Jurnal Teknologi

Full Paper

APPRAISAL OF APPLICATION OF VALUE ENGINEERING METHODOLOGY IN MECHANICAL AND ELECTRICAL SERVICES INSTALLATIONS

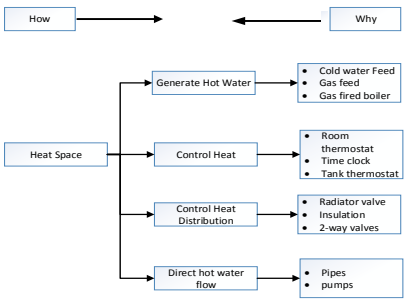
Amuda–Yusuf Ganiyu[a*], Sanni Afeez O.[b], Olowa Theophilus O.O.[b]

[a]Faculty of Built Environment, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Institute of Environmental studies, Kwara State Polytechnic, Ilorin, Kwara State, Nigeria

Article history
Received
15 April 2015
Received in revised form
29 September 2015
Accepted
12 November 2015

*Corresponding author
akatech4real@yahoo.com

Graphical abstract



Abstract

Value engineering (VE) is a structured team-oriented problem solving approach that can be applied throughout the lifecycle of a building project. However, the methodology is rarely applied in mechanical and electrical services (M&E) installations in buildings because clients are not aware of the potential benefits of adopting VE and different members of design team lack the requisite knowledge about VE methodology. As a result, a great deal of unnecessary cost is created due to the increasingly complex nature of M&E services in buildings leading to cost overruns and unhappy clients. The purpose of this study is to investigate the level of adoption of VE methodology in the design and installations of M&E services in buildings in Malaysian construction industry. The research method adopted is questionnaire survey to industry practitioners and inferential statistics was adopted for data analysis. Findings from the study show that, VE is not well appreciated in the industry and there is no structured approach adopted for its adoption for the procurement of mechanical and electrical services. Practitioners are of the opinion that implementation of VE could lead to: significant capital and life cycle cost savings in buildings generally; alignment of stakeholders and construction process improvement; improved client satisfaction, and shared understanding among key participants. An implementation framework was developed which emphasised on the need for early involvement of consultants and collaboration between the downstream supply chain for effective implementation of VE methodology on mechanical and electrical services.

Keywords: Design, framework, mechanical and electrical, value engineering

© 2015 Penerbit UTM Press. All rights reserved

1.0 INTRODUCTION

Construction industry constitutes one of the pillars of domestic economy in Malaysia, contributing about 3.5% to the National GDP. The Malaysian construction industry contributes significantly to the national economy. The annual output of the sector in 2011 is worth about RM50 billion accounting for 3.5% of the GDP. The sector employs about 800,000 labour forces [1]. Meanwhile, under the 10th Malaysian Plan, a total of RM138 billion has been allocated to various capital projects to be executed directly by the construction industry. The activities of the sector are championed by the Construction Industry Development Board (CIDB). CIDB a government agency established under the Construction Industry Development Board Act 1994 (Act 520) with a mission to develop the Malaysian Construction Industry [2]. The board is entrusted with the sole duty of coordinating the activities of the Malaysian construction industry and planning the direction of the activities of the sector in line with government policies. In pursuance of improved global relevance, continuous improvement and adoption of best practices in the construction sector of the economy, CIDB established a 10 year strategic roadmap christened the Construction Industry Master Plan (CIMP 2006 – 2015) which is aimed at refocusing the strategic position of the industry.

Evaluating practitioners' preparedness for the aspirations of the construction industry, the Construction Industry Development Board [3] lamented that practitioners engaged in the procurement of building services are not meeting up with the expected challenges of globalisation, especially in the areas of building services specifications, tendering and cost management. [4] considered that, this could be as a result of slow learning curve by practitioners' and lack of generally accepted building services standard method of measurement. [5] suggested the need to develop and adopt building services standard method of measurement (BSSMM) for preparing BoQ for building services so as to reduce the financial risk associated with its price uncertainty. They go on to argue that, such standard could be adopted as basis for teaching quantity surveying students as well as providing a basis for training existing industry experts. This will enhance the quantity surveyor's ability to provide more reliable building services pre-contract budget estimate [6]. To achieve this, Amuda–Yusuf and Mohamed [5] considered that:

- There should be a conscious effort from industry stakeholders and academics to resolve some pedagogical issues on building services technology as its relates to quantity surveying
- Strategy should also be developed to involve major downstream supply chain at the inception of M&E services project to reduce the risk of incomplete design information which will affect the quality of cost information generated
- The need for early collaboration between quantity surveyors and building services consultants' engineers.
- Application of value engineering in processing client's requirements on major building services components.

