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A decision support model for IT procurement for construction organizations

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Abstract

IT knowledge has become increasingly essential to the success of today's construction and will become more so in the future. Lack of effective IT exploitation in construction organizations often creates difficulty in justifying future expansion and use of benefits of IT innovations. The problem of identifying best IT products, procurement approaches, costs and benefits is one reason behind that. It is a global problem experienced in all types of business sectors and organizations. However, it is more acute in the construction industry as a result of its structure, fragmentation and under capitalization.

This paper presents Decision Support Model for IT procurement for construction organizations, which inbuilt with value management techniques. **Value Management is incorporated to model to identify best value IT procurement option for various IT solutions.** Value Management is an organized approach to providing the necessary functions at the lowest cost.

1 Introduction

Rapid evolution and spread of *Information Technology* (IT) during the last few decades has increased usage of IT in every category of business. The challenge is to minimize cost and upheaval, while making upward leaps in efficiency and performance. It is clearly evident in the world of business that IT represents an enhanced opportunity and methodology for competitive advantage (Siong, 1996). Nevertheless, it encompasses a fair share of risk. Inappropriate application of IT can spell disaster for the whole business.

Paulson (1995) states that *IT knowledge has become increasingly essential to the success of today's construction engineers and managers and will become more so in the future.* However, lack of effective IT exploitation methods in construction organizations often creates difficulty in justifying future expansion and use of IT innovations. The task of identifying best IT products, procurement approaches, costs and benefits are some reasons behind that. This problem is global and drawbacks are experienced in all types of businesses and organizations (Hochstrasser and Griffiths, 1991). It is more acute in the construction industry and is caused by its structure, fragmentation and under capitalization. A recent 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*. These underline the necessity of having proper approach to procurement.

A survey on the usage of IT in the construction industry of Sri Lanka revealed that there is organization wide poor utilization of IT (Athukorala, 2000). This demands the introduction of a tool to evaluate and prescribe procurement approaches and provides 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 approaches. This research hypothesizes the use of the tried and tested technique of Value Management (VM) as an appropriate methodology for providing a solution for the problem of IT procurement system selection. Value management is an organized approach in providing necessary functions at lowest cost (Kelly and Male, 1987) and will be discussed in detail in section 4.

The primary aim of this study on IT procurement is to investigate challenges associated with and development of Decision Support Model for construction organizations to assist in IT procurement which is capable of increasing customer satisfaction while removing unnecessary expenditure on IT procurement through incorporation of value management principles.

2 Research Methodology

The approach was to review previous theoretical considerations and current industry practices and then to synthesize a new approach drawing from the best practices in construction procurement. This new

approach was modeled through a value based framework drawn from value management. The conceptual model was then further developed using object oriented modeling techniques allowing the users to make an intelligent and informed decision on the procurement route. The model was tested with real life IT procurement scenarios and refined accordingly. The evaluated model was then implemented to a computer based Decision Support System (DSS) prototype with the intension of providing a user-friendly guide for IT procurement in construction organizations. The research involved experienced academics and industry representatives all of whom had direct experience in the IT based systems within construction organizations.

3 Litreature Review

Literature review on IT procurement 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). A recent article by Central Unit of Procurement in UK (quoted before) identified the importance of IT procurement from a value perspective. World Bank Report, (2001) defined IT procurement as *a common term used to designate all procurement having to do with computing and communications technologies regardless of whether they are hardware, software, supply or service components*. Also there are various articles on IT relating to budgeting, developing IT strategies, measuring benefits and procurement strategies. Techniques such have been used as marketing strategies to popularize their products by various leading companies in the world. There is no evidence for the availability of a standard guide for IT procurement in general or one that is specifically applicable for construction organizations. However, there are examples of application of management techniques such as cash flow forecast, life cycle costing and investment appraisal for the evaluation of IT investments (Drabble and Jenkins 2001; Thomasion 1999; Abbott and Blundell 2000). A much-detailed discussion on IT procurement is provided in Perera and Karunasena, 2004.

Literature review on Value Management reveals many definitions for VM (Albert et.al., 1996; Fong et al 1998; Green and Popper 1990; Kelly & Male 1992:1987, Kelly et.al., 2002; Norton and McElligott 1995; Martin 1997; Kelly, Male and Graham, 2004; Shen, and Liu 2003:2004; Sung and Connor 2005; Robert, Wood & Heep 2005). Larry Miles (1961) defined good Value as: "*a product or service that has appropriate performance and cost and as a problem solving system aimed at reducing expenditure of time and money whilst maintaining or increasing performance*". This is the view that has been promoted by most value associations worldwide and has found its way into national standards, from the seventies to the nineties. The new vision of VM as defined by the European VM standards is "*a style of management that evolved out of previous methods based on the concept of value and functional approach*". It claims that VM uniquely brings together (Kelly, Male and Graham 2004): Management style, Positive human dynamics, Consideration of external and internal environment and Effective use of methods and tools. As identified above VM is a systematic process for the improvement of value of functions but not a conflict orientated design review, a cost cutting process or a standardization exercise. However, it not the intention of this paper to analyze VM as a technique in detail but to explain its usage in IT procurement system selection. A much-detailed discussion on Value Management is provided in Perera, Karunasena, and Selvardurai (2003).

