Value Engineering in Construction Between Theory and Practice

by

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Conceptual Formulation

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Abstract

Value Engineering as a methodology or a process aiming to optimize performance and minimize cost and resources has proven success in the industrial sector which inspired other sectors to adopt it. One of these sectors that adopted this methodology is the construction sector.

The objectives of this thesis are to evaluate the magnitude of implementation of Value Engineering in construction in different countries, evaluate its success, effectiveness, and success criteria, examine the challenges and hindering factors for its implementation specifically in developing countries and establish some guidelines for the successful implementation in these countries. While these objectives were dealt with separately in different researches previously, this research aim to provide a more comprehensive understanding, and to act as a guide for construction professionals, graduates and post graduates who do not have in depth knowledge of Value Engineering but are interested in improving their knowledge. To achieve these objectives some vital questions related to the application of Value Engineering or Value Management in the construction industry need to be addressed.

These research questions are: what is value engineering? What is the relation between value engineering and sustainability? How far value engineering is currently involved in the construction industry? What is the role of value engineering in different phases of construction? what can be done to improve the role of value engineering in construction? What are the new technologies, techniques and methodologies that are already used? and to what extent? And are there more that can be used to improve the value in construction? What is the relation between organizational structure and value engineering?

The methodology was to use abductive approach to analyse secondary data and primary data to less extent, where these data were sorted in multiple case studies style, the was cross checked to conclude findings and recommendations.
The Recommendations

Keywords: Value Engineering, Value Management, Value Analysis, Construction Management, Theory and Practice.

Dedication

I dedicate this work to family for their continuous support and encouragement through these stressful times. Especially to my parents who left fingerprints of grace on my life, they will never be forgotten.

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Declaration

I declare that, except where reference is made in the text, the contents of this dissertation are entirely my own work. I further declare that the contents, in whole or in part, have not been submitted to this or any other institution as an exercise for a degree. The author agrees that the library may lend or copy the dissertation upon request for study purposes, subject to the normal conditions of acknowledgement.

Author's Signature: _____

Dated: September 14, 2018.

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List of Acronyms

VA	**Value Analysis**
VE	**Value Engineering**
VE	**Value Engineering Study**
VM*	**Value Methodology.**
VM	**Value Management**
SAVE	**The Society of American Value Engineers**
SAVEI	**SAVE International (is the name of SAVE Since 1996)**
BOK	**Body of Knowledge**
FAST	**Functional Analysis System Technique**
FCC	**Federal Construction Council**
VETC	**Value Engineering Team Co-ordinator**
AVS	**Associate Value Specialist**
CVS	**Certified Value Specialist®**
VMA	**Value Methodology Associate**
VST	**Value Study Team**

1 Introduction

Value engineering have been practiced in the industrial sector for nearly 70 years now, the success and the economic impact of VE resulted in the spread of this technique into other sectors including construction industry. Although VE was introduced in to the construction sector in the mid of 1960s by the US Navy Bureau of Yards and Docks (Kelly, Male, & Graham, 2004, p. 1). However, the application of Value Engineering did not gain the same level of popularity in construction as in manufacturing. In an era where resources are becoming absolute and sustainability being a major concern for mankind, also considering the competitive nature of the construction industry, it is bizarre and inapprehensible that VE is not applied in most construction projects.

While hundreds, maybe thousands of researches have been done over the topic, however, most of these researches are examining a specific point in relation to Value engineering. This research on the other hand tries to establish a more comprehensive overview on the subject, and to utilize the huge amount of available data weather in books, governmental reports, trade journals or other sources of data aims to explore variety of these researches to explore the general scheme of Value engineering, the extent and limitation of its use in construction.

1.1 Literature Review

The literature review employs historical background of Value Engineering as a gate or entrance to examine the world of Value Engineering. History, has a significance impact on how people develop, criticize and interpret theories. “Popper (1989) uses the term ‘historicism’, whilst Clegg (1992) employs ‘indexicality’ to consider history’s impact on how people understand, interpret and behave” (Fellows & Liu, 2015). Then the literature follows on the historical development of Value Engineering, moving from generic (Value Engineering in general) to the more specific (the application of Value Engineering in Construction)

The literature review relied on diverse sources of information, with focus on American sources for many reasons as follow:

1- USA is the home land where the technique was first developed.

2- It has been long practiced there both by public and private sector which means that knowledge based on long experience and practice is more persistent in the case of U.S.A. than other countries, especially considering institutional experience. This was observed by the author in majority of available VE literature, the same believe is adopted by Kelly& male on their subsequent researches in the field of VE which focused on the application of VE in U.S.A.

3- It is the home land of SAVE International which is the oldest VE society in the world and followed by majority of VE specialists worldwide.

1.2 Research Objectives

One of the objectives of this thesis is to evaluate the benefits of applying the value engineering techniques. Based on that we need to examine if the degree of application of value engineering and value management in the construction business are reflecting the benefits of applying them. Moreover, it is also important to understand what are the obstacles that delay or prohibit the application of value engineering in construction industry. Another objective is to examine the interchangeable relationship between value engineering, new technologies and sustainability in relation to construction business. In order to do that a certain number of research questions was set initially to investigate that matter as detailed in section.

1.3 Research Questions

The research questions are as follow:

1- What is value engineering?

2- What is the relation between value engineering and sustainability?

3- How far value engineering is currently involved in the construction industry?

4- What is the role of value engineering in different phases of construction?

5- What can be done to improve the role of value engineering in construction?

6- What are the new technologies, techniques and methodologies that are already used? and to what extent?

7- Are there more that can be used to improve the value in construction? What is the relation between organizational structure and value engineering?

1.4 The Structure of The Thesis

The thesis is divided into seven chapters as follow:

Chapter 1. Introduces the research objectives, research questions and research structure.

Chapter 2. Introduces different fundamental information about Value Engineering including: historical background terminology, societies, standards, brief explanation for the different stages of Value Engineering Studies, fields of application and timing of application.

Chapter 3. Introduces a brief description for the styles of Value Engineering application in construction both in USA and Worldwide and identify timing for application and critical success factors.

Chapter 4. Introduces the research design and methodology.

Chapter 5. Introduces different case studies, and initial findings and analysis

Chapter 6. Introduces findings related to the research questions.

Chapter 7. Introduces Conclusion and Recommendations.

2 Value Engineering

2.1 Value Engineering History

In this section of the literature review, the history of Value Engineering (VE) will be tracked from different sources, to examine the different phases of VE development since its foundation until now.

2.1.1 Roots of Value in Old History

Although the terminology of value engineering is reasonably new as it emerged in the 20th century as will be detailed later in this section. However, it is necessary to stress that the roots of value engineering are as old as the human civilization. The concept of value engineering has been long practiced and can be traced back in history. Many examples can be given to illustrate the practical application of value engineering in history of mankind. One of these examples is the tools which people used: initially the use of stone to fabricate tools during the stone age which developed with time to the use metal instead during the bronze and iron age. Another example of value engineering as a practice in ancient history can be observed by tracking the history of cement.

"The Egyptians used calcined gypsum as a cement and the Greeks and Romans used lime made by heating limestone and added sand to make mortar, with coarser stones for concrete. The Romans found that a cement could be made which set under water and this was used for the construction of harbors. This cement was made by adding crushed volcanic ash to lime and was later called a "pozzolanic" cement, named after the village of Pozzuoli near Vesuvius". **(History of cement, 2018)**

Cement was used to improve buildings' durability, and hence to improve the value. However, the materials which were used to make the cement changed with time, either to improve cement further as in the case of adding volcanic ash, or to consider availability and productivity as in case of recent ages.

The historical presence of value in literature is also evident in the Greek literature as stated by De Marle that "the Greeks believed that there are certain primary or essential principles that exist in our environment. These indwelling principles give value to the items they inhabited. Thus, ethics contained 'the good' religion, 'the holy'; and aesthetics, 'the beautiful'. When the indwelling principle was present the object had value, when it was absent the object was worthless" (Shillito & De Marle, 1992). Aristotle is one of the most famous Greek philosophers who is considered the founder of the value theory. He classified value into seven classes as economic, political, social, aesthetic, ethical, religious and judicial value. However, all these classes except for economic value are highly subjective and totally individually oriented rather than group or society oriented (Charantimath, 2011).

2.1.2 Value Engineering (VE) in Modern History

Unless otherwise cited, sections **2.1.2.1** and **2.1.2.2** of this research are entirely based on the article **"Origins and History of Value Engineering"** written by Professor **Richard W. Sievert** and published in the fall of 2010 by Value World Journal, which deals intensively with the history of VE. While section **2.1.2.3** is based on multiple sources and were cited accordingly.

2.1.2.1 The Birth of VE Techniques[1]

The term value analysis in modern literature came in to existence in the late 1940s, to overcome the difficulty in obtaining certain materials during World war II, as the war resulted in material scarcity and lack of certain finished products. Lawrence D. Miles, who was working as an expediter in the purchasing department of the General Electric company in the USA during that time, was appointed to find alternatives for materials needed to produce turbo chargers, capacitors and resistors for aircrafts B24s and B29s. Instead of thinking of the parts or products itself he looked into their functions and asked what else can do the job. Miles Using functions as a basis to analyze products and costs generated outstanding results during the war years. In 1947, Harry L. *Erlicher (GE* vice-president)

[1] Sievert, R. W. (Fall 2010). Origins and History of Value Engineering. *Value World*, 4-8

assigned him to performing cost reduction work in the central purchasing department. During this period Miles worked on formalizing the functional approach to Value engineering techniques (Sievert, Fall 2010, pp. 4-8).

According to Sievert, the astonishing saving led to increasing the value engineering staff in GE. Miles initiated training and education programs and taught his VE techniques to GE divisions and outside clients.

2.1.2.2 The Spread of VE in the USA[1]

Sievert stated that Miles capitalized on the achieved results to promote his methodology, as many trade journals published many articles about VE. The success of VE encouraged other industrial firms to use it including large companies such as RCA, Westinghouse, and IBM. In 1950, Miles was awarded the coffin award as the highest award of honor awarded by GE to any employee. In 1953, Miles was invited to give a presentation in the U.S. Navy Bureau of Ships. This led to the adaptation of VA techniques within the U.S. Navy in 1954 which changed the name to Value Engineering. In 1958, Miles expanded the use of VE techniques from the cost reduction of existing products to a redesigning tool for those products and a designing tool for new products as well. Miles, with the help of Tom Snodgrass who was the engineering manager at GE, developed customer oriented VE studies as an alteration to technically oriented VE studies to improve products' marketability and acceptance by customers. Many groups resisted the application of VE techniques, especially manufacturing engineers who resisted the multidisciplinary team approach.

In 1959, the Society of American Value Engineers (SAVE) was founded by Miles and other VE leaders and Miles was chosen as its first president. Also, in the same year the contractual requirement for VE was added to the Armed Services Procurement Regulation but it was not mandated until June 1962 when the Defense Department's procurement regulations were modified (Mandelbaum & Danny L. Reed, 2006).

"VE remained basically a DoD program until Office of Management and Budget (OMB) Circular A-131 was issued in 1988 to expand the program into other organizations 'where appropriate'. OMB Circular A-131 contained some loopholes, which were closed by a

1993 reissuance. The circular now requires that all Federal Departments and Agencies use VE and that OMB be advised annually of top VE projects, and net life-cycle cost savings, cost avoidance, and cost sharing achieved through VE. In 1996, VE was given further support when President Clinton signed P.L. 104-106, which requires each executive agency in the Government to establish and maintain cost effective VE procedures and processes|" (Mandelbaum & Danny L. Reed, 2006).

In 1961, McGraw Hill Co Miles published Miles first book about VE with the title "Techniques of Value Analysis and Engineering", this book was later republished in around 12 different languages or more. In 1964, Miles retired from GE after he lost his high power as the company merged VE group into internal consulting unit and VE became a voluntary option after it was mandatory.

2.1.2.3 The Spread of VE Worldwide

In the 1970s, according to Barton the term Value Management was first used, however, it was in the late 1990s that it emerged as a distinct discipline from VA/VE, drawing on management techniques and fully integrating it in the project life cycle as a "collaborative group-learning approach" (Thiry, 2013)

Moreover, the term Value Management was selected by the European Community's SPRINT programme (Strategic Programme for Innovation and Technology). The term was changed; however, the concept and philosophy were the same but forecasted in European management approach. Moreover, the term Value Management expanded to broader definition to include different value techniques, whether applied at strategic or tactical level. (CIOB, 2018)

"Several countries have also adopted value management in various sectors of their economy. For instance, the practice was first introduced to manufacturing companies owned by the Chinese states in 1978; Australia adopted it through the activities of some multinational companies in 1960s; it was pioneered in Hong Kong in 1988, while it was introduced in Nigeria in the 1990s through workshops, seminars, and conferences organized by stakeholders in manufacturing, production, and the construction industry (Liu and Shen 2005; Shen and Yu 2012; Oke and Ogunsemi 2013)" (Oke & Aigbavboa, 2017).

2.1.2.4 Summary of Significant Milestones in VE

Del l. Younker has quantified VE milestones in his book **(Value Engineering Analysis and Methodology, 2003)**, and while some of these milestones were mentioned in the previous sections, **Table 1** below aims to summarize the significant VE milestones in a tabulated chronicle order to facilitate the tracing of VE development .

Table 1 Summary of VE Significant Milestones

Year	Milestone
1947	Lawrence D. Miles develops VA techniques during his work at GE
1952	Miles conducts the first VA workshop seminar
1954	U.S. Navy Bureau of Ships applied VA during design calling it Value Engineering.
1956	The initiation of the VE program in Watervliet Arsenal
1958	Miles is awarded the Navy Distinguished Public Service Award for his assistance to the Bureau of Ships in VE
1959	The foundation of Society of American Value Engineers (SAVE)
1961	Establishment of VE contractual clauses in the Armed Forces Procurement Regulations
1962	D.O.D. announces that it is making VE a prerequisite for all its contracts over $100,000.
1964	U.S. Army Corps of Engineers starts its VE program
1965	Start of Japanese VE programs when the Japanese delegation visits SAVE for assistance
1966	U.S. Bureau of Reclamation begins placing a VE incentive clause in their construction contracts.
1967	Institution of a formal VE program in the US Post Office Department.
1969	Start of formal VE studies and training in U.S. National Aeronautics and Space Administration, Office of Facilities
1970	• Endorsement of VE by the U.S congress by recommending its use of Federal-Aid highway projects • General Services Administration (GSA) started its building-contractor VE program
1971	U.S. Department of Health, Education, and Welfare (HEW) adopt the use of VE on its construction project
1972	The Veterans Administration join the VE group
1973	SAVE establishes a program for certification of value specialists
1974	FHWA establishes an office to administer the VE program on federal aid projects
1975	U.S. Federal Highway Administration starts its national training program “VE for
1976	Florida Department of Transportation establishes a VE Program
1977	The incorporation of The Lawrence D. Miles Foundation
1980	Miles is awarded the Presidential Citation by the Society of Japanese Value Engineers
1982	The Department of Defense establishes its honorary VE award programs
1985	The death of L. D. Miles, the father of value engineering
1993	The Office of Management and Budget issues a circular calling for government wide use of Value Engineering

1996	Public law 104-106 requires each government executive agency to establish and maintain cost-effective VE procedures and processes.
1997	FHWA expand the rule by publishing the 23 CFR Part 627 requiring VE analysis on all federal aid highway projects on the national highway system with an estimated cost of more than $25 million

2.2 Value engineering Societies

According to Oke and Aigbavboa, since the evolution of Value Engineering techniques many VE societies have been established, with the aim to regulate value engineering and value management practices in different countries. **Table 2** Below we state some of them and their year of establishment:

Table 2 List of Some of VE Organizations Worldwide

Year	Country	Organization Name	Acronym
1959	USA	Society of American Value Engineers	SAVE*
1965	Japan	Society of Japanese Value Engineering	SJVE
1965	UK	The Institute of Value Management	IVM
1967	Germany	Vereine Deutscher Ingenieure/Gesellschaft Systementwicklung Wirtschaft.	VDI-GSP
1977	India	Indian Value Engineering Society	INVEST
1977	South Africa	The Value Engineering Management Society of South Africa (Huber, 2018).	VEMSSA
1977**	Taiwan	Value Management Institute of Taiwan	VMIT
1983	S. Korea	Society of Korean Value Engineers	SKVE
1984	Brazil	Associacao Brasileira de Engenharia e Analise do Valor	ABEAV
1984	Canada	Canadian Society of Value Analysis	CSVA
1984	Netherlands	Dutch Association of Cost Engineers, Special Interest Group Value Management	DACE
1985	Italy	Associazione italiana per l'analisis del valore (AIAV, 2018)	AIAV
1990	Hungary	Society Hungarian Value Analysis (SHVA, 1990)	SHVA
1990	Saudi	Arabian Gulf Chapter (AGC, 1990)	AGC
1990	Spain	Associacio Catalana d'Analisi del Valor	ACAV
1991	Australia	Institute of Value Management Australia	IVMA
1993	France	Association Francaise pour l'Analyse de la Valuer	AFAV
1995	Hong Kong	Hong Kong Institute of Value Management	HKIVM
1998	Portugal	Associacao Portuguesa para a Analise do Valor	APAV

2000	Malaysia	Institute of Value Management Malaysia	IVMM***
2001	China	Value Engineering Society of Beijing (VESB, 2001)	VESB
2002	Iran	Society of Iranian Value Engineering (SIVE, 2018)	SIVE
Notes	*It is important to note that SAVE has changed its name to SAVE International (SAVEI) in 1996 (Thiry, 2013). ** this date contradicts with the date mentioned on the data stated on VMIT official web site which stated it was officially formed in 2000 (VMIT, 2005) *** Data stated in Thiry was corrected according to the data stated on IVMM website.		

The distribution of these organizations is represented as shown on the map in **Figure 1** below.

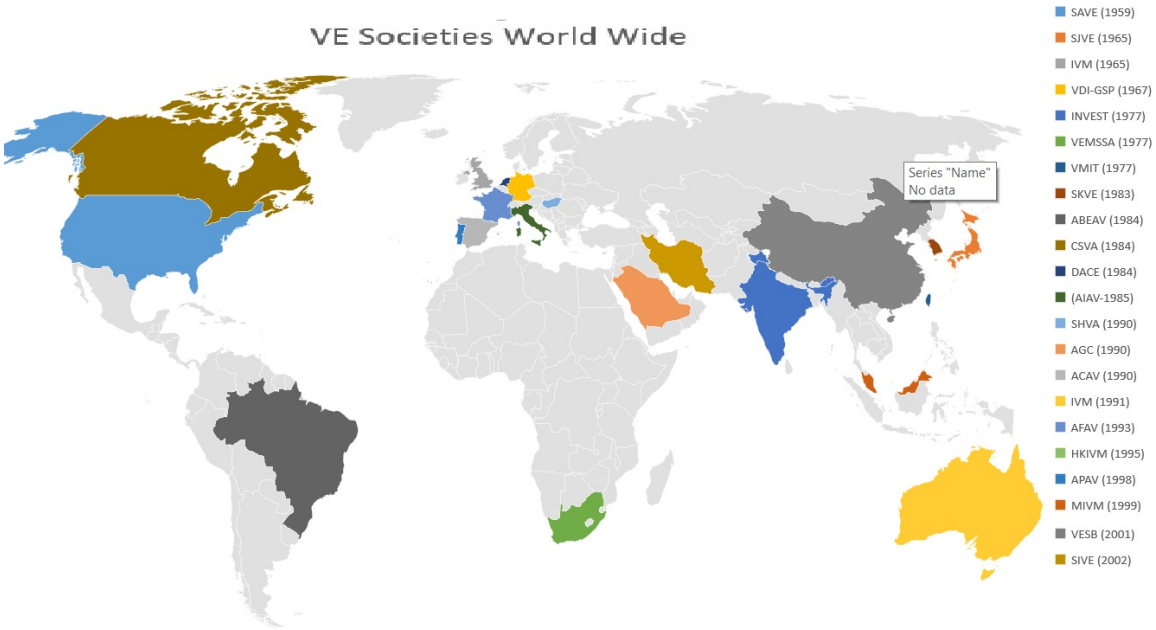


Figure 1 Map of VE Societies Worldwide

2.3 VE/VM Standards

As stated earlier Miles and other VE leaders organized the Society of American Value Engineers (SAVE) to organize efforts to develop and increase awareness of VE and its benefits. In 1997, Paul Revere Chapter and John W. Bryant drafted the value methodology standard based on the value engineering techniques founded by Miles. This standard was aiming to guide participants and managers for the application of value engineering

principles in a consistent manner. the standard was periodically updated to meet the latest requirements of business and international standards organization **(SAVE International , VALUE METHODOLOGY STANDARD, 2015, p. 2).**

While the first VE society was found in USA, however it was not USA who issued the first VA/VE standard but it was Germany, other VE national standards were drafted as well in different countries as in the **Table 3** below **(Thiry, 2013)**:

Table 3 List of VA/VE/VM Standards

Country	Year	Standard
Germany	1973	DIN 69 910 on "Wertanalyse"(va1ue analysis)
France	1985-1990s	Standards X50- 100, 150,15 1, 152, and 153 on value analysis
India	1987	Standard IS:11810-1986 on value engineering
Australia	1994	Value Management Standard AS/NZS 4183 (Committee OB-006, 2007)
USA	1995	ASTM E1699-14
Europe *	2000	DIN EN 12973 **(EUROPEAN COMMITTEE FOR STANDARDIZATION, 2017)**
Notes	Some of these data were based on data provided in Thiry's book while others were based on author search.	

2.4 VE Certification

According to Thiry, SAVE started its certification program based on request from General Services Administration (GSA) to SAVE to develop a certification program for value practitioners in 1973. However, certain countries have started their own certification programs, and particularly Europe (started as national certification programs in France, Germany and UK), Australia, Japan, South Africa and Malaysia as detailed in **Table 4.**

Table 4 Certificate Levels for Different VE Societies

Society	Certificate levels
SAVEI	Two levels including: 1- First level as Associate Value Specialist (AVS) which was changed in June 2016 to Value Methodology Associate (VMA) 2- second level which is Certified Value Specialist (CVS) (SAVE International, SAVE International Certification Program Manual, 2017)

Value for Europe*	Three levels Including **(Value for Europe, 2018)**: - 1- A Qualified Value Associate (QVA) 2- A Professional in Value Management (PVM) 3- A Trainer in Value Management (TVM)
Australia	Three levels including **(IVMA, 2018)**: - 1- Value Management Study Facilitators 2- Value Analysts 3- Value Management Trainers
Japan	SJVE has two levels of national certificates, additionally it is partnering with SAVEI to award CVS) Certificate, accordingly we can consider 3 certificate levels: 1- Value Engineering Leader (VEL) 2- Value Engineering Specialist (VES) 3- Certified Value Specialist (CVS)
Malaysia	1- Certified Value Manager (CVM) **(Institute of Value Management Malaysia, 2018)**
South Africa	Three levels including **(Thiry, 2013)****: 1- VA/VE/VM Practitioner 2- VA/VE/VM Facilitator 3- VA/VE/VM Trainer
Notes	* Value for Europe is a non-profit company which represent the National Value Organizations (NVOS) and National Certification organizations (NCOS) in many European countries including; Austria, Belgium, France, Germany, Hungary, Italy, Netherlands, Portugal, Spain and UK **(Value for Europe, 2018)**. ** It is to be noted that these levels were stated by Thiry, however could not be found on the website for this society.