The other issues considered by [5] include early involvement of major downstream supply chain during design, collaboration between QSs and engineers and adoption of value engineering in processing client's requirements. Currently, in the Malaysian Construction industry, there are various road maps by government agencies and professional bodies to encourage the adoption of Building Information Modelling (BIM) in the industry and this will go a long way to address those issues [7] Building Information Modelling (BIM) is an emerging technology that incorporates a methodology based around the notion of collaboration between stakeholders using ICT to exchange valuable information throughout the project lifecycle. Such collaboration is seen as the answer to the fragmentation that exists within the building industry, which has caused various inefficiencies [8]. Generally, application of VE methodology to process clients' requirements at the early stage of mechanical and electrical (M&E) services projects is an area that has not been properly investigated in the context of Malaysian practice. Meanwhile, it is argued that VE could be adopted in M&E services design and components selection to overcome design related and coordination problems at both pre and post contract stages of M&E services procurement. Therefore, the objective of this study is to identify the challenges and benefits of applying value engineering in mechanical and electrical services

2.0 LITERATURE

2.1 Value Management/Value Engineering

The provision of the client's needs is the only key to providing value and satisfaction [9]. Value refers to materials, parts or products – something materialistic which is possible to understand and to specify. Construction is a process of delivering this value to the client through a temporary production system [10]. Therefore, the identification and definition of exact client requirements is paramount in achieving client perception of value for money [11]. This can be achieved by applying the principles of value engineering (VE) at the early stage of a building project. The term is used interchangeably by some author [12]. However, for the purpose of simplicity and to avoid confusion, the term is referred to as Value Engineering Methodology (VE) in this study.

Reasonable evidence exists in literature which shows that VE has its foundation in the North America in the late 1940s, and was initially called value analysis (VA). According to [13] value analysis is an organised approach to the identification and elimination of unnecessary cost, where unnecessary cost is defined as a cost which provides neither use, nor life, nor quality, nor appearance, nor customer features. The use of VE in UK manufacturing sector started in 1960 and the name was changed to value management in 1972 by the UK Institute of Value Management and the term value management is commonly used in Europe with the exemption of France which uses value analysis [13]. VE employs multi–disciplinary team and draws upon the collective viewpoints, experience as well as their knowledge at the early stage of design process to identify high cost function with improvement potential to achieve client requirements [11]. When implemented correctly, it can substantially reduce cost without harming quality and encourages greater integration of the design team [12]. Kelly and Male [13] identified a series of critical success factors for VE to be implemented correctly and these include:

- Multi-disciplinary team/appropriate skill mix
- The skill of the facilitator
- A degree of VE knowledge on the part of participants
- Presence of decision takers in the workshop
- Participant ownership of the VE process output
- Preparation prior to the VE workshop
- Functional analysis
- Participant and senior management support for VE and
- A plan for implementation

2.3 Value Engineering Principles

Generally, value is the relationship between function, need and cost. However, when function meets the need at the lowest cost, then good value is considered to be obtained. The basic philosophy of value engineering is to eliminate the cost which does not contribute to the performance of the required function [14]. The term value engineering is sometimes referred to as value methodology, value analysis, and in some other countries value for money [15]. VE is a structured approach to defining what value means to a client in meeting perceived objectives. It addresses overall project objectives, questioning the need for the project in the first place and seeking to clarify the clients' priorities in achieving the project [16]

2.4 The Job Plan

VE job plan is defined through special phases ranging from five to eight in various versions, all following the same concept [17]. A typical version comprising of five phases is described in this study.

- Phase 1 - Information: Information relating to cost, drawings, and specifications, manufacturing methods, sample and prototypes are secured in this phase.
- Phase 2 - Creative Phase: - Identification and classification of functions are carried out here. It takes the questions: what else could do the job? And how much does it cost?
- Phase 3 - Evaluation Phase: - Rank and rate ideas to select the best alternatives. Here the questions: will it work? Is asked and the total costs are compared along with intangible factors.
- Phase 4 - Development phase: - Benefit analysis is carried out to for final 'value engineering proposal' (VEP)
- Phase 5 - Recommendation and approval phase: - recommending VEP change and improvement proposal.