4 Survey Of The Construction Indsutry

A comprehensive survey of industry was conducted to establish current status of industry in terms of use of value management and methods of IT procurement. The survey also served as a method to establish the need for greater guidance in IT procurement for construction organizations.

Construction organizations in Sri Lanka are primarily represented by construction contractors and consultants. Therefore, the survey sample selected included over 90% of representatives of contractors and consultants. This included all the large-scale construction organizations, as they are capable of significant investments in IT. 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 was carried out by visiting the organizations and getting the person responsible for IT procurement to fill the survey responses within an interview session since it achieve a 100% response rate.

4.1 Main Findings of Survey

Following are the main findings of the survey. These are analyzed under two headings: VM related and IT Procurement related findings.

4.1.1 Use of Value Management in the Construction Industry of Sri Lanka

Most construction organizations consider value management as a relatively new concept. The only reported significant application of value management was in the construction of the World Trade Centre (Colombo). In this project value management techniques were applied throughout the project (Perera and Karunasena, 2003; Perera, Karunasena, and Selvardurai 2003). The survey identified the following as key factors contributing to poor usage of VM:

- Greater fragmentation of the industry.
- Professionals were educated separately in their isolated disciplines and accustomed to working independently (less collaboration and project approach).
- Less knowledge about benefits of value management among clients, developers etc.
- Unavailability of standards or guide for value management in Sri Lanka.
- Construction industry regulatory body i.e., the ICTAD does not actively encourage the practice of value management (they do not provide documentation, advice or guidance on VM).

4.1.2 IT Procurement Methods used in Industry

The Sri Lankan construction industry is IT backward and is no different to construction industries of most other developing countries (Premasiri, 2000). However, Kodikara and Costa (1993) show that the Sri Lankan construction industry has realized the potential of IT to a reasonable degree and that has resulted in a trend of greater investment on IT. Current practices regarding IT procurement in construction organizations reveal the following (Perera, Karunasena and Silva, 2004; Perera and Karunasena, 2004; Perera and Karunasena, 2005):

- 97% of organizations consider IT as a strategy to improve organizational performance. However, it is rear to see the full utilization of IT resources among these organizations.

- 75% of organizations hardly adhere to any rules and regulations for procurement of IT. Only 10% of government organizations involved with construction even adhere to the government prescribed "*Guidelines on Government Tender Procedure*" for procurement of material and equipment including IT.

- Absence of software licenses for purchased products. This is in fact violation of international copyright regulations. Only 3% had licensed software. It was also revealed that those who had legitimate software enjoyed the benefits of greater effectiveness, efficiency and security of the work than those who used pirate copies.

- 20% of organizations adopt a strategic plan for development of IT within their organizations while others have not even provided budgetary allocations for IT in their organizations. They tend to find finances as and when the need arises rather than pre-plan (an ad-hoc approach).

- Approaches available for IT Procurement include: Consulting services, Off-the-shelf IT supply and maintenance, System supply & installation and System Engineering. Each of these options can be used with different payment methods; direct purchase, hire or leasing.

- Although organizations consider the value of investments, there is no evidence of application of VM techniques to evaluate the IT procurement. The main reasons for non-usage of VM to evaluate IT procurement are the lack of knowledge, time and interest.

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.
- Inadequate knowledge on IT among the construction professionals.

Inadequate knowledge of professionals, difficulty of identifying best products and unsatisfactory after sales service is major causes of concern in procurement of IT for construction organizations. Although other factors do not directly affect IT procurement, they do indirectly towards decision making in investments on IT. The irresponsible attitude of construction industry authorities towards enhancement of IT in the construction industry is a significant issue. All these factors underline the need for guidance for IT procurement to assist professionals in the construction industry.

5 Decision Support Model

The main function of the model is to facilitate its users in intelligent and informed decision making on available procurement routes for various IT solutions identified. Primarily, it guides on *How to procure* IT solutions. This approach was adopted as various companies have various IT requirements based on size, activities and nature of business they are involved with. The IT solutions identified shall 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 selection and procurement of IT. It is designed to assist them with obtaining a ranked list of best-valued procurement methods, procedures and associated merits and demerits.

