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RESEARCH ARTICLE

Value Engineering Application in the American Transportation Industry

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Abstract
Value Engineering is systematic application used by multi-disciplined team focused on the functionality identification at the possible lowest overall costs.
The paper presents research findings concerning benefits resulting from Value Engineering applying in American transportation industry within highway improvements programmes. The research aim is to determine economic benefits of VE projects using for highway organization improvements.

Keywords
transportation, highway, Value Engineering

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1 Introduction

Value Engineering (VE) is connected originally with Value Analysis aimed at obtaining the necessary functionality level at the lowest cost without compromising the quality, reliability, and without deterioration of service and delivery (Crum, 1973). It is a systematic method to improve the "value" of goods and services by using an examination of function what affects the cost amount. In literature there are numbers of definition given by the different expertise and practitioners of VE technique:

Miles (1972) defined Value Engineering as a discipline action system, attuned to one specific need: accomplishing the functions that the customer needs and wants at the lowest cost. Zimmerman (1982) said about Value Engineering that it 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. Connaught on and Green (1996) defined VE as a systematic approach to delivering the required functions at lowest cost without detriment to quality, performance and reliability. Creativity and proactive team approach within VE projects was underlined by Hayles and Simister (2000). Value Engineering as a project at the lowest cost that consists of efficient identification and the elimination of unnecessary cost without detriment to: safety, quality, reliability, performance and delivery was identified by Standing (2001).

Development of the Value Engineering concept is associated with General Electric Company, USA. This method was invented by Electrical Engineer Lawrence. D. Miles within General Electric Company, who noticed that many of the substitutes were providing equal or better performance at lower cost and from this evolved the first definition of Value Engineering. The General Electric Company is generally credited with developing the technique, then known as "Value Analysis." In 1954, the U.S. Navy's Bureau of Ships applied the concept, which it called "Value Engineering," to reduce costs during the design stage. The Department of Defense (DOD) accepted VE as a sensible means of obtaining the best practical value from its procurements and, in 1961, adopted VE in contract clauses under the Armed Forces Procurement Regulations (AFPR), permitting contractor incentives in sharing VE contract cost reductions.

Currently, all of the DOD's operating agencies have adopted VE in their procurement programs, including construction, as have agencies of the DOT, including the FAA, Federal Highway Administration (FHWA), and the Federal Transit Authority (FTA). The FAA, the FTA, the Environmental Protection Agency (EPA), the General Services Administration (GSA), and the U.S. Army Corps of Engineers have reported lifecycle savings through the use of VE. VE provides both the funding agency and the sponsor of a project the opportunity and means of improving the project and substantially reducing costs (U.S. Dep. of Transportation Federal Aviation Administration, 2008).

Due to U.S. Federal Acquisition Regulations (Part 52.248), Value Engineering (VE) is defined as an organized effort to analyze the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving essential functions at the lowest lifecycle cost consistent with required performance, quality and safety. It is management tool applied in the case of optimizing expenditures for transportation facilities.

In the United States, Value Engineering is specifically spelled out in Public Law 104-106, which states "Each executive agency shall establish and maintain cost-effective value engineering procedures and processes." Value engineering is an important and flexible tool in the U.S. Department of Defense's (DoD) effort to reduce costs while retaining required performance aptitude. The VE method saves money, increases quality, and improves mission capabilities across the spectrum of DoD systems, processes and organizations.

A great number of government units and enterprises are aware that VE as a management tool enables achievement of significant savings and it can be applied in different production and service fields. It can be also used in transportation issues improvements. Value Engineering consists of concepts to optimize the difference between the cost of doing the construction and the cost of satisfying the final user. Crucial characteristics of VE approach is related to user-orientation that includes answers for some questions as: What is it? What does it do? What does it cost? What else will do the job? What does that cost?

Value Engineering is associated with an engineering and design of projects. It is said that it is most effective when it is accomplished early in the design phase because the ideas are still conceptual and the sponsor and the designer can be flexible with decisions without incurring delays in the project schedule. It allows identifying high cost elements before the budget is decided. Cost analysis and team work are basic approach in the analysis (Mátrai, 2013; Stachová and Stacho, 2013). There are some features of VE that are crucial for its success such as:

- using many widely accepted analysis concepts and techniques,
- systematic process following an eightstep job plan,
- focusing on identifying and analyzing the function the project component(s) or activity fulfils,
- using creative analysis techniques,
- performed by a team not associated in any way with the design team and draws upon the individual and collective viewpoints, experience, and knowledge of its members.

In accordance to Federal Highway Administration in USA (2015), Value Engineering is defined as a systematic process of review and analysis of a project, during the concept and design phases, by a multidiscipline team of persons not involved in the project, that is conducted to provide recommendations for:

- providing the needed functions safely, reliably, efficiently, and at the lowest overall cost;
- improving the value and quality of the project;
- and reducing the time to complete the project.

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are studied through a coordinated program of cooperative research. In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques (McCarthy et al., 2013).

Value Engineering was applied in the mentioned programme. The aim of this paper is to identify and analyze successful applications benefits of VE process, that has contributed measurable benefits to the quality of the surface transportation improvement projects and to the effective delivery of the overall Federal-Aid Highway Program (FHWA).

2 Research findings and discussion

The Federal Highway Administration became involved in VE in 1970, with the Federal-Aid Highway Act's provision giving the secretary of transportation the authority to require a VE or other cost-reduction analysis on any federal-aid highway project. In 1973, FHWA assigned to its headquarters staff a full-time coordinator with the responsibility for administering FHWA's VE program. The FHWA's VE program is focused on continuously improving the development and delivery of highway improvement projects. The following goals and measures were developed in FY 2009 to monitor and report on the progress of FHWA's VE Program:

Goal 1: Maximize the influence VE studies have on a project's cost and performance;

Goal 2: Enhance the quality of VE programs; and

Goal 3: Improve FHWA's stewardship and oversight of the VE Program.

Table 1 Summary of Past VE Savings Federal-Aid and Federal Lands Highway Programs

	FY 2013	FY 2012	FY 2011	FY 2010	FY 2009
Number of VE Studies	281	352	378	402	427
Cost to Conduct VE Studies and Program Administration	$9.8 M	$12.0 M	$12.5 M	$13.6 M	$17.08 M
Estimated Construction Cost of Projects Studied	$23.0 B	$30.3 B	$32.3 B	$34.2 B	$29.16 B
Total Number of Proposed Recommendations	2,381	2,905	2,950	3,049	3,297
Total Value of Proposed Recommendations	$2.91 B	$3.78 B	$2.94 B	$4.35 B	$4.16 B
Number of Approved Recommendations	1,011	1,191	1,224	1,315	1,460
Value of Approved Recommendations	$1.15 B	$1.15 B	$1.01 B	$1.98 B	$1.70 B
Return on Investment	118:1	96:1	80:1	146:1	99:1

FY – Fiscal Year

The following projects that require a VE analysis are (FHWA Order 1311.1B, 2013):

1. Each project located on the National Highway System (NHS) (as specified in 23 U.S.C. 103) with an estimated total project cost of $50 million or more that utilizes Federal-aid highway program (FAHP) funding.
2. Each bridge project located on the NHS with an estimated total project cost of $40 million or more that utilizes FAHP funding.
3. Any major project located on or off of the NHS that utilizes FAHP funding in any contract or phase comprising the major project.
4. Any project where a VE analysis has not been conducted and a change is made to the project's scope or design between the final design and the construction letting which results in an increase in the project's total cost exceeding the thresholds.
5. Any other project FHWA determines to be appropriate that utilizes FAHP (Federal-Aid Highway Program) funding.

The FHWA annually collects information on VE accomplishments achieved within the Federal-aid Highway Program, including the projects administered by Federal Lands Highway. Research findings presented in the paper concern Value Engineering projects savings achieved within U.S. Federal-Aid and Federal Lands Highway Programs.

The FHWA is updating the existing value engineering (VE) regulations to make them consistent with the statutory changes in the Moving Ahead for Progress in the 21st Century Act (MAP–21) and to make other non-substantive changes for clarity (U.S. Department of Transportation, 2014).

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.

Table 1 presents summary of VE project savings in FHWA projects that are representative for economic benefits of VE method application in transportation.

Summary of VE savings in Table 1 confirms decreasing tendency in a number of VE Studies applied in Federal-Aid and Federal Lands Highway Programs. ROI indicator is the most significant for VE project approval in 2010 (146:1), since the analyzed year 2010 has the greatest number of VE studies (402) result in the highest number of proposed recommendations (3,049).

Review of the Value Engineering Summary Reports submitted by U.S. Department of Transportation within Federal Highway Administration confirms, that the significant number of VE projects on transportation has been submitted in the following states: Virginia (36), California (26), North Carolina (26), Florida (21), Texas (13), Minnesota (13), Georgia (13), Illinois (11).

Reports of FHWA in 2009 provides information about number of approved VE recommendations that directly benefit the following key indicators:

- Safety: Mitigation or reduction hazards on the facility;
- Operations: Improvement of real-time service and efficiency of the facility; improvement of local, corridor, or regional level of service of the facility;
- Environment: Avoidance or mitigation of impacts to natural and cultural resources (Glavonjić, Oblak, 2012);
- Construction: Implementation of innovative techniques that enhance or expedite the project delivery or improve work zone conditions;
- Other: Recommendations not readily categorized by the above features.

Summary VE projects benefits for approved Value Engineering Change Proposals in 2009 for the most active states within FHWA program is presented in Table 2.

Table 2 Performance indicators on VE benefits within Federal-Aid and Federal Lands Highway Programs in 2009

State	Approved Value Engineering Change Proposals				
	Safety	Operations	Environmental	Innovative Construction	Other Features
Florida	1	2	0	11	0
Georgia	2	2	0	2	0
Iowa	2	0	0	9	4
Kentucky	3	3	2	4	0
Louisiana	0	0	0	2	0
Michigan	0	0	0	7	0
Missouri	1	5	0	74	1
Ohio	0	1	1	1	0
Pennsylvania	1	0	0	3	0
Utah	1	3	0	3	5
Vermont	1	1	0	2	0
West Virginia	0	0	0	10	0
Wisconsin	0	0	0	0	18
Wyoming	0	0	1	3	13
Total (all U.S. states)	13	21	8	161	41

It is noticeable (Table 2), that most active U.S. state within the VE Change Proposal category "Innovative Construction" is Missouri state with 74 proposals what constitutes almost the half of the total domestic proposals. This category is the most popular in the range of VE Change Proposals what is related to implementing innovative techniques that enhance or expedite the project delivery or improve work zone conditions.

In Colorado VE projects in transportation have been implemented in the form of the following projects (FHWA VE Program Performance Form, 2012):

1. CDOT Project No. FBR 0704-224, "Pecos Street over I-70 Bridge Replacement" - A VE study produced 12 approved recommendations that included changes to the bridge foundation, traffic phasing and routing, and other areas for potential savings of $5.4 million.
2. CDOT Project No. IM C040-029, "I-25 North of Colorado Springs" – A VE study produced 7 approved recommendations that included changes to managing runoff, pavement mix design, and the method of construction for estimated savings of $2.27 million.
3. CDOT Project No. NH 0361-103, "US 36 Managed Lanes Phase II" – A VE study produced 12 recommendations; approval has not been finalized.

California was the first state that demonstrated benefits of VE projects within transportation industry. The California DOT program started in 1969 - three years before FHWA began promoting VE. During the last five years, California has conducted more than 200 studies and, as a result, has saved more than $400 million.

Key to California VE study is a Caltrans VA study connected with "Best Practices", where Value Metrics and Risk Analysis are used in conjunction with the FAST Diagram (VE tool) to thoroughly analyze the project. This deeper understanding of the project leads to innovative and meaningful changes.

The example of California "Best Practices" aided projects includes e.g.: SR78 / Nordahl Road interchange. The project allows identifying the Opportunity Risk to the schedule associated with the effect that the need to maintain the pedestrian access during construction had on the project. The VA Team developed a solution using a temporary pedestrian/bicycle crossing structure to permit 2 stage versus the original 3 stage construction. This solution also resulted in reducing project construction cost $1,200,000, and $875,000 in highway user costs (25%).

In 2012, in California, Caltrans went through a huge internal and external program review. There were many recommendations for improvement including lowering decision making to the lowest responsible party, decrease duplication, and streamline

Table 3 Summary of VE Savings Federal-Aid and Federal Lands Highway Programs for California

	FY 2013	FY 2012	FY 2011	FY 2010	FY 2009
Number of VE Studies	26	34	59	54	48
Estimated Construction Cost of Projects Studied (mil. $)	$3,537,000,000	$1,843,281,000	$4,783.59	$4,875.60	$3,398.00
Total Number of Proposed Recommendations	157	201	329	260	199
Number of Approved Recommendations	90	90	161	119	135
Value of Approved Recommendations (mil. $)	$347,454,000	$64,309,000	$192.31	$305.00	$171.00
Return on Investment	285	44	71	126	80:1
% of Project Costs Saved	9.8%	3.5%	4.0%	6.3%	5.0%

FY – Fiscal Year

customer service to internal and external partners. Caltrans used the VE job plan to conduct internal program reviews at the HQ level to streamline, e.g.: traffic electrical re-organization.

Along with these organizational enhancements, Caltrans used the VE job plan to develop several "Strategic Plans" to align the divisions with Caltrans mission, vision, and goals and enhance the communication with external partners. These included California Bridges and Structures Strategic Direction and Caltrans Geospatial Strategic Direction. Review of VE Savings for FHWA in California in 2009 – 2013 is presented in Table 3.

Research findings presented in Table 2 confirms significant decrease of VE Studies number in Federal Highway Program in California in 2012 (34) comparing with 2011 (59). Comparing with results on general summary of VE projects in Federal Highway Program for all U.S. states, decrease of VE projects number in 2013 differs from data for California, where decrease of VE projects number is noticed in 2011-2012.

3 Conclusion

Value Engineering Program is identified as the collection of studies and workshops implemented with a set of recommendtations including proposals for the transportation organization. It includes established policy and best practices that are aimed at VE project integration with transportation reorganization process toward its improvement.

Success of VE programm is affected by the state and private engineers and experts encourage because VE is perceived as the creative analysis process resulting not only in cost savings, but also in organization changes related to: environment, safety, operation and cosntruction innovations.

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