VALUE ENGINEERING FOR SMALL TRANSPORTATION PROJECTS

by

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Abstract

Although Value Engineering (VE) studies are mandated by the Federal Highway Administration for large ($25 million or more) federal-aid highway projects, many state Departments of Transportation do not conduct voluntary VE studies on smaller projects. Those who have done so have seen project improvements and savings as a result. The success of the existing voluntary VE programs indicates that VE application to small transportation projects represents a significant opportunity for savings.

The goal of this thesis work was to develop a methodology for conducting VE studies on small transportation projects that would make efficient use of available personnel and require little VE training. The author examined the results and procedures of several DOT VE programs, including some that conduct studies on projects as small as $1 million. The analyses revealed sources of past savings, trends and common methods in VE studies, and procedures and forms that are best suited to the types of project under study. Based on the research and analyses, the author developed a VE study methodology that is tailored to small transportation projects, including a workbook and both general and specific guidelines. This report proposes an approach to VE on small transportation projects using this methodology, which is characterized by conformance with accepted VE practice and FHWA guidelines, efficient use of personnel, and ease of use. In particular, these recommendations are intended for use by any state DOT with an existing but limited VE program, such as MassHighway, which currently conducts only mandated studies.

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I. INTRODUCTION

1.0 Motivation and Goal

In its 1998 *Federal-Aid Policy Guide*, the Federal Highway Administration (FHWA) summarized its policy on Value Engineering (VE) as follows:

> The FHWA will assure that a VE study is performed on all Federal-aid funded NHS projects with an estimated cost (includes design, right-of-way, and construction costs) of $25 million or more, and on other Federal-aid projects where its employment has high potential for cost savings. In addition, FHWA will strongly encourage State Departments of Transportation to use VE throughout highway project development, design, and construction[1].

During the fiscal year 1998, thirty-nine of the state Departments of Transportation (DOTs) conducted one or more VE studies in-house or through a consultant[2]. Many of these states have an existing but limited VE program that conducts only FHWA-mandated studies (as described above). However, as illustrated by the results of a few DOT VE programs, VE can be and often is used successfully on highway projects under $25 million[3]. Several states routinely review projects estimated at $2 or $3 million for VE potential. Still, doubts about the cost-effectiveness of performing studies on small projects lead to many missed opportunities for savings and project improvements.

The goal of this thesis work was to develop a methodology for conducting VE studies on small transportation projects that would make efficient use of available personnel and require little VE training. While the same VE process could be applied to all transportation projects, this thesis focused on only small projects due to their strong need for efficient use of time and money. The author defined a "small transportation project" by the following characteristics:

(1) use of federal or state funds (from FHWA or a state DOT);

(2) non-transit transportation facilities (roadway, intersection, bridge, bikeway, etc.); *and*

(3) estimated cost of under $10 million (including design, right-of-way, construction, and mitigation).

2.0 Methodology and Report Organization

The author used the VE programs of several state DOTs as a starting point, namely those of California, New Jersey, Utah, Virginia, and Washington. These are referred to as the "source DOTs." Massachusetts was selected as an example of a state with a limited transportation VE program, which is the type of program that this thesis attempts to aid in expanding.

The first objective (see **Chapter II**) was to research and analyze recent and current use of VE on transportation-related projects. The author collected information on federal policies and guidelines, the VE programs of the states listed above, and statistics on studies of small transportation projects. Specific areas of VE savings in transportation were investigated by searching recent publications and analyzing data from the California Department of Transportation, or Caltrans (see **Chapter III**). The results of this task were used in the development of the VE methodology for small transportation projects.

The next objective was to develop a set of criteria for selection of projects for VE study (see **Chapter IV**). These criteria were based on (1) the selection criteria of the source DOTs and (2) the results of the analysis of Caltrans data. The product of this task was a form containing a list of criteria, to be completed for each project being considered for a VE study (see **Section IV.3.0**).

The third objective (see **Chapter V**) was to examine the current VE study practices of the source DOTs, determine the best components to be applied to studies of small transportation projects, and propose a methodology for such studies. These practices were evaluated for conformance with accepted VE practice and FHWA guidelines for mandated studies, efficient use of personnel, and ease of use. The author then combined selected components to develop a job plan and detailed methodology. The product of this task was the body of a document entitled *Value Engineering Workbook for Small Transportation Projects,* which contains forms for each step of the proposed methodology and instructions for their use. The workbook appears in **Appendix C** of this report.

The final objective was to address the implementation and audit phases of the VE study (see **Chapter VI**). Again, the author examined the current practices of the source DOTs, evaluated their applicability to small transportation projects, and produced forms to aid in carrying out the necessary activities.

The conclusions and recommendations (**Chapter VII**) contain further discussions about the application of this thesis, the author's recommendations, and suggestions for future study. The proposed methodology, contained in the *Value*

Engineering Workbook for Small Transportation Projects, has not yet been tested, and feedback is welcomed.

[1] Federal Highway Administration (FHWA), *Federal-Aid Policy Guide*, 1998, Par. 4

[2] FHWA, "FY 1998 Annual Federal-aid Value Engineering Summary Report"

[3] See **Chapters II, III**

II. VALUE ENGINEERING & TRANSPORTATION PROJECTS

1.0 Overview of Value Engineering

Fundamentally, value engineering (VE) is a systematic process to improve the value of a product. VE began in the industrial sector in the 1940s and 50s, in the context of product design. Its beginnings are usually attributed to Lawrence Miles, who pioneered its use at General Electric in 1947. Since then, VE methods and applications have expanded significantly and have been applied in a wide variety of environments, from building construction to health care[1]. Similar processes appear under several different names, including Value Analysis and Value Management. The Society of American Value Engineers International, or SAVE, uses the broad term "Value Methodology," defined as "the systematic application of recognized techniques which identify the functions of the product or service, establish the worth of those functions, and provide the necessary functions to meet the required performance at the lowest overall cost."[2] This thesis report uses the terminology "value engineering," or VE, except for specific program names such as the Caltrans Value Analysis Program.

A few descriptions of VE concepts are necessary to understand what is considered to be part of VE. First, the *product* under consideration: this product may be virtually anything; some examples are manufactured objects, buildings, management plans, and road segments. SAVE states that the Value Methodology, or what we shall call VE, "can beneficially be applied to virtually all areas of human endeavor," "wherever cost and/or performance improvement is desired."[3] In the construction industry, VE is usually applied to individual projects at various points in their development, particularly between the design and construction phases.

Next, it is important to understand what constitutes the *value* of the product, since "the main objective of VE is to improve value."[4] Several approaches have been proposed to define and measure "value." Dell'Isola describes value using the relationship in Equation 1.

Equation 1: Value = (Function + Quality) / Cost, where

Function = The specific work that a design/item must perform;

Quality = The owner's or user's needs, desires, and expectations;

Cost = The life cycle cost of the product;

and so, Value = The most cost-effective way to reliably accomplish a function that will meet the user's needs, desires, and expectations.[5]

Under this definition, value is an index, essentially a benefit-cost ratio. SAVE defines value similarly, as "the lowest cost to reliably provide the required functions at the desired time and place with the essential quality and other performance factors to meet user requirements."[6] The definition of quality varies to suit the project under study.

Finally, the *process* by which the value of the product is maximized: while different authors and practitioners divide the study process into different phases, the basic methodology is common to most. In Figure II-1, Dell'Isola refers to the Information Phase, Creative Phase, Analytical Phase, Proposal/Presentation Phase, and Implementation Phase. In the Information Phase, the VE team gathers necessary information, estimates target quantities (via cost, space, or energy models), selects areas with savings potential, and performs a function analysis of those areas. The Creative Phase basically involves generating alternatives to provide the same or better value for selected items. During the Analytical Phase, the feasibility of the alternatives is evaluated, and the alternatives are ranked according to project-specific criteria. In the Proposal/Presentation Phase, the team works out the details of the best ideas, calculates the benefits and drawbacks including a life-cycle cost (LCC) analysis, and presents its recommendations to the owner/user.[7] In the Implementation Phase, any VE proposals approved by the owner/user are carried out and documented.

In Figure II-2, SAVE identifies six VE study phases, Information Phase, Function Analysis Phase, Creative Phase, Evaluation Phase, Development Phase, and Presentation Phase, which encompass essentially the same activities as Dell'Isola's five phases.[8] SAVE also includes Pre-Study and Post-Study activities for a more complete picture of the process. Finally, Figure II-3 presents the Job Plan developed by the Federal Highway Administration (FHWA), which simply outlines the phases of the VE process. The "VE Team Study" phases correspond closely to the SAVE study phases, while Selection is a Pre-Study activity and Implementation and Audit are Post-Study activities according to SAVE.