2.5 Team Composition

A team consisting of five to seven persons usually produces the best results, and the ideal groups for VE should embrace different disciplines [15]. This should include design group; Value engineering facilitator, and Experts. The team is referred to as VE team and are often multidisciplinary and integrated to achieve common project goal [18]. In short, all stakeholders must be part of VE study [19]. It is consider important for a person who has the authority to make and take decisions during the workshop as the most effective workshop in terms of implementation is the one where the client representative has the authority to take decisions and is a member of the workshop team working with the project team [13]

2.6 Value Engineering Workshop

The value engineering workshop involves a number of steps that comprise the job plan earlier discussed. During the implementation of job plan an additional step is introduced in the workshop known as the functional analysis. The job plan and functional analysis are very important in VE workshop. VE workshop is best optimised when it is applied at the following stages of construction process: the pre-brief workshop; the brief workshop; the concept design workshop; the detail design workshop

2.7 Brainstorming

A Brainstorming session, usually, includes four to six people meeting to suggest solutions for a specific problem [19]. It is implemented during creativity phase of the VE session. At this stage, the aim is to generate ideas that will fulfil the required function(s) and quality at no cost, increase function(s) and quality for the same costs; or increase functions(s) and quality for less cost [20]. Although, brainstorming has been described as an effective tool to generate hundreds of ideas in a short time but some researchers has pointed out that Brainstorming is nothing more than 'mental popcorn' and that it does more harm than good [20]. Yamaguchi

[25] believed that brainstorming was not a good way of generating implementable ideas while [21] argued that there are other creativity techniques, which are, more useful than brainstorming.

2.8 Functional Analysis

Function analysis is a systems approach to technological design integrating both cost and performance criteria [22]. It is used to define the problem and identify the various parts to the project. This is done by using Function Analysis System Technique (FAST) diagram in Figure 1. This diagram captures the "how – why" (and sometimes when) relationship between the function of an item, system, or process. Functional analysis recognises that there is always more than one way to achieve project objectives and that examination of the alternatives will produce the most acceptable conclusion [23]. The analysis is constructed so when read left to right it shows how the objective is to be determined and when read from left to right to left it answers the why as shown in Figure 1 [24].

Most researchers [25,26,27,28] seems to agreed that FAST diagrams are an outstanding analytical technique, which can be used to analyze and manage the most complex processes. In contrast, Green [29] argued that the same sequential methodology central to traditional design development is adopted therefore making parallel decision a difficult task to consider. Green concluded that functional analysis is no more than the application of standard problem solving to building design.

2.9 Timing

According to [30], VE is best applied at the early stage of a project. Hayden and Parsloe [16] observed that VE occurs at the scheme design and detailed design stages.

However, [15] stated that VE is most effective when it is undertaken during the early stages of a project when the ideas are still conceptual and the sponsor and designer can be flexible with regard to their decisions without incurring delays in the project schedule. [31] believes it is best at 35% design completion. While it was put on a sliding scale of 30 – 35% by [26]. However, previous studies on the subject suggest that the maximum cost reduction potential and opportunity to change occurs at the early stage of the project life cycle [32].

2.10 Value Engineering of Building Services

Harden and Pasloe [16] explained that application of value engineering in building services could lead to improved communication and team working; a shared understanding among key participants; better quality project definition, and design briefing as well as increased innovation. They considered that, the adoption of VE by building services consultants and contractors will give them a competitive edge for optimum performance. According to [33], maximizing value and minimizing waste at the project level is difficult when the contractual structure inhibits coordination, stifles cooperation and innovation, and rewards individual contractors for both reserving good ideas, and optimizing their performance at the expense of others.