Later, SAVE changed its name to SAVE International (SAVEI) and currently certify professionals around the globe. The number of certified professionals from different countries is listed in obtained from SAVEI.

2.5 VE Terminology

As explained earlier VE techniques, methods and knowledge grow with time and many definitions have been used since the evolution of the methodology. Hence, this section of the literature will mainly list the main definitions related to VE with focus on the similarities and/or differences between the definitions of value analysis, value engineering, value management and other main VE definitions, since its birth on the hands of Lawrence

D. Miles and as it progressed to its current status, both in the USA according to the Society of American Value Engineers (SAVE), the organization which were founded by Miles as explained earlier, and in Europe.

2.5.1 VA/VE Terminology During its Beginnings

In this section the main VE definitions as presented by Lawrence D. Miles in his book Techniques of Value Analysis and Engineering are listed below: -

Value Analysis (VA): according to Miles "Value analysis is a problem-solving system implemented using a specific set of techniques, a body of knowledge, and a group of learned skills. It is an organized creative approach that has for its purpose the efficient identification of unnecessary cost, i.e., cost that provides neither quality nor use nor life nor appearance nor customer features" **(Miles, 1989, p. 3)**.

In other terms the aim of value analysis is to achieve user or customer requirements at a lower cost. Miles considers it mandatory for business survival, and when mastered it can help competitive organizations to become leaders or "winners". But he explains that it can't help bad organizations to become successful as the application of value analysis techniques require competency, good organization and a level of knowledge which would not be available in such bad organizations or companies. **(Miles, 1989, pp. 1-4)**

Value: is a function of two variables (performance, cost) where the value increase by increasing the performance and/or lowering the cost.

Maximum Value: is the maximum value possible to achieve using value analysis techniques. Which is rather a theoretical value as achieving maximum value would mean trying all ideas, alternatives, materials, processes and so on to reach optimum which is practically impossible

Normal Degree of Value: is the value achieved when the product combines set of ideas, materials, functions that are a bit better with a competitive cost enabling the product or service to not lose its market share.

Miles explains that competition is not a measure for good value as studies showed that a margin that varies between 25% to 75% of unnecessary costs can be identified in these products.

“The Value Analysis Job Plan”: is a five-step sequential process where problems are recognized and faced with functions to be accomplished clearly in mind, those five steps are: Information step, Analysis step, Creative step, Judgement step and Development Planning step.

After introducing Miles’ definition of value and value analysis it is important to go further to check the current used terminology by SAVE International as one of the main Value engineering organizations in USA and in the world.

2.5.2 SAVE International Terminology

SAVE International as the professional society devoted to advancing and promoting the Value Methodology has published the Value Methodology Glossary in which the main definitions below can be found (SAVE International, Value Methodology Glossary, 2017).

“**Cost** The expenditure of resources expressed as a monetary valuation of effort, material, time and utilities consumed, risks incurred, and opportunity forgone in production and /or delivery of a project, product, or process”.

“**Life – Cycle Cost (LCC)** The sum of all initial development, acquisition, production, or construction cost; cost of annual operations, maintenance, energy, or use; cost of periodic replacement of components; and disposal cost or salvage value for a product or project over a specified period of time. Costs are adjusted based on the time value of money to determine the total life - cycle cost. LCC is measured in net present value (present worth) or annualized cost.

“**Value** An expression of the relationship between function and resources where function is measured by the reliable performance of the functional requirements of the customer and resources are measured in the cost, time, energy, space, materials, labor, etc. required to accomplish the function. This relationship is expressed equivalently by the following equations: Value ≈Function÷ Cost, Value ≈Function ÷ Resources, and Value ≈ Performance ÷ Resources”.

“**The Value Methodology (VM*)** is a systematic process used by a multidisciplinary team to improve the value of a project, product, or process through the analysis of functions. The

value methodology is applied during the three stages of a value study: 1. Pre-Workshop, 2. Workshop (Using the Six- Phase VM Job Plan), and 3. Post-Workshop".

"**Value analysis (VA)** according to SAVE International is "the application of the Value Methodology to an existing project, product, or process to achieve value improvement".

"**Value Engineering (VE)** is the application of the Value Methodology to a planned or conceptual project, product, or process to achieve value improvement".

"**Value Management (VM)** The application of the value methodology by an organization to achieve strategic value improvement".

"**Value Methodology Job Plan (VM* Job Plan)** A sequential approach for conducting a value workshop used during the workshop stage of the Value Methodology, consisting of the following six sequential phases: 1. Information, 2. Function Analysis, 3. Creative, 4. Evaluation, 5. Development, and 6. Presentation."

2.5.3 European Terminology

According to Thiry and as stated earlier in the historical review section, Europe played a fundamental and central role in the development of VE from a technique applied at certain stage of the product or project life cycle into a management process that can be applied to the entire products or projects. It can also be noted that the VE European approach is more focused on the organizational structure and frame work, such focus is reflected in European Value Management standard (DIN EN 12973). The same can be noted also on German standard for VA (VDI 2800 part 1) in which section 3.5 focuses on the impact of management style on the successful application of VA techniques. Below we list some of VE terminologies as stated in DIN EN 12973:2017 **(DIN EN 12973, 2017)** except for VA job plan definition which is stated in EN 1325-1 **(BS EN 1325-1 , 1997).**

"**Value analysis/Value Engineering (VA/VE**) is an organized and creative approach, using a functional and economic design process which aims at increasing the value of a VA/VE subject."

"**Value Management(VM)** Is the underlying concept applied within existing management systems and approaches based on value and function-oriented thinking, behavior and methods, particularly dedicated to motivating people, developing skills, and promoting

synergies and innovation, with the aim of maximizing the overall performance of the organization"

"**Value Culture** is the attitude, awareness and sufficient knowledge of what the concept of value represents for an organization and its stakeholders and of the factors that may affect this value."

"**Value Management Structure** is a set of interrelated or interacting elements of an organization which coordinates and strengthens the value management approach within the organization."

"**VA job plan** is an organized and methodical procedure consisting of a certain number of phases intended to ensure successful application of value analysis"

2.6 VE Job Plan Development

Lawrence Miles introduced VA job plan as a plan that consist of five steps, namely: Information step, Analysis step, Creativity step, Judgement step and Development planning step **(Miles, 1989)**.

The SAVEI standard on the other hand defines a job plan that consists of six phases as one stage of three stages that constitute a value study and those stages are; Pre-Workshop (Preparation), Workshop (Execution of the six phase Job Plan namely: Information Phase, Function Analysis Phase, Creative Phase, Evaluation Phase, Development Phase and Presentation Phase) and Post-Workshop (Documentation and Implementation).

The sequence is mandatory as each phase provides substantial data and conception needed for the completion of the phase that follows. It is also a dynamic process in which a previous phase might be revisited, as the team gains more information and knowledge. The flow of the job plan process is illustrated in **Figure 2**.

The standard mandates the satisfaction of three conditions for the value engineering plan to qualify as a valid value engineering plan, and those three conditions are:

1. The Value Study Team (VST) follows at least all the six phases in sequence as stated in the standard and in **Figure 2**.

2. The VST is chosen based on experience and knowledge related to the project and is a multidisciplinary group of professionals and project stakeholders.

3. The Value Team Leader shall be a Certified Value Specialist® (CVS®) to have enough knowledge and training relevant to value methodology techniques.

The SAVEI standard focuses on the phases, the value study team and the manager qualifications. In total it aims to organize, formalize and structure the value engineering techniques building on the original ideas of Miles. It is also noted that different literature considers Pre-workshop and post-workshop stages just as two other phases of the job plan. Unlike the standard which focuses on the workshop stage while other literature included those two stages as a part of eight phases job plan. However, SAVEI includes further details about pre-workshop and post-workshop stages in SAVEI BOK. Such exclusion from the standard for those two stages can cause confusion, but at the same time it could also be argued that this is because the job plan is the core of the value study.

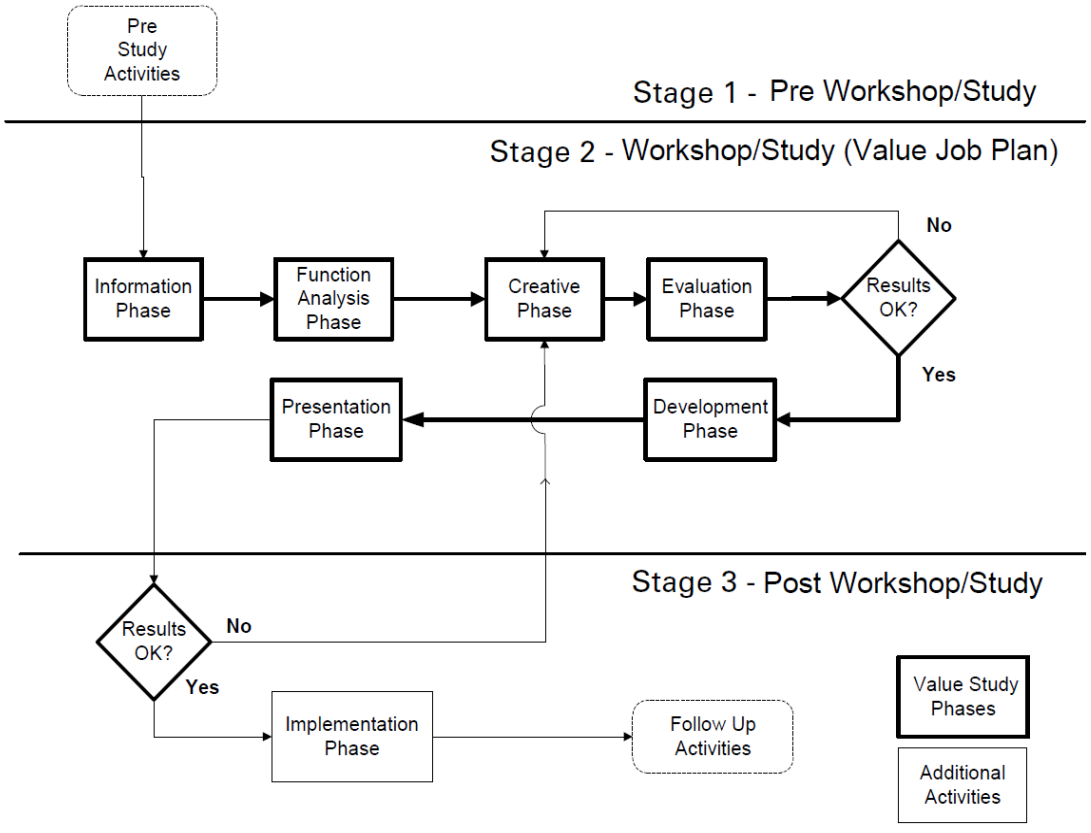


Figure 2 Job Plan process flow

2.7 VE Job Plan in Details

As explained earlier that VE job plan has changed since the times of Miles, and also the number of phases vary slightly from one literature source to another and from one organization to another, however, in the following sections we are going to detail the different phases according to the SAVEI job plan. However, other sources will be included as well to provide further details.

2.7.1 VE Pre-workshop Preparation Stage

The pre-workshop stage as stated in the SAVEI VALUE STANDARD and BOK is summarized in the paragraph below:

This stage has a strategic nature and is focused on the preparations needed for the value engineering study. Its main objective is to plan and organize value study by conducting a number of activities. These include developing VE scope and objective, collect data and documents, prioritize strategies and set schedules, select team members, gather customer, user data, develop informational models and agree with the management on the requirements. The expected outcome is to understand management needs that should be addressed and prioritize strategies to increase value. It also determines the scale and magnitude of the study in relation to objectives and cost **(SAVE International, VALUE STANDARD and BODY OF KNOWLEDGE, 2007, p. 13)**

2.7.2 Workshop or Job Plan Stage

This stage Consists of six phases as previously introduced, which will be detailed in the coming subsection of this chapter. The project cost, its scope, complexity and stage of development play a decisive factor in the exact duration, which varies between five to fifteen days or more.

2.7.2.1 Information Phase

This phase is focused on the customer and project tactical and operational level. Its main objective is to understand the current state of the project and the constraints that influenced

project decisions. This phase intersects with the preparation stage on many areas such as collection of data and documents, prioritizing strategies and setting schedules. However, it follows a more analytical approach to gain deeper understanding of the project information. It uses a number of analyzing tools such as Quality Function Deployment, SWOT, Benchmarking, Tear Down Analysis and Design for Assembly. It also includes confirming the current project concept, identifying high level functions, visiting the facility and confirming success parameters.

2.7.2.1.1 Identifying functions

Miles suggested identifying the functions using a verb and a noun that can be quantified by measurable parameters which allows them to be evaluated relative to their cost later in the evaluation phase. **(Miles, 1989, p. 27)**

This system of using a verb and a noun to define functions is the most commonly used and is known as abridgment. However, in some cases more than two words can be used if it gives a better description to the function; it can include adjectives, participles and nouns **(National Economic and Development Authority, 2009, p. 17)**

2.7.2.2 Function Analysis Phase

This phase is considered the most important phase in the value methodology or the value engineering study. According to SAVEI this phase is focused on functions of the project and their interrelationships with customer and cost. Its main objective is to understand the function perspective of the project. The main activities in this phase include the five activities detailed in the following subsections.

2.7.2.2.1 Classifying project functions

According to Miles products, services or projects have functions that are either use functions or aesthetic functions or a combination of both, while use functions are responsible for performing actions needed by the customer, aesthetic functions aim to please the customer and are totally subjective. Miles classifies functions into basic functions and secondary functions. However, SAVEI extends the classifications to include Required Secondary, Secondary, Unwanted Secondary, Higher Order, Lower Order,

Design Objective, One-Time, and All-the-Time (SAVE International, Value Methodology Glossary, 2017).

Miles stated that basic functions are those functions which are required by the customer, while secondary functions are the functions chosen by the designer to achieve the basic functions. However, we list here in below all definitions related to function as defined in SAVE International, Value Methodology Glossary.

"**Basic Function**: The specific purpose(s) for which a project, product, or process exists. It answers the question, 'What must it do?'".

"**Secondary Function:** A function that supports the basic function or required secondary functions and results from the specific design approach to achieve the basic function". Also called Independent Supporting Functions (Value Innovation, 2011).

"**Required Secondary Function:** A function that is necessary in a project, product, or process to perform the basic function. Required secondary functions fall on the Critical Function Logic Path within a FAST diagram". Also called Dependent Critical Functions **(Value Innovation, 2011)**.

"**Unwanted Secondary Function:** A negative secondary function caused by the method used to achieve the basic function, e.g., heat generated from lighting, which often must be cooled".

"**Higher-Order Function:** The specific goal or need for which the basic function exists and is outside the scope of the subject under study".

"**Lower-Order Function:** The function that is selected to initiate the project, product, or process (an input) and is outside the scope of the subject under study".

"**One-Time Function:** A secondary function that occurs only once in the performance of the project, product, or process".

"**All-the-Time Function:** A secondary function that happens continuously, anywhere in the performance of the project, product, or process".

It is noted here that this classification is ambiguous considering the examples selected by Miles on the refrigerator while secondary function in this case will affect the efficiency of

the refrigerator and hence it will affect its performance. While Miles insists in his book that performance shall not be compromised in value engineering. It is also to be noted that the customer can't always evaluate certain performance characteristics as that requires people with specific extent of knowledge in certain fields. So, customers' measures are not always reflecting performance.

2.7.2.2.2 Developing function models

Different tools are being used to develop function models, the most common and most popular is Function Analysis System Technique (FAST). FAST is the "Analysis of the dependent relationships of functions within a project, product, or process, which helps to identify and analyze functions to stimulate creativity and innovative thinking" (SAVE International, Value Methodology Glossary, 2017). It was developed by Charles Bytheway in 1964. In general, the classical basic FAST Diagram is a graphical representation that organizes functions and the interrelationship to each other in a "how-why" logic. However, different orientations of the FAST diagram exist such as Hierarchy FAST, Technical FAST and Customer-Oriented FAST, each orientation has its usage. An illustration for a basic FAST Diagram is shown in **Figure 3** below.

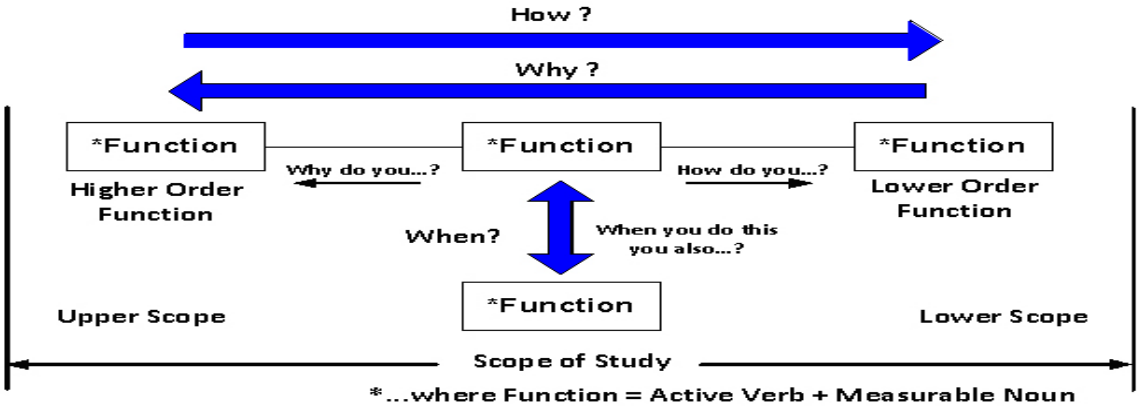


Figure 3 Basic Fast Diagram

SAVEI defines FAST Diagram as "a graphical representation of the dependent relationships of functions within a project, product, or process. The critical function logic path lines connecting higher-order, basic, required secondary, and lower order functions by their "how" and "why" relationships; and the vertical lines connecting secondary functions to required secondary functions by their "When" relationships" (SAVE International, Value Methodology Glossary, 2017).

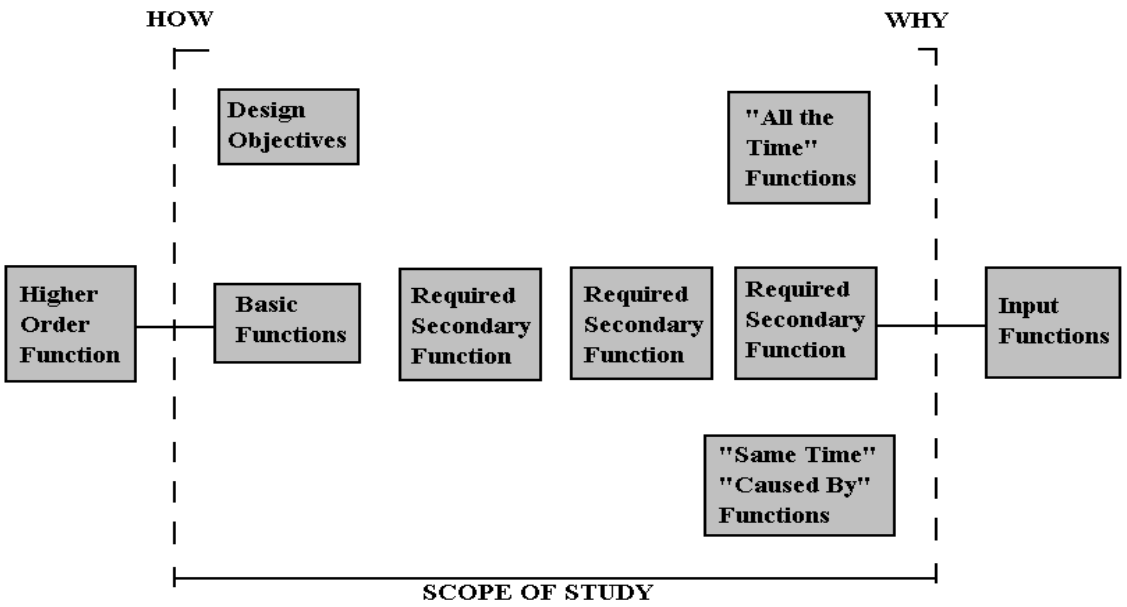


Figure 4: FAST Diagram (National Economic and Development Authority, 2009, p. 8 ch 3)

The FAST diagram as shown in **Figure 4** above, is a horizontal and vertical arrangement of functions based on logical relationships, where the horizontal arrangement develops from the left side to the right side by asking "how" with the higher order function on the far-left side and lower order function on the far-right side and all other classifications of functions which define the scope of the study are arranged in between. The answer to the "how" question would be the basic function listed to the right of the higher order function. Then, to verify this answer the question "why" is asked and the answer should be the function on the left. Then again, the question "how" is asked, and the answer would be the required secondary function listed on the right side of the basic function. The same procedure is repeated for each new function until we end at the lower order function on the far-right side of the diagram. While, the vertical arrangement is defined by answering the question "when", the answer will be one of the supporting functions which are not critical to the performance of the basic function, with the all time function listed above the row that represents critical functions and the other supporting functions listed below it **(National Economic and Development Authority, 2009, p. 8 of ch3)**. While **Figure 5** below shows an explanatory example for the FAST Diagram for a PC Projector **(Value Innovation, 2011, p. 5)**.

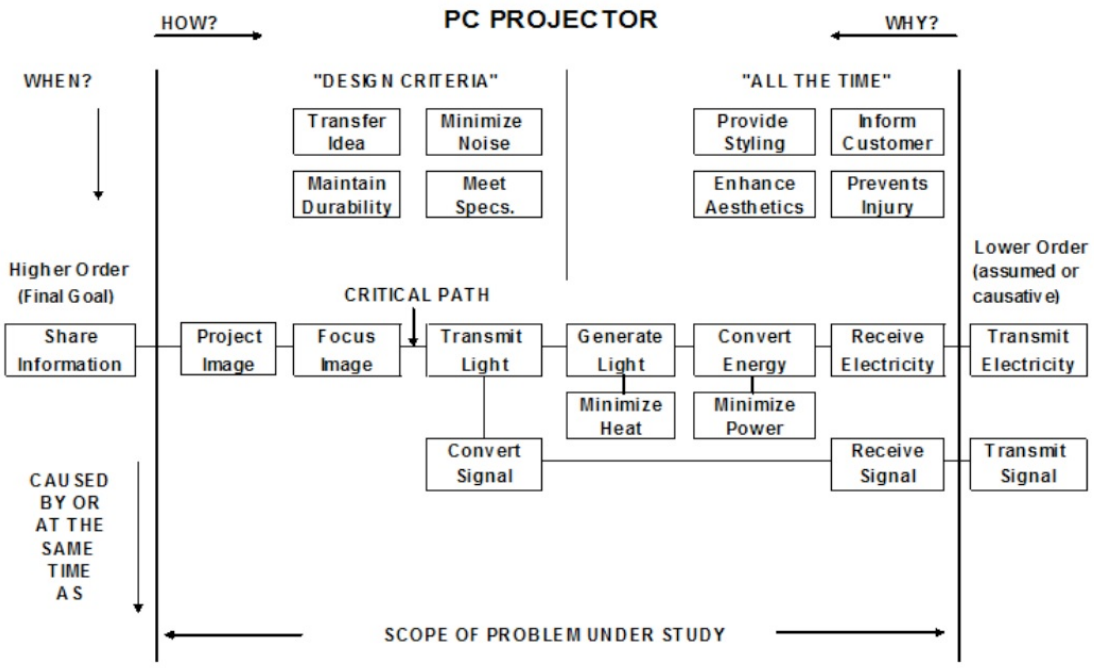


Figure 5 FAST Diagram for a PC Projector

2.7.2.2.3 Determining Functional Cost

The SAVEI BOK states that during this activity the cost of the function is listed and related to the measurable performance indicators and user preferences. Different tools are used during this activity such as Cost to Function Analysis (Function Matrix), Performance to Function Analysis, Relate Customer Attitudes to Functions.