Figure II-1*: Typical VE Job Plan / Flow Chart*[9]

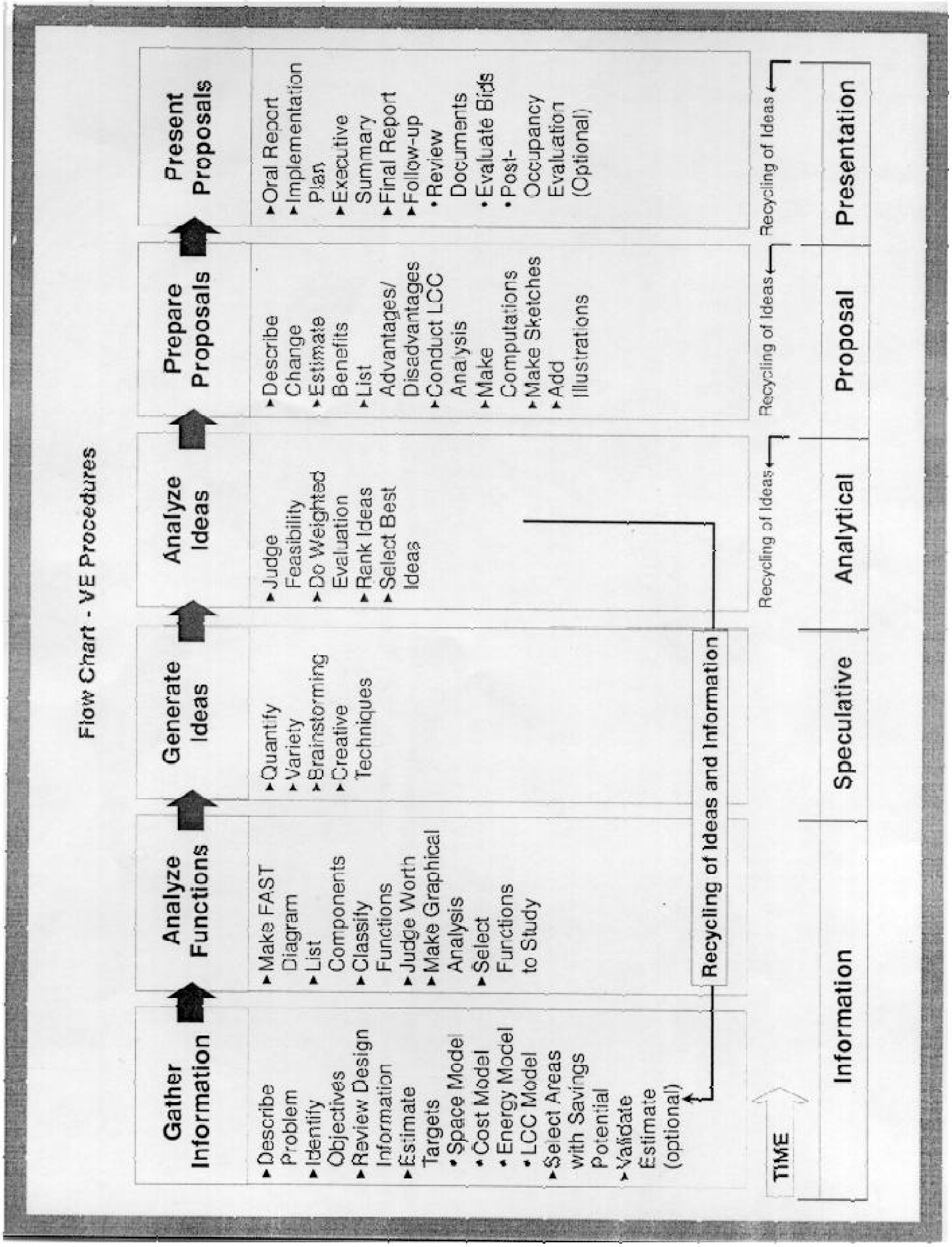
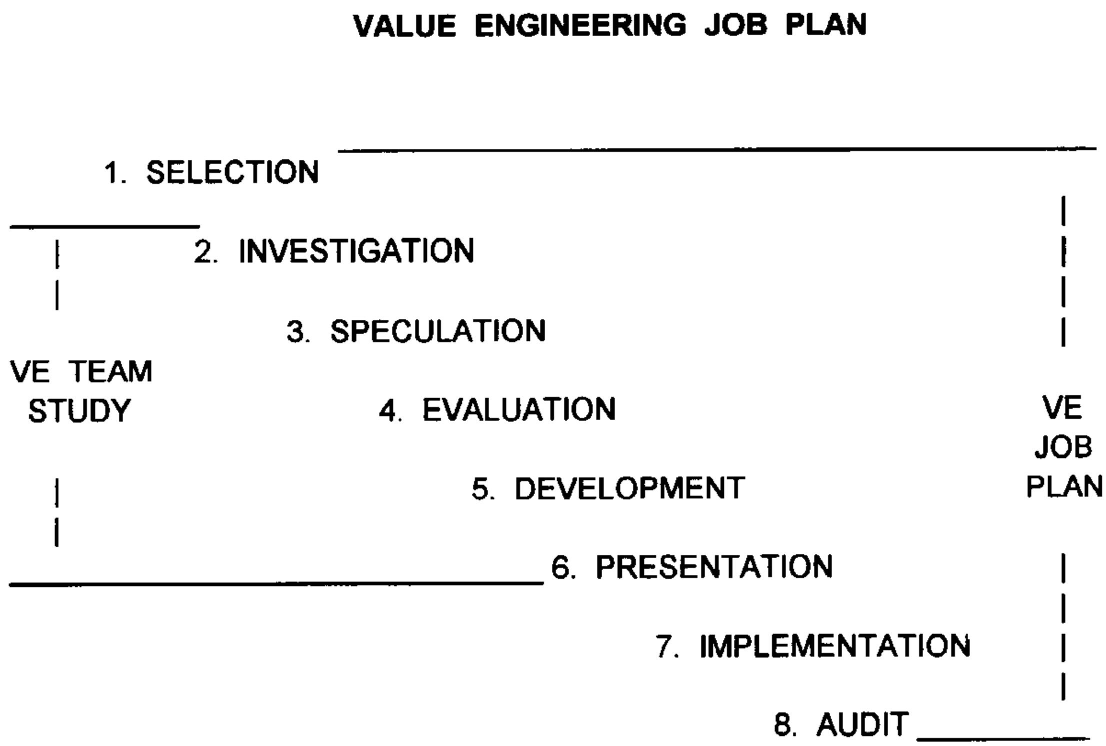


***Figure II-2**: SAVE Value Management Job Plan*[8]

PRE - STUDY User/Customer Attitudes Complete Data File Evaluation Factors Study Scope Data Models
VALUE STUDY ***Information Phase*** Complete Data Package Finalize Scope ***Function Analysis Phase*** Identify Functions Classify Functions Function Models Establish Function Worth Cost Functions Establish Value Index Select Functions for Study ***Creative Phase*** Create Quality of Ideas by Function ***Evaluation Phase*** Rank and Rate Alternative Ideas Select Ideas for Development ***Development Phase*** Benefit Analysis Technical Data Package Implementation Plan Final Proposals ***Presentation Phase*** Oral Presentation Written Report Obtain Commitments for Implementation
POST - STUDY Complete Changes Implement Changes Monitor Status

Figure II-3: FHWA VE Job Plan Phases[10]



2.0 Use of Value Engineering by Federal and State Governments

At most levels of government in the United States, VE is encouraged and in many cases required. When contemplating any VE program or study in the public sector, the guidelines and policies of the various governing layers must be taken into account.

2.1 Federal Policy & Regulations

2.1.1 U.S. Government

On May 21, 1993, the Office of Management and Budget (OMB) issued Circular number A-131, which set forth its requirement that all "federal departments and agencies... use value engineering (VE) as a management tool, where appropriate, to reduce program and acquisition costs."[11] The "appropriate" use of VE appears to be left to the discretion of the individual departments and agencies. This circular defined Value Engineering as the following:

> An organized effort directed at analyzing the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety. These organized efforts can be performed by both in-house agency personnel and by contractor personnel.[12]

The circular also established agency responsibilities and annual report requirements relevant to VE activities.

2.1.2 U.S. Department of Transportation (USDOT)

As a result of the OMB requirement just discussed, the USDOT issued Order DOT 1395.1A to establish "the procedures for implementing the requirements of OMB Circular A-131 and ... the framework for a Departmentwide VE program."[13] This Order describes two categories of DOT VE efforts: VE Change Proposals, which are "contractor initiated change proposals submitted under a DOT contract," and VE Proposals, which are "developed by employees of the Federal Government or contractor VE personnel employed by DOT to provide VE services for a contract or program."[11] The USDOT requires that either type of proposal "result in measurable cost savings while maintaining equal or achieving improved efficiency and quality."[14] Among other policy details, the Order gives a vague guideline for selecting projects or programs for VE study: “VE should generally be undertaken when there is an assumed potential for a significant ratio of savings to cost of the VE.”[12] It also points out that VE studies should be conducted early in the project/program development, since “the potential savings are generally greatest during the planning, design, and other early phases.”[15]

2.1.3 Federal Highway Administration (FHWA)

As the part of the USDOT responsible for the nation’s highways, FHWA produced its own VE regulation, which is contained in 23 CFR Part 627, “Value Engineering.” This regulation covers all highway projects in the United States. Section 627.1 outlines the goals of the VE program: “to improve project quality, reduce project costs, foster innovation, eliminate unnecessary and costly design elements, and ensure efficient investments.” The state highway agencies are responsible for “[assuring] that a VE analysis has been performed on all applicable projects and that all resulting, approved recommendations are incorporated into the plans, specifications and estimate.” “Applicable projects” are defined as “all Federal-aid highway projects on the National Highway System (NHS) with an estimated cost of $25 million or more.”

Section 627.3 defined Value Engineering in more detail than the USDOT, as:

> the systematic application of recognized techniques by a multi-disciplined team to identify the function of a product or service, establish the worth for that function, generate alternatives through the use of creative thinking, and provide the needed functions to accomplish the original purpose of the project, reliably, and at the lowest life-cycle cost without sacrificing safety, necessary quality, and environmental attributes of the project.

This process can be summarized as performing functional analysis, brainstorming, and analyzing proposals. Figure II-3 on page 9 is the Job Plan developed by the FHWA as an overview of the process. Two items should be noted in this definition: (1) for the first time, there is an emphasis on a team approach; and (2) the components of the generic "quality" of an item are listed as reliability, safety, quality, and environmental impact, while cost is specified as life-cycle cost.

Section 627.5 lays out the principles and procedures which are to govern the State VE programs. Among the highlights are a requirement for studies to be performed "using multi-disciplined teams of individuals not personally involved in the design of the project" and suggestions that the program include provision for identification of candidate projects, formal concluding report, review of recommendations, and monitoring implementation. FHWA also points out that "studies should be employed as early as possible in the project development or design process so that accepted VE recommendations can be implemented without delaying the progress of the project."