Development of IT procurement model consisted of two main phases as design and implementation. The Design phase was again considered in two stages as conceptual designing and information modeling. Conceptual design illustrates the principles of the model while information

model deals with contents of the model. Next stage was evaluation of contents to ensure accuracy and validity of data through industry based case studies. Evaluated model was further developed with computer-aided software to increase user friendliness and was tested with actual data for its accuracy and workability. Finally, an expert opinion survey was conducted to verify validity of the research and model through a series of demonstrations, unstructured interviews, and discussions.

5.1 The Conceptual model for Best Value IT Procurement

The conceptual design illustrates the basic concept behind the IT procurement model, which was based on secondary data collected through literature and individual experiences. Figure 1 illustrates this conceptual design of proposed IT procurement model.

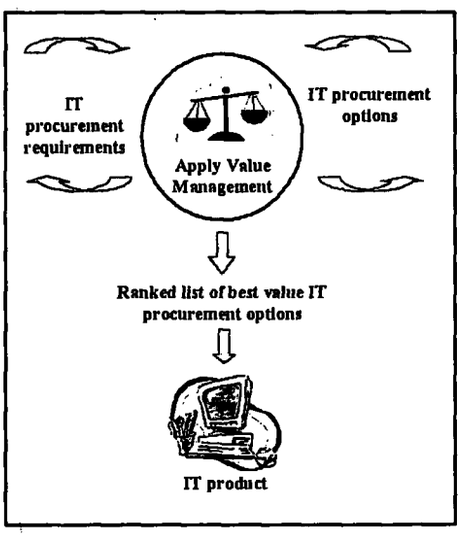


Figure 1: Conceptual design for IT procurement model

As illustrated above, value management act as the center technique incorporated to identify a ranked list of best value IT procurement options of selected IT solutions. Preferred IT procurement requirements identified by organizations and existing IT procurement options are considered in the value management process to identify best-valued procurement options, which will match procurement options to IT requirements. This was further designed to incorporate knowledge gained through industry and expert opinion surveys, as illustrated at Figure 2. This facilitated incorporation of new IT procurement options, procurement requirements and opportunity to address problems identified in current practice.

The model assumes that IT solutions already identified have satisfied functional, financial and technical requirements of organizations. Moreover, requirements are diverse and difficult to define, highly sensitive to changing business objectives, organizational politics and capacity of end users and are subjected to rapid technological changes over time.

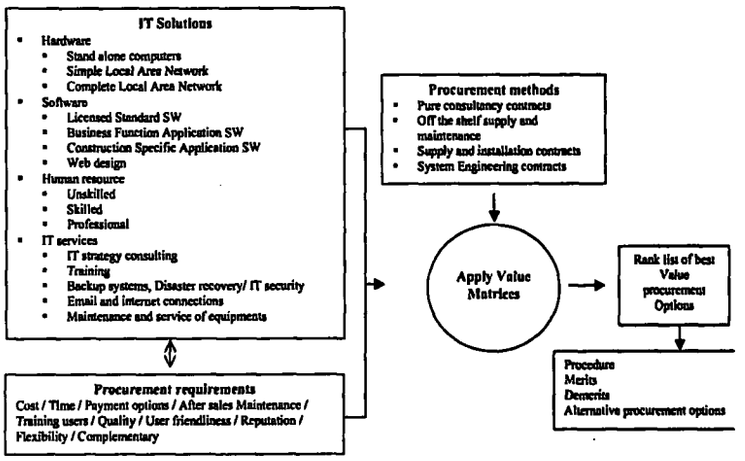


Figure 2: Detailed design for conceptual model

As illustrated at Figure 2 IT procurement requirements and procurement options identified are incorporated as inputs while a ranked list of best procurement options, procedures, merits, demerits and alternative procurement options are outputs of the model. The model uses value matrices (Refer 6.2) as a useful technique to match and compare competing alternatives to identify the best-valued procurement routes relevant to the identified IT solutions. It initially weighs evaluated criteria according to their relative importance and then scores alternatives based on weighted criteria to determine those that are optimal. In this IT procurement requirements are scored against IT procurement options to determine the ranked list of best-value procurement options for the IT solutions. An example of application of value matrices is illustrated in section 6.2.1.