The SAVEI glossary defines function cost as **"**the percentage of directly related resources allocated to a function performed by a project, product, or process". An item can perform just one function or more than one function, when the item performs more than one function, the item cost is distributed according to a weight factor related to different functions.

2.7.2.2.4 Estimating the worth of functions

The SAVEI BOK states that during this activity the function worth is estimated, then functions with inappropriate costs in comparison to worth are selected as the focus for the creativity phase. The main tool used is Value Index (VI).

SAVE International glossary defines Function worth as "The lowest overall cost to perform a function without regard to criteria or code". It is the cheapest way to achieve a function, and although probably the hardest step.it is an essential and fundamental one in the functional phase. What makes it the hardest is that it doesn't only require creativity but also is subjective. Accordingly, information alone is not enough to determine worth, but rather skilled judgement is the main measure of worth in terms of cost. Different alternatives to achieve the functions are considered and the cheapest alternative is the Function Worth. Then the ratio of function cost to function worth defined as value index is used to evaluate the value- the lower the VI the better the value. It is also necessary to consider the whole life cycle costs, not just the initial costs, otherwise, the resulting Value Index would not be reliable representation of Value **(WVDOH, 2004 revised to 2014, p. 9 of Ch 3)**. According to the resulting VI the best opportunities for improvement can be determined.

2.7.2.3 Creative Phase

Unless otherwise cited the description of this phase and its steps in subsections 2.5.2.3.1, 2.5.2.3.2 and 2.5.2.3.3 is summarized from Value Engineering Handbook[2] **(Mandelbaum & Danny L. Reed, 2006)**.

The Creative Phase (also called the Speculation Phase) aims at finding as many ideas as possible to perform the selected functions differently using a creative approach. Creative problem solving is a process that is meant to produce many different solutions by combining all the team members' expertise and ideas and to then single out the one solution that works best using an analytical approach. In order to do so, it is important to first discourage creativity inhibitors, then to establish the ground rules of creative idea generation and finally generate an uninhibited flow of ideas to find an alternative solution to perform the function in the best way. Some of the techniques to possibly be used in the context of Value Engineering are brainstorming, the Gordon technique, checklists, morphological analyses, attribute listings, the Input-Output technique or the Theory of

[2] *Mandelbaum, J., & Danny L. Reed. (2006). Value Engineering Handbook. Alexandria, Virginia 22311-1882: INSTITUTE FOR DEFENSE ANALYSES*

Inventive Problem Solving. All three common activities for creative phase will be detailed in the following subsections

2.7.2.3.1 Discouraging Creativity Inhibitors

The VE team's awareness of creativity inhibitors would help them to overcome them, hence those inhibitors should be pointed out by the VE facilitator to all team members. Donald E. Parker[3] in his book Value Engineering Theory identifies and classifies creativity inhibitors, **Table 5** below list them in a tabulated format (Parker, 1998 Revised Edition):

Table 5 Creativity Inhibitors / Blocks

Habitual Blocks	Continuing to use "tried and true" procedures even though new and better ones are available.
	Rejection of alternative solutions that are incompatible with habitual solutions.
	Lack of positive outlook, lack of effort, conformity to custom, and reliance on authority.
Perceptual Blocks	Failure to use all the senses for observation.
	Failure to investigate the obvious.
	Inability to define terms.
	Difficulty in visualizing remote relationships.
	Failure to distinguish between cause and effect.
	Inability to define the problem clearly in terms that will lead to the solution of the real problem.
Cultural Blocks	Desire to conform to proper patterns, customs, or methods.
	Overemphasis on competition or cooperation.
	The drive to be practical above all else, thus making decisions too quickly.
	Belief that all indulgence in fantasy is a waste of time.
	Faith only in reason and logic
Emotional Blocks	Fear of making a mistake or of appearing foolish.
	Fear of supervisors and distrust of colleagues.
	Too much emphasis on succeeding quickly.
	Difficulty in rejecting a workable solution and searching for a better one.

[3] Donald E. Parker, *Value Engineering Theory*, The Lawrence D. Miles Value Foundation, Washington D.C., 1998, revised edition, p. 93.

	Difficulty in changing set ideas (no flexibility) depending entirely upon judicial (biased) opinion.
	Inability to relax and let incubation take place

2.7.2.3.2 Establishing Ground Rules

Parker[3] lists seven ground rules for creative idea generation which should be established during the creativity phase, and those rules are summarized as follows:

1. Avoid judging and focus on generating new ideas, judgment and evaluation shall take place during the Evaluation Phase.

2. Generate a large number of possible solutions (5 to 10 times the solutions produced in the first rush of thinking) with focus on quantity not quality.

3. Seek a wide variety of solutions that represent a broad spectrum of attacks on the problem; the greater the number of ideas conceived, the more likely there will be an alternative that leads to better value.

4. Freewheeling is welcome. Intentionally aim at unorthodox ideas.

5. Watch for opportunities to combine or expand ideas as they are generated. Include them as new ideas; do not replace anything.

6. Avoid neglecting any ideas, even if they appear to be impractical.
7. Avoid criticism of any ideas by, for example, implying a penalty on criticizers.

2.7.2.3.3 Generating Alternative Ideas[2]

Different tools and techniques are used for the generation of ideas for alternatives that can perform the function(s) selected for the study, the selection and depth of application of specific techniques is judgement dependent and varies according to subject complexity **(Mandelbaum & Danny L. Reed, 2006)**. Although there are plenty of tools and techniques that can be used, however within this paper it was chosen to focus on the ones listed in SAVEI BOK which includes Brainstorming, Gordon Technique, Nominal Group Technique, TRIZ and Synetics. The brief explanation below for each of these techniques is summarized[2]:

Brainstorming*:* is a free-association technique to solve specific problems by recording ideas spontaneously contributed by a group's individuals, were one idea suggests others,

and these suggest others, and so on. Based on experience Group Brainstorming is more efficient than individual Brainstorming as it can generate more ideas collectively than the same number of persons thinking individually. Sperling[4] found that after the group brainstorming process was complete, individual brainstorming can generate additional ideas of comparable quality.

Gordon Technique: is a variation of group brainstorming, were only the group leader select a topic for the session closely related to the problem, but he only discloses the exact nature of the problem under investigation after the closure of the discussion. This to avoid creativity blocking, that happens when a participant adopts the proposed ideas as the best solution to the problem, and stop to produce new ideas, or concentrate on defending these ideas.

Nominal Group Technique: is a structured method for group brainstorming that encourages contributions from everyone **(ASQ.Org, 2018)**. NGT encourages all group members to participate and prevents a single person to dominate the discussion, this done by recording individuals' responses to questions posed by a moderator, and then asking participants to prioritize the ideas or suggestions of all group members[5] (Center for Disease Control and Preventation(CDC), 2018).

Theory of Inventive Problem Solving (TRIZ): is a proven management tool incarnated in a five-step process namely: problem documentation and preliminary analysis, problem formulation, prioritization of directions for innovation, development of concepts, and evaluation of results. Dull points out that combining VE and TRIZ especially for more technically complex projects where the resulted additional benefit is worth the effort can lead to more reliable and comprehensive results compared to the results of using them separately. He provides examples for integrating TRIZ into the VE job plan which he believes is easier than integrating VE into TRIZ[6] **(DULL, 1999)**. Clarke illustrates how

[4] Roger B. Sperling, "Enhancing Creativity with Pencil and Paper," *SAVE International Annual Conference Proceedings*, Volume XXXIV, San Antonio, Texas, 27–30 June 1999, pp. 284–289.

[5] https://www.cdc.gov/healthyyouth/evaluation/pdf/brief7.pdf

[6] C. Bernard Dull, "Comparing and Combining Value Engineering and TRIZ Techniques," *SAVE International Annual Conference Proceedings*, Volume XXXIV, San Antonio, Texas, 27–30 June 1999, pp. 71–76.

TRIZ can be used to boost traditional brainstorming in the Creative Phase[7] **(Clarke, 1999)**. Ball emphasizes Clarke's conclusion by stating that TRIZ method is a more powerful than commonly other used methods in VM study[8] **(Ball, 2003)**. Moreover, it is noted that TRIZ has a lot in common with VE techniques, while VE contributed to a great deal into the development of the functionality aspects of TRIZ, it is also noted that the foundation of both methods started around same time **(triz-journal.com, 2018)**.

Synectics according to National Chiao Tung University Synectics is a method of creative problem solving that stimulate conscious and subconscious levels of minds using metaphor to promote creative thinking, typically among small groups of people with diverse expertise (National Chiao Tung University, 2018). The principles of three main assumptions of Synectics are (Gordon, 1961):

1. "The creative process can be described and taught;"
2. Invention processes in arts are similar and motivated by the same "psychic" processes as in sciences.
3. Individual creativity is similar to group creativity.

2.7.2.4 Evaluation Phase

According to Value engineering Handbook, unlike creative phase which is based on creative approach, this phase is based on critical assessment and analytical approach where the best ideas developed during creative phase are selected and refined then further developed in development phase be presented to the decision maker as value improvement recommendations. This phase can be thought of as preparatory phase for the development phase where the selected ideas undergo cost-benefit analyses before the final presentation (Mandelbaum & Danny L. Reed, 2006). The common activities for this phase is summarized below from the same Handbook:

[7] Dana W. Clarke, Sr., "Integrating TRIZ with Value Engineering: Discovering Alternative to Traditional Brainstorming and the Selection and Use of Ideas," *SAVE International Annual Conference Proceedings*, Volume XXXIV, San Antonio, Texas, 27–30 June 1999, pp. 42–51.
[8] Henry A Ball, "Value Methodology—The Link for Modern Management Improvement Tools," *SAVE International Annual Conference Proceedings*, Volume XXXVIII, Scottsdale, Arizona, 8–11 June 2003.

2. Classification of ideas based on feasibility and effectiveness and elimination of ideas with low potentials, that include ideas that are not feasible or doesn't perform the essential needed function.

3. Grouping and prioritization of ideas, in this step ideas are grouped into categories based on subject, then it is decided whether similar ideas shall be combined into one main idea or rather it would be better to combine two or more different ideas into a winning idea. Then these ideas are prioritized for further development

4. Comparison between advantages and disadvantages of each idea, in this step the impact of each idea is tested and analyzed. It is mandatory to at least identify for each idea the Cost, ease and time of implementation as well as the ability to meet needed requirement, also success and savings potentials, moreover methods to overcome disadvantages should be considered.

5. Ranking and selection of ideas for further development, using advantages and disadvantages as selection criteria. Explain the risk associated with each of the selected ideas in comparison to the relative improvement potentials.

2.7.2.5 Development Phase

According to Value engineering Handbook, development phase includes a more detailed technical analysis to exclude weak alternatives and select best one(s) to be presented for the decision makers, the activities of this phase as presented in the same handbook is summarized in the following subsections.

2.7.2.5.1 Conduct a Life-Cycle Cost Analysis

Life cycle cost analysis shall be conducted for all alternatives to rank them economically based on the savings achieved in comparison to the present method. The L.C.C. shall be inclusive of all costs, precise and robust to avoid errors in ranking the alternative. It is mandatory to agree with management on length of life cycle and discount rate to be used for all alternatives.

2.7.2.5.2 Determine the Most Beneficial Alternatives

The selection of the most beneficial alternatives shall consider life cycle savings, performance, technical issues, risk and risk mitigation. It is usual while considering all

these factors to recommend more than one alternative and present them in descending order based on saving potentials when they all have considerable economic feasibility.

2.7.2.5.3 Develop Implementation (Action) Plans

The implementation plan shall be all inclusive and shall include implementation time, schedules, assign people and resources, approval process and documents. It shall suggest solutions for all expected problems and predict them in advance.

2.7.2.6 Presentation Phase

The presentation phase is the last phase of the workshop stage and the first in the approval process, Presenting the results of the Value Engineering team's findings is an important step to getting the decision maker's approval for an alternative to an existing practice. The oral presentation is the focus for this phase and fundamental for its success, where the VE team is giving a chance to clarify any misunderstood points in the written proposal. It explains the precise objective of the workshop and shows the costs as well as the advantages and disadvantages for each suggested alternative. It also addresses possible difficulties and make suggestions as to how to implement the alternative.

Helpful strategies to achieve the desired approval include, for one thing, being mindful of who is actually addressed. For a technical audience the engineering details are more important, for an audience with an administrative background it is more important to highlight the financial effects of the change. Furthermore, it is important to mention not only benefits, but also the risks involved. It is also helpful to keep the organization's overall goals in mind and relate the benefits to them. Finally, not only financial benefits, but all possible improvements that come with a change of practice should be mentioned.

In order to make it more likely for the management to actually implement an alternative to the current practice, in addition to the oral presentation there should also be a written report that includes the backup documentation and data. It also crucial to include everyone affected by the change and inform them also as well as setting up another meeting for a proposed alternative to be approved.

2.7.3 Post-Workshop Activities

Post-workshop stage consists of Implementation phase and follow-up activities. In the Implementation Phase an alternative should be decided for and the VE team should be monitoring its implementation making sure it is smooth and effective.

As mentioned above, a written report should be prepared in addition to just an oral suggestion in order to make sure the proposal is not forgotten. It serves to answer possible questions and shows, supported by detailed documentation, how the organization will benefit from the change. The Value Engineering team should also give a summary and action plan in a separate letter.

What is also very important is to keep managerial staff involved by repeatedly discussing the proposal with them. This way their needs, concerns and ideas can be considered and the proposal adjusted accordingly.

Then, the implementation progress should be closely monitored by Value Engineering team to make sure it continues until the change is established.

Whenever problems come up, the VE team should be ready to address and solve them. Additionally, they should also facilitate the change by drafting the necessary documents in order for handbooks, specifications etc. to be updated.

Finally, the success of the implementation is to be examined by comparing of goals and actual results. Benefit and technical reports are to be sent to the management and for identified problems there is a corrective action plan to be set up.

Possibly, in the course of the study just conducted new ideas might come up that need to be formulated into a recommendation for a follow-up study.

2.8 Application of VE

Although VE started as an industrial technique that was focused on analysis of existing products, Miles in his book stress that it can be used as management tool to solve management problems, service problems, and in construction as well **(Miles, 1989)**. The same is stressed in different literature relating to VE, while VM definition by SAVE International state clearly it can be applied to products, services or project. Also SAVE International BOK states that VE can be employed by organizations on the strategic level

to improve organization performance and enhance quality programs, or to develop products, or within the architectural and engineering design, Also, it can and have been used in services including medical industry. Moreover, it may be applied to respond to a specific problem **(SAVE International, VALUE STANDARD and BODY OF KNOWLEDGE, 2007)**.

2.9 VE Implementation Phases or Times

In his book Miles explained that VE before product design and purchasing tools and materials which achieve better value than conducting it after design, however, he encourages performing VE periodically during product life cycle. Later on, SAVE International confirmed the same, stating that VE may be applied in a single phase of the project, service or product lifecycle or applied in different phases. However, the application of VE in the early phases or stages is much more effective than the application in late phases, specifically the application of VE during the conceptual phase achieve the greatest savings and benefits by avoiding the waste of the major design and development resources if the VE is applied in later stages **(SAVE International, VALUE STANDARD and BODY OF KNOWLEDGE, 2007)**. The same BOK also advise the repeated application of VE during major phases development phases to revise the project based on the updated or modified information.

3 Application of VE in Construction

3.1 Introduction

Construction Management or Construction Project Management is the branch of project management that deals with construction projects or the built environment. There are different definitions for construction management, however, the definition that was selected and cited below is the one defined by the "International Construction Project Management" 3rd forum, which were held in July 2003 in Berlin.

Construction Project Management (CM) is a professional service that uses specialized, project management techniques to oversee the planning, design, and construction of a project, from its beginning to its end. The purpose of CM is to control a project's time, cost and quality. **(ICPM, 2003)**.

This chapter is focused on the application of VE in construction, where VE has been adopted as a management tool in construction since the mid of the 1960s **(The Federal Constrcution Council, 1990)**.

This chapter will briefly detail the styles of application of VE studies in construction both in USA, and worldwide based on the findings of Kelly and Male as presented in their book "Value Management of Construction Projects". Those two authors have been involved in a series of extensive researches about the application of VM in construction. Their research work included a benchmarking research project, sponsored by the Engineering and Physical Sciences Research Council in the UK, which was undertaken during the period 1995-8 **(Kelly, Male, & Graham, 2004)**.

3.2 The Best Timing for VE

According to Kelly & Male all VE literature agrees that the highest cost savings opportunities happen in early in briefing/design phase (before the commitment of resources), while lower savings are still possible in later stages, but this will consume more resources **(KELLY & MALE, 2005)**. The same was stated earlier by Dell'Isola who stated

that late application of VE doesn't only increase the cost required to implement the changes, but also increase resistance to change as shown in **Figure 6 (Dell'Isola, 1997)**.

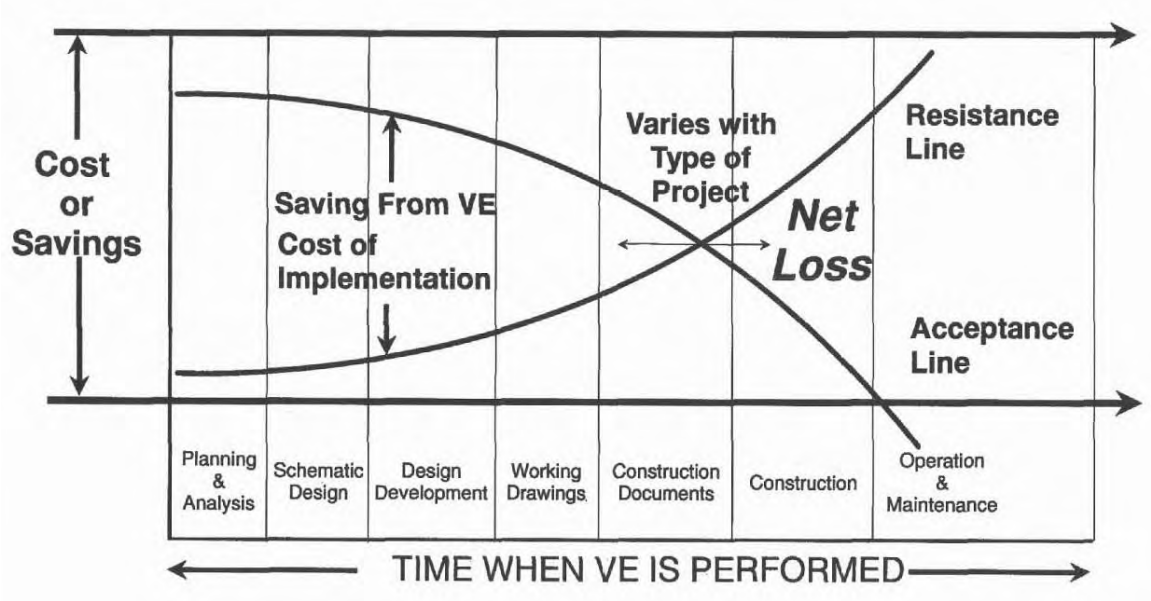


Figure 6 Potential Savings from VE Application

Dell'Isola stated that while the designer fee is the smallest percentage of the initial project costs, the impact of the decisions made during design on the total costs is about 50% of the total costs, therefore the VE studies shall start in early stage of the design and focus both on the owner and designer as "Major Decision Makers" with the greatest influence on the project cost as shown in **Figure 7** (Dell'Isola, 1997).

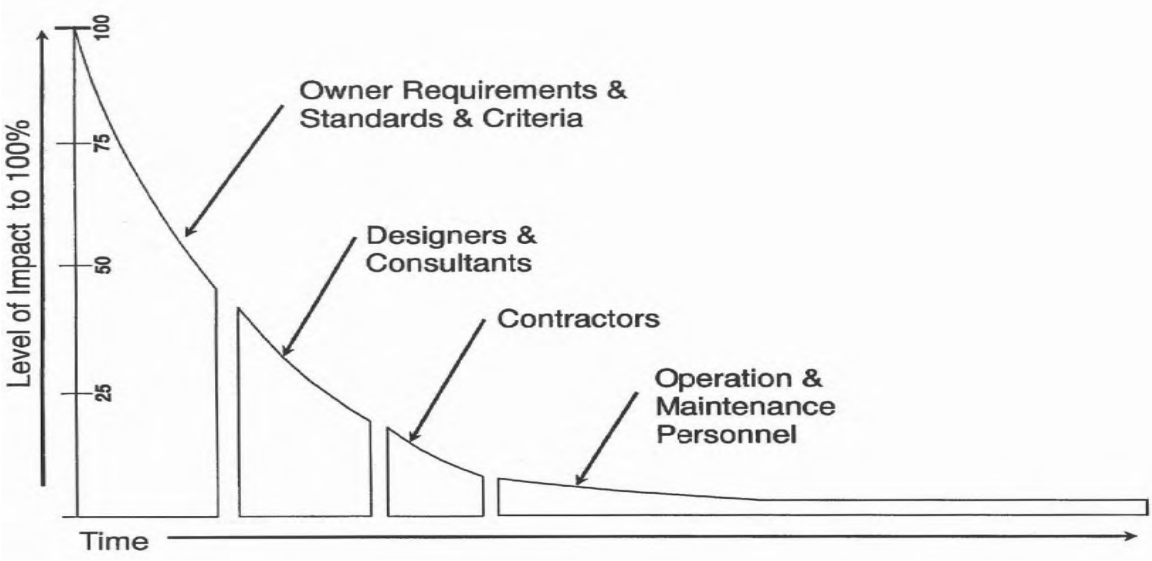


Figure 7 Major Decision Makers' Influence on Building Costs

He elaborated to explain that wisely spending money to improve design decisions would have huge enhancing impact both on the project's LCC and quality, the same concept was confirmed by Kelly & Male later as can be shown in **Figure 8**.