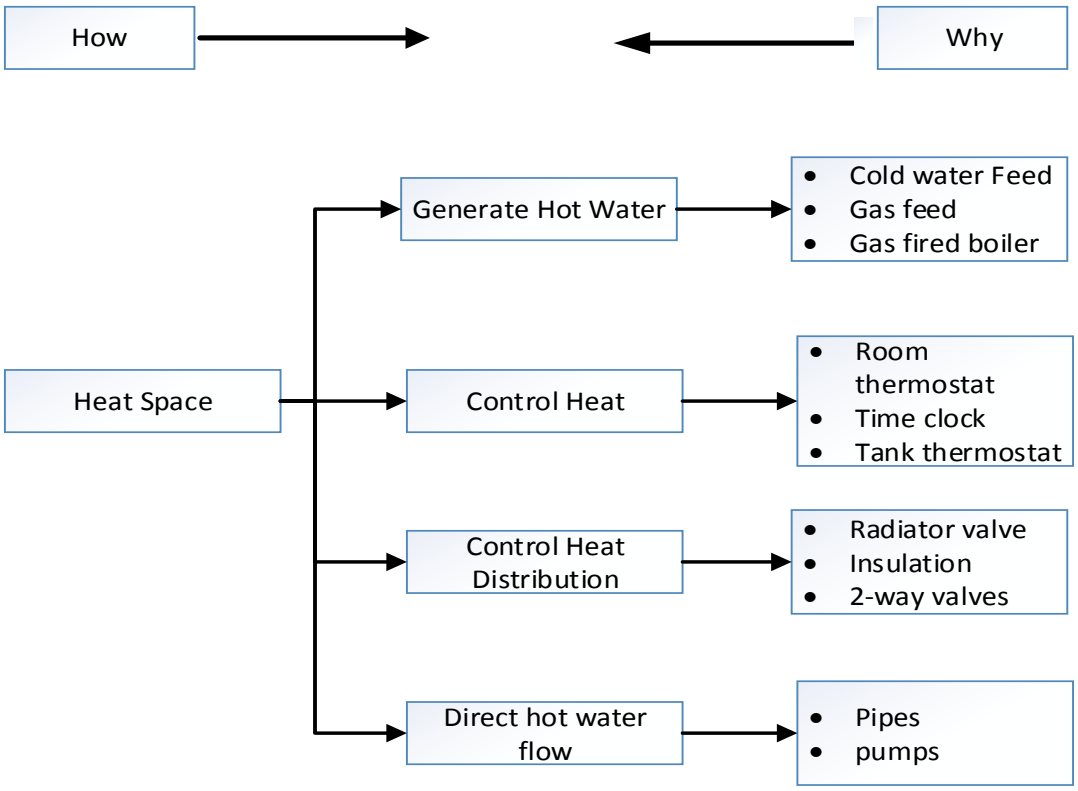


Figure 1 A function logic diagram building services heat installation [24]

Application of VE will ensure the consideration of all available options to ensure that optimal solution is achieved for clients' value criteria by the team involved in the process.

2.11 Causes of Unnecessary Cost in Building Services.

Hayden and Parsloe [16] stated that when comparing any two design alternatives, it was found that one was lower in cost than the other but met all of the functional requirements, then the difference in cost between the two alternatives is unnecessary. Therefore unnecessary cost occurs as a result of:

- Lack of idea – first workable solution comes to mind
- Poor information- the engineer may not have all the information he needs in order to make decision
- Honest wrong beliefs – engineers believe in a pre–defined procedure of performing a task may turn out to be wrong when examined
- Habits and attitudes – old habits can be very difficult to shelf
- Reluctance to seek advice
- Out of date specification
- Poor human relations,

2.12 Benefits of Value Engineering

Evidence abounds that cost savings of between 10 to 25% can be made from a careful application of VE methodology on building services installations and the cost of achieving these savings is estimated to be between 0.5 and 1% of the building services cost [16]. Since the objective of value engineering is to achieve maximum value for client's money, then it can be argued that the process will deliver the following benefits: better business decisions; increased effectiveness; improved product and services; enhanced competitiveness; a common value culture; improved internal communication; multidisciplinary and multitask teamwork, and decisions which can be supported by all stakeholders [26].

In addition to cost savings, VE can bring about the following benefits: improved communication and team working; a shared understanding among key participants; better quality project; better definition and design briefing, and increased innovation. While it is believed that VE approach brings about high degree of clients' satisfaction; improved functionality, and cost savings ranging from 5–15%. This standpoint was supported in the work of [18] when they consider that FAST diagram is a powerful tool for analysing function and functional relationships, which mentally equips and enables the team to think "outside the box". Cell and Arratia goes on to argue that the use of functional analysis facilitates communication by diverse team member with different backgrounds, thereby, providing for new points of view and ideas, as well as a better understanding of how one area impacts other portions of the value stream. However, [15] observed that the greatest benefits of VE are the

cost saving potentials, determination of project mission and identifying possible alternative directions.

2.13 Challenges of Value Engineering

Despite the well documented benefits of value engineering. Recent research has identified a number of specific challenges that contribute to poor value being achieved. For instance, [34] observed the following challenges to the implementation of VE in South East Asia:

- Divided authority and decision making process among project stakeholders;
- Conflict of interests among the various parties;
- Lack of communication among the different stakeholders;
- Lack of time to implement especially when value engineering is applied to a specific project rather than a more permanent production management system;
- Lack of knowledge/ awareness about value engineering in the industry.

Furthermore, [23] state that biggest danger to the development of VE in UK include; the drive towards "tick box" approaches by clients; economic drive towards shorter studies, and VE being seen purely as workshop facilitation. [31] think that managing team dynamics is not easy; difficulties in using FAST diagramming; leadership transference to the VE facilitator, and fall down of VE at implementation stage. In another study, [25] also identified Conflict between VE and design team, non-consideration of result of VE workshop by client, lack of understanding of the principle behind functional analysis, knowledge imbalance and difficulty in achieving cultural change among VE team. The lack of time to complete the study, poor communication and insufficient coordination between parties, outdated standard and specifications, habitual and prejudicial thinking, lack of expertise and unnecessary restrictive design criteria, excessive changes and lack of information has been identified as impediments to the implementation of VE.