2.2 FHWA Value Engineering

In September of 1998, the FHWA issued its revised *Federal-Aid Policy Guide*, including a chapter on VE, to assist state DOTs in carrying out FHWA policies. The VE chapter summarized the FHWA policy as follows:

> The FHWA will assure that a VE study is performed on all Federal-aid funded NHS projects with an estimated cost (includes design, right-of-way, and construction costs) of $25 million or more, and on other Federal-aid projects where its employment has high potential for cost savings. In

> addition, FHWA will strongly encourage State Departments of Transportation to use VE throughout highway project development, design, and construction.[16]

The second sentence is of particular relevance to this thesis. The emphasis continues in Paragraph 6, which states:

> A VE analysis shall be applied to all Federal-aid funded NHS projects with estimated costs of $25 million or more, however, VE should not be limited to only projects of this scope. It can also be highly effective when used on other projects when there is potential for a significant ratio of savings to the cost of the VE study or substantial improvements in project or program effectiveness. . . . While all projects will not necessarily benefit from the application of VE, the review process should be set up to consider all projects and a VE analysis should be applied to those projects offering the greatest potential for improvement and/or savings.

The *Policy Guide* also describes the characteristics needed for an analysis to be considered VE:

> a multi-disciplinary team approach; the systematic application of a recognized technique (VE Job Plan); the identification and evaluation of function, cost and worth; the use of creativity to speculate on alternatives that can provide the required functions (search for solutions from new and unusual sources); the evaluation of the best and lowest life-cycle cost alternatives; the development of acceptable alternatives into fully

supported recommendations; and the presentation/formal reporting of all VE recommendations to management for review, approval, and implementation.[17]

The FHWA provides further details of the process and instruction in VE fundamentals in a text and course entitled *Value Engineering for Highways* (National Highway Institute Course No. 13405).

2.3 AASHTO Guidelines

Prior to the government requirements discussed above, in 1985, the American Association of State Highway and Transportation Officials (AASHTO) established a Task Force for Value Engineering in order to "develop, maintain and revise Guidelines to assist state agencies in establishing and administering value engineering (VE) programs."[18] After the FHWA VE policy went into effect, AASHTO revised its guidelines to advise the states in meeting FHWA requirements effectively. The guidelines emphasize the importance of "management support, a policy directive, and a Value Engineering Administrator."[16] They also briefly describe each phase of the VE study and make recommendations concerning state VE programs.

3.0 Value Engineering in State Departments of Transportation (DOTs)

FHWA's *VE Policy Guide* requires the state DOTs to submit annual information about their VE studies, which is then condensed into an annual "VE Summary Report." The data discussed in this section can be found in the Summary Report for fiscal year 1998. According to the data provided to FHWA, during fiscal year 1998, thirty-nine of the states conducted one or more VE studies in-house or through a consultant. A total of

431 VE studies were conducted on federal-aid highway projects in the fiscal year, at a cost of $6.579 million. These studies resulted in approved recommendations valued at $769.72 million, for a savings of $117 for every dollar spent on the studies. Although money (i.e., costs and savings) is not the only important factor, it is a widely accepted measure of success because it is easily quantifiable and comparable.

The 1998 summary is helpful in indicating which states currently have active and successful programs. Three common methods of ranking VE programs are the number of VE studies, the ratio of recommended savings to study costs, and the ratio of approved savings to study costs. The number of studies indicates a level of activity rather than of success. Simply performing many studies does not lead to a successful VE program, although it does lead to more VE experience and thus hopefully to increased success in the future. A high recommended-savings-to-study-cost ratio indicates that the VE teams performed well at generating money-saving alternatives. On the other hand, a high approved-savings-to-study-cost ratio indicates not only that the teams generated good alternatives but that the decision-makers were receptive to the VE analyses. This acceptance of VE at various management levels is essential to the success of the VE program.

Table II-1 summarizes the "top ten" states by each of the three ranking strategies. It is interesting to note that some states appear in only one or two of the lists. One example is Nevada, which apparently excels at generating money-saving alternatives but not at getting them approved. Possibly, the management levels of the DOT are skeptical of VE studies and merely include them to fulfill the FHWA mandate. Another possibility is that the VE teams fail to adequately take into account the project participants and issues when making recommendations. Without further information, it is impossible to diagnose the specific problem.

***Table II-1**: "Top Ten" States in VE, FY 1998, from FHWA "VE Summary Report"*

State	Studies		State	Recommended / Cost		State	Approved / Cost
Virginia	77		Nevada	5523		Oklahoma	1249
Florida	55		Oklahoma	2000		Alabama	1049
Pennsylvania	24		Florida	1607		Michigan	344
New Jersey	22		Oregon	1294		Ohio	343
California	19		Alabama	1049		S. Carolina	303
Texas	16		California	729		California	276
Washington	14		Michigan	646		Florida	258
New York	14		Tennessee	579		Washington	196
N. Carolina	12		Texas	574		Virginia	183
Arizona	12		Ohio	571		New Jersey	157

Representatives of DOTs in several states (California, Massachusetts, New Jersey, Utah, Virginia, and Washington) have generously provided documents and information relevant to their programs for use in this thesis. Two of them, California and Virginia, appear in all three of the "top ten" lists in Table II-1. New Jersey and Washington appear in two of the lists, including the most important, "Approved/Cost." Utah does not appear in the lists at all, probably due to its extensive use of consultants (see **Section II.3.3**), but has developed a detailed manual for VE studies. Massachusetts is an example of a state with a limited transportation VE program, which is the type of program that this thesis attempts to aid in expanding. The following sections summarize these programs, including their organization, applications, and results.

3.1 California: Caltrans[19]

The California Department of Transportation (Caltrans) uses both consultants and in-house team leaders to conduct VE studies, which it refers to as Value Analysis (VA) studies. Three full-time VA engineers in Sacramento manage a twelve-district statewide VA program, with a VA coordinator in each district. Caltrans performs VA studies on highway construction projects, both NHS (mandated) and district-identified (voluntary); engineering products; and organizational processes.

In fiscal year 1998, Caltrans completed twenty-seven VA studies, including the nineteen highway project studies shown in Table II-1, resulting in $155 million in implemented savings. In addition, twenty-five Value Engineering Change Proposals were submitted, resulting in $1,296,965 of savings to the state.

3.2 New Jersey: NJDOT

Within the New Jersey Department of Transportation (NJDOT), the Value Engineering Section of the Bureau of Configuration Management performs VE studies. The VE Section is composed of a Design VE Unit and a Construction VE Unit. The Design VE Unit conducts studies on design projects and on standards, policies, procedures, and specifications, through VE proposal and design development and life cycle analysis. The Construction VE Unit manages construction VE proposals and initiates safety and design improvements.[20]

The VE Section is involved in the "Feasibility Phase" of projects with cost estimates exceeding $3 million. A full independent VE analysis is performed for projects exceeding $25 million, as mandated.[21]

3.3 Utah: UDOT

Steven Anderson of the Utah Department of Transportation (UDOT) summarizes UDOT's VE program this way:

> In Utah we have one Value Engineer manager and that's me. I work with UDOT Project Managers from all over the state and they develop a three year VE work plan. All projects over $2 million are looked at for a possible VE Study and are documented why or why not they had a formal study. We have a pool of VE consultants that work with me on a project by project basis. They usually provide the Team Leader and any other engineering experts that we can't provide from UDOT personnel.[22]

UDOT has produced a Study Workbook and a VE Manual of Instruction to educate its own personnel and ensure that consultants follow a consistent methodology. It also encourages construction VE in the form of VE Change Proposals.

3.4 Virginia: VDOT

The Virginia Department of Transportation (VDOT) has arguably the most prolific state highway VE program, perhaps due in part to its proximity to Washington, DC. T his program consists of a State VE Manager, three Regional VE Managers, and a Management Analyst. The VE Managers report to VDOT's Management Services Division, which is independent of the engineering design divisions to encourage objectivity in the studies. VE studies are conducted in-house by trained personnel from VE staff, preliminary engineering divisions, district office staff, city and local engineering staff, and/or VDOT management. Since 1990, Virginia has required the use of VE on all transportation projects exceeding $2 million.[23]

In fiscal year 1998, VDOT conducted VE studies on seventy-two highway construction and maintenance projects and five "special projects." VDOT's VE staff also conducted VE studies for Indiana and Maine. They received FHWA's 1997 National VE Outstanding Achievement Award for state highway programs and AASHTO's 1997 National VE Award for outstanding process study.[24]

3.5 Washington: WSDOT[25]

The VE program of the Washington Department of Transportation (WSDOT) is headed by a Statewide VE Program Manager, in cooperation with Region VE Coordinators. The VE teams may be selected from the WSDOT regions, other state or federal agencies, or private individuals or firms. WSDOT's Value Engineering Policy stresses the goal of "Value Improvement" rather than simple cost reduction.

3.6 Massachusetts: MassHighway[26]

MassHighway has a part-time state VE coordinator who also works in the Engineering Expediting office. VE teams made up of both consultants and MassHighway staff conduct approximately three to five VE studies each year. These studies are for only the mandated projects, i.e., those estimated to cost $25 million or more. Recently, that has meant that most VE is done on the Central Artery project in Boston.

MassHighway VE teams, made up of six members, spend six days on each study, including a one-day site visit followed by a five-day workshop. After the workshop, staff spends approximately sixteen hours preparing a VE report. According to the current VE coordinator, a MassHighway VE procedures manual has existed in draft form for several years and includes several spreadsheets that are difficult to work with. He is doubtful about the cost-effectiveness of performing VE studies on smaller projects, mainly due to the trend of good VE proposals being discarded due to political pressures.

4.0 VE Studies on Small Transportation Projects

This thesis focuses on "small transportation projects," which includes projects with the following characteristics:

(1) use of federal or state funds (from FHWA or a state DOT); *and*

(2) non-transit transportation facilities (roadway, intersection, bridge, bikeway, etc.); *and*

(3) estimated cost of under $10 million (including design, right-of-way, construction, and mitigation).

