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Utilizing of Value Engineering in Highway Projects

[1]Hossam El-Din Helal, [2]Ibrahim Hassan Hashim, [2]Ahmed Ebrahim Abu El-Maaty
[1]Lecture Assistant, Construction Program, Faculty of Engineering, Egyptian Russian University
[2]Associate Professor, Civil Engineering Department, Faculty of Engineering, Menoufia University, Menoufia, Egypt

***Abstract*:** Value Engineering (VE) is the systematic review of a project, product, or process to improve performance, quality, and/or life-cycle cost by an independent multidisciplinary team of specialists. Its focusing on the functions that the project, product, or process must perform sets it apart from other quality improvement or cost-reduction approaches. This paper provides the background and history of VE, key terminology, definitions and approaches to VM in construction. It also demonstrates the accumulated experience of VE related to transportation field and how VE can be utilized in highway projects in both scientific research and construction fields.

Keywords: *Value Engineering; transportation feild; highway projects.*

I. INTRODUCTION

For many years in different countries in Europe and North America, VE has been used to improve highway projects. It was initially applied during construction, in the form of Value Engineering Change Proposals (VECP) to reduce overall construction costs. Many transportation agencies in these countries now recognize that greater benefits can be realized if VE is introduced earlier in the development of the project. VE can be used to establish project scope, support effective decision making, increase project performance and quality.

Many agencies in different countries recognized the need for the prudent use of diminishing resources and revenues while providing a quality transportation program.VE is a function oriented technique that has proven to be an effective management tool for achieving improved design, construction, and cost-effectiveness in transportation program elements. It is anticipated that the successful implementation of a VE program will result in additional benefits beyond design and cost savings; for example, constant updating of standards and policies, accelerated incorporation of new materials and construction techniques; employee enthusiasm from participation in agency decisions; increased skills obtained from team participation [1].

II. VALUE MANAGEMENT VERSUS COST MANAGEMENT

To distinguish between both value management and cost management, a brief comparison prepared to summarize the major differences between them according to the literature of this issue as shown in Table 1.

Table 1: Literature Comparison between Value anagement and Cost Management

Reference	Value Management	Cost Management
[2]	• A service which utilities structured functional analysis and other problem solving tools and techniques in order to determine explicitly a client's needs and wants related to both cost and worth	• A service that synthesis traditional quantity surveying skills with structured cost reduction or substitution techniques using a multidisciplinary team
[3]	• Looks holistically at the project as a whole. • Project scope changes are often considered. • Focuses on the value rather than the cost. • Seeks to achieve a balance between quality, life cycle costs and time. • Seeks to maximize the creative potential of all project participants.	• No major changes to the project scope and concept. • Focuses on the cost rather than the value.
[1]	• Doesn't nibble at costs to make the item "cheaper". • Sets a target cost, and finds the design alternative(s) meeting all needs at a lower overall cost • Yields more cost reduction without adversely affecting performance. • Improve design simplification, reliability, maintainability and quality.	• Nibbles at costs to make the item "cheaper". • Analyzes an item from the standpoint of how to reduce the cost of the elements that make up the item. • May scarify quality and performance to reduce cost.
[4]	• Incorporates the customer's perspective. • Establishes the value they place on each function to determine precisely where cost reduction can be achieved.	• Have an inward focus, concentrating on a firm's operations without a specific consideration of the owner needs.
[5]	• Focuses on function analysis which is regarded as the cornerstone of VM study and the key factor of VM.	• Concentrates on making the same item, only cheaper.

III. TERMINOLOGY AND MATHEMATICAL EXPRESSION OF VALUE

Definitely, value is one of the most fundamental concepts in value techniques. However, value is a term with different interpretations within different situations. In order to obtain a clear understanding of the term, the following paragraphs will examine what value is in the context of VM and explore its root in economics [6].

The constituents of economic values in today's economic environment are as following:

- Exchange value
- Esteem value
- Use value
- Cost value [7].