In United states of America [15] reported that VE is under–utilised because of lack of appreciation by client, lack of knowledge by some participants, lack of cooperation from the clients personnel, lack of trust and reluctance in disclosing genuine project mission. [35] investigates factors inhibiting the wider use of VE in UK and identified the following:

- Clients are unwilling to pay for the service;
- There is insufficient time to carry it out;
- Clients don't request the service;
- The quantity surveyor provides the service already;
- VE skills are unavailable, and
- There is resistance from design consultants.

However, team perspective, [36] pointed out that differences exist between the design team and value engineering team. He illustrated the differences by considering their structures, goals, processes and their communications and styles. Design team is usually organised hierarchically with a design manager that all team members report to. With low level of lateral communication between team members. In this case, responsibility rests at the top of the team, with delegation to team members. On the other hand, Sperling go on to explain that, the value team is organised as an egalitarian group with a facilitator who is part of the team. All members interact with each other as required by the facilitator and the main focus is the team activity. In VE team, responsibility rests within the team, with all task delegated to team members. The goal of the design team is to design what can be done. The goal of the value team is to find what must be done. The design team follows a project management protocol, why the value team uses the VA job plan.

3.0 RESEARCH METHOD

A questionnaire was designed with the objectives of understanding the practitioners' level of understanding and participation in VE programme generally in construction industry. Respondent were requested to provide information relating to practice of value engineering in Malaysia, respondents participation in value engineering workshop, the need to adopt value engineering for building services. The questionnaire also contains brief explanation of life cycle of value engineering job plan. A total of 15 variables were identified and a questionnaire was designed based on the variables. The questionnaire was prepared in 3 sections. The first section contained 4 nominal questions on background information. The second section comprises of 5 ordinal questions on the level of understanding and application of value engineering methodology in building services design and installations. The third section contains 2 ordinal questions on the potentials of and factors preventing application of value engineering in building services procurement (this section is not reported in this paper). The survey was conducted in Malaysia.

4.0 SURVEY RESULTS AND DATA ANALYSIS

A total of 239 questionnaires were sent out, only 116 were returned. Five (5) of the questionnaires were not properly completed and could not be analysed and therefore discarded. Resulting in effective response rate of 46%, therefore, only the remaining 111 properly completed questionnaires were analysed. A total of 27% of the respondents are from clients' organisations, while 24% are from contracting organisation and the remaining 49% are from consultancy type of organisations. The years of construction experience of

the respondents are 1-5 years (15%); 6-10 years (7%); 11 – 15 years (24%); 16 – 20 years (32%); and 20 years and above (22%). About 78% of the respondents have more than 10 year's construction experience. This observation suggests that the data collected from these respondents are reliable.

4.1 Data Analysis

Data analysis was carried out using the SPSS software package version 20. The statistical t–test of the results was first carried out to understand the pattern of response to the questions based on the sample ratings. The hypothesis H0:μ =μ0 and the alternative hypothesis H1: μ > μ0 was set out. Where μ is the population mean. μ0 is the critical rating above which the variable is considered to contribute to the factors contributing to non–adoption of VE for building services. In this study, μ0 was set at 3 because in the rating scale, all ratings above 3 are considered as a contributory factor. Table 1 shows the t–test results with the significant level set at 0.05.

Table 1 Results of t-test

Potential Benefits of Applying VE in BS	t-test	p-value	Mean	Std. Deviation	Rank
Improved communication and team work	96.219	.000	4.0541	.44390	1
Ensure that client value criteria are achieved	78.437	.000	4.2793	.57479	2
Shared understanding among key participants	41.682	.000	3.8649	.97688	3
Tendency for sustainable relationship between clients and other project stakeholders	39.657	.000	4.2883	1.13928	4
Reduced maintenance cost	38.351	.000	3.6126	.99244	5
Lead to reasonable cost savings	36.624	.000	3.9910	1.14809	6
Consider optimum life cycle cost	36.287	.000	3.6667	1.06458	7
Improves the relationships between the supply chain	35.650	.000	3.7477	1.10756	8
Improves the quality of the industry	35.028	.000	3.4324	1.03240	9
Lead to a happy client	34.546	.000	3.6937	1.12648	10
Improves quantity surveyors understanding of mechanical and electrical services systems	31.893	.000	4.1171	1.36007	11
Increased innovation	28.345	.000	3.5495	1.31936	12
Better quality project definition and design briefing	27.933	.000	3.7658	1.42034	13
Reduction of interface problem during construction	25.608	.000	3.2523	1.33803	14
Lead to more reliable pre -contract price estimate	25.347	.000	3.5766	1.48660	15