The use of federal or state funds implies that the project is designed and constructed according to federal or state standards and guidelines, and thus adopting FHWA VE standards is appropriate. Although the FHWA regulations do not apply to voluntary VE studies, i.e., those under $25 million, they are useful as guidelines. Also, the process proposed for voluntary studies by this report may indicate improvements that can be made to the mandated study process as well. Therefore, this thesis adopts the FHWA criteria for VE programs, as discussed in **Section II.2.1.3** and **II.2.2**, as guidance in developing specific recommendations.

The second characteristic eliminates transit projects, which generally fall under the jurisdiction of transit authorities rather than highway departments. Roadway, traffic, bridge, and "enhancement" projects such as bike or pedestrian facilities generally fall under the jurisdiction of highway departments.

Finally, the estimated cost of under $10 million defines what is meant by "small." Projects estimated at over $25 million can be considered "major" or "large," and those costing $10 - $25 million can be considered "medium." While the same VE process could be applied to all transportation projects, this thesis focuses on only one category, the *small* transportation project. As discussed above, several states consider these types of projects eligible for VE studies, although larger projects tend to be given priority for studies. For example, VDOT has conducted 273 studies on projects between $2 and $5 million (mostly $3-$5 million). The VDOT minimum cost of $2 million is intended to include all projects with a "fully developed set of construction plans and areas where VE can be applied with success and documented savings."[27] Caltrans uses a minimum project cost of $1 million, in order for the studies to be cost-effective, and has found VE useful even on seemingly typical projects such as paving work.[28]

Chapter III of this report explores the successful use of VE on small transportation projects in greater detail.

[1] Society of American Value Engineers International (SAVE), 1997, p. 1

[2] SAVE, 1997, p. 15

[3] SAVE, 1997, p. 1

[4] Dell'Isola, 1997, p. xx

[5] Dell'Isola, 1997, p. xix

[6] SAVE, 1997, p. 14

[7] Dell'Isola, 1997, pp. xxvii, 66

[8] SAVE, 1997, p. 3

[9] Dell'Isola, 1997, p. 66

[10] FHWA, *Value Engineering Textbook*, 1996, p. 2

[11] Office of Management and Budget (OMB), 1993, p. 1

[12] OMB, 1993, p. 3

[13] United States Department of Transportation (USDOT), 1992, p. 1

[14] USDOT, 1992, p. 2

[15] USDOT, 1992, p. 4

[16] FHWA, *Federal-Aid Policy Guide*, Par. 4

[17] FHWA, *Federal-Aid Policy Guide*, Par. 5

[18] American Association of State Highway and Transportation Officials (AASHTO), 1999, p. 5

[19] State of California Department of Transportation (Caltrans), pp. 4, 6, 7, 11

[20] New Jersey Department of Transportation (NJDOT), 1997, Sections I and II

[21] NJDOT, 1997, Sections III and IV

[22] Steven Anderson (of UDOT), 1999, e-mail

[23] Virginia Department of Transportation (VDOT), *VE Virginia*, 1997

[24] VDOT, *VE Annual Report*, *FY 97/98*, pp. 6-7

[25] Washington State Department of Transportation (WSDOT), 1999, pp. 1-3

[26] Steve McLaughlin (of MassHighway), 1999, telephone interview

[27] Ron Garrett (of VDOT), 1999, e-mail

[28] Charly Ludwig (of Caltrans), 1999, telephone interview

III. Success Stories: Areas of VE Savings

As illustrated by the results of various state DOT VE programs, VE can be and often is used successfully on highway projects under $25 million. Several states routinely review projects estimated at $2 or $3 million for VE potential. However, most state programs, such as MassHighway VE, are not active at that level. Therefore, a distinct opportunity exists for VE application to small transportation projects. This chapter reviews previous work, both theoretical and practical, for trends and sources of savings. Of particular note in this review are the types of projects studied, such as bridge or roadway elements, and the types of recommendations generated and/or implemented, such as scope reduction, design changes, or modifications to materials or methods. The experience of Caltrans (see **Section III.2.0**) also reinforces the importance of making VE recommendations during the design stage, since the majority of the savings realized by Caltrans studies of small transportation projects were generated by scope or design changes.

1.0 Savings on Transportation Projects

1.1 Bridge Project Studies

VE studies are commonly carried out on bridge projects, which are well suited to VE because of their complexity. Savings have been found in new bridge design, bridge system selection, and rehabilitation of existing bridges.

In one case, the designers of a new bridge in Illinois cut about $2 million off the preliminary estimate by using VE.[1] Most of the savings were generated from design changes. Elements of the cross-section were altered, including a reduction in overall width, change of median barrier, and wider sidewalks that included light standards. The horizontal alignment was changed by moving one end of the bridge to shorten a retaining wall. The span arrangement was changed by eliminating one pier and "replacing the short approach spans with an embankment."[2] Other items altered were the piers, where changing from solid wall piers to cantilevered piers "reduced [the] size of forms, footings, excavations and cofferdams," and the construction traffic pattern, where routing all traffic through local streets during bridge construction eliminated "extensive temporary construction and time delays."[2] The preliminary estimate was not given in the article, but at completion, the bridge cost about $16.6 million.

In another example[3], a materials-and-methods VE proposal from a contractor saved $100,000+ on a $4.2 million bridge rehab project for New York DOT. The original design for "the 32,000 SF twin decks called for 3" concrete-filled steel grids plus a polymer-overlay wearing surface," and the accepted proposal substituted "exodermic deck modules… made of an unfilled steel grid that is a composite with a thin reinforced concrete overlay" placed on site.[4]

GangaRao *et al* discussed their use of VE principles to "identify areas for improvement and increased cost efficiency in the construction of low-volume road bridges" in a 1988 research article.[5] A "low-volume road bridge" according to this study carries an average daily traffic volume of less than 200 vehicles[6]. Functional and cost analysis led the researchers to "concentrate their efforts on the superstructure in general and specifically the deck and stringers."[7] They then identified the "most desirable type of superstructure" for each of three span lengths. Interestingly, "the bridge systems selected for all three span lengths involve precast components."[8] The recommended systems compared to the systems selected intuitively by federal bridge engineers showed a potential savings of 24% for the 30-foot span, 22% for the 60-foot span, and 42% for the 100-foot span.[9] The conclusion of the article was that using VE in making design decisions should lead to project savings.

Another team of researchers focused on a similar issue, the task of selecting bridge systems for several different site conditions.[10] They used VE techniques to analyze eight systems (including precast girders, prefab steel, precast segments, and cast-in-place concrete) under three different site conditions (under/over running traffic, across navigable waterways, and at accessible sites). The authors concluded that following their VE process to select a bridge system would result in higher value bridges, although they did not quantify the cost savings. Their criteria for selecting the optimal alternative were construction cost, maintenance, durability, service life, resource availability, ease of construction, progress rate, and design efficiency.

1.2 Maintenance Studies

Since the late 1970s, FHWA has produced several reports on value engineering studies conducted by representatives of multiple states. For the most part, these studies have focused on optimizing maintenance procedures. The recommendations developed from the studies fall into two major categories.

Most of the recommendations are concerned with providing adequate preventative maintenance. Bridges, pavement, striping, and roadside appurtenances function better and last longer with proper maintenance. This conclusion appears obvious, but it illustrates the importance of evaluating alternatives based on life-cycle costs rather than initial costs alone. The management systems initiated in several states in compliance with requirements of the Intermodal Surface Transportation Efficiency Act (ISTEA) are an example of a program-level response to the issue. These systems track the condition of various components of the roadway network, such as pavement and bridges, and by evaluating the cost-effectiveness of repairs, aid in selecting the highest priority maintenance and repair projects. However, since preventative maintenance is a program-level issue rather than a project-level recommendation, it is beyond the scope of this thesis.

The rest of the recommendations are aimed at increasing the economic or useful life of the item in the design stage. New or replaced components can be chosen for their long life and/or low maintenance requirements, so that their life cycle costs are lower. This concept is an obvious but important part of project-level VE. The FHWA publications may be helpful as a starting point for project VE studies, since they suggest alternative materials and methods for construction of bridge and road elements. The following FHWA reports were identified as relevant to this thesis:

- *VE Study of Bridge Deck Maintenance, Repair, and Protection* (1990), performed by the state highway agencies of California, Washington, Kentucky, Missouri, Virginia, and New Hampshire. Report No. FHWA-TS-90-041.
- *VE Study of Traffic Striping* (1979), performed by teams from Florida, Illinois, New Mexico, and North Carolina. Report No. FHWA-TS-79-219.

- *VE Study of Highway Shoulder Maintenance* (1977), performed by teams from Arizona, Idaho, Iowa, West Virginia, and FHWA. Report No. FHWA-TS-77-210.
- *VE Study of Crack and Joint Sealing* (1984), performed by Delaware, Georgia, Montana, Tennessee, and Utah. Report No. FHWA-TS-84-221.
- *VE Study of Guardrail and Impact Attenuator Repair* (1987), performed by Florida, North Carolina, Virginia, and FHWA. Report No. FHWA-TS-87-226.
- *VE Study of Curbs and Drainage* (1990), performed by Michigan, Minnesota, West Virginia, and Wisconsin. Report No. FHWA-TS-90-040.

1.3 Other Studies

In 1980-81, the Oregon State Highway Dept assembled a five-member team to study "potential cost savings on four major state projects."[11] The four projects were selected from over 40 that the VE team had examined for VE potential. The team's recommendations for the four projects included changes in surfacing design on a 3-R project (rehabilitation, resurfacing, & restoration) and an overlay project, changes in subsurface drainage design on an Interstate gap closing project and the 3-R project, and pavement reconditioning (full-depth cold-planing) on a maintenance project. The total anticipated savings for the 4 projects were about $2.5 million, or $80 for each dollar spent on the VE study.