Value can be described as the relationship between function, quality and cost. It can also defined as the most cost-effective way to reliably accomplish a function that will meet the user's needs, desires, and expectation [5].

$$\text{Value} = (\text{Function}+\text{Quality})/\text{Cost} \quad (1)$$

Based on the above equation, value of a product or service could be theoretically increased either by:

- Increasing the function with the same cost;
- Decreasing the cost with the same function;
- Increasing the function with reduction of cost;
- Increasing the function significantly with slight addition of cost;

- Decreasing the cost significantly with slight reduction of function.

IV. VALUE METHODOLOGIES EVOLUTION

Although the difference between VM, VE and Value analysis (VA) are not very remarkable, even some professional schools believed they are just the same technique named differently, the clarification of them can provide a good understanding of the evolution of value techniques. This evolution can be traced from typical definitions of the three terms in literature [6].

A. Definitions of VM, VE and VA

1) Value management (VM): A proactive, creative, problem-solving or problem seeking service which maximizes the functional value of a project by managing its development from concept to use through structured, team-oriented exercises which make explicit, and appraise subsequent decisions, by reference to the value requirement of the client [2].

VM is concerned with defining what 'value' means to client within a particular context. This is achieved by bring the project stakeholders together and producing a clear statement of the project's objectives. Value for money can then be achieved by ensuring that design solutions in accordance with the agreed objectives. In essence, VM is concerned with the 'what', rather than 'how' [8].

2) Value engineering (VE): Value engineering is a proven management technique using a systematized approach to seek out the best functional balance between the cost, reliability, and performance of a product or project [9].

3) Value analysis (VA): Value analysis is a philosophy implemented by the use of a specific set of techniques, a body of knowledge, and a group of learned skills. It is an organized creative approach, which 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 [10].

B. The Evolution of VM

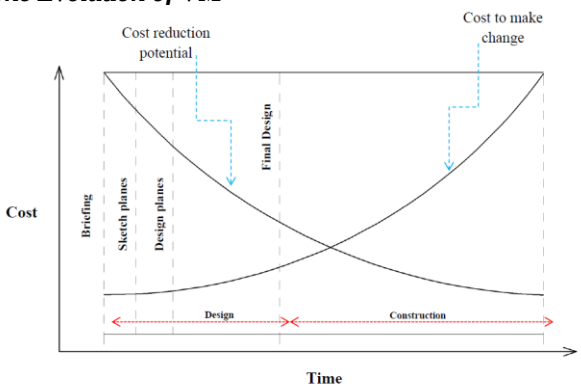

Figure 1: Evolution of value management.

While the above definitions provide a distinction between VM, VE and VA, it is not correct to perceive them as three totally different processes. VM in construction is increasingly being seen as the term to describe the total process of enhancing value of a project for the client from concept to occupancy. VE and VA can be viewed as special cases of the generic discipline of VM, whose focus is on improving value in the design and construction stages of a project [11]. VM evolved from the traditional paradigm of VA and VE. However, VM is not only used to treat hard, static and unitary problems on tactic level as well as traditional VA and VE practices, but also used to resolve soft, dynamic and multi-faceted problems on strategic level. It is appropriate to view VA and VE as subsets of the total VM process (as illustrated in Figure 1) [6].

V. JOB PLAN OF VE

A value study must follow a systematic process - The Job Plan - which consists of six sequential phases as indicated in Table 2 below. There are 3 stages to a value study, the preparatory pre-workshop stage, the workshop (using the 6 phase job plan) and the post workshop stage for implementation and follow up. Figure 2 show the flow diagram for Value Study Process [12]. The precise number of stages and the specific names of these stages in the job plan often vary but the same general process is always identifiable. The principles of the value engineering job plan, reflecting classical research techniques, are generally regarded to be sound [2].

Table 2: The six sequential phases of VE Job Plan

The Job Plan sequential phases	Outline
Information phase	Project definition and goals
Function analysis phase	Function definition and analysis
Creative phase	Identification of alternatives
Evaluation phase	Structured evaluation of alternatives
Development phase	Development of alternative into proposals
Presentation phase	Report / Presentation of the opportunities

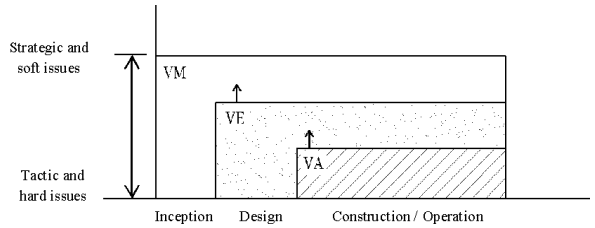

Figure 2: Value Study Process Flow Diagram [12].

VI. TIMING OF VE STUDIES

The timing of VE studies is a controversial issue. The major alternatives are to have a study at concept design, 35% design or both [6]. All VM authors agree that the maximum cost reduction potential occurs early in the briefing/design process. Therefore, VE should be performed as early as possible to exert its potential for value enhancement. The potential for saving, as shown in Figure 3, is much greater when VE is applied earlier. When VM is used later, the cost required to make any changes and resistance to chance increase.

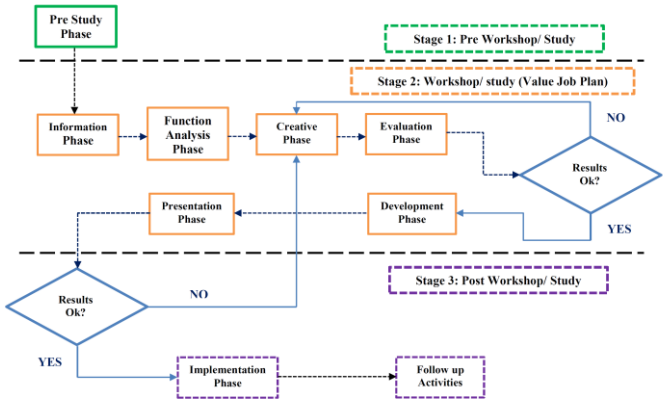

Figure 3: Cost reduction potential versus cost to implement changes [6].

VII. FUNCTION ANALYSIS SYSTEM TECHNIQUE (FAST - DIAGRAM)

In 1964, Mr. Charles W. Bytheway developed a system for function analysis that has become known as the Function Analysis System Technique (FAST). Mr. Bytheway, the Value Engineering and Cost Reduction Administrator for UNIVAC, was searching for a way to analyze, in depth, the functions of the Walleye Missile System. The technique that he devised and refined was presented by him in 1965 to the Society of American Value Engineers at their National Conference in Boston. FAST diagramming has since been used by Value Engineers throughout the world as a tool to correctly identify the interrelationship of the functions under study. As in the case with most Value Engineering tasks, the development of a FAST diagram is best accomplished as a team effort. The interplay of different viewpoints causes deeper thinking about the subject and, therefore, more thorough investigation [1].

FAST diagram developing required asking the questions, HOW is the basic function; (verb) (noun); actually accomplished, or HOW is it proposed to be accomplished? The answer, expressed as a verb and a noun, is written in the next block to the right of the scope line. Asking HOW is continued to the right for each new function on the diagram until the answer exceeds the scope of the study. To check the answers to the HOW questions, the functions answer the question HOW when read from left to right. If the diagram is read from right to left, the functions answer the question WHY.

Functions connected with a vertical line are those that happen at the same time as, or are caused by, the function at the top of the column. This representation of the functional logic in FAST diagram form provide understanding the project design rationale and shows functions that have best opportunities for cost or performance improvement. Figure 4 depicts the method of graphically representing this technique.

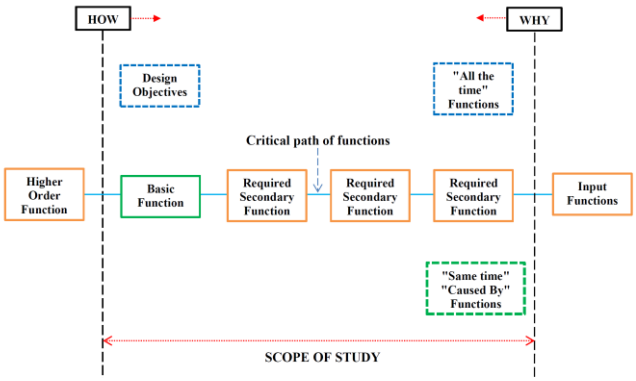

Figure 4: Fundamentals of FAST Diagram.

VIII.VALUE ENGINEERING IN THE TRANSPORTATION FIELD

Transportation in all its facets is an area of central interest to Value Engineering (VE) and benefits by the full spectrum of the value analysis process. Experience has shown that transportation facilities can benefit in both quality and level of service from the systematic application of value engineering in all its phases. Major transportation projects have yielded up to 20 percent of the initial construction costs in VE savings and 2 to 3 percent in collateral annual savings in operation and maintenance. Governmental authorities which frequently deal with major development projects, involving the enormous mobilization of resources (technical, financial and other), are at the top of the list of potential clients for value engineering services [13].

The history of highway development is full of instances where inspiration has produced noteworthy contributions to the financial and operational improvement of highway transportation. Because of rising costs and unemployment it was necessary to provide an opportunity to encourage such inspiration. VE was defined as tool that can make things happen. It is an engineer's means to force the development of, and use of, "bright ideas.". Value Engineering is predicated on the fact that people spend their money to accomplish functions rather than simply to obtain ownership. With today's well established concern for our environment, energy, and rising costs, the functional needs of safe and efficient accommodation of vehicular and pedestrian traffic must be carefully and independently analyzed, so that we may obtain these functions in the most economical manner, with minimal disturbance to the environment [1].

A. Experience Accumulated by VE in Transportation Projects

Value engineering has been used for a period of over 35 years by the U.S. Department of Defense, the U.S. Department of Transportation, the General Services Ad- ministration, the California Department of Transportation, the U.S. Federal Highway Administration (FHWA) and several other American organizations as well as corresponding agencies in Europe and the Far East Japan. In the Middle East, value engineering lectures have been initiated at the King Saud University in Riyadh, Saudi Arabia, while there are also plans to introduce graduate engineering classes at the King Fahd University of Petroleum and Minerals in Dhahran; seminars on value engineering have been carried out also in Kuwait, Bahrain and other areas in the Emirates [13].

Federal Highway Administration (FHWA) annually collects information on VE accomplishments achieved within the Federal-aid Highway Program, including the projects administered by Federal Lands Highway. For VE studies conducted during the preconstruction phase of projects, the FHWA tracks the number of studies conducted; proposed and implemented recommendations; and the value of the implemented recommendations. Additionally, similar information is compiled for the VE change proposals (VECP) that are submitted by contractors during the construction of the projects [14].

Table 3 illustrates summary of past VE savings federal-aid and federal lands highway programs.

Table 3: Summary of past VE savings federal-aid and federal lands highway programs.

Year	2011	2012	2013	2014	2015
Number of VE Studies	378	352	281	135	135
Cost to Conduct VE Studies and Program Administration	$12.5 M	$12.0 M	$9.8 M	$8.7 M	$6.4M
Estimated Construction Cost of Projects Studied	$32.3 B	$30.3 B	$23.0 B	$20.9 B	$14.1B
Total Number of Proposed Recommendations	2,950	2,905	2,381	1,664	1,233
Total Value of Proposed Recommendations	$2.94 B	$3.78 B	$2.91 B	$3.0 B	$2.5B

Number of Approved Recommendations	1,224	1,191	1,011	697	504
Value of Approved Recommendations	$1.01 B	$1.15 B	$1.15 B	$1.73 B	$831M
Percent of Project Cost Saved	3.12%	3.78%	5.01%	8.32%	5.90%
Return on Investment	80:01:00	96:01:00	118:01:00	200:01:00	129:01:00

B. Success Stories of Value Engineering Studies

Among many Value Engineering savings determined and implemented in highway construction projects, the following typical examples demonstrate some of these success stories.

1) Construction of a Highway Bridge near a Flood Control Project: Figure 5 demonstrates that just by simply revising the position of the girders, the extra cost for the function "Facilitate Expansion" was eliminated. The 360-meter long bridge - already under construction - included as a basic requirement the possibility of future widening. During the value engineering study, carried out by the contractor, the function cost distribution showed that the function "Facilitate Expansion" was one of the highest cost functions of the project. Hence, the value engineering study focused on this basic high cost function and generated the alternate solution shown in Figure 5 for a savings of $940,000. This saving was fully documented in a Value Engineering Change Proposal (VECP), submitted by the contractor to the Michigan Department of Conservation [13].