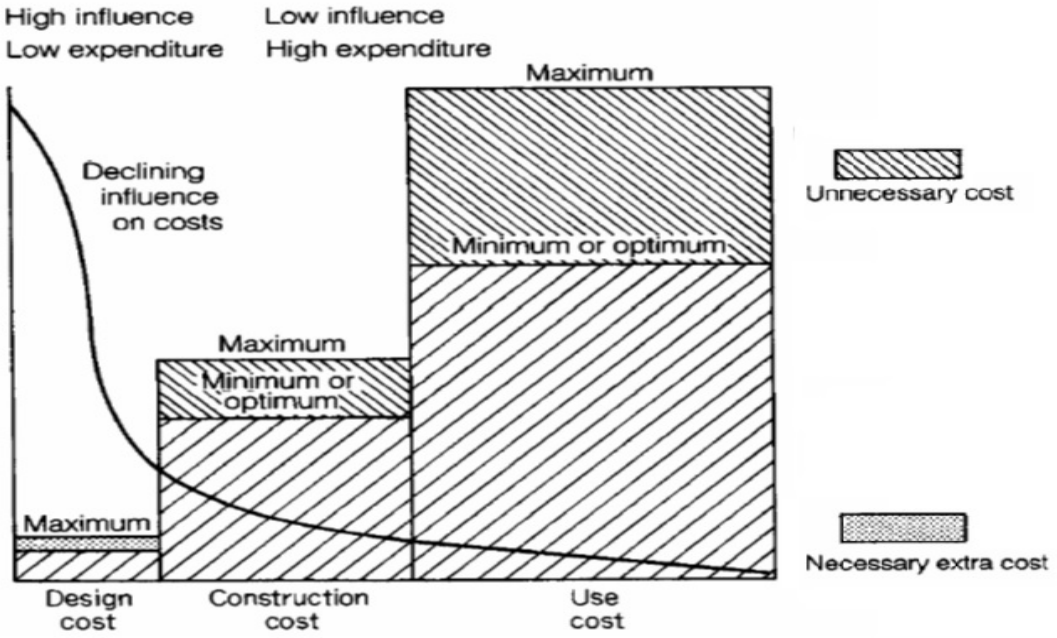


Figure 8 Influence vs Expenditure in different Phases

Kelly and Male et al. identified 6 points in time when intervention by conducting value studies proves to be useful and called these points "Value Opportunities" as will be detailed in section 3.5.

3.3 Formal VE study styles in North America.

This entire section and its subsections are summarized from the book "Value Management in Design and Construction", where According to Kelly & Male the application of VE studies in North America could be categorized in four formal approaches as follow (KELLY & MALE, 2005):

1. The charette takes place after the client's brief, where the client's representatives who participated in the brief meet with the full design team under the leadership of the Value Engineer.

2. The 40-hour study takes place after concept design, but the value engineer is leading a study team formed of independent experienced designers who had no relation to the design of the project subject of the study.

3. The value engineering audit where VE team formed of employers of large organizations (governmental or large corporate) to study the feasibility of funding a project proposed by a subsidiary of the large organization.

4. The contractor's change proposal takes place in contractual agreements that reward contractors a profit when they propose valid alternatives that result in cost savings.

All these formal approaches will be detailed in the following subsections.

3.3.1 The Charette

This study follows the same phases of job plan with the main objective to ensure that the designer fully understands the requirements (the needs & wants) of the client through functional analysis of specified spaces and their performance criterions. The main five advantages of the Charette is as follow:

1- Relatively inexpensive, because the client would nearly only pay the Value Engineer fee while client staff time to be considered but it would not result in an additional fee, also if the meeting was included in the time of the design bid that would not have a significant impact on the design fee.

2- It is considered the best way of briefing the entire design team: the architect, structural engineer, MEP engineers, etc, which ensure that all of them understand what needs to be done.

3- It takes place at stage considered by many of the highest impact on project cost.

4- Short exercise that last for two days or less unless for projects with high complexity.

5- It transcends limits: political, organizational, professional by gathering different stakeholders in one meeting chaired by the Value engineer.

3.3.2 The 40-hour VE study

The 40 hours workshop used as training for value engineers by SAVE International and are highly agreed on as an official VE style. It follows strictly the job plan phases and includes the review of concept design by an external design team which is not involved in the project. It is considered fast and efficient and as the study follows the job plan and takes place for a duration of one working week. Usually the client acknowledges the design team about this study at the time of their bid. Sometimes the client will pay for the redesign cost on hourly basis while sometimes the client agrees with the design team to include the redesign cost in their initial bid. The team is formed from the Value Engineering Team Coordinator (VETC) and six to eight design professionals of different disciplines where the nature of the project defines the dominant discipline(s) within the team. The advantages are listed below as follow:

1- Produces technical alternatives for costly elements at lower initial and LCC.

2- Fixes a concept design completion date, as setting a study date forces design team to finish faster than would otherwise when they are not tied to such date.

3- Saves much more money than it cost with ROI around 10 and expected savings of at least 10% of project contract value.

4- Success of 100% stated by majority of value managers (according to Kelly and Male only one client stated about 2% failure rate)

While the disadvantages or problems related to VE studies are associated with conflict, time and resourcing and are as follow:

1- The misconception by the client that it is the design team responsibility to come with the best solution with no additional tasks or expenses. This misconception could be corrected by clarifying and educating clients that the function of the design team is to deliver practical solution that response to client's demands. Also, that VE studies are done on an existing design with the objective of further improvements.

2- The conflict that result when the design team considers the alternatives developed by the VE team as criticism to their design. This conflict can be eased by informing

design team about the VE study at the time of bidding, and also by training design team on VE and understanding that they will be paid for the redesigning activities.

3- The VE study consumes time that varies from three to four weeks from the design scheduled time. Which is hard to accommodate or accept in certain projects. However, this is countered by the fact that the VE study sets a fixed date for the completion of concept design, and that it acts as a turning point between the concept design and working drawings.

4- The difficulty to withdraw professional designers from their company office for a whole working week.

3.3.3 The Contractor's Change Proposal (VECP)

Also called Value Engineering Change Proposal (VECP) is submitted by the contractor to change original study to improve project value after the tender of the project. The benefits of VECP are to maximize project value for the client through contractors' experience and maximize contractors' profit by earning percentage of the saved costs. Such practice is motivated by the US government by awarding contractors 55% of savings after design approval on VECP. The time used by the design team to review VECP delays the contract which is main disadvantage.

3.3.4 The Value Engineering Audit

It is fast an inexpensive study that usually last for one or two days to provide a general review and is used by large organizations such as: big corporate and governmental departments, Where the value engineer visits the part of the organization (subsidiary company or regional authorities) after they made a proposition to perform VE study considering the main functions. The study follows the job plan phases and the team could be formed from employers of this part of the organization with the proposition, or employers from another part of the organization (another company from the corporate or another regional authority). A report detailing the objectives and the most economical ways for achieving is submitted by the value engineer after the study. Although usually criticized for developing conflicts within an organization however it is considered effective.

3.4 Variations to The Formal VE Styles in North America

According to Kelly & Male formal VE study styles does not fit all situations accordingly the application of job plan involves other variations to these standard styles as follow **(KELLY & MALE, 2005)**:-

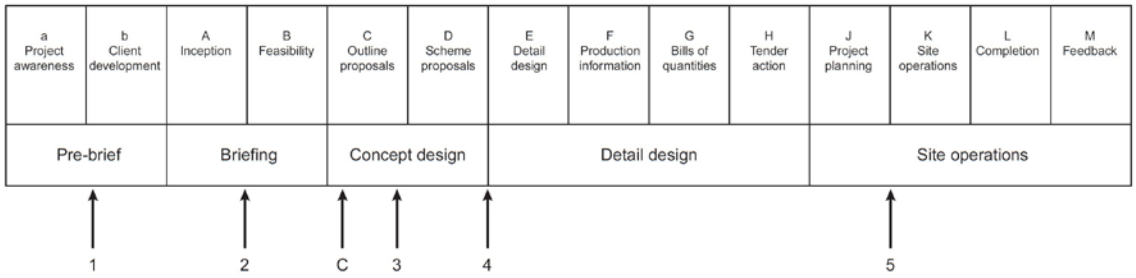
1. The Orientation Meeting: is sort of identical to the charette and is either held after client's brief or concept design. It includes clients' agents, design team and an estimator and is focused on exchanging project information, understanding project requirements, constrains and decide a date for 40 hours study.

2. The shortened study: is a short or a smaller version of 40 hours study where either less persons or less days or both are used for small projects with low cost (usually lower than $2-3millions). The total number of person-days is calculated by fixing study cost to 1% of project value (based on 10% saving and ROI 10). Knowing the cost of one person-days and allowed budget for the study, the total number persons-days can be identified, and study is designed accordingly.

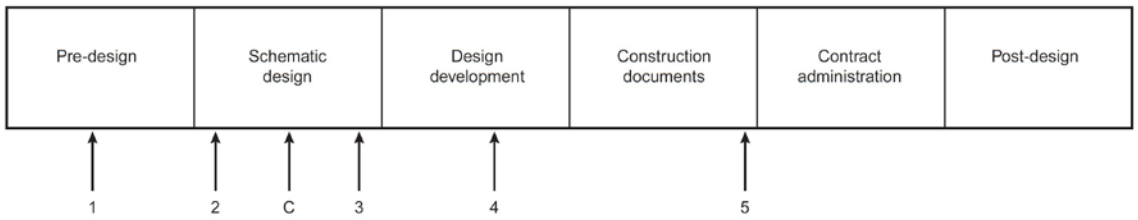
3. The concurrent study: Aims to review design on regular basis where design team meets with VETC. It helps to overcome many of the disadvantages of 40 hours study style, but the main disadvantage is the difficulty of proving its effectiveness.

3.5 Internationally Benchmarked VM Study Styles.

Kelly and Male et al. state that during the execution of a project there are six points in time when intervention by conducting value studies proves to be useful as shown in **Figure 9** (Kelly, Male, & Graham, 2004). These so-called value opportunity points are the strategic briefing study, the project briefing study, the charette, the concept design workshop, the details design workshop and the operations workshop. Studies may be carried out at one value opportunity point only or at several different ones. In the following subsections, details of these opportunity points or study styles will be summarized from the book that was cited in the beginning of this paragraph.



Value opportunities mapped out on a modified RIBA plan of work.
Source: Male *et al.* (1998) *The Value Management Benchmark*[v].



Value opportunities mapped out on an AIA design process.
Source: Male *et al.* (1998) *The Value Management Benchmark*[v].

Figure 9 Value Opportunity Points

3.5.1 Strategic briefing study

Strategic briefing studies take place at the first benchmarked value opportunity point and their aims are explaining the reasons for a particular investment as well as pointing out how it fits in with the aims of the client organization and what is involved when the project is executed. They usually take from four to seven days and the study team consists of 10 to 20 experienced members of the client organization. It is important that all relevant facts and options are considered and that after the strategic briefing study the client can take an informed decision about whether to build or not.

The strategic briefing study consists of two phases, the orientation and diagnostic phase and the workshop phase. In the first phase interviews are conducted, documents are examined, the site is toured, and possibly similar projects are evaluated. In the second phase the study team presents the project and conducts issue, stakeholder, project driver, time, cost, quality and functional analyses. They can also brainstorm alternatives, evaluate and develop ideas and set up a plan for implementation. Finally, the team prepares an action plan and a study report which is then going to be developed into a strategic brief.

This strategic brief needs to contain a mission statement, the project context, the client's value system and a line-out of organizational structures for project delivery. It will be mapping out the overall purpose and the program for the project as well as pointing out risks and is going to include the budget and possible cashflow constraints.

3.5.2 Project briefing study

The second value opportunity point is the project briefing study, which is conducted in order to develop a project brief, which acts as a translation of the strategic brief into technical construction terms. The study team, again comprising of 10 to 20 senior members of the client organization, take around four to eight days to finalize the study, which also divides into an orientation and diagnostic phase and a workshop phase.

Activities in the first phase pretty much correspond to the ones in the strategic briefing study. In the workshop phase, along with previously mentioned techniques, the team typically also may use techniques such as REDReSS, process flowcharting, functional space analysis, spatial adjacency analysis and SWOT. The workshop phase is also finalized with a study report from which the project brief would be developed.

It is important that this document contains, firstly, a summary of the strategic brief. It then needs to map out the aim of the design as well as show the site, the facilities and the project execution plan. Furthermore, it is important for the project brief to include key targets for quality, time and cost, a method for assessing and managing risks and validating design proposals, the procurement process and an environmental policy.

3.5.3 Concept design study

The concept design study may take place at the third value opportunity point and is undertaken when the design needs detailed planning permission. The aim of this study is to either approve of the design or to give suggestions about how to improve it. It should also take from around four to eight days and the study team's number is rather big again,

being composed of 10 to 15 senior members of the client organization and the design and project management team.

Activities undertaken in the orientation and diagnostic as well as the workshop phase of the study are similar to those in the project brief study. What the concept design study should achieve is, for one, a statement of the direction of the design. It should then also contain a project execution plan and the procurement strategy, and it should map out key milestones as well as key performance indicators. Important risks should be mentioned, and a detailed cost plan and budget need to be set up. Activities need to be planned and the site layout should also be included.

3.5.4 The charette

The charette is a combined study and examines the design against the backdrop of the study brief and the project brief plus the client value system. After it is completed, the client value system should be clear, and the project brief should be approved of. The design team should now be able to either continue with its design, knowing that the strategic and project briefs have been analyzed thoroughly and are acceptable to the client or to improve it, following the study's suggestions.

The duration of the charette is four to eight days and the size of the study team ranges from 10 to 15 people, usually senior representatives from the client organization and the design and project management. The techniques used in this study are, again, similar to those used in the previously described studies and its outcome should be a combination of the results of all three of them.

3.5.5 Final sketch design/scheme design workshop

The final sketch design workshop is the fourth benchmarked value opportunity point and its aim is to detail the design and each part of the construction work to come as much as possible. In addition to that, any arising risks will be mentioned, quality requirements will be evaluated, and the measuring parameters of success will be established. This study will

take between four and nine days and the study team will be comprised of 10 to 15 representatives of client organization and design and project management.

In the orientation phase documents are analyzed, information from similar projects is gathered and the site is toured. Techniques used in the workshop phase correspond to the ones mentioned above. The outcome should contain a statement of scheme design, an updated execution plan, key milestones, indicators on how performance is going to be measured, the site location plus all approvals and permissions obtained, risks and strategies on how to manage them, a cost plan and proposals on how to maintain and manage the facility once completed.

3.5.6 Operations workshop

The operations study is taking place at the very last moment before construction work begins and marks the fifth value opportunity point. Its aim is to discuss supply chain and technical development issues and to analyze risks as well as the action that has been agreed on before. This study takes two to six days and the team of six to ten people is made up of representatives of the contractor’s management team as well as suppliers and subcontractors.

In the first phase of the study the team members will conduct interviews, examine the strategy and viewpoint of the contractor, assemble the drawings and programs, prepare histograms and identify major work packages. In the workshop phase the techniques mentioned for the first study are also being used.
What the operations study needs provide is a project execution plan, it needs to mention key milestones and targets as well as key performance indicators and there should be a supply chain diagram and a risk management plan. It will also mention gates in the project development having an impact on subsequent work packages and identify key work items to be targeted.

3.6 Other study styles

- **Single project versus project program studies:** It is not only possible to use the above-mentioned study approaches for a single project but also for a whole program of studies. When this is done, the goals of the complete program and the relationships between the respective projects are evaluated.

- **Organizational change studies:** Moreover, the value study process has proved successful when wanting to reorganize organizational units such as teams, departments or divisions. Using tools such as prioritized issues analysis, functional analysis and migration strategies helps find the functions that are going to add value to the organization in the future.

- **Facilities programming studies:** The facilities programming study merges strategic and project briefing studies and also uses procurement strategy options in order to develop the technical or project brief for a project or to determine the correct procurement course.

- **Project audits and value-for-money studies:** Project audits or value-for-money studies are comparable to the North American VE studies and are conducted in order to analyze whether the project at its current level is providing value for money.

- **Procurement studies:** Procurement studies are generally of two types, either the best procurement method is found together with the client or the value study process helps contractors establish a bid strategy in a bid conference.

3.7 VE/VM Critical Success Factors

The benchmarking study of value management identifies ten critical success factors (Kelly, Male, & Graham, 2004) :

1. The use of a multi-disciplinary team with appropriate skill mix.
2. The skill of the facilitator.
3. The structured approach through the VM process.
4. A degree of VM knowledge on the part of the participants.
5. The presence of decision takers in the workshop.
6. Participant ownership of the VM process output.
7. Preparation prior to the VM workshop.
8. The use of function analysis.
9. Participant and senior management support for VM.
10. A plan for implementation of the workshop outcomes.

Most of these factors are also included in SAVEI value standard as stated previously mentioned in section 2.6. Also, SAVEI BOK focuses on the roles and responsibilities of different VE stakeholders including management, VE team members and VE team leader (also called coordinator or facilitator).

3.8 Establishing an Effective VE Program

To identify the main elements or factors that play a fundamental role in the implementation of a successful VE program, the Federal Construction Council (FCC) formed a consulting committee on VE consisting of experienced VE professionals from different federal agencies which established VE program that has been practicing VE for many years. The focus of this committee was on VE studies conducted during design phase by a study team other than design group. This committee has identified the following three elements of a success listed below **(The Federal Constrcution Council, 1990)**:

1- organization and staffing.

2- policies and procedures.

3- continuity of support.

Those three factors are discussed in details in the following sections 3.2.1, 3.2.2 and 3.2.3 which were summarized from FCC Technical Report #92 cited above[9].

3.8.1 VE Organization and Staffing[9]

An effective organization and staffing are considered the most vital factors on the success of the VE program, as will be detailed in the following subsections.

3.8.1.1 VE Organization[9]

The key to an effective VE organization (in a large organization) is its presence on all levels of the organizational structure of the agency or the organization with VE being the main function of VE staff at each level. Moreover, the VE coordinator must have power and influence proportional to their responsibilities (to demand cooperation between designers and value engineering analysts) and he should report directly and have access to the head of the organization. **Figure10** reflects these organizational requirements for large organizations.

3.8.1.2 VE Staffing[9]

Beside organizational structure of VE staff in an organization the following points should be considered in the staff: -

1- VE should not be an extra duty but rather the main duty of the VE coordinator

2- VE coordinator should be experienced professional having equivalent engineering degree and employee ranking to their counterparts in design.

3- Adaptation for guidelines for number of VE coordinators in an organization to avoid over or under staffing (percentage of total staff for example 0.2%)

4- All VE study team members shall be experienced engineers and preferably they should be trained in VE, and the team leader should have at least 10 years professional experience and all team me

[9] The Federal Constrcution Council. (1990). *FCC Technical Report #92 Effective VE Program.* Washington, D.C.: National Academy Press

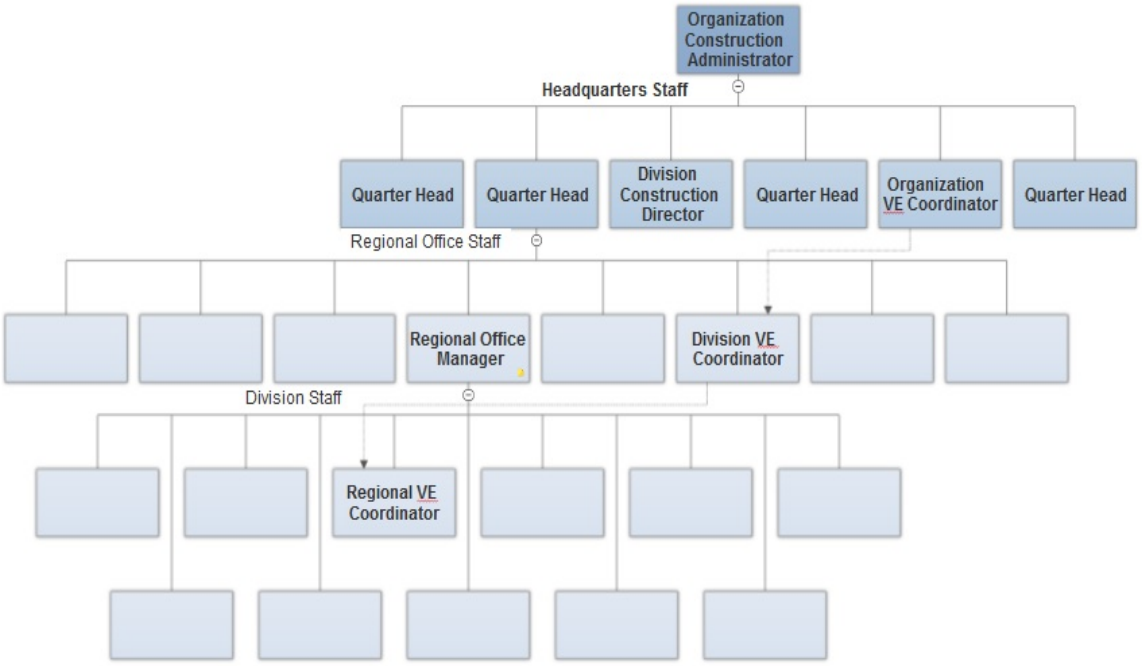


Figure 10 Recommended VE Structure in large Organization

3.8.2 VE Policies and Procedures[9]

3.8.2.1 VE Policies[9]

The polices should focus on the following: -

1- Achieving long term cost saving not short term (LCC).

2- High accuracy and objectivity in preparation of cost estimates.

3- All major decisions and relative reasoning shall be recorded and archived

4- Projects should be selected for VE study based on guidelines such as project size, budget or level of complexity.

5- Expected ROI (percentage of savings to cost of performing the study)

6- VE should be performed as early as possible in design phase preferred at or prior to the end of "design development phase" which is roughly 35% design point (because performing VE at later stages would require intense redesign work and cost)

7- VE studies should require signature(s) of an assigned VE committee member(S) or VE coordinator

3.8.2.2 VE Procedures[9]

The following procedures shall be followed: -

1- Procedures for the execution of VE studies that include the time for assigning the study team, the qualifications and organization of the team members, causes to exclude VE suggestions and a person responsible to follow up the implementation of the approved VE suggestions.

2- To set clear methods for calculating savings from VE alternatives and avoid optimistic assumptions about potential savings by VE team.

3- To maximize benefits of VE studies by generalizing the findings of VE study as design criterion whenever possible or to be used in similar projects. Building a data base and following a standard presentation format or keywords for certain recommendation would ease this process.

4- To set goals and KPI such as ROI, number of performed VE studies or as percentage of the total construction cost.

5- Value engineering training in form of one to four hours VE briefings for managers to familiarize them with aims and benefits of VE, and in form of forty hours training course for VE team practitioners

3.8.3 Continuity of Support[9]

VE programs are more efficient when they are performed as a permanent and systematic procedure in the design process, which require senior management commitment and proper funding.

4 Research Design and Methodology

4.1 Introduction

This chapter explains the research design and the methodology used and compares the different research methods and approaches which were considered. The research follows on conceptual formulation that was initially proposed by the author and approved by HTW Berlin examination board. This research is exploratory in nature, where the author investigates the nature of VE and the synthesis between VE in theory and in practice.

4.2 Data Collection

In research generally, data collection can be categorized into two main categories namely: primary data and secondary data (Saunders , Lewis, & Thornhill, 2009). According to Saunders et al. primary data are the data collected directly by the researcher using different techniques including: observation, questionnaires, interviews. While secondary data are the data that was published in different forms including books, journals, magazines, documents, governmental surveys or other sources (research-methodology.net, 2018). The author in this research relied extensively on data collected from secondary sources with fraction collected through observation from his own work experience.

The research was highly dependent on qualitative data whether from researches, case studies or books; however, quantitative data were used when considered fit for the purpose or necessary.

4.3 Data reliability

As previously mentioned the majority of data are of the secondary type, the reliability of these data where subject to the following criteria when selected: -

1. The use of trusted sources where governmental reports, governmental publications and organizational trusted sources formed the major source of the data utilized in the research. The minor data which were based on academic research, the reliability and validity of these data (including

sampling, questionnaire or interview validity) were checked extensively before being included in this research also comparison to other researches for consistency were utilized.

2. Diversity of data types which included both quantitative and qualitative data and whenever possible triangulation of data were used to reach

3. The use of the most recent available sources of data to assure that all information is up to date and not obsolete.

4.4 Data Organization

This research does not aim to establish generalization of findings but rather attempts to explore the gap between theory and practice in general and the gap between developed and developing countries in practice. Moreover, as highlighted before a combination of case studies, qualitative and quotative data were used, while some of the qualitative data where raw data, other percentage were the result of processing quantitative data (mainly questionnaires in previous researches). Hence, the data were organized and sorted in the form of multiple case studies, where some case studies included multiple embedded case studies from different countries or from different researches that investigate the same or similar topics.

4.5 Data Analysis

Although qualitative analysis is dominant throughout the research, however, whenever the data available were suitable the triangulation between qualitative and quantitative approach were used.

4.6 Research Design

The research design followed the conceptual framework illustrated in **Figure 11** below, where both quantitative and qualitative data were utilized, with qualitative data forming the majority of data used in the research. The approach was to sort secondary data into case

studies, analyze them separately then using abductive approach cross check the common findings, to utilize them along with data in literature review to answer the research questions.

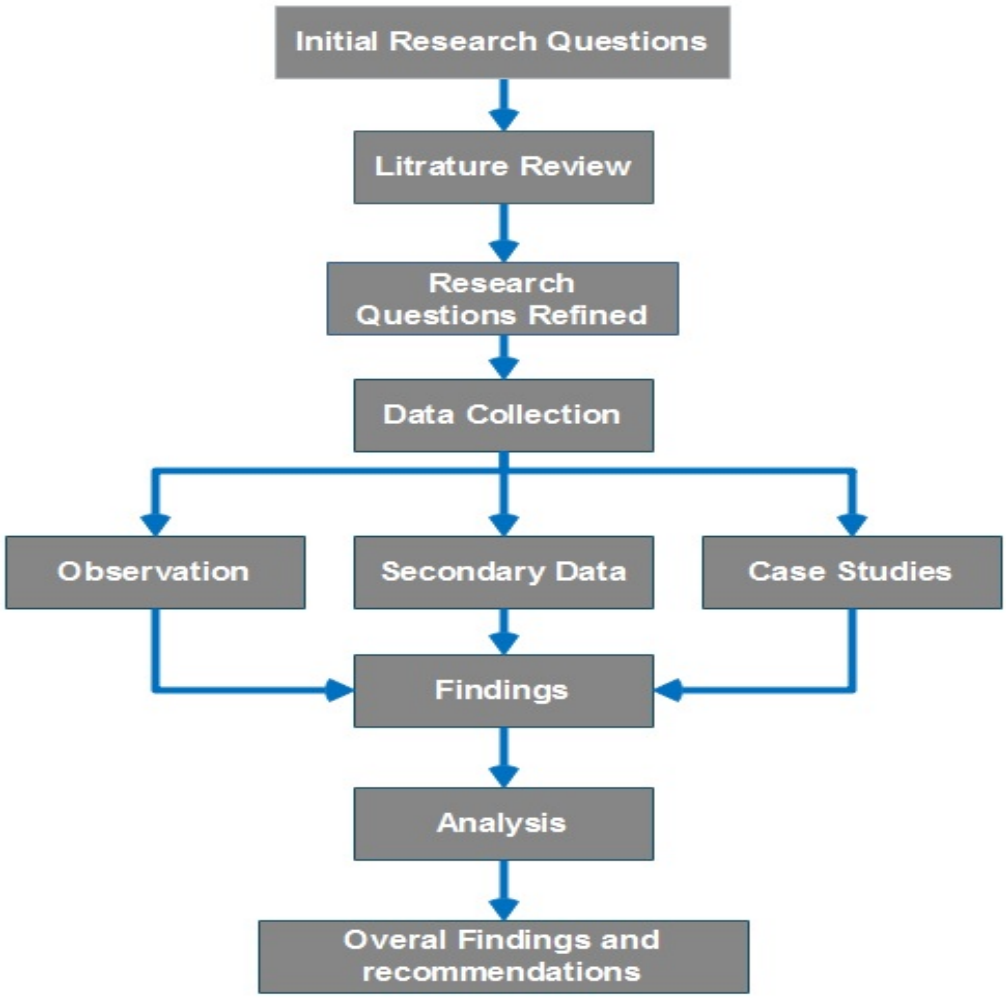


Figure 11 Research Conceptual Framework

5 Case Studies and Data Analysis

5.1 Introduction

Different case studies are included in this section were many of these case studies were included in books or extracted from researches done previously while the case studies about certification were conducted by the author of this research, below is list of the case studies and their referenced sources

Table 6 List of Case Studies and Their Reference

Section No		Name / Research or Book Title (Citation)
5.2		Ireland Consultancy Firms Case Study / An Opportunity for Consulting Engineers to Redefine Their Role **(O'Farrell, 2010)**
5.3	5.3.1	VM: Private Sector's Perception / Value Management: Private Sector's Perception **(Maznan, Jaapar, Bari, & Zawawi, 2012)**
	5.3.2	Addressing a Theory and Practice Gap/Value Management in the Malaysian Construction Industry: Addressing a Theory and Practice Gap
5.4		International Case Studies / Value Analysis Handbook **(National Economic and Development Authority, 2009)**
5.5		International Certification Case Study / based on data obtained by author from different VE societies including SAVEI, IVM, VDI-GSP and SJVE.
5.6.1		Vietnamese Case Study / Barriers to Applying Value Management in the Vietnamese Construction Industry **(Soo-Yong Kim, Yeon-San Lee, Viet Thanh Nguyen2 , & Van Truong Luu3, 2016)**

5.2 Ireland Consultancy Firms Case Study

This case study is part of an academic research with the aim to explore the perception of consulting firms to value engineering and the potential and attitude of providing VE as an additional service in their consultancy firms, the sample of the study included thirty-three

valid respondents 32 of them held director position in their firms. The sample represent nearly 32% of the entire population (104 firms) registered as members in the Association of Consulting Engineers of Ireland (ACEI) in 2010. The of two stages where the first stage included a loosely structured interview followed by the distribution of questionnaire and semi structured interviews in additional to a questionnaire that involved the firms.

While examples of the interviewee responses to the question “what is value engineering?” is listed in a tabulated form **Table 7** for analysis, **Figure 12** shows one of the questions that was included within the questionnaire with the weighted number of responses to this Likert-Scale question.

Table 7 Interviewee Responses to "What is Value Engineering?"

No	Interviewee response to the question “what is value Engineering”
1	*"I don't think they really knew what they were asking for, the first time it* [value engineering] *came up nobody really knew what it was, but because of the word engineering everyone looked at the engineering consultant.* "
2	*"Value engineering as I understand it has not got to do with engineering it's using the word engineering in a different context"*
3	*"in some ways you could say that the new forms of contract are value engineering because you 're getting a fixed price lump sum and to some extent that's value engineering"*
4	*"it's not necessarily cost cutting, but it could be cost cutting ... "*
5	*"At preliminary design stage we do budget casting's and ... look at options one, two, three - I consider that value engineering"*
6	*"No matter what part of a project you 're in, you should always be trying to develop the optimal design, and that's value engineering"*
7	*"It's a new term but I would have said that it is something that we always did"*
8	*"The important distinction* [in the term] *is the engineering of value .. . but when you talk to people, and I would count myself amongst them, is that they use it in the context of alternative construction approaches"*

Q 06. **What level of knowledge has your firm with each of the following ?**

		Expert	Very Good	Good	Fair	Little	None	
(31) ☐	The principles of functional analysis	2	5	6	6	7	7	33
(32) ☐	The application/methods of functional analysis	2	4	7	6	7	7	33
(33) ☐	The principles of value engineering	4	15	9	2	2	1	33
(34) ☐	The application/methods of value engineering	4	13	10	3	1	2	33

QUESTION 6

Variable	Scale (Expert 1 2 3 4 5 6 None) — Question 06 / Statement	Expert	None
31	What level of knowledge has your firm with each of the following ? *The principles of functional analysis*	39%	61%
32	What level of knowledge has your firm with each of the following ? *The application/methods of functional analysis*	39%	61%
33	What level of knowledge has your firm with each of the following ? *The principles of value engineering*	85%	15%
34	What level of knowledge has your firm with each of the following ? *The application/methods of value engineering*	82%	18%

Figure 12 Answers on question 6 in the questionnaire

5.3 VM Practice in Malaysian Construction

The two case studies within the following subsections are focused on the behavioral aspects in relation to VM workshops as detailed below, it is also to be noted that in both researches it was stated that Malaysian law mandate application of VM on projects with estimated construction cost of RM 50 million and above

5.3.1 VM: Private Sector's Perception

The aim of the research is to explore the perception towards implementation of VM among the private consultants of the construction industry in Malaysia. It included five different observed projects owned by one of the Malaysian Government Link Companies (GLC), where each one of these projects was considered as an embedded case study. observation throughout the VM workshops and semi-structured interviews among the consultants who were involved in these workshops. The interviews toke place twice once prior to the

workshop and then after the completion of the workshop activities. The main findings related to cost saving was summarized in **Table 8**, while **Table 9** include summary for behavioral observation of team participants, additionally, **Table 10** include summary of consultants' perception .

Table 8 Savings Achieved from VM Workshops

	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5	Total
Participants	25	23	23	10	7	88
Before VM (USD)	106,909,441.50	89,730,050.63	19,990,322.04	157,660.67	346,885.67	216,849,247.00
After VM (USD)	80,667,582.90	54,855,049.52	17,452,107.48	104,056.04	291,257.82	153,064,085.26
Saving (%)	24.55	38.87	12.65	34.00	16.03	29.41%

Table 9 Summary of behavioral observation of Team Participants

No.	Reasons
1	Many consultants do not understand the philosophy of VM and misunderstood VM study as a cost cutting tool
2	Involve a long time for the fully participate
3	VM workshop does not give immediate benefits to the consultants
4	The VM exercise eventually will reduce their fees
5	The consultants usually busy and do not have time to attend the VM workshop

Table 10 Summary of Consultants' Perception

No.	Perceptions
1	Before attend any VM workshop, the consultants' perceptions are negative; they thought that VM workshop is only in cutting their project budget. Towards the end, they understand that VM has optimized their project cost.
2	Initially, the consultants are sceptical, and some did show their negative feedbacks. They turned around after the study completed.
3	Various perceptions accept from the consultants, but they will change their perception after the VM process completed.

5.3.2 Addressing a Theory and Practice Gap

Another case study in which the researchers used qualitative analysis for data collected using both observation and semi-structured interviews including three different projects where the workshops' data is summarized in **Table 12** . Meanwhile, the behavioral

observation of the VM workshops' participants in accordance with the criteria listed by Leung & Wong (2000) is summarized in **Table 11**.

Table 11 Behavioral Observation of The VM Workshops' Participants

	Workshop 1	Workshop 2	Event 3
The Participation	Not all the decision makers participated in the VM workshop at the beginning of the workshop. However, due to unsolved issues, then only they attended the workshop.	The decision maker participated throughout the VM workshop. Unfortunately, the VMTF and External Participants are being shared by other groups. Hence, the discussion was inconsistent.	The decision maker was available throughout the process. Unfortunately, the VMTF and External Participants are being shared by other groups. Hence, the discussion was inconsistent.
The commitment	VMTF: Participated in the discussion along the process. VM Participants: Fully committed towards the VM exercise. External Participants: Participate whenever needed, whenever being asked by the VM participants & VMTF.	All the External Participants attended. The VMTF diverted his attention towards other VM workshops which had more critical issues after guiding the VM team and justifying their project scope.	All the related consultants participated as VM participants throughout the VM process. VMTF: guides the group on project justification. VMTF needs to divert his attention towards other critical VM workshops which were running concurrently.
Interaction	The VM participants interacted accordingly among each other in order to resolve the related issues.	The group itself is not the main focus of VMTF due to the uncritical conditions of the project. VM participants and External Participants interacted with each other but they were not fully utilised by the VM workshop due to their lack of "know what to do" and "know how to do" along the	Lack of interaction between VM participants with the VMTF due to uncritical conditions of the project.
Conflict & Resolution	The participants faced difficulties in distinguishing the NEEDs and WANTs functions of the projects components. It was only resolved after the main decision maker attended the session.	The group does not have critical issues due to the nature of the project. However, VM workshops contribute in that, the participants gain clearer understanding on project justification from the very early stage of the project cycle. .	The group does not have critical issues due to the nature of the project, but they were concerned about the limited budget for the project. Hence, the VM workshop is beneficial to the project in that, the project was organised and divided into several phases depending on the importance of each project component. The uncritical project component will be executed next time.
Feedback	Positive. All the participants declared that they learnt new knowledge and processes through this workshop.	VM participants' perceptions towards the VM workshop leaned towards cost cutting processes. However, it is interesting to note that the Client gained clearer project justifications through the VM workshop.	Negative. VM participants have negative perceptions towards the VM process despite their success in organising the project into several phases to comply with the limited budget.

Table 12 Summary of Workshop Details

DETAILS	WORKSHOP 1	WORKSHOP 2	WORKSHOP 3
Type of Project	Infrastructure	Apartment	Flood Irrigation
No of VM Workshops at the Venue	4	3	8
Type of Client	Public	Public	Public
Impact of VM Workshop on cost	Reduce	Reduce	Increase
Type of VMF Involved	External & Internal	Internal	Internal
Implementation Stage	Conceptual Design	Conceptual Design	Conceptual Design
Type of Participation	VM Participants, External Participants & VMTF	VM Participants, External Participants & VMTF	VM Participants, External Participants & VMTF
Duration of Workshop	7 days	4 days	4 days
Venue of VM Workshop	Neutral Venue	Neutral Venue	Client Venue
Number of Participants	18	10	7

5.4 Different VE Policies, Programs

These international case studies were included as an appendix within "Value Analysis Handbook" aiming to explore the practice of VE within different countries, including USA, UK, four Asian countries (Japan, S. Korea, Malaysia and Hong Kong) and four Latin American countries (Argentina, Chile, Costa Rica and Nicaragua) as will be detailed in the following subsections which all are summarized from the previously mentioned book **(National Economic and Development Authority, 2009)**.

5.4.1 USA Case Study

Legalizations, policies and programs would be considered as a measure of governmental efforts, a list of the laws, policies, regulation and programs related to the application of VE in USA are summarized in **Table 13** including those who were stated in the case study in additional to the ones previously included in **Table 1** in the literature review section. Additionally, the case study also focus on governmental programs which was initiated in different governmental departments including Department of Energy(DOE), DOD and FHWA with listing some examples of savings achieved through the application of VE in these departments as summarized in **Table 14**, and **Table 15** respectively.

Table 13 VE Related Laws, Policies and Programs.

Year	VE related laws, Policies and Programs
1962	D.O.D. announced that it was making VE a prerequisite for all its contracts over $100,000.
1967	Institution of a formal VE program in the US Post Office Department Program
1970	**The Federal-Aid Highway Act:** Which stated that "in such cases that the Secretary determines advisable, plans, specifications, and estimates for proposed projects on any Federal-Aid system shall be accompanied by a value engineering or other cost reduction analysis"
1971	U.S. Department of Health, Education, and Welfare (HEW) adopted the use of VE on its construction project.
1972	The Veterans Administration joined the VE group.
1993	**Office of Management and Budget (OMB) Circular A-131**: which required the use of VE as a management tool in all federal departments as well as reporting the results of using VE annually for these departments with total budget exceeding US$10 million annually
1995	**1995: The National Highway Designation Act (NHDA)** which instruct all State Transportation Authorities (STAs) to conduct value analysis on all projects costing US$25 million or more.
1996	Public law 104-106 requires each government executive agency to establish and maintain cost-effective VE procedures and processes.
1997	**FHWA issued Regulation 23 CFR part 627**: influenced by (NHDA) the State Transportation Authority (STA) required VE on any National Highway project that cost US$25 million or more.
1998	**The Federal-Aid Policy Guide:** Was revised to include chapter about application of VE in Federal Highway Aid Projects (FHWA)
2002	**FHWA regulations required value analysis on qualifying design- build projects**: This was an amendment to FHWA regulations
2005	Under Public Law 109-59, Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy of Safety for Users (SAFETEA- LU): Require VE studies for all bridges costing US$20 million or more

Table 14 Summary of Value Engineering Practice and Savings—DOE and DOD

Federal Agency	Motivation for value engineering	Year value analysis Studies Conducted & No. of value analysis studies implemented	Cost of value analysis Studies	Net Gov't Savings = Cost Savings + Cost Avoidance	ROI of value analysis Efforts
DOE	Value engineering efforts are primarily focused on improving existing concepts, designs, present practices, processes, safety, and risk management. Cost savings was a supplemental goal.	2005-06 totaled 35	Less than US$60,000 per study	US$277 million	Not available
DOD	Value engineering is used on any contractually specified item, function, process, or deliverable in order to reduce cost while retaining required performance capability. VECPs are used to produce savings in complex acquisition of defense systems for the country in light of curtailment of new acquisitions and heightened importance of maintaining the older existing defense systems	2000 1,696 value analysis projects implemented 61 VECPs awarded and implemented	US$188.5 million	US$1.12 billion	6%

Sources:

1. DOE, 2005-2006 Value Management/Value Engineering Report.
2. DOD, Annual Value Engineering Report, Fiscal Year 2000, USD/AT&L.

Table 15 Summary of Past Value Analysis Savings from FHWA Program

Financial Year	2003	2004	2005	2006	2007	Total/Avrg
Number of value analysis studies	309	324	300	251	316	1,500
Administrative Costs (In millions of US$)	8	8	10	8	13	47
Average Cost per study (thousands of US$)	27	24	33	33	40	31
Estimated Cost of Studied Projects (In millions of US$)	20,480	18,700	31,580	21,530	24,810	117,100
Total number of recommendations	1,909	1,794	2,427	1,924	2,861	10,915
Total value of recommendations (In millions of US$)	1,970	3,040	6,760	3,060	4,600	19,430
No. of approved recommendations	794	793	1,077	996	1,233	4,893
% of approved/ total recommendations	42%	44%	44%	52%	43%	45%
Value of approved recommendations (In millions of US$)	1,110	1,115	3,187	1,785	1,970	9,167
Cost savings	5.4 %	6.0 %	10.1 %	8.3 %	7.9 %	7.8 %
Return on investment	132:1	145:1	325 :1	219:1	157 :1	179:1

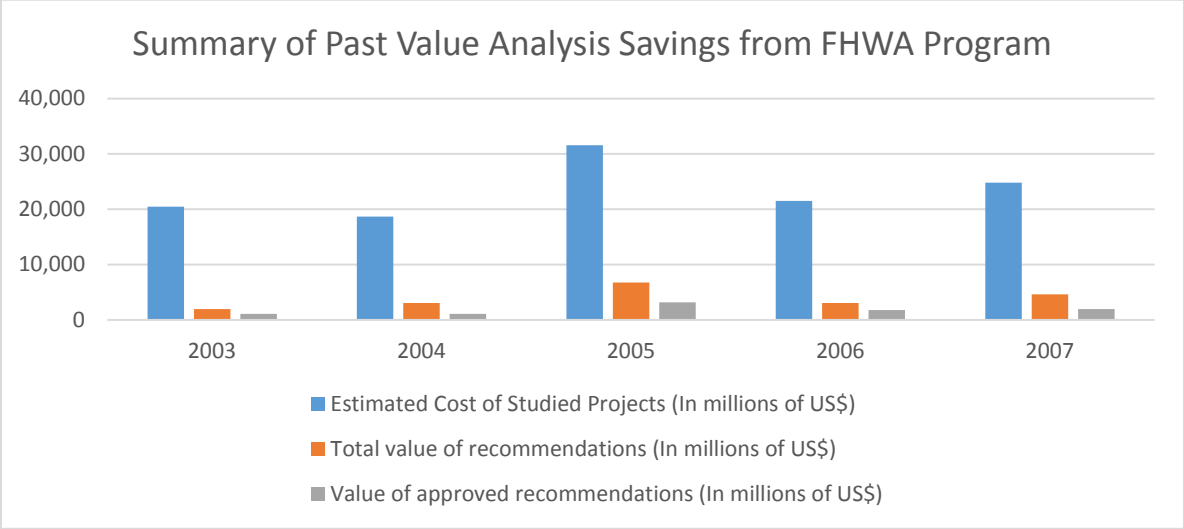


Figure 13 Past Savings from FHWA VE Program

5.4.1.1 Main Findings

From the data presented earlier in addition to the data previously summarized in the literature the following can be concluded: -

1. Although VE practice started in private sector, however different governmental departments followed private sector in its application, including DOD, DOE and FHWA.
2. USA has A bundle of legalizations and policies that mandate the application of VE for projects with estimated construction cost exceeding a certain value.
3. The DOD was the first among the governmental departments to practice VE and initiate VE programs, and it was responsible for the appearance of term VE instead of VA which became more commonly used since then.
4. ROI for DOD projects were 6:1 in 2006 with a net total savings 1.12 billion dollars, while ROI for DOE projects exceeded 130:1 in 20060 with a net total savings 277 million.
5. In the years from 2003 to 2007, the ROI for FHWA projects varied significantly from one year to another and ranged between (132:1) to (325:1), while the savings varied from 5.4% to 10.1% of the total estimated construction cost with an average of 7.8%. The average cost of the VE study within the 5 years is 31,000 US$ with trends of increase, probably due to wages increasement.
6. From points 4 and 5 above and in comparison, to the expected VE ROI which is 10:1, it is obvious that ROI in the case of highway projects is significantly high, and this can be regarded due to the relative simplicity of these projects and also because the impact of applying one recommendation would have high return when applied over long distances. Such finding in particular shall encourage different governments to start a VE program not only to highway projects but also to all infrastructure projects that share the same distance characteristics with highway projects.

5.4.2 UK Case Study

While the terms VE is the most commonly used in USA, the term VM is most commonly used in UK. Unlike the situation in USA were the application of VE in governmental departments were mandated for projects exceeding certain values, the policies in UK is

target oriented. The framework which were set by Her Majesty's Treasury (HM Treasury) sets policies and initiate programs through documents called "guidance". These policies act as governing framework for all Public Service Agreements (PSA) and Privately Financed Investments (PFI). These PSAs are underpinned by single Delivery Agreement that is used in different governmental departments. There are number of VfM programs being managed by HM Treasury, where **Table 16** shows a list of the most important guidance documents, PSAs and VfM programs within UK.