2.0 Savings on Small Transportation Projects - Caltrans

As mentioned previously, Caltrans conducts VE studies on projects as small as $1 million. Between 1985 and 1999, over 90 studies were conducted on projects that were estimated at under $8 million after VE.[12] From the Caltrans database, the author chose sixteen VE studies for discussion because (1) they fit the criteria of "small transportation projects" and (2) the data on their recommendations were complete enough to analyze. The projects analyzed ranged in pre-VE cost from $881,000 to $11,527,000, averaging $4,270,719. This cost includes road and bridge construction and right-of-way procurement. The 21 adopted recommendations saved from $95,000 to $8,800,000 per project, averaging $1,605,719. Some details on the projects and recommendations, provided by Caltrans, appear in **Appendix A**. All VE savings and recommendations discussed in this section were "adopted" (approved and implemented). Although the intent of this analysis is to identify characteristics of particularly cost-effective studies, it is important to remember that *all* these studies resulted in savings.

Table III-1 shows the project statistics by project category. This author divided the projects into five broad categories, bridge, roadway, roadside, interchange, and other; each broad category was also subdivided to describe the project more specifically. Some projects fell into more than one category due to their scope.

***Table III-1**: Projects by category (from analysis of Caltrans data)*

Project Category	Percent of Studies	Percent of Project Costs	Percent of Savings	Ratio of VE Savings to Project Costs
Bridge	16	16	19	0.42
Roadway	53	60	39	0.29
Roadside	21	14	14	0.40
Interchange	5	5	27	0.70
Other	5	5	1	0.11
Totals	*100*	*100*	*100*	*0.39*

Note that the number of projects in each category is roughly proportional to the project costs. The savings, however, are disproportional for roadway and interchange projects. The "ratio of VE savings to project costs" is a universally accepted monetary measure of the effectiveness of the VE studies, one suggested by the FHWA in the *Federal-Aid Policy Guide*. For example, bridge and roadside projects generated high savings relative to project costs. The one interchange project appears to have generated unusually high savings, but this is due to a drastic reduction of scope, as will be discussed later in this section.

Since ten of the sixteen projects involved a major roadway component, it is worthwhile to examine the subdivisions of the "roadway" category. Table III-2 is similar to Table III-1, except that it is based only on the ten roadway projects.

***Table III-2**: Roadway projects by subcategory (from analysis of Caltrans data)*

Roadway Project Category	Percent of Studies	Percent of Project Costs	Percent of Savings	Ratio of VE Savings to Project Costs
New Road	36	41	38	0.25
Repair	9	7	19	0.49
Realignment	18	12	36	0.52
Widening	27	30	6	0.07
Paving	9	9	1	0.05
Totals	*100*	*100*	*100*	*0.29*

Again, the number of projects in each category is roughly proportional to the project costs. The savings, however, are generally disproportional. Repair and realignment projects generated by far the highest savings-to-cost ratios.

The next question is, how were these savings attained? Which types of recommendations saved the most money? The author grouped recommendations into four broad categories, scope, design, right-of-way, and materials/methods. Scope changes (scope reduction) on 26 percent of the studies accounted for 58 percent of the savings. Although scope reduction is a valid result of VE, it differs from the other three categories in that no changes are recommended, simply the deletion of one or more components of the project. Right-of-way recommendations are changes in quantity or location of land acquired for the roadway right-of-way; materials/methods recommendations retain the same design but incorporate changes in construction materials or methods; and design recommendations include any design changes that do not fall into one of the other categories. Table III-3 shows the distribution of the studies and savings by category, excluding scope changes, to compare the cost-effectiveness of different types of recommendations.

Table III-3*: Recommendations by category (from analysis of Caltrans data)*

Recommendation Category	**Percent of Studies**	**Percent of Savings**
Design	50	80
Right-of-Way	21	9
Materials & Methods	29	11

The table illustrates that design changes are responsible for a disproportionately large percentage of non-scope-related savings. Further examination shows that 96 percent of the total savings from design changes was due to changes in alignment or to choosing to modify an existing structure rather than replacing it.

The analysis thus far has revealed which types of projects and which types of recommendations led to the highest savings for Caltrans. Probably the most interesting result of the data analysis, however, is a matrix illustrating the distribution of savings by project type and recommendation type, which appears in Table III-4.

Table III-4*: Data matrix (from analysis of Caltrans data) - Distribution of savings by Project Category and Recommendation Category*

	Recommendation Category			
Project Category	Scope	Design	Right-of-Way	Materials/Methods
Bridge	0%	100%	0%	0%
Roadway	19%	49%	7%	3%
Roadside	85%	0%	0%	15%
Interchange	100%	0%	0%	0%
Other	0%	0%	0%	100%

In all cases except the "other" category, which consisted of one ITS (Intelligent Transportation Systems) project, scope and design changes were responsible for the majority of the savings. Design changes were successful on bridge and roadway projects, and scope changes were primarily implemented on roadside and interchange projects. An analysis of this sort conducted on a larger scale would likely be invaluable in studying the results of VE in practice. However, this small sample (sixteen projects out of over 90 of similar size) illustrates the effectiveness of scope and design changes on "small" bridge, roadway, roadside, and interchange projects.[13]

[1] American Society of Civil Engineers (ASCE), 1984, pp. 38-40

[2] ASCE, 1984, p. 40

[3] ASCE, 1992, pp. 10-12

[4] ASCE, 1992, p. 12

[5] GangaRao *et al*, 1988, pp. 1962-77

[6] GangaRao *et al*, 1988, p. 1964

[7] GangaRao *et al*, 1988, p. 1969

[8] GangaRao *et al*, 1988, p. 1974

[9] GangaRao *et al*, 1988, p. 1975

[10] Basha and Gab-Allah, 1991, pp. 393-401

[11] Hunter and Tabor, 1981, pp. 45-47

[12] Caltrans VA database, 1999

[13] Charly Ludwig (of Caltrans), 1999, telephone interview

IV. Project Selection Criteria for VE Studies

The first step in conducting a VE study is selecting a project to study. As discussed in **Section III.2.0**, characteristics of a project such as type, cost, and complexity contribute to the savings that can be realized through VE. In order to narrow down the list of study candidates, a set of selection criteria should be established. This section of the report gives an overview of the selection process used by several states for VE studies in general and describes the criteria the author proposes for small transportation project studies in particular.

1.0 State DOT Criteria

1.1 Caltrans

Criteria for value analysis appear in the *Caltrans Project Development Procedures Manual (PDPM), Chapter 19*. Value analysis is considered for "any State transportation projects developed by Caltrans, local agencies, consultants, or private developers that are estimated to cost over $1,000,000," as well as for any "item or process with Statewide or District-wide implications." Projects are chosen for study from this pool of candidates based on their apparent VE potential and project manager requests. VE potential is evaluated based on past Caltrans VE experience.

1.2 NJDOT

NJDOT's criteria are also primarily cost-based. *VE Design Unit Procedures* indicates that "it is desirable to value engineer $5-$25 million projects." Other projects that are considered for VE analysis are "high VE potential projects" and others as requested by the Project Manager or the Scope Development unit. "High VE potential" is not defined, but seems to indicate complexity of the project, as measured by factors such as those shown in Table IV-1. The *Scope Development Procedures* indicate that "all projects with a construction cost estimate of $5 million or more", excluding "resurfacing, guiderail, pavement marker, signalization/intersection improvement, and bridge repair projects," should be considered for value engineering. This list is interesting, considering that many studies have been done on resurfacing and bridge repair projects in other states (see **Chapter III**). The following ranking system is used to determine the priority of project studies: "one point is awarded for each project characteristic [listed in Table IV-1] that applies. Most projects selected for a VE study have been awarded at least 7 points."

Table IV-1*: NJDOT Project Selection Criteria*

Roadway work over 25% of total project cost
Bridge work over 25% of total project cost
Right of way impacts over 10% of total project cost
New alignment of roadway
New alignment of bridge(s)
More than two construction stages
More than four construction stages
Night work construction required
Wetland mitigation
Hazardous waste cleanup
Utility cost over 10% total project cost
Total project cost over $10 million
Total project cost over $20 million
Total project cost over $50 million
Total project cost over $100 million

1.3 UDOT

According to UDOT's *Manual of Instruction: Value Engineering*, projects are selected at UDOT based on construction cost and overall complexity (higher-cost, more complicated projects are given higher priority). All projects over $2 million are considered for a VE study. A check list of indicators of VE potential, described as "areas or causes of high cost, which may indicate poor value," contains the following: complexity in design; advancement in the state-of-the-art; accelerated design (tight design schedule); a component or material that is critical, exotic, hard-to-get, or expensive; overly long material haul (excessive borrow, excessive waste); expensive construction traffic control; long foundation piles; excessive reinforcement; cofferdam de-watering; architectural embellishment; record-seeking design; large safety factors; curbs, gutters, and sidewalks (rural); specially designed components that appear to be similar to off-the-shelf items; non-standard fasteners, bearings, grades, or sizes; sole-source materials or equipment; highly-skilled or time-consuming labor; items with poor service or cost history; items with maintenance and field operation problems; project costs that exceed the budget; standard plans in use more than 3 or 4 years; and possible solutions or benefits in areas other than cost, such as noise, safety, maintainability, time, quality, energy use, reliability, fire protection, standardization, performance, weight, water quality, aesthetics, simplification, vibration, air quality, or employment rate. No point system is given by which to rate the projects, but projects with many high-cost indicators are given higher priority than those with only a few.

1.4 VDOT

VDOT reviews all projects with an estimated construction cost of over $2 million for VE potential, as well as conducting special studies requested by management. "VE potential" refers, as in other DOTs, to the complexity and cost of the project.

1.5 WSDOT

At WSDOT, projects are selected for study based on their size and/or complexity, described on their web page[1] as follows:

> In addition to the cost, other issues adding to the complexity of the project design should be considered in the selection process. These complexities may include: critical constraints, difficult technical issues, expensive solutions, external influences, or complicated functional requirements. The types of projects which usually provide the highest potential for value improvement are:
>
> - Projects with alternate solutions which vary the scope and cost
> - New alignment of by-pass sections
> - Widening existing highways for capacity improvements
> - Major structures
> - Interchanges on multi-lane facilities
> - Projects with extensive or expensive environmental or geotechnical requirements
> - Difficult materials requirements or inferior material sources
> - Major reconstruction of existing highways
> - Projects with major traffic control
> - Projects with multiple stages.