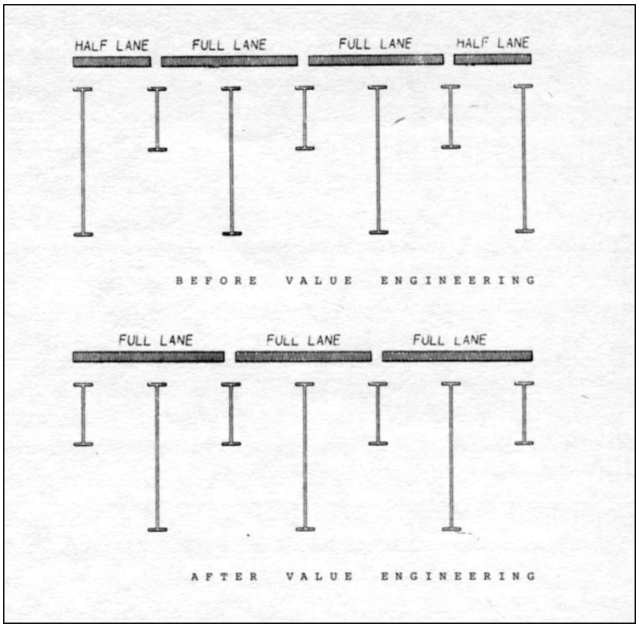

Figure 5: Highway bridge in Michigan - Positioning of bridge girders before and after value engineering study [13].

2) Robert Street Improvements "Value Engineering Study conducted for the Minnesota Department of Transportation (MnDOT)": The subject of the VE Study was TH 952A, Robert Street Improvements, SP 1908-84. The study was conducted September 10-13, 2013 with the presentation of findings held September 13, 2013. The primary objective of the team through application of the VE Job Plan was to:Department of Conservation. The VE Recommendations - as shown in Table 4 - are presented as written by the team during the VE Study. While they have been edited from the VE report to correct errors or better clarify the recommendation, they represent the VE Team's findings during the VE Study. Table 4 is a summary of all recommendations generated and their impact to the project [15].

Table 5: Summary of Recommendations [15].

Idea Description	Cost Savings	Schedule Savings	Performance
Use Traffic Barrels	$0.20 M	1-2 weeks	9%
Contractor/Business Weekly Meetings	None	None	3%
Relocate Utilities First	N/Q	6 months	11%
Risk Mitigation – Separate Utility Contract	N/Q	N/Q	9%
Innovative Contracting	N/Q	6 months	11%
Total	**$0.20 M**		
NQ = Not quantifiable at this time			

IX. SUMMARY OF FRAMEWORKS FOR IMPLEMENTING VE

The following list summaries publications produced by the academic, practitioner community, government, professional bodies and influential VM gurus in the form of guidance notes, standards, manuals and papers on the application of VM [6].

- The Value Management Benchmark: A Good Practice Framework for Clients and Practitioners, Male et al., 1998.
- Value Methodology Standard, SAVE International, 1998.
- Australian/New Zealand Standard - Value Management: AS/NZS 4183, Joint Technical Committee OB/6, 1994.
- European Standard - Value Management, European Committee for Standardization, 2000.
- Value Management Handbook, European Commission, 1995.
- British Standard: Value Management Practical Guidance to Its Use and Intent, BS EN 12973, 2000.
- Creating Value in Engineering: Design and Practice Guide, Institution of Civil Engineers, 1996.
- Fact Sheet on Value Management, construction Industry Board, 1997.
- Value Engineering: The Search for Unnecessary Cost, The Chartered Institute of Building, Green and Popper, 1990.
- A SMART Methodology for Value Management, The Chartered Institute of Building, Green, 1992.
- A Clients' Guide to Value Management in Construction, Building Services Research and Information Association.
- Value Management in Construction: A Practical Guide, Norton and McElligott, 1995.

CONCLUSIONS

The quality and costs of highway and other public work sector projects can benefit by the application of well elaborated VE methodologies. Specifically, the VE process provides

sound methodology for analyzing the project objectives and attributes, which, in turn, focuses the development of alternatives in the value study [18].

VE can be used to reduce or avoid excess capital construction expenditures. VE can play a broader role to support effective decision making for highway projects to increase project performance and quality, balance project objectives, and manage community expectations.

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