The model provides for the adoption of experience gained from building procurement as alternatives learned from the construction industry. This will enable to device new procurement methods for IT procurement based on the experience of building 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; Tuner 1997). 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 designs. 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 (Ramakrishnan and Johannes 2004). 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,

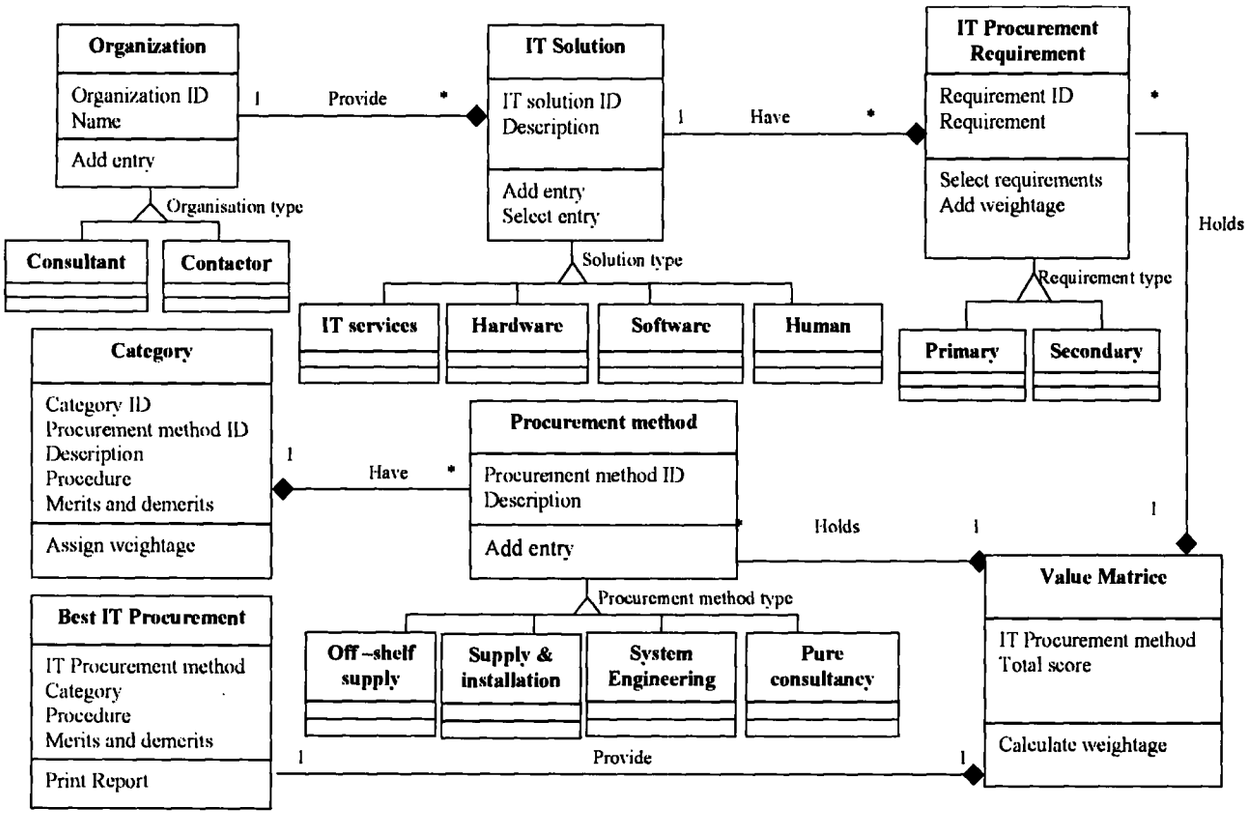


Figure 3: Object oriented model for IT procurement

furnishing a components based programming framework (Rumbaugh *et al* 1991; Booch 1991). The Unified Modeling Language (Collins, 2005) standard notations were used to express the content of the information model generated.

The object-oriented model for IT procurement is illustrated below at Figure 3.

Object models represent entities and their relationships. Model consists of seven classes as: Organization class (containing *organization. ID* and *name* fields), IT solution class (containing *IT solution ID* and *description*), IT procurement requirement classes (containing *requirement ID* and *requirement*), Procurement method class (containing *procurement method ID* and *description*), category classes (which contains *category ID, procurement ID, description, procedure* and *merits and demerits*), Value matrices class (containing *IT procurement ID* and *total score*), best valued 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 or process carried out by the system. The inheritance (labeled "organization type", "solution type" etc.) shows the categories or types belong to each.

5.2.1 Use of Value Matrices

The model 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.

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.

An example value matrix for a selected IT solution (purchasing stand-alone computers) is illustrated below (Table 1 and Table 3).

Table 1 Weightage 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

Application of points based on the manner in which selected alternatives satisfy procurement requirements (identified above in Table 1). The satisfaction point scale used is given below.

Table 2 Degree of Satisfaction Points Scale

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

Table 3: Alternative analysis matrices

	T	C	PO	AS	M	Q	R	F	CO	Total	Rank
	10	**10**	**7**	**9**	**9**	**10**	**8**	**5**	**3**		
P1	5	3	1	3	3	3	3	5	1		
	50	*30*	*7*	*27*	*27*	*30*	*24*	*25*	*3*	*223*	*3*
P2	5	3	3	3	3	3	3	3	3		
	50	*30*	*21*	*27*	*27*	*30*	*24*	*15*	*9*	*233*	*2*
P3	5	5	5	5	5	5	5	1	3		
	50	*50*	*35*	*45*	*45*	*50*	*40*	*5*	*9*	*329*	*1*

Alternative procurement options;

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)

Above example illustrates the use of value matrices for an identified IT solution for purchasing stand-alone computers. Initially weightage is assigned to each IT procurement requirement according to its relative importance (code denotes shorten form for IT procurement requirements). In this example cost, time, quality, and maintenance and after sales services are considered as critical factors.

Then at alternative analysis matrix weighted IT procurement requirements are scored against alternative IT procurement options identified to determine a ranked list of best valued procurement options for the IT solutions identified. Application of points for each alternative is based on above criteria, which represent state of satisfaction of procurement requirements among selected alternatives where zero represents non-satisfaction and 5 points represents full satisfaction of requirements.

The summary of knowledge content of the information model identifying IT category, identified IT solutions, procurement requirements of each IT solution and ranked list of best valued IT procurement options that provide information for the value matrices process for each IT solution is illustrated at Table 4.

Table 4: Summary of model

IT category	IT solutions	IT procurement requirements	Ranked list of best valued IT procurement options
Hardware	Stand alone computers	Cost, Time, Payment options, After sales, Maintenance, Quality, User friendliness, Reputation, Flexibility, Complementary	Off the shelf supply contracts: *Calling quotation, Through nomination,* Direct purchasing
	Simple Local Area Network		Supply and installation contracts: *Calling quotation, Open tendering, Through nomination*
	Complete Local Area Network		Supply and installation contracts: *Open tendering, Calling quotation, Through nomination*
Software	Licensed Standard SW	Cost, Time, Payment options, After sales, Maintenance, Training users, Quality, User friendliness, Reputation, Flexibility,	Off the shelf supply contracts: *Through Agents, Through original manufactures*
	Business Function Application		Off the shelf supply contracts: *Open tendering, Bespoke development, Through agents, Original manufacturer, Calling quotation, Through nomination*
	Construction Specific Application	Cost, Time, Payment options, After sales, Maintenance, Training users, Quality, User friendliness, Reputation, Flexibility, Complementary	Off the shelf supply contracts: *Bespoke development, Open tendering, Through agents, Original manufacturer, Calling quotation, Through nomination*
	Web design		Supply and installation contracts: *Calling quotation, Open tendering, Through nomination*
Human resource	Unskilled	Experience, Educational and Professional qualifications, Time, personality	Nomination, *Through Agents, Paper advertisement*
	Skilled		Paper advertisement, *Through Agents, Nomination*
	Professional		Paper advertisement, *Through Agents, Nomination*
IT Services	IT strategy consulting	Cost, Time, Payment options, Quality, Reputation, Flexibility Complementary	Pure consultancy contracts; *Calling quotation, Open tendering, Through nomination*
	Training		Off the shelf supply contracts: *Calling quotations, Through Agents, Open tendering, Through nomination*
	Backup, Disaster recovery /IT security Email and internet connections	Cost, Time, Payment options, After sales, Maintenance, Training users, Quality, User friendliness, Reputation, Flexibility, Complementary	System supply contracts: *Open tendering, Calling quotations, Through nomination*
	Maintenance and service of equipments		Off the shelf supply contracts: *Calling quotations, Open tendering, Through nomination*
			Off the shelf supply contracts: *Open tendering, Calling quotations, Through nomination*

5.3 Results of model evaluation

Model evaluation was aimed at verifying contents of model with industry practice. Case studies were carried out among large-scale construction and non-construction organizations (numbering 30) within the Colombo metropolitan area to obtain an industry-wide perspective. The results indicated the existence of some variations in the selection of best-valued IT procurement options compared with the industry practice. Following summarizes the comparison between model-derived options over current practice.

Out of fifteen, only seven IT solutions (stand-alone computers, simple LAN, standard licensed software, web design, unskilled, skilled and professionals) represent similar results to best-valued IT procurement options derived by the model. However, order of ranking of best-valued procurement options differs in most cases except in purchasing stand-alone computers and standard licensed software. Rest of IT solutions represents different results. This is significant as it means that industry has not been using best value procurement options. Assignment of weightages for IT procurement requirements was almost similar to model assigned values except two requirements: time and maintenance. The significant fact was that all the case studies did not cover all the IT solutions identified in the model.

From the model evaluation it was clear that model performance was different to industry practice. Where differences exist, further evaluation proved that model performance was acceptable over industry practice. This was then verified using domain experts. The verification and expert evaluation process is explained in detail in section 6.5.

5.4 Decision Support System Developments and Evaluation

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

5.4.1 Database development

DSS database uses a structure of relational model as it provides the ability for end users to create and change records in the database in a user-friendly manner (Lonnie and David, 1997). Moreover, many standard software packages facilitate development of relational databases. Relationships among entities of the DSS were illustrated at object model in section 6.2. There are various software programmes available for database development such as Oracle, Microsoft SQL and IBM™ DB compatible with Java development. Microsoft™ Access 2000 was used for database development for the present DSS because development is restricted to a prototype (Only for demonstrative purposes).

5.4.2 System interfaces

System interfaces were developed using Java programming language, 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). Net Beans IDE 3.6 (Integrated Development Environment) was made use of as the tool to develop system interfaces due to its user-friendly development environment avoiding basic programming complexities. It is a free product with no restrictions, which can write, compile, debug and deploy Java programs. Also, it enables delivery of high quality, highly functional software faster with lesser maintenance over time. There are four user interfaces including main and sub menu in DSS as explained below.

5.4.2.1 Main menu

This is the gateway to the DSS. It consists of four main menus and some carry sub menus.

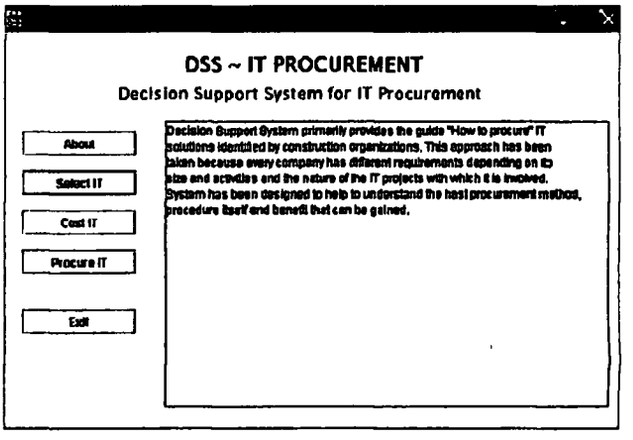


Figure 4: Main Menu

The five main options available in the main menu (**Figure 4**) are explained below:

- About - Provides introduction to DSS
- Select IT - Provide details of particular considerations that should be considered during selection of IT categories as discussed above (refer annex 6.1).
- Cost IT- Provides understanding of true cost of IT (refer annex 6.1).
- Procure IT - This is the main component of the DSS. This provides a guide to identify better-valued IT procurement options, procedures, merits and demerits of identified IT solutions with preferred IT procurement requirements.
- Exit- Exit from the system.

5.4.2.2 IT procurement requirements entry

This form (Figure 5) facilitates input of procurement requirements to the system.

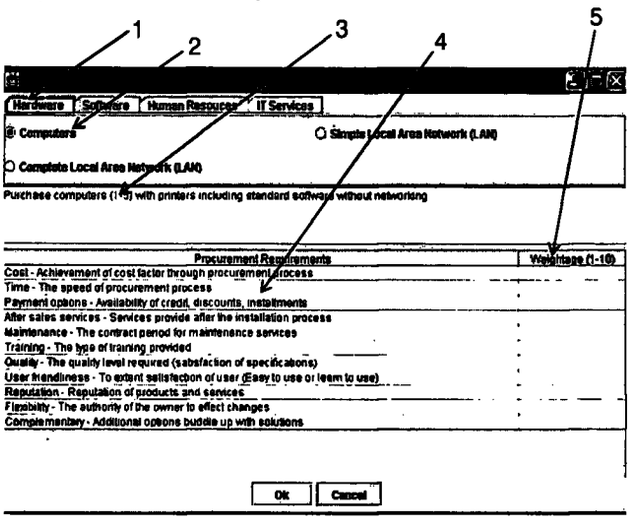


Figure 5 : IT procurement requirements entry form

This form is used to enter IT procurement requirements for identified IT solutions. The main parts of the input screen are explained below.

1. Select IT category
   E.g.: Hardware, Software, Human resource and IT services

2. Select IT solutions identified under each category

Hardware - Purchase computers, network design and implementations

Software - Standard licensed software, business function software, construction specific software and web development

Human resource - Unskilled, skilled and professional
IT services - IT strategy consulting, training, backups/ disaster recovery/ IT security, maintenance and servicing and email and Internet connections.

3. Provides descriptions of selected IT solution
4. Select IT procurement requirements
5. Place preferred weightage for selected IT procurement requirements (Rank 1-10)

5.4.2.3 Ranked list of better valued IT procurement methods

This form (**Figure 6**) provides ranked list of better-valued IT procurement options for identified IT solutions.

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

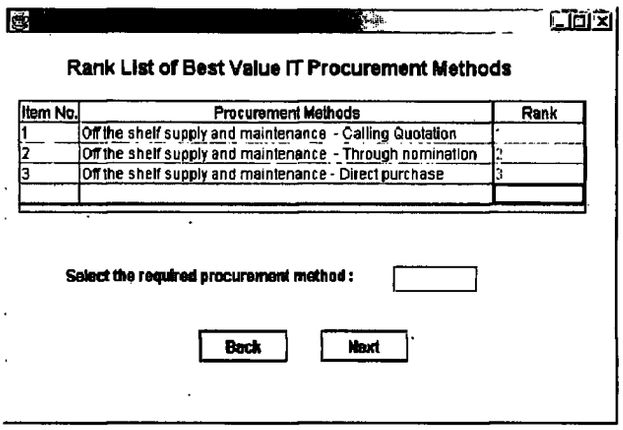


Figure 6: Ranked list of IT procurement methods

5.4.2.4 Reports

This form **(Figure 7)** 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

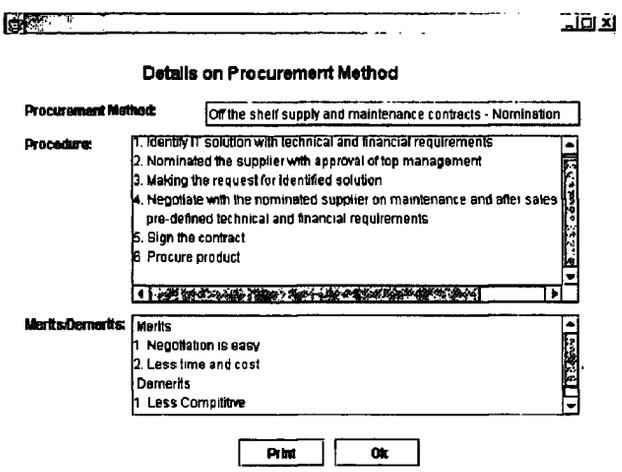


Figure 7: Reports on IT procurement methods

The main objective of this report is to provide more information on selected procurement method to give a clear and overall overview. 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.

5.4.3 System Testing

The DSS prototype was tested in two stages by using sample data and actual data. In the first stage it was tested by using hypothetical cases to validate the development process. Then the model was tested with actual scenarios developed by results extracted from the industry-based case studies to verify accuracy.

If the DSS to be implemented as a industry software it should be developed further by the use of same software programmes or any other to make it a fully functional software. Since at present it is a prototype most interfaces are saddled with default outputs.

5.5 Evaluation of system and Feedback

An expert opinion survey was conducted among five industry experts on IT, value management and construction to validate the model and the DSS and to verify its industry acceptability. It 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.

5.5.1 Results of expert opinion survey

Expert opinion survey concluded that this model assists the initial decision making process and is specifically useful for non-IT literate personal to procure IT in construction organizations. The summary of information reveled from the expert opinion survey is illustrated in **Table 5**.

below table illustrates results extracted through the expert opinion survey. 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.
- Although public sectors organizations cannot directly adopt this model due to policies imposed on procurement by the government, still it can be used as a base to improve procurement polices.
- Model was designed, evaluated and developed based on results obtained by surveys and case studies obtained from construction organizations. Therefore, model is more suitable for construction organizations.
- Although development of model to fully functional software is not an issue of this research, by enhancing it up to that extent will provide more benefits to construction industry.
- Also extension of research to other industries and new areas, holding a forum to gather information to improve content and accuracy of the model were not incorporated due to time and resource restrictions of this research.

However ten cases of data collection and two cases of model evaluation were conducted on IT industry (IT service providers) to act as a benchmark against which construction industry can be reviewed, compared with other industries and also to learn from successes and failure.

5.6 Benefits and Special Features of Decision Support System

Following are the key features and benefits of the DSS:

1. It creates a knowledge base on IT procurement that includes all aspects of procurement and the knowledge content modeled to facilitate best value IT procurement.

Table 5: Summarized information of expert opinion survey

Category	Description	Expert opinion
IT procurement model (DSS)	General view	-Model will assist non-IT literate personal in construction organizations -Does not provide significant assistance in case of other industries.
	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.
	Suggestions	-Research should be expanded to other industries to obtain more accurate and broader concepts.-Should be flexible to accommodate future expansions. -Expansion of details of demerits of IT procurement methods. -Improve prototype to a fully functional software.
Value management application		-Technique of value management was approved as a suitable method.
Whole research	General view	-Provides a clear guide on IT procurement for non-IT literate personnel. -Very useful.
	Shortcomings	-Inability of adopting model in public sector organizations due to availability of imposed government procurement procedure. -Model is limited for the construction industry organizations.
	Suggestions	-Expand guide to accommodate identification of best IT solutions and evaluation of procurement bids. -Incorporates new techniques to identify best value IT procurements. -Conduct a forum to obtain information from selected organizations.

2. Provide awareness of factors to consider in the selection of IT procurement methods.System provides IT procurement requirements with standard definitions for each IT solutions included in the system.
3. A decision support system designed for IT procurement. System provides clear overview of best-valued procurement options including procedures, merits and demerits, which assist in the initial decision making on IT procurement. It encourages users to properly adhere to the standard IT procurement methods.
4. Provides a methodology for selecting a procurement system.
5. Flexibility of indicating preference (weightage) for IT procurement requirements.
   System provides opportunity to indicate preference (weightage) for selected IT procurement requirements according to their importance on a 1 to 10 scale. Based on the relative importance of factors the system provides a ranked list of best valued IT procurement options.
6. Reports on procedures, merits and demerits of best valued IT procurement methods on screen and as printed documents.
7. It provides an understanding of true cost of IT and assures the best value, cost savings and better performance in the procurement process.
8. Systematic IT procurement will encourage greater investment in IT.

5.7 Limitations of IT procurement model

Following are some of the limitations of both the model and research. These limitations were identified, understood and appropriate measures 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 only provide assistance in the selection of IT procurement method.
4. Model development restricted to a scaleable prototype.
5. Mapping of building procurement was not incorporated into model due to time and resource limitations.
6. No flexibility for the user to query for reports.

5.8 Possibilities for 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, banking etc.) which will improve contents and accuracy of the model and enable the creation of a comprehensive knowledge base on IT procurement.
2. Similarly, extension of the research beyond the geographical boundaries of Sri Lankan to encompass other countries.
3. Incorporation of building procurement methods as alternatives to methods of IT procurement.
4. Enhancement of DSS to a web-based user guide allowing broader access. Although this is not a research issue, by enhancing prototype to fully functional software (real time system) will benefit industries in IT procurement.

6 Conclusions

Organizations are extremely pressurized through evolving and demanding markets to increase productivity more than ever before in history. Increasing productivity has become a key to remain competitive and viable in today's post industrialized, information oriented society. But the very resource that organizations need to remain competitive costs more. The only available exception is the computer technology (Whitten, 1989). According to Ahmad and Russell (1995) IT can no longer be viewed as an enhancement of traditional business procedures but rather as an innovative agent that enables new and different alternatives to organising, administering and operating business enterprises.

As a result, organizations tend to invest on IT. Although organizations have recognized adequate IT solutions to prevailing problems, identification of an appropriate approach for procurement of IT that achieves best value remains a barrier or a key constraint faced by potential investors of IT. The construction industry is not an exception to this. However, due to fragmentation and complex nature of the construction industry IT procurement has taken back stage in modern construction organizations resulting in unsatisfactory selection of IT procurement options. 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 decision-making process for IT procurement specially aimed at non-IT literate top and middle management of construction organizations. Thus the aim of this research was focused at the development of a Decision Support System for IT procurement for construction industry organizations.

The approach was to review previous theoretical considerations and current industry practices to synthesize a new approach drawing from best procurement practices prevalent in construction industry. It was also designed to incorporate principles of value management in selection of best procurement route. The data extracted were then modeled into an

object oriented model allowing users to make intelligent and informed decisions on available procurement routes. The model designed was also tested with real life IT procurement scenarios and then subjected to necessary alterations and refinement, where necessary. Finally, the evaluated model was successfully enhanced into a Decision Support System to provide a user-friendly guide for IT procurement in construction organizations.

IT procurement model (and DSS) was designed to help understand merits and demerits of prevailing procurement methods for which IT investment can be directed. It is modeled using object –oriented development methodology to assist them to obtain a ranked list of best-valued procurement methods, procedures, and their merits and demerits. Decision Support System was developed using a relational database system and operates in menu driven mode. Microsoft Access for databases and Java (Net Beans IDE 3.6) for system interfaces were used as development tools for DSS. The benefits expected are the assurance of best value and cost savings and better performance in the procurement process.

6.1 Further research

This research can be further developed in many ways as identified below:

1. Application of value management for decision-making process of selection of IT solutions in construction organizations.
2. Development of value based framework for assessment of benefits of new IT innovations in construction organizations.
3. Introduction of valued based Decision Support System for bid evaluation for IT procurement.

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