2.0 Analysis of Selection Criteria for Small Transportation Projects

2.1 Items Other Than Project Cost

Indicators of "high VE potential" are similar for transportation projects of all sizes. Besides project cost, the items in Table IV-2 are criteria suggested by the various state DOTs for selection of projects for VE study. These criteria have been grouped for easier evaluation.

***Table IV-2**: Suggested Project Selection Criteria*

Type of Criteria	Criteria
Cost	Roadway work over 25% of total project cost
	Bridge work over 25% of total project cost
	Right of way impacts over 10% of total project cost
	Utility cost over 10% total project cost
	Project costs that exceed the budget
Complexity	Major changes to existing structures, such as: new alignment of roadway, bridge(s), or by-pass sections; widening existing highways for capacity improvements; adding or altering interchanges on multi-lane facilities; or major reconstruction of existing highways
	Expensive solutions, such as: a component or material that is critical, exotic, hard-to-get, or expensive; overly long material haul (excessive borrow, excessive waste); long foundation piles; excessive reinforcement; cofferdam de-watering; architectural embellishment; curbs, gutters, and sidewalks (rural); non-standard items; sole-source materials or equipment; highly-skilled or time-consuming labor; or difficult materials requirements or inferior material sources.
	Accelerated design (tight design schedule)
	Expensive construction traffic control
	Multiple construction stages
	Night work construction required

Impacts	Statewide or districtwide impact
	Wetland mitigation
	Hazardous waste cleanup
	Extensive / expensive environmental or geotechnical requirements

Section III.2.0 of this report discussed the savings generated by VE on small transportation projects by Caltrans. That analysis revealed that bridge and roadside elements generally had a high ratio of VE savings to project costs compared to roadway and other project elements. Within the roadway category, repair and realignment projects had by far the highest savings-to-cost ratios. The analysis also showed that scope reduction and design changes accounted for the vast majority of VE savings. The selection criteria for small transportation projects were therefore modified to take this information into account.

In the "cost" category, two of the suggested criteria were retained, namely "bridge work over 25% of total project cost" and "project costs that exceed the budget." Based on the Caltrans data, "roadway repair and/or realignment over 50% of total project cost" and "roadside work over 25% of total project cost" were added. High right-of-way and utility costs did not appear to be sources of savings in the Caltrans studies, so they were not included. Also, since previous studies have repeatedly concluded that life-cycle costs are more significant than initial costs, another factor, "high estimated life cycle/maintenance costs," was added.

In the "complexity" category, the three construction-related items were combined into one criterion (multiple construction stages, night work construction, and/or expensive construction traffic control). Otherwise, the suggested criteria were adopted without modification. The criteria in the “impacts” category were also adopted with no changes.

The selection criteria for small transportation projects proposed by the author appears in Figure IV-1. Adopting the NJDOT's method of ranking projects, one point should be assigned to each criterion in the table, for a possible total of 13 points.

2.2 Project Cost

Projects evaluated by the five state DOTs discussed previously range from $1 million to $5 million minimums. A major concern is that the VE study be cost-effective, that is, that the savings-to-cost ratio be high enough to encourage future studies. Two elements of the savings-to-cost ratio must be analyzed further to estimate an appropriate minimum project cost, namely the cost of a VE study and the savings realized.

First, the cost of a study must be estimated. As a basis for comparison, the average cost per study during fiscal year 1998 for the five DOTs under consideration appears in Table IV-3. Of primary interest is the cost of studies performed on smaller projects. According to their database, VDOT has conducted 273 studies on projects estimated at $5 million or less, with an average cost of $4,348 per study.[2]

Table IV-3: *FY 1998 Study Costs*[3]

State	In-House Studies	Consultant Studies	In-House Cost ($)	Consultant Cost ($)	Average In-House Cost ($)	Average Consultant Cost ($)
CA	10	9	147,000	414,000	14,700	46,000
NJ	22	0	300,000	85,000	13,636	3,864
UT	1	6	53,000	191,000	53,000	31,833
VA	77	0	345,000	0	4,481	0
WA	10	4	104,000	86,000	10,400	21,500
Total	**120**	**19**	**949,000**	**776,000**	**96,217**	**103,197**

Obviously, the cost of a VE study can vary widely. Another way to estimate the cost is to break it down into components. Table IV-4 is based on a six-day study performed by four in-house staff and two VE consultants, similar to the format used by MassHighway and other DOTs.

Table IV-4: *Study Estimate*

Study Phase/Activity	In-house staff	Staff hours	Consultants	Consultant hours
Pre-study (1 day)	1	8	1	8
Team Study (4 days)	4	128	2	64
Presentation (1 day)	1	8	1	8
Total hours		**144**		**80**

The above calculations assume 8-hour days. At $40 per staff-hour and $100 per consultant-hour, the total study cost would be $13,760.

Based on all the preceding information, a conservative estimate for the cost of a VE study is $15,000. The next question is, what savings-to-cost ratio is desired for a VE study? For comparison purposes, see the following tables summarizing costs and savings on VE studies for the five DOTs. As Table IV-6 indicates, state DOTs have value engineered projects with an estimated cost as low as $1,000,000.

Table IV-5*: FY 1998 Costs and Savings of VE Studies*[2]

State	# of Studies	Cost of Studies	$ of Approved Proposals	Savings-to-Cost Ratio
California	19	$561,000	155,000,000	276
New Jersey	22	$385,000	60,540,000	157
Utah	7	$244,000	18,559,000	76
Virginia	77	$956,341	62,967,000	66
Washington	14	$190,000	37,312,000	196

Table IV-6*: Minimum Costs of Projects Studied by DOTs*

State	Minimum Cost of Projects Studied
California	$1 million
New Jersey	$5 million
Utah	$2 million
Virginia	$2 million
Washington	?

As an example, VDOT conducted 273 studies on projects under $5 million, for a total study cost of $1,187,089. These studies generated $40,768,190 in approved VE proposals, which represents a savings-to-cost ratio of 34. Although the savings-to-cost ratio does seem to drop as the project cost drops (compare a ratio of 34 to those in Table IV-5), a 34 still represents a rate of return of 3300%. For VDOT, the average value of accepted recommendations per small-project study was $149,323, or 3.7% of a $4 million project.[3] Admittedly, this does not take into account the added cost of redesigning components of the project as needed based on VE proposals. However, if the VE study takes place between preliminary and detailed design, the additional design costs should be limited. The estimated overall savings for Virginia is based on 196 approved recommendations out of 387 total proposed recommendations, or approximately 50% of recommendations being approved; for projects under $5 million, 30% of the proposed savings were accepted.

Using $15,000 as the study cost and assuming an average savings of 3.7% of the project cost, a $1 million project should yield $37,000 in approved recommendations, for a net savings of $22,000. A $10 million project should yield $370,000 in approved recommendations, for a net savings of $355,000. Therefore, it is reasonable to say that cost should be included with the other selection criteria. Any projects between $1 and $10 million should be considered, with priority going to those of higher cost and showing several characteristics of VE potential.

3.0 Summary of Selection Criteria

The proposed selection criteria for small transportation projects are summarized in a form in the *VE Workbook*, which appears in **Appendix C**. This form, “Selection Criteria,” is also reproduced in Figure IV-1.

***Figure IV-1**: Selection Criteria for Small Transportation Projects*

Criteria Satisfied?	Criteria Description	Comments
	Project cost (initial estimate) greater than $5 million	
	Project cost (initial estimate) exceeds the budget	
	Bridge work over 25% of total project cost	
	Roadway repair &/or realignment over 50% of total project cost	
	Roadside work over 25% of total project cost	
	Major changes to existing structures (new alignments, new interchanges, widening, major reconstruction)	
	Multiple construction stages, night work construction, &/or expensive construction traffic control	
	Expensive solutions (overly long material haul, non-standard items, difficult materials requirements, highly skilled labor, etc.)	
	Accelerated design (tight design schedule)	
	Statewide or districtwide impact	
	Wetland mitigation	
	Hazardous waste cleanup	
	Extensive environmental or geotechnical requirements	
	High estimated life cycle / maintenance costs	
	Total Criteria Points (14 maximum)	

[1] http://www.wsdot.state.wa.us

[2] Ron Garrett (of VDOT), 1999, e-mail

[3] FHWA, "FY 1998 Annual Federal-aid Value Engineering Summary Report"

V. VE STUDY PROCESS

The objective of this chapter is to examine the job plans and major tasks conducted by several state VE programs, discuss the elements of these programs selected as a foundation for small transportation project VE studies, and describe the resulting workbook developed for such VE studies. The criteria used to select elements for use were: (1) conformance with accepted VE practice and FHWA guidelines; (2) efficient use of personnel; and (3) ease of use, or limited training required.