[a]n =111; df=110 at 95% confidence level. Items are rated on 5-points Likert scale (1=strongly disagree;2=disagree;3=moderately agree; 4=agree and 5=Strongly agree)

4.2 Practitioners' experience, Practice and understanding of VE

Respondent were requested to rate their level of understanding of VE on a five point ordinal scale ranging from "poor" to very. The result shows that, about 65% of the respondents expressed that they have experience ranging from poor to fair, 11% with moderate experience of VE. The remaining 12% have good experience of value engineering. On the practices of VE in Malaysia, 35% of the respondents seems to agree that VE is well practiced in Malaysian construction industry. About 12% were not sure, and the remaining 53% were of the opinion ranging between poor to fair. On the extent of participation in value engineering, 24% of the respondents expressed that they have participated to a very large extent, 5% to a large extent and the remaining 71% have not participated in VE workshop before. In a follow up conversation with some of the respondents that expressed that they had previously participated in VE, it was found that some of the respondents actually took part in VE study outside Malaysia. The study shows that VE methodology adopted routinely on construction projects in Malaysia. On the question that requested the respondents to rate their level of agreement on the need to adopt VE on building services projects. About 60% of the respondents agreed that VE can be applied in the procurement of building services. However, this result may be a result of the fact that respondents belief that VE is a good concept since they have little knowledge about it. A total of 15% of the respondent are not sure and the remaining 25% disagreed.

4.3 Application of VE in building services

This section request for respondents' level of agreement on the potential benefits of VE if adopted in the design and installation of building services projects. The main purpose of this section is to understand practitioners' perception on the identified benefits of application of VE on construction project. The t-test result of the result is shown in Table 2.

From the t-test result all the fifteen variables are significant and based on the magnitude of t-value, the three most important potential benefits of adopting VE for building services from the perspectives of practitioners are: improved communication and team work; ensure that client

value criteria are achieved; and shared understanding among key participants.

4.4 Implementation Model of VE on M&E Services

It has been established that the acclaimed benefits of VE can be realised in M&E services installations in buildings if the challenges identified can be overcome. Therefore, implementation model is divided into two. The first part is the team structure as shown in Figure 2

The team must be made of all mechanical and electrical subcontractors, suppliers, specialist designers in addition to the design team and main contractors. All participants would know what is expected of them by other parties, what works and what does not work. This will be applied at all decision points in the VE study. VE principles must be applied at each decision point and a full VE study conducted before proceeding to design development.

.

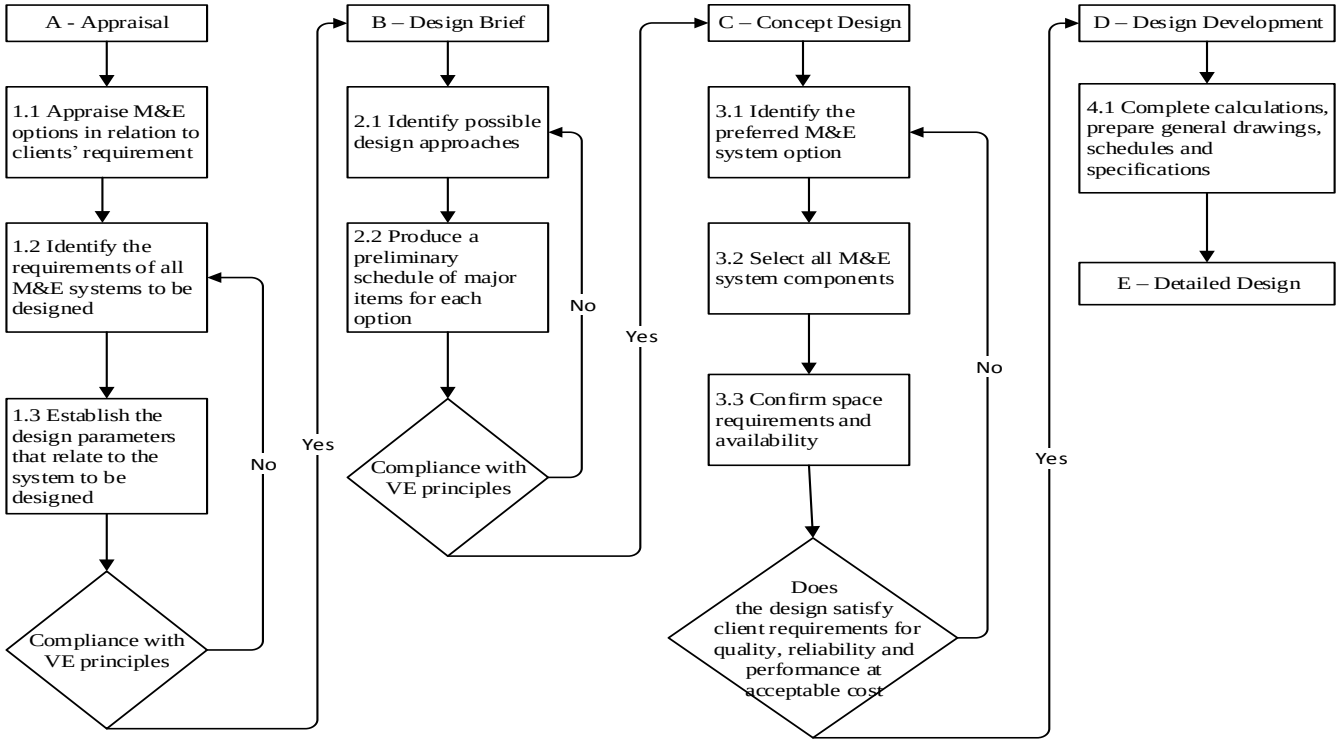


Figure 2 VE Implementation frame work following the RIBA Plan of work

5.0 CONCLUSION

The study provided an understanding of application of value engineering in mechanical and electrical services installations in buildings. Research findings revealed that when carefully applied it will lead to capital and life cycle cost savings; alignment of stakeholders and construction process improvement; improved client satisfaction, and shared understanding among key participants. However, the most important challenges that must be overcome to realise the benefits are: lack of knowledge/experience about value engineering and stakeholders' resistance to change/Culture.

Further, empirical study revealed that lack of database to capture, store, retrieve and disseminate knowledge gained on VE study is a significant barrier to wider application of value engineering. In recognition of the significance of M&E services in buildings and to overcome the aforementioned challenges, an implementation model was developed which emphasised the need to engage all M&E supply chain at about 5% design completion of buildings to apply value engineering principles in developing client business case and to continously apply the principles until design completion.

It is important to state that further research is required into the reasons and how to deal with the main problems of applying value engineering to process clients' requirements in M&E aspects of building projects. It is also important to mention that performance measurement of VE studies is another area requiring further research. This will assist in convincing clients on the potential benefits of VE.

References

[1] Kwai Kwan Foh. 2011. Overcoming the Challenges of Economic Transformation Programme. Kuala Lumpur Malaysia: Master Builders Association of Malaysia.

[2] CIDB. 2009a. Annual Report: Strategic Thrust 2 - Strethen the Construction Industry Image. Kuala Lumpur: Construction Industry Development Board.

[3] CIDB. 2009b. CIDB, Seminar on SMM in Construction-Towards Enhancing Standardization and Best Practice. News Letter of the Construction Industry Development Board, Malaysia. Issue 2.

[4] Sabaria, D. H. 2009. Roles of Standard Method of Measurement (SMM) in Construction. Seminar on Standard Method of Measurement (SMM) in Construction Procurement. Kuala Lumpur, Malaysia. Construction Industry Development Board.

[5] Amuda–Yusuf, G. and Mohamed, S. 2012. Examination of Pre- Tender Budgetary Techniques for Mechanical and Electrical Services in Malaysia. Kuala Lumpur. A paper Presented at *the World Academy of Science Engineering and Technology Conference*. 19th – 21st February.

[6] Amuda-Yusuf, G., Mohamed, S. F. & Remeli, S. 2013. Factors Inhibiting the Adoption of a Uniform Pricing Mechanism for Building Services. *International Journal of Engineering Business Management.* 5(3):1-10.

[7] Keat, Q. J. 2013. Private Sector Approach in Standardizing the Method of Measurement (SMM) for 5D BIM in Malaysia. *A Case Study of the Collaboration between the Royal Institution of Surveyors Malaysia (RISM) Quantity Surveying Division BIM Technical Committee and a Private*. Hong Kong. The Hong Kong Institute of Surveyors. 157-177.

[8] Arayici, Y., Egbu, C. and Coates, P. 2012. Building Information Modelling (BIM) Implementation and Remote Construction Projects: Issues, Challenges, and Critiques. *Journal of Information Technology in Construction (ITcon)*. 17: 75 – 59.

[9] Langmaid, J. 2004. Choosing Building Services: A practical Guide to System Selection. BSRIA.

[10] Mossman, A. 2009. Creating Value: A Sufficient Way to Eliminate Waste in Lean Design and Lean Production. *Lean Construction Journal*. Forum Paper. 13 – 23.

[11] Cartlidge, D. 2013. *Quantity Surveyor's Pocket Book*. 2nd ed. Oxon: Routledge.

[12] Palmer, A. 1990. A Critique of Value Management. Technical Information Service. CIOB, 24, CIOB.

[13] Kelly, J. and Male, S. 2002. Value Management. In: J. Kelly, R. Morledge & S. Wilkinson, eds. *Best Value in Construction*. Oxford: Blackwell Publishing and RICS Research Foundation. 77-99.

[14] Green, S. D. 1991. Value Engineering During Early Design, Facilities. 9: 9.

[15] Witschey, W. and Wulff, R. 1998. How to Ensure Quality and Cut Costs With Cultural Institution Value Methodology. A case study of Value Engineering on a Historic Renovation Project at the Science Museum of Virginia, Museum Management and Curatoship. 17(1): 65 – 83.

[16] Hayden, G. & Pasloe, C. 1996. *Value Engineering of Building services. Application Guide 15/96*. London: BSRIA.

[17] Assaf, S., Jannadi, O. A. and Al- Tamimi, A. 2000. Computerised System for Application of Value Engineering Methodology. ASCE. *Journal of Computing in Civil Engineering*. 14(3): 206 – 214.

[18] Cell, C. L. and Arratia, B. 2003. Creating Value with Lean Thinking and Value Engineering. *SAVE International Conference*. www.value-eng.org [Accessed on 20 /07/09].

[19] Naderpajouh, N. and Afshar, A. 2008. A Case – Based Reasoning Approach to Application of Value Engineering Methodology in Construction Industry. *Construction Management and Economics*. 26: 363 – 372.

[20] Al–Ghamdi, M. A. 2004. Five Steps for More Effective Implementation of Brainstorming in Value Engineering Studies. *SAVE International Knowledge Bank*. www.value-eng.org.[Accessed on 20 /07/09].

[21] Hannan, D. 2002. A Re-Evaluation of Our Profession: Customized Role Specific Training Programs & Client Specific VE Workshops. *SAVE International Annual Conference Proceedings*. XXXVI. Fort Lauderdale, Florida.

[22] Seni, D. A. 2004. Function Analysis as a General Design Discipline. *SAVE Knowledge Bank*. www.value-eng.org [Accessed on 12 /08/09].

[23] Male, S. and Kelly, J. 2004. A Re – Appraisal of Value Methodologies in Construction. *SAVE International Knowledge Bank*. www.value-eng.org [Accessed on 20 /07/09].

[24] Marsh, C. 2003. *Building Services Procurement*. London: Spons Press.

[25] Yamaguchi, Y. 1995. The 3 Minute Think and Show – Off Method for Idea Generation. *SAVE International Conference Proceedings*. www.value-eng.org. [Accessed on 12 /08/09].

[26] Hunter, K. and Kelly, J. 2004. Is One Day Enough? The Argument for Shorter VM/VE Studies. SAVE International Knowledge Bank. www.value-eng.org. [Accessed on 20 /07/09].

[27] Kelly J, Male S and Graham D. 2004. Value Management of Construction Projects. Blackwell.

[28] Hanik, P. and Kaufman. 2006. VE/TRIZ: A Technology Partnership. *Save Knowledge Bank*. www.value-eng.org [Accessed on 20 /07/09].

[29] Green, S.D. 1994. Beyond Value Engineering: SMART Value Management for Building Projects. *International Journal of Project Management*. 12(1): 49 – 56.

[30] Male S.P. and Kelly, J. R. 1999. The Professional Standing of Value Management: A Global Study of Legislation, Standards, Certification, and Institutions. *Proceedings of SAVE International*, San Antoni. 158-166.

[31] Palmer, A., Kelly, J. and Male, S. 1996. Holistic Appraisal of Value Engineering in Construction in United States. ASCE *Journal of Construction Engineering and management*.122 (4): 324 – 328.

[32] Hunter, K. and Kelly, J. 2007. The Supporting Factors That Make Value Management Attractive Option in Meeting the Best Value Requirements of the UK Public Service Sector. *SAVE International Knowledge Bank* A. www.value-eng.org. [Accessed on 20 /07/09].

[33] Mathew, O. and Howell, G. 2005. Integrated Project Delivery: An Example of Relational Contracting. *Lean Construction Journal*. 2(1): 46 - 61.

[34] Cheah, C.Y.J. and Ting, S.K. 2005. Appraisal of Value Engineering in Construction in Southeast Asia. *International Journal of Project Management.*

[35] Hogg, K. 2000. Factors Inhibiting the Expansion of Value Methodology in the UK Construction Sector. *SAVE International Conference Proceeding.* www.value-eng.org.[Accessed on 20 /07/09].

[36] Sperling, R. B. 1996. Value Analysis as a Collaborative Process. S.L. *SAVE International Conference Proceedings.*