Table 16 List of VM "Guidance" Documents, PSAs and Programs in UK

Type	Name (Year issued)	Description
Guidance	U.K. Green Book — Appraisal and Evaluation in Central Government (2003)	Sets the techniques and issues that should be considered when carrying out assessments of all new policies, programs and projects, whether revenue, capital or regulatory.
	Value for Money (VfM) Assessment Guidance (2006)	Outlines a process for ensuring that Privately Financed Investments (PFI) in public services is likely to be a suitable procurement route for securing VfM for government and the public
	U.K. Orange Book — Management of Risk, Principles and Concepts' (2004)	Supplements the Green Book and provides guidance for developing and accessing proposals that affect the risk of fatalities, injury and other harms to the public.
PSAs (2008-2011)	(PSAs 1-7)	Sustainable growth and prosperity
	(PSAs 8-17)	Fairness and opportunity for all
	(PSAs 18-26)	Stronger communities and a better quality of life
	(PSAs 27-30).	A more secure, fair and environmentally sustainable world
VfM Programs	Efficiency Programme (SR04) —	This is Government's approach to improving spending efficiency between 2004-2008 spending period. While targeting a total of £20 billion savings within that period it achieved a total of £23 billion savings until 2009.
	VFM Programme (CSR07)	Builds on the success of the SR04 Efficiency Programme, targeting an additional £30 billion of sustained, cash-releasing, net VfM savings by 2011.
	Public Value Programme	Launched at Budget 2008, looks at all major areas of public spending to identify where there is scope to improve VfM and VfM incentives.

	Operational Efficiency Programme	draws on private sector expertise to examine cross-cutting areas of government spending. Initial scope of work covers back office and IT; collaborative procurement; asset management and sales; property; and local incentives and empowerment.

5.4.2.1 Main Findings

From the data presented earlier in addition to the data previously summarized in the literature the following can be concluded: -

1. The frame work of VM in UK is implemented indirectly under the VfM program, which has a focus on value as culture to more reflect the philosophy adopted in the **EN 12973** Standard. However, it still has a lot in common with the in USA, as both have general governing frame work that shall be considered in different departments.

2. The VM in UK is showing success which reflected on the savings highlighted in **Table 16**.

3. Both VE programs in USA, and VM programs in UK report regularly to an authority that monitor and analyze the implementation of these programs. Where these reports are used for auditing and improving these programs.

4. UK's VfM programs is not triggered by project estimated cost like in the case of USA, but rather set general policy and target a certain cost savings, which probably gives more flexibility to the different departments to select projects regardless their estimated cost.

5. The integration of VM and risk management is becoming more interconnected while VM deals with the opportunities and risk management deals with the threats.

5.4.3 Asian Countries Case Study

The data included in the case study are related to the practice of VE in four different Asian countries, namely; Japan, South Korea, Malaysia and Hong Kong. These data are summarized and compared in **Table 17.** The main findings from this case study are as follow: -

1. Different objectives and goals for VE practice are listed including higher competitiveness and quality of services and /or products. However, Cost reduction remains the main motivation of VE practice in Asian countries.

2. VE were introduced by Governmental Sector for some countries or Private Sector for other countries.

3. The institutionalization of VE practice is fundamental for its development and growth, whether it is a governmental (by initiating VE programs or policies), an academic center or a community of practice (VE Society).

4. VE practice always start in manufacturing then followed by construction, other forms of application of VE comes in later.

Table 17 Comparison of VE Practice in Asian Countries

Item	Country	Description
Year Introduced	Japan	1957
	S. Korea	2003
	Malaysia	1986
	H. Kong	1990
Motivation for Introducing Value Analysis	Japan	To improve industry Competitiveness by managing costs
	S. Korea	To reduce public Construction costs
	Malaysia	To introduce cost reduction/cost control in automotive parts manufacturing and value for money
	H. Kong	To create awareness on the benefits of value analysis with end-view of encouraging its use in industries
Mode of Institutionaliza-tion	Japan	Private industry driven, complemented by government mandate — "Action Guidelines for Public Works Cost Reduction" and academic knowledge build-up
	S. Korea	Government mandated via federal statute — "Management of Construction Technology"; complemented by private practice and academic research
	Malaysia	Government, but indirect and not mandated, the issuance of the country's National Automotive Policy in early 2000 prompted the industry to adopt cost control methods.
	H. Kong	Private sector driven and supported by academe and two HKSAR government issuances that strongly recommend a wider adoption of value analysis techniques in order to achieve an excellence in the quality of construction products.

		• WTBC16/ 1998 (1998) Technical Circular (works) no. 16/1998 – Implementation of Value Management in Public Works Projects, Environment, Transport and Works Bureau, Government Secretariat, The Government of HKSAR. • WTBC35/ 2002 (2002) Technical Circular (works) No. 35/2002 – Implementation of Value Management in Public Works Projects, Environment, Transport and Works Bureau, Government Secretariat, The Government of HKSAR, dated 13 August 2002.
Organizational Base or Institutional Home of value analysis	Japan	Ministry of Land, Infrastructure and Transport
	S. Korea	Ministry of Construction and Technology
	Malaysia	Institute of Value Management Malaysia (IVMM) (1995)
	H. Kong	Hong Kong Institute of Value Management (1995) (HKIVM)
Key VA Publications and Knowledge management Tools	Japan	• Guidebook for VA Activities (1971 and 1981) • SJVE's website
	S. Korea	• Manual and Guideline for VA of Constructed Facilities. • Publicly accessible database for VA suggestions.
	Malaysia	• VE manual produced by IVMM
	H. Kong	• The Value Manager, HKIVM's regular newsletter. • HKIVM's website. • A web-based Value Management Technique Centre for Construction Undergraduate students (www.bcm.cityu. edu.hk)
Quantified VA Benefits (In % cost reduction vis-a-vis original cost)	Japan	Up to 34% (In private sector) 10 — 20% (In public sector)
	S. Korea	Up to 50% (Based on Seoul Toll Project value analysis studies)
	Malaysia	No data available
	H. Kong	No data available
Current Level of institutionalize-tion — High or Low?	Japan	High- Government is catching up. Local regulation like the one established in the Oita Prefecture indicates future place of value analysis policy, at least among local governments.
	S. Korea	High- Government mandate assures permanence of policy in place
	Malaysia	Low- Practice is limited to specific industries. Efforts are fragmented due to lack of government imperative especially in

		construction sector, where value analysis is perceived to be most needed.
	H. Kong	Low- Practice is limited to specific industry and has no government imperative yet 95
Prospects for Future Growth of value analysis Usage	Japan	High Industries' incentive to conduct value analysis is linked with their survival in globally competitive markets for products.
	S. Korea	High Government mandate will ensure long-term application
	Malaysia	High VE may be made mandatory by government for all capital projects. With increased pressure of global competition, there is motivation for Malaysian industries like the automotive sector, to maximize their products' values, processes, projects or services. There is also a strong advocacy from academic sector.
	H. Kong	Uncertain Depends on how current efforts by academe and HKIVM will move. According to surveys done before 2002, with construction professionals, perspectives on VM were polarized: • "Value management is one of the most useful decision tools for the industry" • "Most of the practitioners in the HK construction industry misunderstood and had false perceptions of value management
Reference Document	Japan	Society of Japanese Value Engineering Guidebook For VE Activities - A Basic Value Analysis Manual, English translation of "VE KATSUDO-NO -TEBIKI", Originally published in August 1971 (Japanese Version), Translated in 1981 (English Version).
	S. Korea	"Seoul Toll Plaza Value Analysis Study Considering Performance Measurement and Life-Cycle Costs", J. Lim, M. Lee, G. Hunter, S. Kim
	Malaysia	“A Case Study of Value Analysis as an Innovative Tool in Malaysian Automotive Component Manufacturing Company", A. Ramli, S. Sulaiman, F. Mitchell
	H. Kong	• HKIVM Website • Mei-Yung Leung, Why Offer VM at Universities? : The Hong Kong Experience, 20 Volume 29, Number 1, Summer 2006 Value World

5.4.4 Latin American Countries Case Study

This Case study include date about number of VE workshops and studies, training and training institutions for four Latin American countries (Argentina, Chile, Costa Rica and Nicaragua). These data are summarized in **Table 18**. The main findings are as follow: -

1. The practice of VE in these countries started late in the 1990s or later and remains very limited.

2. The practice of VE in these countries is highly dependent on institutionalized efforts, mainly in governmental sector, with a limited academic support in case of Chile.

Table 18 VE Workshops and Training Data in Latin American Countries

Elements	Argentina	Chile	Costa Rica	Nicaragua
Year value analysis was introduced	1993	1995	1992	2006
Institutions trained/ capacitated	National Highway Administration Ministry of Interior	Ministry of Public Works, Transporta-tion and Telecoms HabitaCoop (Country's Largest Housing Coop) Ministry of Interior	n.a.	Ministry of Public Works
No. of value analysis trainings and workshops	4, all for public officials (1993 and 1995-96)	7, for public and private organizations (1995-96 and 2000	n.a.	2, for public officials (1993;95-96)
No. of value analysis studies conducted	5; national road and school construction projects (1994-1997)	3; pedestrian way, postal, and housing projects (1995)	1; hospital project (1992)	n.a
Estimated potential value analysis savings over initial project cost	18.4%	13% -22%	23.7%	n.a
Funding source(s) for value analysis studies/ Trainings	Inter-American Dev't Bank (1998/95) The World Bank (1995-1998)	Chamber of Construction Industry; Habitacoop; Government	Inter-American Development Bank	n.a
Value analysis programs in academe	n.a	Graduate Course in value analysis at Universidad Mayor de Santiago (2004) – SAVE Certified	n.a	n.a

Source: Report prepared by J. Devincenti for Castalia, 2008

5.5 International Certification Case Study

This case study focusses on the number of VA/VE/VM certified professionals in different countries that initiated VA/VE/VM certification program. The importance of this case study that it can be used not only as a measure for the status of VE practice now in different countries, but also an indication that can help to forecast the future of VE application in different countries and different sectors. The data was obtained by contacting different VE/VM societies including SAVEI, SJVE, Value for Europe (V4U), IVMM and IVMA. The data inquiry directed to these societies aimed to get historical record for the number of certified professionals year by year since the foundation of the certification program, and also their field of work (industry, construction, services…etc.). However, some societies did not respond while others could not provide a complete record of data either for privacy reasons or for the lack of record.

5.5.1 SJVE Certified Professionals (Japan)

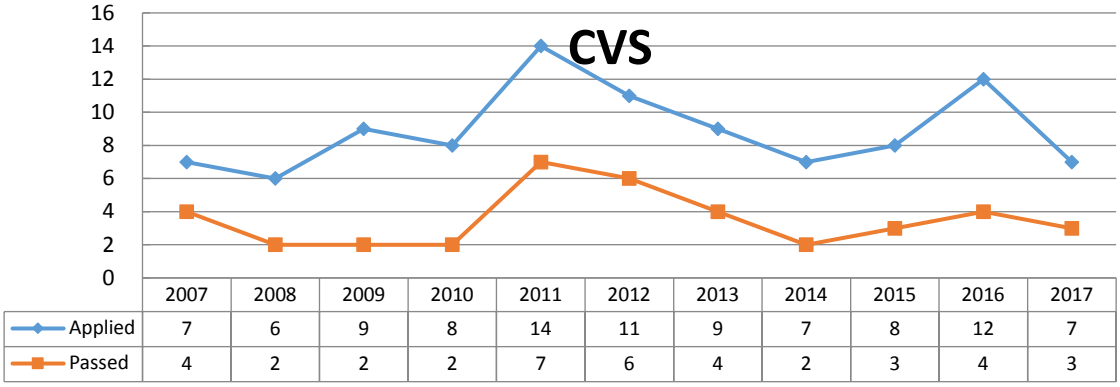
The Society of Japanese Value engineers while partnering with SAVEI in awarding CVS certificate, it also started a domestic certification program which has two levels of certificates namely VEL and VES. The data obtained from SJVE are summarized in **Table 20** which show total number of certified professionals(passed) and percentage of passing the exam. While **Table 19** shows the percentage of distribution of the actively certified professionals on different work fields.

Table 19 Distribution of Actively Certified Professional on Different Work Fields as of May 2017

Active CVS		Active VEL		Active VES	
Work Field	**%**	**Work Field**	**%**	**Work Field**	**%**
Manufacturing	28%	Manufacturing	73%	Manufacturing	86%
Independent consultant	26%	Construction	15%	Service	9%
Unemployed	19%	Service	7%	Public	5%
Consulting	12%	Government	1%	Total	100%
Service	7%	Student	1%		
Academic	4%	Other	2%		
Construction	3%	Total	100%		
Other	1%				
Total	100%				

Table 20 Annual number of Certified Professionals

Certificate		CVS		VEL		VES	
#	Year	Passed	Pass Rate (%)	Passed	Pass Rate (%)	Passed	Pass Rate (%)
1	1981	11	68.8%				
2	1981	7	53.8%				
3	1982	11	78.6%				
4	1983	6	23.1%				
5	1984	8	28.6%				
6	1985	9	42.9%				
7	1986	4	21.1%				
8	1987	11	52.4%				
9	1988	6	50.0%				
1	1989	7	53.8%				
1	1990	10	37.0%	82	70.1%		
1	1991	6	23.1%	112	73.7%		
1	1992	14	51.9%	181	66.3%		
1	1993	11	52.4%	424	65.9%		
1	1994	3	21.4%	814	66.3%		
1	1995	2	14.3%	1,009	51.8%		
1	1996	4	25.0%	1,154	40.6%		
1	1997	0	0.0%	2,062	50.6%		
1	1998	2	14.3%	4,379	53.1%	13	52.0%
2	1999	4	26.7%	6,549	65.0%	15	27.8%
2	2000	2	22.2%	5,595	61.4%	14	27.5%
2	2001	5	55.6%	4,557	52.4%	10	32.3%
2	2002	1	20.0%	4,588	54.9%	16	59.3%
2	2003	1	14.3%	3,947	48.7%	11	44.0%
2	2004	2	22.2%	3,549	55.9%	7	43.8%
2	2005	2	33.3%	3,663	60.7%	5	33.3%
2	2006	2	33.3%	4,147	67.3%	20	41.7%
2	2007	4	57.1%	5,962	79.2%	29	42.0%
2	2008	2	33.3%	8,517	75.2%	43	42.6%
3	2009	2	22.2%	4,359	75.7%	34	40.0%
3	2010	2	25.0%	2,935	76.1%	31	43.7%
3	2011	7	50.0%	3,066	79.0%	37	50.7%
3	2012	6	54.5%	2,625	80.7%	18	20.5%
3	2013	4	44.4%	2,414	76.3%	28	32.6%
3	2014	2	28.6%	2,250	78.8%	31	37.3%
3	2015	3	37.5%	2,422	76.6%	45	55.6%
3	2016	4	33.3%	2,319	76.4%	21	33.3%
3	2017	3	42.9%	2,024	78.6%	37	45.7%
Total/Ave		190	36.7%	85,7	64.5%	465	39.6%



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Applied	7	6	9	8	14	11	9	7	8	12	7
Passed	4	2	2	2	7	6	4	2	3	4	3

Figure 14 Numbers of Annual Applied to Numbers of Certified CVS Professionals

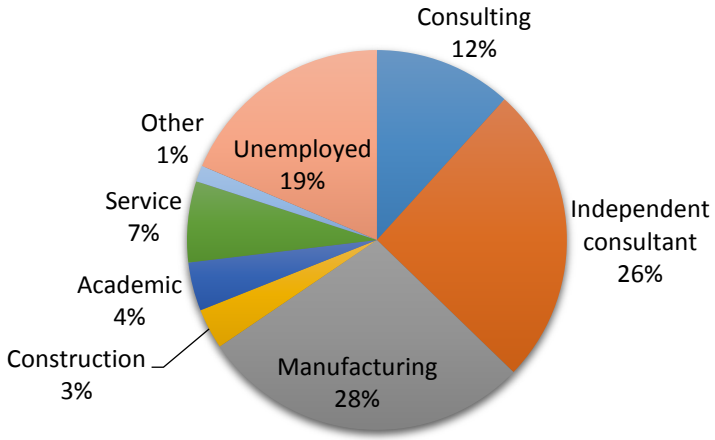
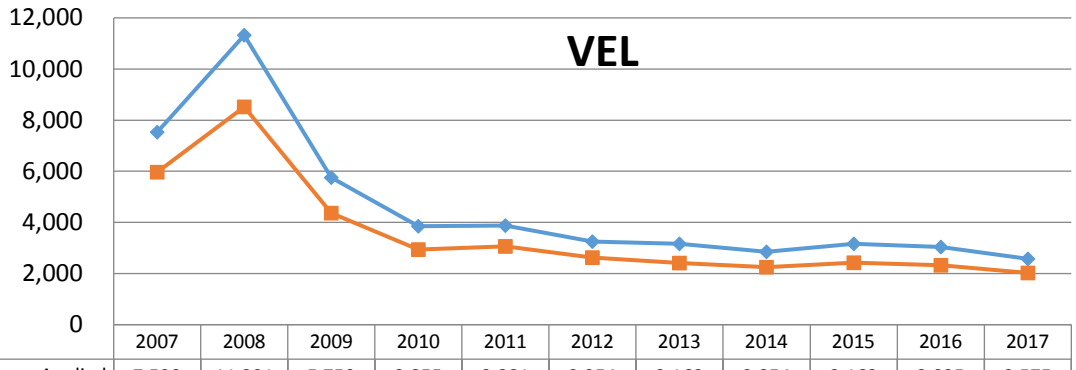


Figure 15 Distribution of CVS Certified Professionals in Different Work Areas



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Applied	7,529	11,321	5,759	3,855	3,881	3,254	3,162	2,854	3,163	3,035	2,575
Passed	5,962	8,517	4,359	2,935	3,066	2,625	2,414	2,250	2,422	2,319	2,024

Figure 16 Numbers of Annual Applied to Numbers of Certified VEL Professionals

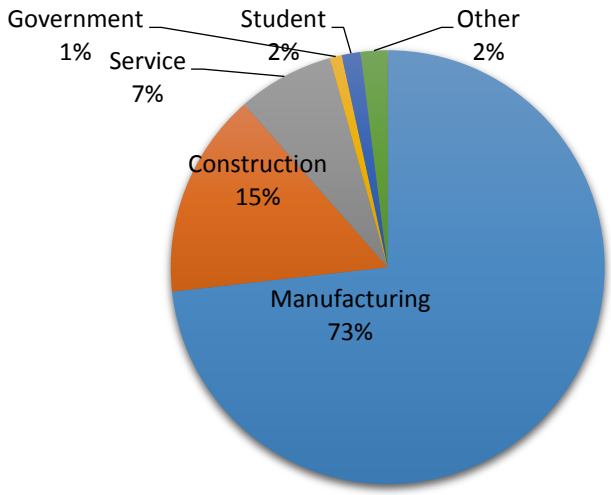
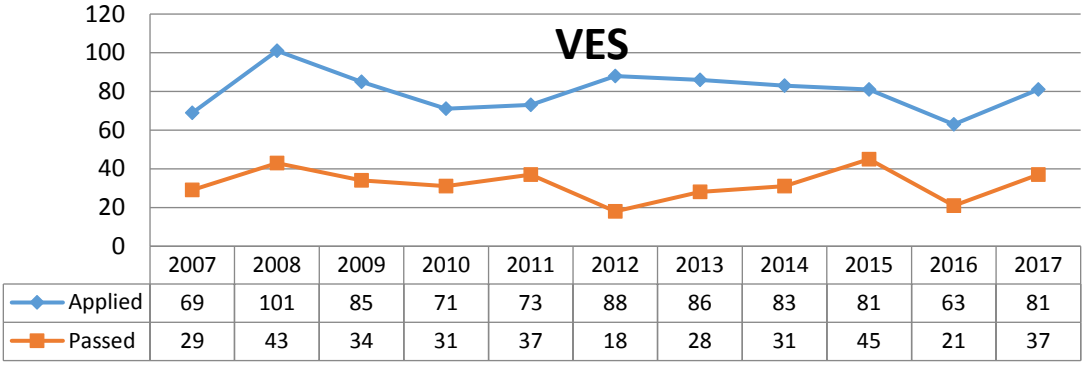


Figure 17 Distribution of VEL Certified Professionals in Different Work Areas



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Applied	69	101	85	71	73	88	86	83	81	63	81
Passed	29	43	34	31	37	18	28	31	45	21	37

Figure 18 Numbers of Annual Applied to Numbers of Certified VES Professionals

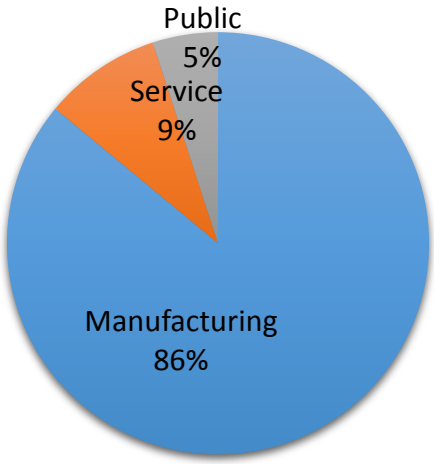


Figure 19 Distribution of VES Certified Professionals in Different Work Areas

5.5.1.1 Data Analysis

The data is analyzed quantitively and graphically represented based on the numbers provided by SJVE as in below: -

1. The total number of Japanese professionals who were examined for CVS certification between 1981 and 2017 is 518 professionals, with an average passing rate of 36.6%, with the passing rate ranging between lowest of 22.2% and highest of 57.1% in the period between 2007 and 2017.

2. The total number CVS certified Japanese professionals since 1981 till 2017 is 190 among which 145 is still active. The annual average of CVS certified professionals dropped from 7.55 during the period from 1985 to 1995 to 2.27 during the period from 1996 to 2006. Then rose to 3.55 during the period between 2007 to 2017 with a total average of 5 persons per year.

3. The highest percentage of CVS certified professionals (28%) work in manufacturing, while 12% work in consulting firms and 26% work as independent consultants, and 3% work in construction.

4. The total number of Japanese professionals who were examined for VEL certification between 1990 and 2017 is 132,801 professionals, with an average passing rate of 64.5%, with the passing rate ranging between lowest of 75.2% and highest of 80.7% in the period between 2007 and 2017.

5. The total number VEL certified Japanese professionals since 1981 till 2017 is 85,705, 45.4% of them were certified in period between 2007 to 2017, with an annual average of 3536 certified professional/year within that period.

6. The highest percentage of VEL certified professionals (73%) work in manufacturing, while 15% work in construction, and 1% work in the government.

7. The total number of Japanese professionals who were examined for VES certification between 1990 and 2017 is 1,173 professionals, with an average passing rate of 39.6%, with the passing rate ranging between lowest of 20.5% and highest of 55.6% in the period between 2007 and 2017.

8. The total number VES certified Japanese professionals since 1981 till 2017 is 465, 76.1% of them were certified in period between 2007 to 2017, with an annual

average of 32.2 certified professional/year within that period which is relatively high compared to 12.3 which is the average between 1998 to 2006.

9. The highest percentage of VES certified professionals (86%) work in manufacturing, while 5% work in the government and the remaining 9% work in services.

5.5.1.2 Main Findings

The main findings from this case study is as follow: -

1. The number of VEL certified professionals is significantly high but less than 2% of VEL certified professionals undertake the examination for VES or CVS and less than 0.8% get certified.

2. The number of VEL certified professionals is significantly high which reveal high interest and awareness of VE in Japan, especially considering that even students seek to be VEL certified (certification fee is nearly 180 US$ + training fees +tax). Which confirm both with the data in **Table 17** and with the findings reported by Kelly and Male when they stated that "the practice of VE in Japan value engineering is not an event (like in USA,UK and Australia) but rather a continuous process carried out within a philosophy of continuous improvement across all phases of the construction process" **(Kelly, Male, & Graham, 2004)**.

3. The number of the VES certified professionals is nearly two and half times the numbers of CVS certified professionals, with that all VES certified professionals are employed while 19% of CVS certified professionals are unemployed as reported by SJVE. Knowing that in addition to points 1&2 above suggests that VES is favored over CVS by employers in Japan. Also, suggests that the number of VE experts in exceed job market demand which is also supported by points 2& 5 in the data analysis **subsection 5.5.1.1**.

4. VE is applied in different aspects of business as suggested by the distribution of percentages indicated in **Table 19** with manufacturing ranked number one

revealing high level of application of VE in industry. while Percentage of certified professionals who work in public and governmental sector is low which suggests that the application of VE in public sector is far less than in private sector which again confirm with the data in **Table 17**.

5.5.2 IVMM Certified Professionals (Malaysia)

No response was received from IVMM, however data about the number of registered professionals with Fellow designation (FIVMM) according to their website is nine professionals **(IVMM, 2018)** and a total number of 193 with Member designation and 129 with Associate Member designation. However, both Member & Associate Member designations require no VM experience. While Fellow designation is given to Malaysian members who has more than five years of VM experience. Accordingly, the only conclusion we have is that there are only nine professionals registered with IVMM with experience of 5 years or more and total number of members of nearly 331. While No data available about the number of Certified Value Mangers. The conclusion that the practice of VM in Malaysia is relatively new with few experienced professionals which is evident in **Table 12,** as it indicates that the VMTF was leading more than one workshop at the same time. However, the number of members also indicate a growing interest in VM within Malaysia which is supported by the findings in **Table 17.** Also, the laws that mandate application of VM for projects with estimated construction value of RM 50 million and above as stated in **section 5.3**.

5.5.3 Value for Europe

Value for Europe is the organization responsible for VM certification in Europe, it has three levels of VM certification, namely: Qualified Value Associate (QVA), Professional in Value Management (PVM) and Trainer in Value Management (TVM). The organization was contacted repeatedly but no response was received. Accordingly, three national VM societies who are members of Value for Europe were contacted including IVM(UK), VDI-GSP (Germany) and AFAV(France). Only VDI-GSP and IVM responded. The response of each of those VM societies will be detailed in the following subsections.

5.5.3.1 VDI-GSP(Germany)

According to the response received from VDI-GSP, there are domestic certification based on the VDI 2801 standard, and the designation of this certification is “Wertanalytiker VDI". On the European level of Certificate an annual rate one thousand professionals who participate in the training for VM1, which is a three-days course required to qualify for the QVA certificate. However, as QVA is relatively new there are no significant number of certified professionals who hold this designation. Moreover, there are a total of sixty-five certified professionals (mainly working in manufacturing or as consultants), forty-one of them are certified with TVM designation and twenty-four are certified as PVM. Although, there are always three to eight new PVMs every year, but there are also experts retiring or changing their jobs so that their certificates are not renewed every 4 years (which is necessary).

5.5.3.2 IVM(UK)

According to the response received from IVM there is a total of nineteen certified VM professionals, ten of them hold the PVM designation and the remaining nine hold the TVM designation. While the numbers might have been higher previously. No additional data were provided about the training courses, as the society does not provide training directly, but rather it is being provided by independent, accredited training organizations.

5.5.4 SAVEI Certified Professionals(worldwide)

As stated in **section 2.4** SAVEI has two levels of certificates as follow: -

1. First level is Value Methodology Associate (VMA) which is the entry level this designation used to be called (AVS) before July,2016.
2. Second Level is Certified Value Specialist® (CVS®) which is the designation for expert level experience, while the CVS-Life is a designation granted upon request prior to June 30, 2015 when a CVS had been recertified three times. While renewal take place every 4 years.

The Data which were provided by SAVEI about the number of certified VE professionals with different designation from each country are listed in **Table 21**. As shown the data

doesn't have any annual rate, accordingly, the certificate designation itself will be used as indication for raising or decreasing trends as will be explained in the Analysis subsection.

Table 21 Number of Certified Professionals from SAVEI In Different Certificate Designation

No	Country	AVS	CVS	CVS-Life	VMA	No	Country	AVS	CVS	CVS-Life	VMA
1	Australia	2		1	1	26	Kuwait	45			7
2	Austria	4				27	Lebanon	6			31
3	Bahrain	48			3	28	Malaysia	2			20
4	Belgium	1				29	Mexico	40			4
5	Brazil	3				30	Netherlands	20	2		2
6	Canada	75	7	10	32	31	Nigeria	1			
7	China	63	7		9	32	Norway	3			
8	Colombia				2	33	Oman	71			7
9	Denmark				3	34	Palestine	6			
10	Egypt	94	1		37	35	Philippines	3			2
11	Estonia				1	36	Poland				2
12	Finland	1				37	Qatar	100	1		46
13	France	15			19	38	Romania	1			
14	Germany	5	1	1	1	39	Saudi Arabia	551	11	8	175
15	Greece				2	40	Singapore				1
16	Hong Kong	19	1		8	41	South Africa	2		3	
17	Hungary	46	4	10	1	42	South Korea	1	418	31	1
18	Iceland	1				43	Spain	14		1	2
19	India	372	6	13	27	44	Sweden	1			
20	Indonesia	31		1		45	Switzerland				9
21	Israel	5		1		46	Taiwan	11	1	3	10
22	Italy	17			8	47	United Arab Emirates	72			10
23	Jamaica	3				48	United Kingdom	9	2	1	
24	Japan		42	107	10	49	United States	570	56	206	191
25	Jordan	52			6	50	Unknown	19	17	32	
Total								2333	577	429	671

The CVS-Life designation indicates being CVS certified for three consecutive times, accordingly it can be used as an indication for VE practice as VETC before 2003. While the CVS designation indicates current practice of VE as VETC. On the other side, the VMA designation has been used since 2016, hence it can indicate the recent trends of getting VE

training. While both VMA and AVS designation can be used as an indication for the future of the VE. Using this logic, the data will be sorted and analyzed according to each type of designation to conclude the training and certification trends in different countries after taking into consideration the data the was previously presented about other certification programs.

5.5.4.1 Data Analysis

1. As shown in **Table 22** and in **Figure 20**, only fifteen countries have professionals who are certified as CVS-Life, All these countries are industrial countries with exception to Saudi Arabia. Meanwhile, the number of certified professionals who work in construction industry were also referenced between parenthesis (investigated from members directory). USA ranks first with nearly 13% of the total certified CVS-life work in construction and construction related firms. While, Japan comes in the second rank (even when adding 79 VESs who were certified by that time). South Korea comes third rank respectively came second with no indication of any of those who are certified as CVS-Life being related to the construction industry. Canada and Hungary rank in the fifth place with nearly 10% of the CVS-Life related to the construction industry. Saudi Arabia ranks sixth with more than one third of the CVS-Life related to the construction industry which indicate a relatively matured practice of VE in construction more than a decade ago. These findings confirm with what Dell'Isola stated in his book as shown in **Figure 21 (Dell'Isola, 1997)**.

Table 22 Ranking Countries Based on CVS-Life Designation

NO	Country	CVS-Life (construction)	CVS	AVS	VMA	%
1	United States	206 (27)	56(50)	570(34)	191(58)	48%
2	Japan	107	42	0	10	24.9%
3	South Korea	31(0)	418(20)	1(1)	1(1)	7.2%
4	India	13(0)	6	372	27	3.0%
5	Canada	10(1)	7	75	32	2.3%
6	Hungary	10(1)	4	46	1	2.3%
7	Saudi Arabia	8 (3)	11(6)	551(100)	175 (25)	1.9%

8	South Africa	3(0)	0	2	0	0.7%
9	Taiwan	3(0)	4(4)	11	10	0.7%
10	Australia	1(0)	0	2	1	0.2%
11	Germany	1(0)	1	5	1	0.2%
12	Indonesia	1(NA)	0	31	0	0.2%
13	Israel	1(NA)	0	5	0	0.2%
14	Spain	1	0	14	2	0.2%
15	United Kingdom	1(1)	4(3)	9(1)	1	0.2%
16	Unknown	32	17	19	0	7.5%

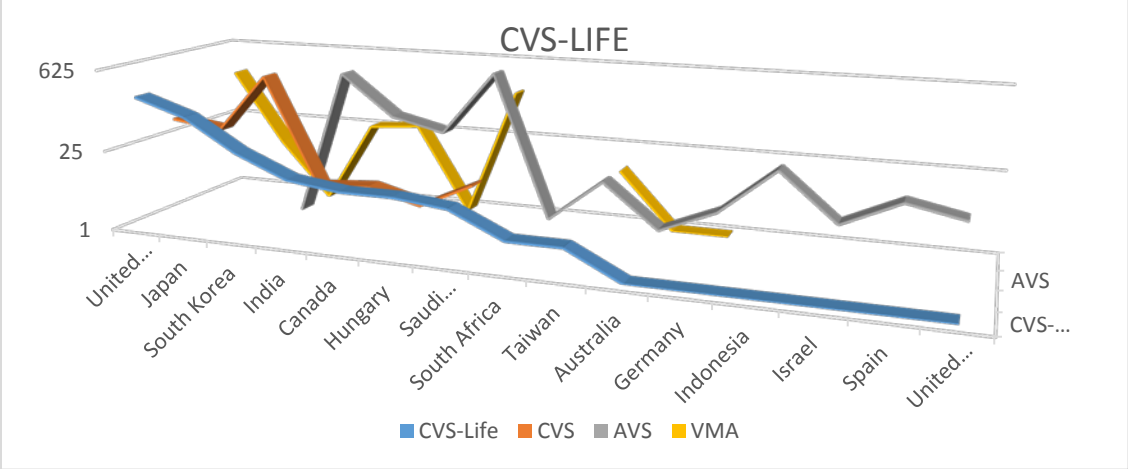


Figure 20 Comparing Certification Trends Based on CVS-Life Ranking

Outside of the United States, approximately twenty countries have active VE practitioners. One of the leaders is Japan. There are more members in the Society of Japanese Value Engineers (SJVE) than SAVE International members in the United States. SAVE International chapters are located in Korea, India, France, Germany, Hungary, Saudi Arabia, and Australia. In addition, there are currently programs throughout Europe, Canada, South America, Taiwan, and South Africa. In Saudi Arabia, the General Directorate of Military Works (GDMW), under General Otaishan, retired, of the Saudi Arabian Ministry of Defense and Aviation (MODA), has had a fulltime program for more than eight years. The GDMW has saved from $30 million to $75 million per year. Through the efforts of the GDMW, the VE concept has spread in Saudi Arabia. Recently, a Saudi chapter of SAVE International was established which includes three Saudi professionals who are Certified Value Specialists (CVS), and eight Saudi Associated Value Specialists (AVS). In the government sector, the Ministry of Municipalities,

Figure 21 Text Highlighted from Dell'Isola Book

2. As shown in **Table 23** and in **Figure 22**, the top three ranks remains occupied by South Korea, USA and Japan, noting that if the number of Japanese professionals who are

domestically VES certified are being considered then Japan will be ranked first. Also, the numbers of certified professionals from European countries do not represent the total number of certified professionals as many are having the European VM certificate as shown in section 5.5.3. It is also noted that countries like Canada, Saudi Arabia, India, Taiwan, Hungary, Germany and UK still appear among the ranked countries which reveals continuous interest of VE in these countries. Also, new countries including China, Netherlands, Qatar, Hong Kong and Egypt joins this table which indicate the spread of VE technique into these countries and a development compared to times before 2003, especially considering the number of AVS certified professionals in these countries which shows significant increasing trends in VE awareness.

Table 23 Ranking Countries Based on CVS Designation

No	Country	CVS	CVS-Life	AVS	VMA	%
1	South Korea	418	31	1	1	72.4%
2	United States	56	206	570	191	9.7%
3	Japan	42	107		10	7.3%
4	Unknown	17	32	19	0	2.9%
5	Saudi Arabia	11	8	551	175	1.9%
6	China	7	0	63	9	1.2%
7	Canada	7	10	75	32	1.2%
8	India	6	13	372	27	1.0%
9	Hungary	4	10	46	1	0.7%
10	United Kingdom	2	1	9	0	0.3%
11	Netherlands	2		20	2	0.3%
12	Taiwan	1	3	11	10	0.2%
13	Qatar	1	0	100	46	0.2%
14	Hong Kong	1		19	8	0.2%
15	Germany	1	1	5	1	0.2%
16	Egypt	1		94	37	0.2%

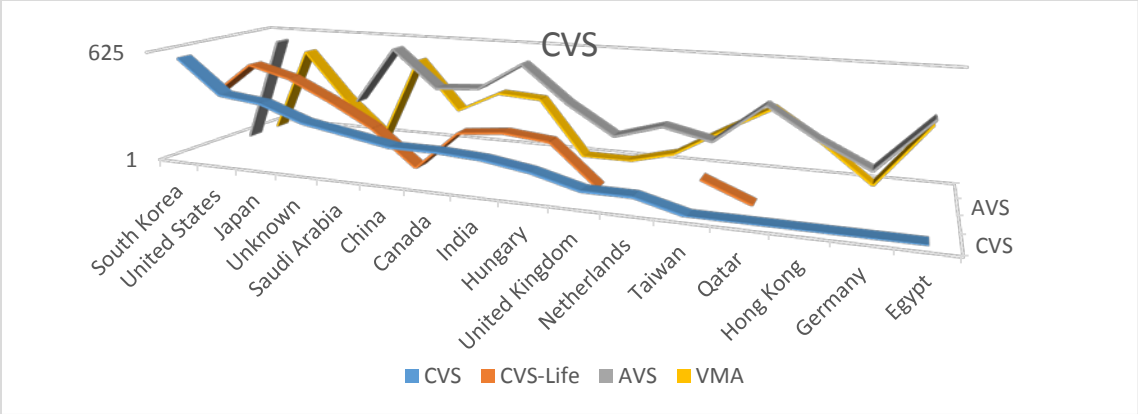


Figure 22 Comparing Certification Trends Based on CVS Ranking

3. A total of 2405 AVS certified professionals distributed between forty-two countries. While as shown in **Table 24** and in **Figure 23** Saudi Arabia ranks second after USA, while other Arabic countries including Qatar, Egypt, UAE, Oman, Jordan, Kuwait coming in ranks that varied between 4th to 13th. This indicate the spread of VE into new countries including non-industrial countries, especially gulf countries with strong economy and relatively booming construction industry. Also, the consistent appearance of Japan, and European countries reveal continuous interest in SAVEI VE certificate even in countries were other VE/VM certificates are available. However, in general the interest in the domestic certificates are relatively higher

Table 24 Ranking Countries Based on AVS Designation

No	Country	AVS	VMA	CVS	CVS-Life
1	United States	570	191	56	206
2	Saudi Arabia	551	175	11	8
3	India	372	27	6	13
4	Qatar	100	46	1	
5	Egypt	94	37	1	
6	Canada	75	32	7	10
7	United Arab Emirates	72	10		
8	Oman	71	7		
9	China	63	9	7	
10	Jordan	52	6		
11	Bahrain	48	3		
12	Hungary	46	1	4	10
13	Kuwait	45	7		

14	Mexico	40	4		
15	Indonesia	31			1
16	Netherlands	20	2	2	
17	Hong Kong	19	8	1	
18	Unknown	19		17	32
19	Italy	17	8		
20	France	15	19		
21	Spain	14	2		1
22	Taiwan	11	10	1	3
23	United Kingdom	9		2	1
24	Lebanon	6	31		
25	Palestine	6			
26	Germany	5	1	1	1

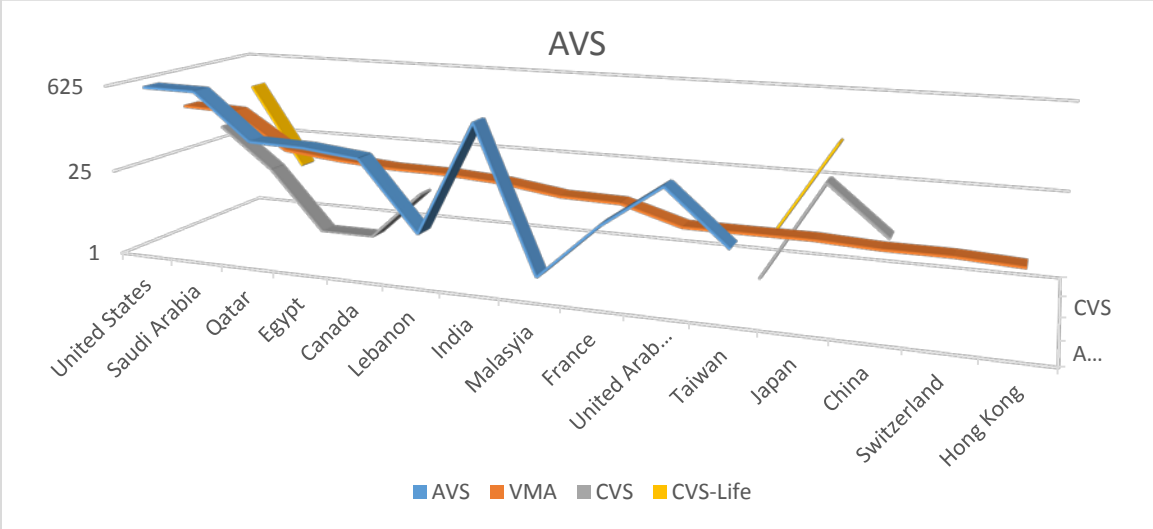


Figure 23 Comparing Certification Trends Based on AVS Ranking

4. A total of 690 certified VMA distributed in 34 countries, with 27.7% of them based in USA, 25.3 % in Saudi Arabia and 35% distributed between countries ranked from 3rd to 12th.

Table 25 Ranking Countries Based on VMA Designation

No	Country	VMA	AVS	CVS	CVS-Life
1	United States	191	570	56	206
2	Saudi Arabia	175	551	11	8

3	Qatar	46	100	1	
4	Egypt	37	94	1	
5	Canada	32	75	7	10
6	Lebanon	31	6		
7	India	27	372	6	13
8	Malaysia	20	2		
9	France	19	15		
10	United Arab Emirates	10	72		
11	Taiwan	10	11	1	3
12	Japan	10		42	107
13	China	9	63	7	
14	Switzerland	9			
15	Hong Kong	8	19	1	
16	Italy	8	17		
17	Oman	7	71		
18	Kuwait	7	45		
19	Jordan	6	52		
20	Mexico	4	40		

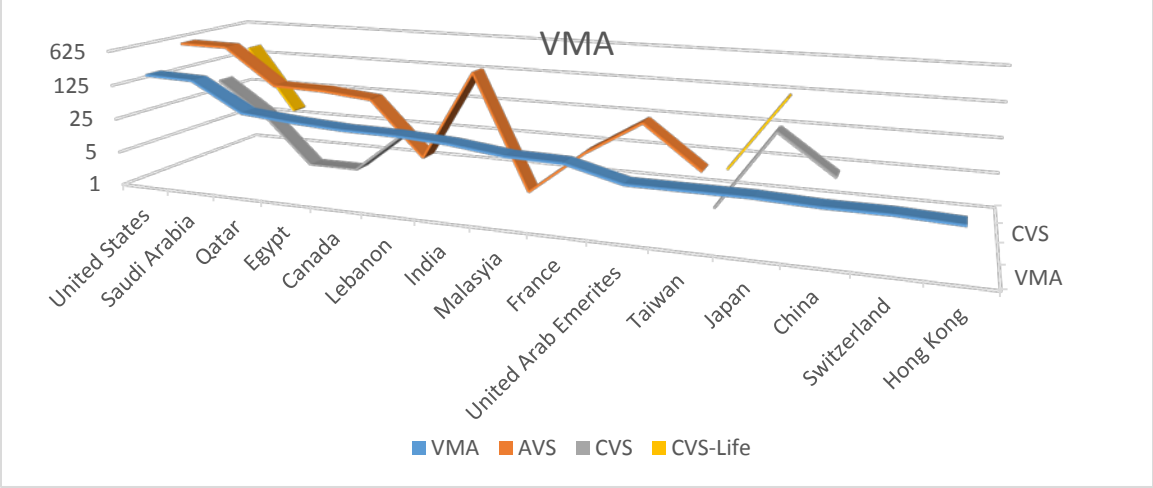


Figure 24 Comparing Certification Trends Based on VMA Ranking

5. Although the number of certified professionals is a strong indication for the practice of VE in different countries, however it is not the only indication. Also, it doesn't reflect the complete picture but when combined with other findings in the other case studies it can help to form general perspective, both about the current practice levels in different countries and the futuristic trends.

5.6 Challenges and Barriers to VE Implementation

Many researches were conducted to evaluate and rank the barriers, challenges or hindering factors facing the application of VE in different countries. However, only one of them were selected because it is believed to have a solid framework and results were validated using a second questionnaire were the sample consisted of professionals whom all participated in VM or who were implementing VM in their companies. Unlike other researches where there were no indication of respondent VE/VM knowledge.

5.6.1 Vietnamese Case Study[10]

In this research the conceptual framework is shown in **Figure 25,** where the challenges were identified based on literature review and experts opinion as shown in **Table 27**, this case study includes two questionnaires where the 1st questionnaire were validated using a pilot study with nine VM experts. All hindrance factors were rated on a five-point Likert scale (1= Not a hindrance to 5 = Extreme hindrance). The aim was to rank the hinderance factors listed in using the value of the mean for each one, and the resulting ranking was listed in **Table 28**. The profile of the 98 respondents which represent the sample for questionnaire 1 is shown in **Table 26**.

Table 26 Profiles of Respondents

Variable	Category	Frequency	Percentage
Field of work	Owner	23	23.5
	Contractor	34	34.7
	Designer	22	22.4
	Consultant	19	19.4
	Total	98	100.0
Designation of respondents	Directorate (Assistant director, general manager, engineering manager, project manager)	26	26.5
	Construction manager	11	11.2
	Specialist	17	17.3
	Civil engineer/Architect	28	28.6
	Quantity surveyor	2	2.0
	Site supervisor	14	14.3
	Total	98	
Years of experience	Less than five	15	15.3
	Between five and 10	45	45.9
	More than 10	38	38.8
	Total	98	100.0

[10] Soo-Yong Kim, Yeon-San Lee, Viet Thanh Nguyen and Van Truong Luu. (2016). Barriers to applying value management in the Vietnamese construction industry. Journal of Construction in Developing Countries

Table 27 The Hindrance Factors Impeding the Application of VM in the Construction Industry

Codes	The Hindrance Factors	References
HF1	Too few construction projects applying VM	Experts' opinion
HF2	Complexity of proposed projects to apply VM	Experts' opinion
HF3	Lack of knowledge about VM	Shen (1997); Cheah and Ting (2005); Lai (2006); Li and Ma (2012); AI-Yami (2008); Fard et al. (2013); Aduze (2014); Jaapar et al. (2009); Latief and Kurniawan (2009); Whyte and Cammarano (2012)
HF4	Lack of support and active participation from owners and stakeholders	Cheah and Ting (2005); Lai (2006); AI- Yami (2008); Aduze (2014); Malla (2013); Jaapar et al. (2009); Whyte and Cammarano (2012)
HF5	Lack of contract provisions for implementation VM between owners	Cheah and Ting (2005); Fard et al. (2013); Malla (2013); Latief and Kurniawan (2009)
HF6	Inexperienced and incompetent contractors	Experts' opinion
HF7	Defensive attitude of original design team	Lai (2006); Li and Ma (2012); Fard et al. (2013)
HF8	Lack of investments, support policies and human resources to conduct VM in construction companies	Experts' opinion
HF9	Lack of VM experts	Li and Ma (2012); Latief and Kurniawan (2009)
HF10	Lack of cooperation and interaction with internal VM team	Latief and Kurniawan (2009)
HF11	Lack of VM team competence to accurately estimate costs	Latief and Kurniawan (2009)
HF12	Inexperienced and incompetent VM team members	Malla (2013); Latief and Kurniawan (2009)
HF13	Unqualified VM facilitator	Jaapar et al. (2009)
HF14	Lack of gathered information in early stage causing difficulties in creating ideas and alternatives	AI-Yami (2008); Jaapar et al. (2009)
HF15	Difficulties conducting analysis and evaluating alternatives	Lai (2006)
HF16	Lack of time to conduct VM studies	Shen (1997); Cheah and Ting (2005); Lai (2006); Li and Ma (2012); AI-Yami (2008); Malla (2013); Whyte and Cammarano (2012)
HF17	Lack of local VM guidelines as well as technical norms and standards	Lai (2006); Li and Ma (2012); Perera and Karunasena (2004); Fard et al. (2013)
HF18	Lack of legislation providing for application of VM in the construction industry	Perera and Karunasena (2004); Aduze (2014); Latief and Kurniawan (2009)

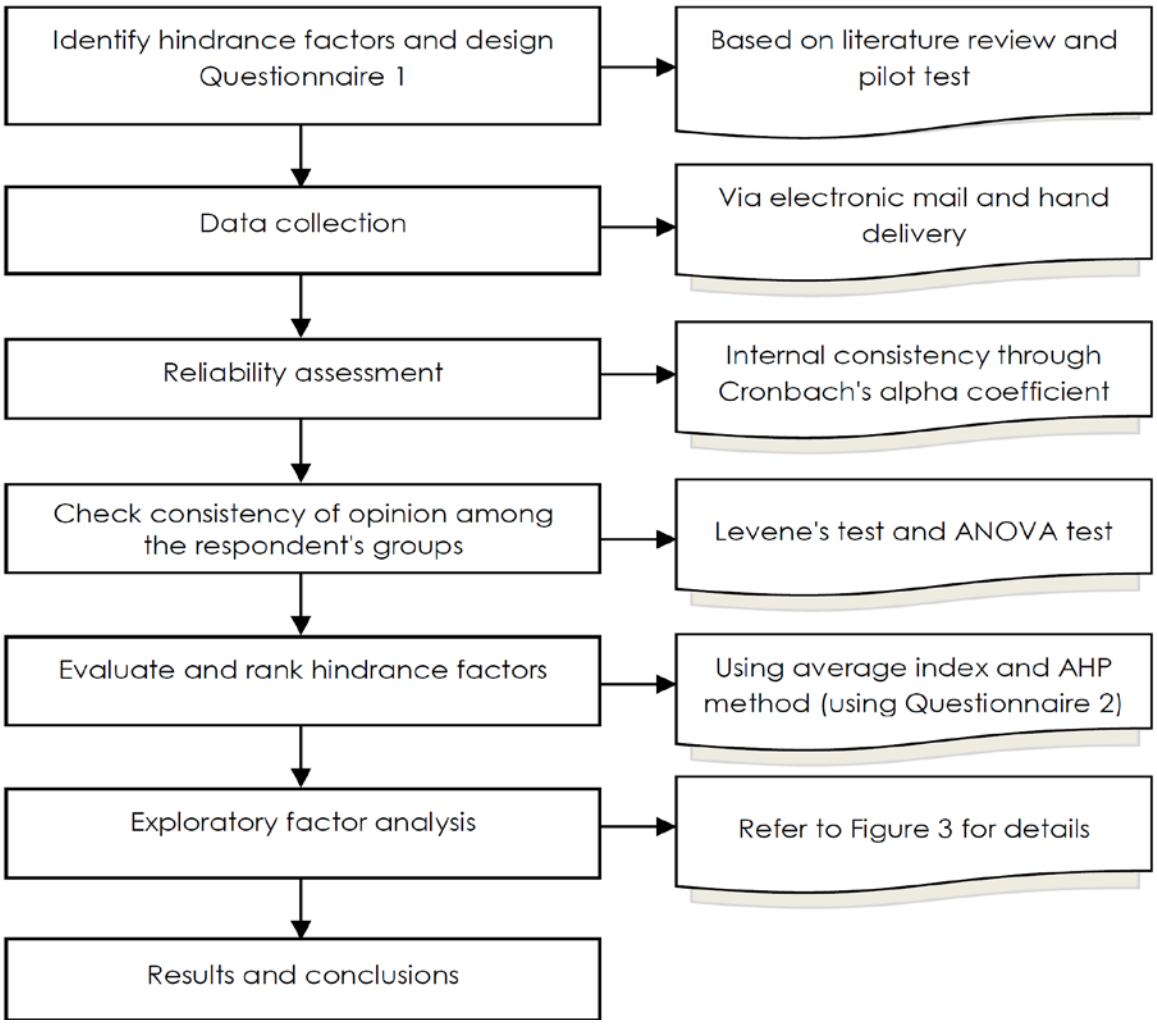


Figure 25 Conceptual Framework

Table 28 Ranking of Hindrance Factors for VM Application

Codes	Factors	Mean	Standard Deviation	Rank
HF9	Lack of VM experts	4.17	0.84	1
HF3	Lack of knowledge about VM	4.13	0.90	2
HF17	Lack of local VM guidelines as well as technical norms and standards	4.11	0.85	3
HF8	Lack of investments, support policies and human resources to implement VM in construction companies	4.01	0.90	4

HF18	Lack of legislation providing for application of VM in the construction industry	3.98	0.98	5
HF4	Lack of support and active participation from owners and stakeholders	3.97	0.92	6
HF14	Lack of gathered information in early stage causing difficulties in creating ideas and alternatives	3.85	0.91	7
HF6	Inexperienced and incompetent contractors	3.68	1.00	8
HF5	Lack of contract provisions for implementation of VM between owners and stakeholders	3.65	0.86	9
HF12	Inexperienced and incompetent VM team members	3.60	0.99	10
HF13	Unqualified VM facilitator	3.52	0.88	11
HF10	Lack of cooperation and interaction with internal VM team	3.43	0.96	12
HF1	Too few construction projects implementing VM	3.42	1.04	13
HF11	Lack of VM team competence to accurately estimate costs	3.40	1.09	14
HF7	Defensive attitude of original design team	3.35	1.15	15
HF2	Complexity of proposed projects to apply VM	3.24	0.95	16
HF15	Difficulties conducting analysis and evaluating alternatives	3.10	0.90	17
HF16	Lack of time to conduct VM studies	3.04	1.07	18

5.6.2 Main Findings

1. The ranking of the hindering factors which challenge the application of VE is not the same, but it is rather it is highly relative to the location (when comparing the ranking in the case study above to other case studies performed in Ghana, Iran and South Africa). Bon-Gang Hwang highlighted the same findings about critical success factors in his research on Value Management in Singaporean Building Projects (Hwang, Zhao, & Ong, 2015)
2. In many researches related to VE/VM, especially those done in countries where the technique is not widely practiced, the respondents don't have enough knowledge, experience nor practiced VE/VM. Hence, the author believe that this highly impact the findings.

3. Also, the author believes that a clear distinguish shall be made between Critical success factors of VM when being applied and practiced and the hindering factors that challenge its spread within a certain country. However, this distinguish is highly confused in different researches which probably impact the reliability of the findings as well.
4. In general, there are different critical success factors that impact the success of VE and mainly can be grouped into factors related to:
   a- Timing of the application of VE studies.
   b- The application of job plan stages and process.
   c- The VE team composition, experience, skills and dynamics.
   d- Senior management and stakeholder's commitment to the implementation of VE and their participation in the VE workshops.
   e- The experience, knowledge and personal skills of the VE team facilitator.

6 Research Questions and Related Findings

6.1 Introduction

This chapter focuses on the research questions and tries to use the data presented in the case studies and its relevant analysis to answer these questions using abductive approach.

Section	Research Question
6.2	what is value engineering?
6.3	What is the relation between value engineering and sustainability?
6.4	How far value engineering is currently involved in the construction industry?
6.5	What is the role of value engineering in different phases of construction?
6.6	what can be done to improve the role of value engineering in construction?
6.7	What are the new technologies, techniques and methodologies that are already used? and to what extent?
6.8	are there more that can be used to improve the value in construction?
6.9	What is the relation between organizational structure and value engineering?

6.2 1st Research Question "What is Value Engineering?"

In Answering this question within the context of this research, two major aspects shall be addressed. Those two aspects are Value Engineering in theory, and Value Engineering as perceived and/or understood by the professional in the construction industry as well be detailed in the following subsections

6.2.1 VE/VM in Theory

The following key findings could be found by analyzing the literature will be used to answer this question: -

1. The methodology has developed through years in which the name was changed from Value Analysis to Value Engineering then to Value Management, all these different names are used alternatively and interchangeably for the methodology.
2. The most commonly used name for the methodology within North American countries is Value Engineering which is the favored term by SAVE International, although it uses Value Methodology as the terminology used to describe the process.
3. While the names can be used to distinguish the phase of life cycle where the methodology is applied, however such distinguish is not significant nor in literature nor among the users of the methodology
4. Within the European literature the term Value Management which is the adopted terminology by the EN 12973 is more favored as it is being used as a management philosophy adopted on the strategic level and applied to all stages of the business rather than a technique applied on a single phase of the project.
5. Among the different definitions that describe the methodology the definition of value methodology adopted by SAVE International is the most comprehensive because: -
    A. Clarify the functional analysis as distinguish characteristic between VE and other management tools and techniques, which was stress by Miles the founder of the methodology and were confirmed later by SAVE International and different authors including Kelly and Male.
    B. Include value study with its stages including the job plan and its six phases.
    C. Include a multidisciplinary team with in the definition
    D. State value improvement as the main objective of using VE.

6.2.2 Perception of VE

There is a difference between VE as found in theory and the common perception of the term Value engineering within the construction industry. These differences can be seen from the following case studies where one case study: -

1. The perception of value engineering among designers is not the same and can be further divided as follow-
    A. Some who do not really have any knowledge of VE as reflected in responses 1&2 in Table 7.
    B. Some who consider it something that is focused on cost (either by fixing or cutting) as reflected in responses 3& 4.
    C. Those who consider VE same as a part of the design such as selecting between design alternatives based on budget or developing optimum design as in responses 5,6 and 7.
    D. Those who consider it is being used only in the context of alternative construction approaches. As in response number 8
2. The questionnaire in the survey done in the same research in point 1 and shown in **Figure 12** reveal contradiction between the answers related to understanding VE and functional analysis, while the response of 28 out of 33 respondent confirm a knowledge of VE principles varying between good to excellent only 13 respondent have a knowledge of functional analysis principles that varies between good to excellent. The same misunderstanding is also confirmed in the Case study two research where it was stated that "63 percent of the private sector's consultants did not fully understand the VM concept" (Maznan, Jaapar, Bari, & Zawawi, 2012).

3. In a questionnaire designed to investigate client perception of VE in Hong Kong that toke place in 1996 and involved 56 valid respondents. Most of the respondents (62.5 percent) never heard of the term VE. While only10.925 percent only heard of it but did not clearly understand the concept, and the remaining 26.625 percent of them believed that they have clear understanding of the VE concepts. Such percentage indicate that only one quarter of the clients have knowledge of VE.

6.3 Second Research Question

The Second research question is “What is the relation between value engineering and sustainability?”, in this regard the research did not handle this question in depth. However, the relationship between sustainability and VE is fundamental and conceptual, it is engraved within the definition of value. VE is a tool to achieve the required (functional) needs with minimum resources, and to avoid waste of resources, While Sustainability is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”. Also, VE take into consideration both initial and LCC as shown previously in the literature review.

Moreover, the rising interest and awareness of sustainability all over the world, places it as an essential requirement or basic function for different construction stakeholders. Accordingly, VE is a tool to achieve sustainability, and achieving sustainability improve the value by considering the resources. Also, VE is a technique that motivates and encourage innovation which highly required for the achievement of sustainable development. The application of VE in green buildings and renewable energy is evident in VE literature.

Also, VE can help to provide material alternatives that has less cost which indirectly helps to achieve sustainability, as usually materials with less cost would be more redundant than costly materials.

6.4 Third research Question

The third question is “How far value engineering is currently involved in the construction industry?”, this question aims to understand the magnitude of VE involvement within the construction industry. In this regard it is important to state that, while it was not possible to investigate the percentage of construction projects where VE were utilized neither in the public sector nor on the private sector. However, from VE literature in general, and specifically from international case studies in section there are certain criteria that can be considered as indication for the magnitude of involvement or use of VE within the

construction industry in different countries. The following summarize the main findings in this regard: -

1- Generally, the application of VE in construction is more practiced and established in industrial countries compared to non-industrial countries, especially in USA, Japan, South Korea, UK, Canada, Australia, Germany and the newly industrial Asian countries in General.
2- There are strong indicators that the American DOD played a significant rule in the spread of VE both within USA and outside USA, by noticing that most of the countries where VE spread to first either had American military bases on their soil (Germany, Japan, South Korea, Saudi…. etc.).
3- The development of the application of VE in the industrial countries usually followed the same sequential pattern that was followed in USA, which starts with the foundation of VE society, then drafting a national guide then initiating training and certification programs.
4- There are some countries where the practice of VE in construction projects where mandated and/or encouraged using group of governmental legalization and/or policies including USA, UK, Japan, South Korea, Malaysia and Saudi Arabia. Mostly, the application is related to the value of these projects or level of complexity. However, the number of countries that follow these policies are still relatively low.
5- The magnitude of application of VE in industrial countries is more significant in manufacturing when compared to construction.
6- For non-industrial countries indications strongly suggests the application of VE in these countries is highly focused on construction when compared to industrial countries.
7- The countries which developed VE standards were listed in **Table 3** as well as the countries that has national VE societies were listed in **Table 2**.
8- In general, there are progress towards more implementation of VE in construction, not only in industrial countries but also in non-industrial countries especially in Gulf Countries.

6.5 The Fourth Research Question

The Fourth Research question is “What is the role of value engineering in different phases of construction?” in this regard the findings are as follow: -

1. As seen in the literature review VE can be applied in different phases of construction from feasibility to disposal. This is applicability is reflected in different VE literature starting by Miles to Dell’Isola and confirmed by nearly all VE literature authors including guiding manuals like SAVI BOK and standards such as DIN EN 12973. Also, the findings of Kelly & Male in the international VE Benchmarking which indicated different VE study styles with different points of application or opportunities. Moreover, the varied VE terminology which include Value Planning, Value Engineering, Value Analysis, not only that but the development of the terminology from VE to VM reflects the maturity of the VE from a technique used for design to a strategic level which act as all governing framework applied to all stages of the process.

2. It is also noted that while the application of VE in construction in some countries, especially USA is highly focused on pre-construction phases (specifically during briefing, concept design and VECP before construction). Other countries, like Australia tend to adopt VM approach and apply it into the through the whole project life cycle including UK, Australia and European countries in general.

3. This can also be observed in the title of different VE/VM societies worldwide.

6.6 The Fifth Research Question

The fifth question is what can be done to improve the role of value engineering in construction? In this regard the findings are as follow: -

1. The establishment of domestic or national VE societies is a major step to popularize, increase awareness and activate the implementation of VE.
2. VE training and/or educational program is mandatory to develop VE knowledge and skills.
3. The institutional and governmental role in creating policies and programs to activate the implementation of VE in public sector is vital, especially in highways and infrastructure projects, where ROI is very high. This is evident in the case of FHWA program.
4. The academic role in providing educational programs which focus on the value and encourage value related research, and the role of both private and public sectors in funding and supporting these researches.
5. The cooperation between VE societies, government and academic organization to align all efforts to achieve maximum benefits of VE. This cooperation should be directed at the first towards developing a national and domestic VE guidelines and standards, that take into consideration the demographic and cultural dimensions of value within each country.

6.7 The Sixth Research Question

The sixth research question is "What are the new technologies, techniques and methodologies that are already used? and to what extent?" the answer to this question is as follow: -

1. VE employs different techniques and methodologies through the different phases of the job plan. This include the following (SAVE International, VALUE STANDARD and BODY OF KNOWLEDGE, 2007):
   a. During information Phase: Quality Function Deployment, SWOT, Benchmarking, Tear Down Analysis.
   b. During Function Analysis Phase: FAST, Function Tree, Function Matrix and Performance to Function Analysis.

c. During Creative Phase: Brainstorming, Gordon Technique, Nominal Group Technique, TRIZ and Synetics. However, it is noted that brainstorming is the most practiced technique, and although it is the simplest, but it doesn't hold the same potentials when compared to the more sophisticated techniques like TRIZ and Synetics.
d. During Evaluation Phase: Life Cycle Costing, Choosing by Advantages (CBA), Value Metrics. It is noted that LCC is the most utilized technique.
e. Other techniques stated in EN 12973 which include: functional performance specification for new products, (and) design to cost / design to objectives studies to establish the production system for the new products, etc.

2. One of the strongest features of VE/VM is its ability to adapt and/or integrate different methodologies and techniques. This was also apparent in the case of integrating VM with risk management in case of UK application. Moreover, the integration with different enterprise change models including: Lean thinking, Theory of Constraints, and Business Process Reengineering (Mandelbaum & Danny L. Reed, 2006).

3. VE relies heavily on finding alternative materials, which was the main motivation for the evolution of the VE on the hands of Miles. Also, achieving savings using material alternatives is one of the most commonly used methods to achieve savings, specifically in relation to VECP. Hence, VE team members, and facilitators shall keep up to date with newly developed construction materials.

4. VE/VM training centers are using online web conference software to conduct VE/VM training workshop, moreover the author of this research also used the same technology to conduct VE workshop in one of the mega projects where the design team, the construction team and the VE team members were based in different locations.

5. VE/VM also uses management software such as Primavera Contract Management (PCM) and other software to share project documents between different VE team member (Author Experience)

6. Also, departments that has established a VE program keep Data Base record for effective previous VE proposals that can be utilized in new projects which have similar features.

6.8 The Seventh Research Question

The seventh research question is “Are there more that can be used to improve the value in construction?”. There is no easy answer to this question, but generally the combination of all previously recommended steps shall be followed with a focus on building research and building materials and building technology, furthermore the following is essential to be considered:

1. Means and methods to reduce the complexity of construction projects.
2. Optimization of design is fundamental, poor procurement routes such as lowest bid shall be avoided at all costs as its implication both on building cost and performance is extreme.

6.9 The Eighth Research Question

The eighth research question is “What is the relation between organizational structure and value engineering?” the answer to this question was detailed in 3.8.1.1. but the summary is as follow: -

1. A balance between organization size and degree of representation of VE/VM professionals plays a vital role in the successful implementation of VE.
2. For small organizations, where dedicating an employee to VE/VM tasks is not possible, then training for key personals is important. Moreover, the use of external VE/VM consultant shall be considered.

7 Conclusion and Recommendations

7.1 Conclusion

VE is a process that aims to increase value through a group of techniques oriented about the use of functional analysis, the process structured into three stages: pre-workshop, workshop and post-workshop, while workshop stage has six sequential phases. The use of VE in construction generally is still limited, while it is being practiced more in some countries including Japan, USA, South Korea, UK, Australia and to lesser extent in India, Saudi Arabia and Eastern Asian countries (such as Singapore and Malaysia). There is a gap between VE in theory and in practice, this gap can lead to the failure of VE application and is generally related to the following: the use of functional analysis, the multidiscipline team and the implementation of all phases of job plan. Also, there are a number of critical success factors that play a vital rule in the success of the implementation of VE/VM.

VE proved successful in construction achieving cost savings that varies from 5% to 30%, with an average ROI of 10:1. While implementation to highway projects achieve ROI in excess of 100:1 in most cases. Surprisingly with such impressive outcomes its application is still limited especially in developing countries.

The earlier VE is applied the more successful its application especially during briefing and concept design, however VE can be applied in different phases during the project life cycle.

VE in practice can be applied in formal style where it keeps the sequential phases of job plan structure while in some other situation variation to the formal styles is adopted to respond to varying situations.

The limited application of VE can be best associated to many factors including the following:

1- Lack of awareness
2- The misconception among most clients that VE is automatically applied in design, such misconception is also apparent among consultants.

3- The confusion between VE and cost reduction.

7.2 Recommendations

The following is recommended: -

1. The establishment of domestic or national VE societies is a major step to popularize, increase awareness and activate the implementation of VE.
2. VE training and/or educational program is mandatory to develop VE knowledge and skills.
3. The institutional and governmental role in creating policies and programs to activate the implementation of VE in public sector is vital, especially in highways and infrastructure projects, where ROI is very high. This is evident in the case of FHWA program.
4. The academic role in providing educational programs which focus on the value and encourage value related research, and the role of both private and public sectors in funding and supporting these researches.
5. The cooperation between VE societies, government and academic organization to align all efforts to achieve maximum benefits of VE. This cooperation should be directed at the first towards developing a national and domestic VE guidelines and standards, that take into consideration the demographic and cultural dimensions of value within each country.
6. Utilization of all job plan phases, unless situation mandates otherwise.
7. The selection of skilled and experienced VETC is vital to the success of VE.
8. The selection of VE team members is also important, members with moderate or good knowledge of VE techniques (especially FAST and LCC) is preferred and in all cases, members shall have strong technical knowledge in their fields.
9. VE professionals shall be represented in staffing and also reflected in the staffing.
10. Continuous training for VE staff and training for senior managers is critical to success of VE programs.
11. Commitment and participation of senior management is mandatory.

12. Utilization of software's such as BIM, data base and web-based internet conference software is advised.
13. Keeping up to date with technology advance in areas of building materials, building technologies and new techniques shall be a focus concern for VETC.
14. The alteration between different techniques (brainstorming, TRIZ…etc.) can help VETC to overcome difficulties related to creativity blocks.
15. VETC experience and personal skills plays a great role in overcoming communication problems, also team size shall be kept within limits, big teams shall be divided to groups with a smaller number of participants.

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