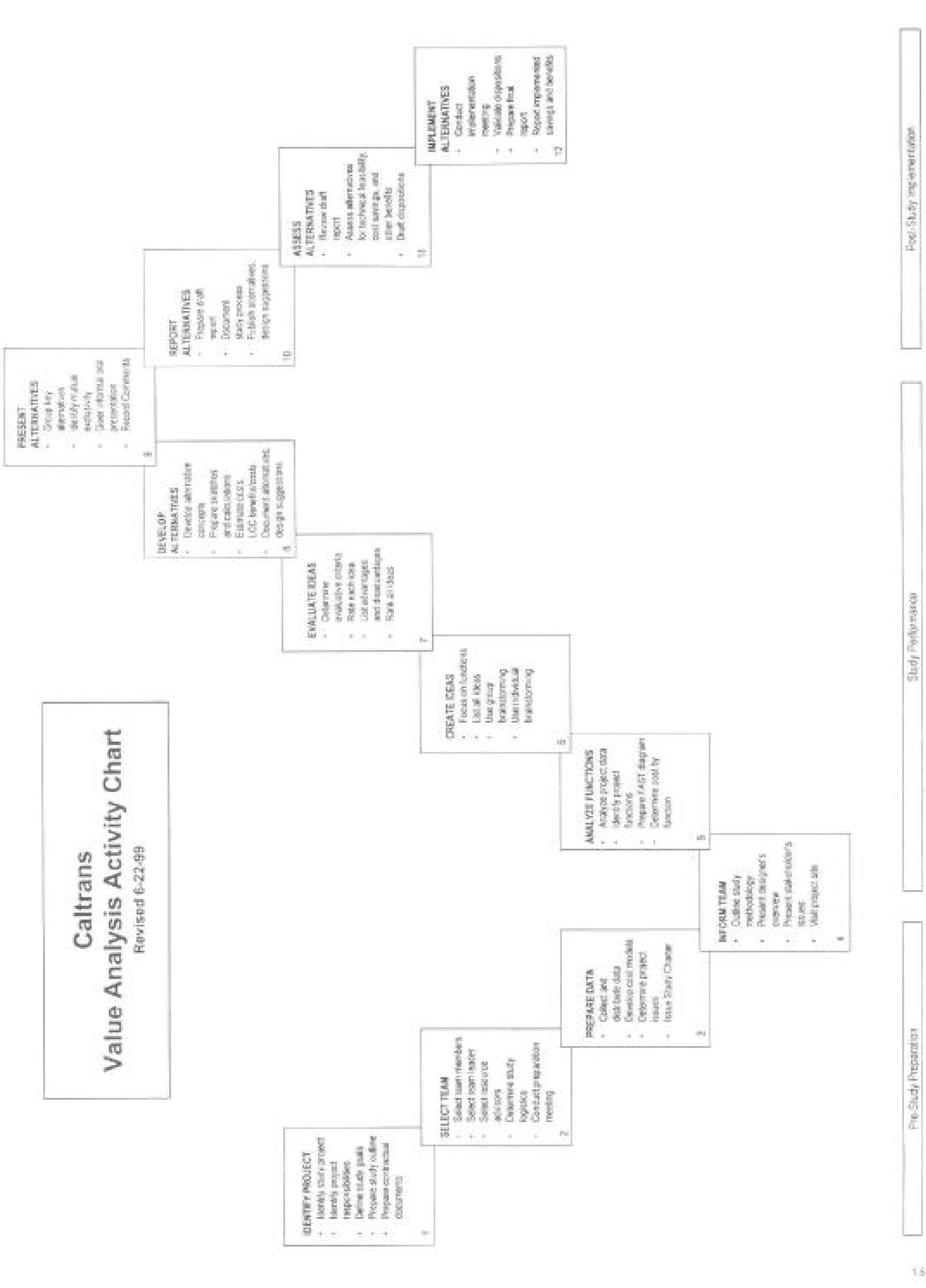
1.0 Overview of State DOT VE Procedures

The five state DOTs considered in this chapter are Caltrans (California), NJDOT (New Jersey), UDOT (Utah), VDOT (Virginia), and WSDOT (Washington State).

1.1 Caltrans

The Caltrans Value Analysis Activity Chart (Figure V-1) summarizes the tasks performed by the Caltrans VA (VE) Team. The *Value Analysis Team Guide* describes these tasks in more detail and provides examples and forms for training purposes.[1] The first three steps, "Identify project," "Select team," and "Prepare data," make up the pre-study preparation. A study identification form is filled out to summarize the project, and project briefings and site visits are conducted. From the project cost estimate, a cost model (cost summary) is prepared. Once all the data are gathered, summarized, and distributed to the VA team, the study can begin.

***Figure V-1**: Caltrans Value Analysis Activity Chart*



After presentations by the designer and stakeholders, the VA team members begin their study by conducting a function analysis, which leads to a FAST (Function Analysis System Technique) diagram. The FAST diagram illustrates relationships among the functions. They then merge the cost model and the FAST diagram to develop a "Cost/Function Analysis." The next step is a brainstorming session to create multiple alternatives. An "Evaluative Criteria Matrix" (see Figure V-3) is used to select the most important criteria for judging alternatives, and the team judges and ranks the alternatives. The highly ranked ideas are developed into "workable, alternative solutions," complete with sketches, calculations, benefits, and costs. Less highly ranked ideas are partially developed into single-page write-ups, or "design suggestions." Finally, the alternative solutions are summarized, compared via a weighted comparison matrix, and ranked. The study concludes with an oral presentation to the project stakeholders, and the various forms are incorporated into a study report.

1.2 NJDOT

NJDOT's *Value Engineering Unit Procedures Manual* gives an overview of the process followed by a NJDOT VE team.[2] After receiving a project and its background data, the team begins its study by investigating the project scope and objectives. Function analysis is used "to determine high cost items," and the team develops alternatives. To help team members generate ideas, the manual includes an outline of suggested areas of improvements, such as "simplify traffic control & staging" and "construct new parallel structure versus widening existing." In addition, all recommendations that include bridges are required to include a life cycle analysis.

A VE Proposal is prepared to discuss all recommendations, which are developed further with costs, cross sections, and other data. This proposal is submitted to the Project Manager, who is responsible for review and implementation of recommendations.

1.3 UDOT

UDOT's *Value Engineering Manual of Instruction* describes the UDOT VE process in detail. This process was taken from FHWA's *Value Engineering Textbook*, used for the National Highway Institute course, "Value Engineering for Highways." The VE Job Plan is illustrated in Figure V-2. The investigation, speculation, evaluation, development, and presentation phases make up what is generally termed the VE study.

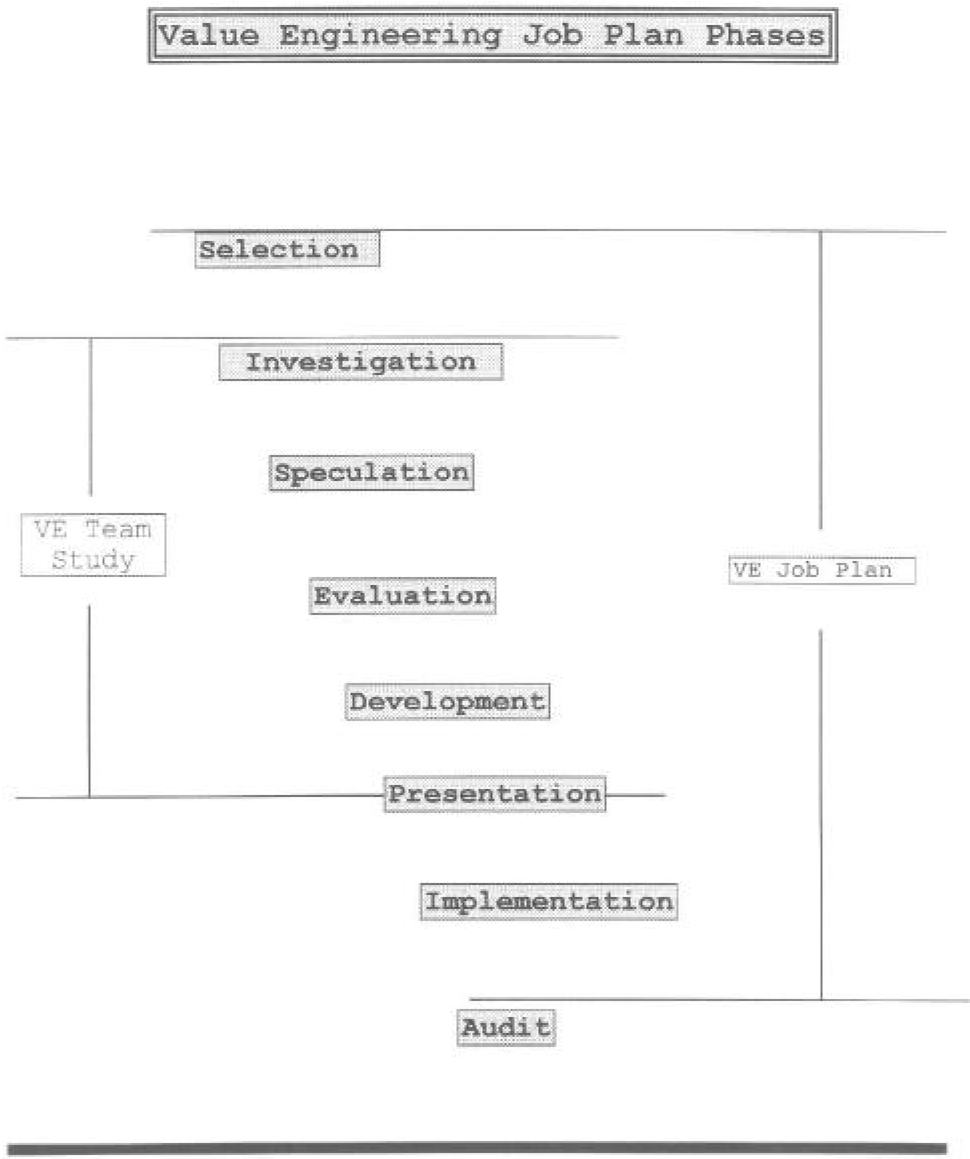
During the investigation phase, the VE team collects project information; determines the functions and their cost, worth, and value; and analyzes the project for potential areas of savings. The function analysis consists of defining and classifying functions and their relationships, identifying high-cost functions, and identifying areas of poor value. The team also considers life cycle costs in their choice of elements for further study.[3]

The speculation phase consists of selecting creative techniques and conducting creative sessions to generate alternatives.[4] In the evaluation phase, the team screens and evaluates these alternatives. Criteria and objectives are developed, and the alternatives are judged and ranked.[5]

The best alternatives continue on to the development phase, where they are developed into detailed design ideas. The team collects data to assess the technical and economic feasibility of the alternatives, and implementation plans are developed.[6]

Finally, the selected alternatives are presented to decision-makers in a written proposal and oral presentation.[7]

***Figure V-2**: UDOT VE Job Plan*



UDOT also has a *Value Engineering for Highways Study Workbook* that contains multiple forms and instructions for their use. These forms provide consistent documentation for the VE study.

1.4 VDOT

VDOT provided a blank study report and a report for project # 0275-007-102, P101, which was conducted April 14-16, 1999. These reports not only describe the recommended alternatives, but also document the VE process followed.

A standard Project Description form, accompanied by a location map, summarizes the project under study. The investigation phase includes aggregating the project cost data into several categories, producing a bar chart of the cost categories, and performing a function analysis. The function analysis, which can be performed on the project level, involves identifying functions and categorizing them as basic or secondary. The speculation phase consists of a brainstorming session that results in a list of creative ideas. The team evaluates and rates these ideas in the evaluation phase.

The development phase is the best documented. Each recommendation is described in more detail on a one-page form, including a brief discussion and cost/savings estimate. A sketch is also attached to the recommendation form, as well as any other backup data. The recommendations and potential savings are summarized in a table that is included in the report.

The presentation phase of the study appears to be quite simple. The VE study report consists of the study forms (transcribed) and an executive summary.

1.5 WSDOT

The WSDOT's Value Engineering web page at *http://www.wsdot.state.wa.us* describes their VE program. In the investigation phase, the team investigates project information, performs a function analysis, and develops study objectives. The speculation phase includes brainstorming alternative solutions, which are analyzed in the evaluation phase for technical feasibility, benefits, and life cycle costs. In the development phase, the team develops supporting data to prove technical and economic feasibility of the alternatives and recommends selected solutions. The presentation phase consists of an oral presentation, written report, and completed workbook.

2.0 Analysis of State DOT VE Procedures

2.1 Pre-Study Preparation

Preparation for a VE study does not need to be a team activity. The team leader can work with the project manager and other involved parties to obtain the necessary background information and documents for the study. The Caltrans process seems to be the best model for this phase. Although the District Coordinator and team leader carry out the pre-study activities for Caltrans, this author believes that the project manager should also be involved, since he or she has the most complete knowledge of the project and its issues. The project manager and team leader should define the study goals, collect data and documents, complete a project summary form, and develop a cost model similar to the one used by Caltrans. All these activities can be completed prior to the team VE workshop. Maximizing the work done outside the team environment will result in more efficient use of the team personnel. The final step in study preparation should be, as

Caltrans describes it, to inform the team. This includes presentations by the designer and project manager giving an overview of the project, design, and issues, as well as a site visit if practical.

2.2 Investigation Phase

The investigation phase differs widely among the state programs, from Caltrans and UDOT's heavily function-oriented approach to VDOT's perfunctory inclusion of function analysis. Although it is tempting to cut down on the work involved in function analysis, SAVE points out that "function definition and analysis is the heart of the Value Methodology."[8] When trimming the process for greater efficiency, the "heart" should be left as intact as possible. Therefore, the methodology for small transportation project VE studies will remain function-oriented. The analysis should include identification and classification of functions as well as determination of their cost and worth.

2.3 Speculation & Evaluation Phases

The speculation phase is consistent among the five programs. All of them include a team brainstorming session to generate ideas. NJDOT's guidelines and UDOT's creative techniques may be helpful for stimulating ideas, so they should be included in the study process documentation.

Although the details of the evaluation phase differ among states, the basic tasks are the same. Criteria must first be developed for judging the alternatives, and then the alternatives are judged. A combination of the weighted criteria matrix and the simple multiple criteria ranking (see Figures V-3 and V-4) would be helpful for presentation purposes, so both should be included. In any case, ranking alternatives by each criterion separately is a necessary step before ranking them by a weighted combination. The author also suggests adding a standard list of criteria that should be considered in all studies, including FHWA's criteria of reliability, life-cycle cost, safety, quality, and environmental impact.[9]

Figure V-3*: Weighted Criteria Matrix*

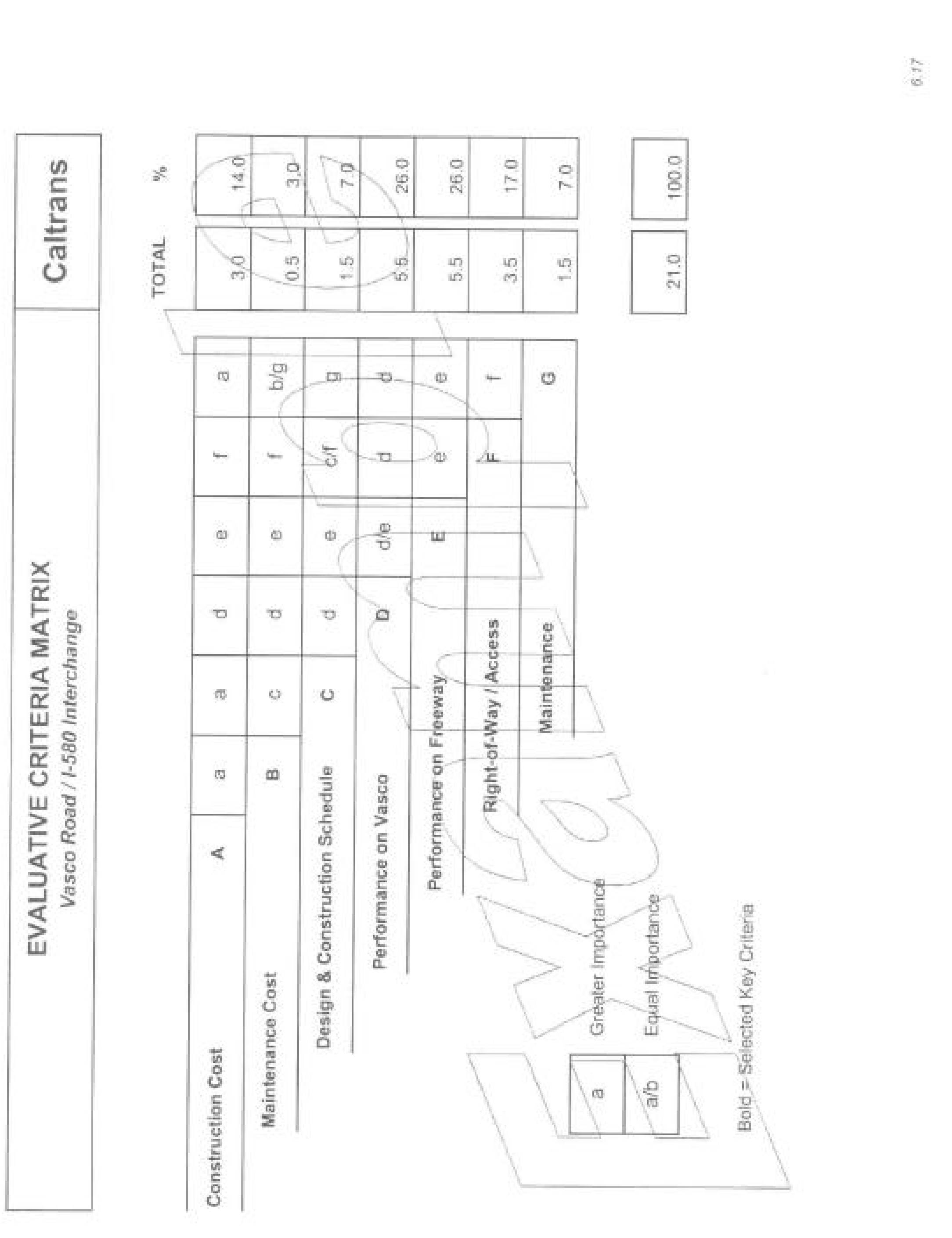


***Figure V-4**: Multiple Criteria Ranking*

CREATIVE IDEAS EVALUATION
Vasco Road / I-580 Interchange

Caltrans

Function: ACCOMMODATE BART

		IDEA EVALUATION						
		Criteria						
No.	Creative Idea	S	V	F	R	Advantages	Disadvantages	Rank
AB-1	Utilize existing structure by widening	+2	+1	0	0	• Improves sight distance • Saves cost • Reduces staging • Improves Vasco performance	• Limits room for BART	8
AB-2	Move columns to accommodate BART	-2	0	0	0	• Retains existing bridge/structure	• Benefits questionable • Increases cost	4
AB-3	Use steel girders in lieu of prestressed box	-2	0	0	0	• Requires less falsework • Helps constructibility	• Needs deeper structural section • Increases cost	4
AB-4	Lengthen existing bridge	+1	-1	0	0	• Reduces cost • Reduces demolition	• Does not improve Vasco performance	7
AB-5	Reduce BART median width	+1	0	0	+1	• Reduces right-of-way take • Reduces cost	• BART approval needed • May delay schedule	8
AB-6	Build new bridge at the same elevation as the existing bridge	0	0	-2	0	• None apparent	• Vertical clearance not increased	2
AB-7	Realign BART to north of I-580 west of Vasco interchange	+2	0	0	+2	• Reduces cost	• BART pays later for right-of-way	6

2.4 Development Phase

In the development phase, the VDOT process is markedly different from that used by the other states. The others seem to put much time and effort into developing the selected alternatives before presenting them to the decision-makers, while VDOT produces a one-page write-up, preliminary estimate of savings, and sketch. Looking at any of the annual reports or summaries of these programs, such as FHWA's fiscal year summaries, one can readily see that the ratio of implemented savings to proposed savings is generally rather low. Highway projects tend to be surrounded by local issues, political pressures, and funding constraints that lead to the discarding of many otherwise promising alternatives. There are two major benefits to VDOT's handling of this phase. First, the team can propose several partially developed alternatives rather than a few fully developed alternatives, which increases potential savings. Second, little personnel time (and therefore DOT money) is wasted on developing alternatives that will be discarded for other than technical reasons. After decision-makers review the VE proposal, either team members or designers can develop any approved alternatives and plan their implementation.

2.5 Presentation Phase

VDOT's presentation phase is also quite efficient, making it the most practical for small projects. