exercise.
3) The DSS is limited to providing assistance in the selection of IT procurement methods.
4) DSS development restricted to a scaleable prototype.
5) Mapping of building procurement was not incorporated into the model due to time and resource limitations.
6) There is no flexibility for the user to query for reports.

5.9 Further Development

There are many options available to expand the research. The following are some suggestions for the expansion of the research.

1) Expansion of survey into other industries (e.g. manufacturing, financial - banking etc.) which will improve contents and improve accuracy of the model and enable the creation of a comprehensive knowledge-base on IT procurement.
2) Learning from the wealth of knowledge available on building procurement methods as alternatives to existing methods of IT procurement.
3) Enhancement of the DSS to a web-based user guide allowing broader access. Although this is not a research issue, by enhancing the prototype to fully functional software will benefit industry users.
4) Expansion of the model to evaluate IT solutions to arrive at best value IT solutions will create a comprehensive IT procurement model incorporating both aspects of selecting the product and selecting the method of procurement.

6. CONCLUSIONS

Modern construction organizations are faced with a plethora of IT solutions to existing construction and organizational management related problems. They are presented as hardware, software, liveware (human resource) and IT service solutions. With the advancement of the information age construction organizations are often confronted with the dilemma of selecting the right IT product and efficiently procuring the selected product. Considerable amount of research has been reported on identifying the optimum IT solution for an organization (Abbott and Blundell, 2000; Cheung et al., 2001). However, identification of an appropriate method for procurement of IT that achieves best value remains a barrier. The construction industry is not an exception to this. However, due to fragmentation and the complex nature of the construction industry IT procurement has taken back stage in modern construction organizations resulting in unsatisfactory selection of IT procurement options and consequent failures. Through a comprehensive construction industry survey, Perera et al., (2003) identifies the adverse effects of poor IT procurement and consequent hesitation in investment on IT. This places emphasis on the need for formal guidance to assist in the decision-making process. This paper presented a decision support model for the selection of best value IT procurement methods. The first part the paper builds up a theoretical review of procurement of IT and the latter part presents a DSS as a solution for selecting the best valued IT procurement method using value matrices.

The approach was to identify and review industry practices established through a detailed two-staged survey and synthesize it with theoretical considerations identified through a comprehensive literature review and expert opinion. Consequently, a conceptual model was developed from the data extracted from the above processes. The technique of value matrices forms the central technique for decision analysis. The conceptual model was further developed to a detailed object oriented model. The model was then converted to a DSS through a rapid prototyping process using Java Net Beans development environment. The DSS model was validated using 30 real life case studies of IT procurement compared with model-derived procurement methods on 15 types of IT solutions. A focus group of 5 industry experts were used to successfully evaluate the system. Finally, through a process of rapid prototyping the validated model was successfully enhanced into a DSS to provide a user-friendly guide for IT procurement for construction organizations. The validation process and expert evaluations clearly revealed the superiority of the model and its greater industry relevance.

The research hypothesises that value matrices provide the basis for selecting best value IT procurement method. The validation process and subsequent evaluation through the focus group of experts proved that IT procurement model (and DSS) provides superior solutions to the existing industry practice. The DSS was designed to help understand procedures, merits and demerits of prevailing procurement methods for which IT investment can be directed. It was modeled using object oriented development methodology, developed using a relational database system (Microsoft Access) and operates in a menu driven mode on a system interface developed using Java (Net Beans IDE 3.6).

The research makes a significant contribution in developing a knowledge base for IT procurement that facilitates the selection of best value IT procurement method. The model serves as a knowledge repository for IT procurement and its object oriented nature allows it to be expanded to incorporate procurement experiences from the construction industry. It provides a methodology that can be further developed as a generic model for IT procurement. The research addressed the key issue of providing a value based framework for evaluating and selecting IT procurement methods.

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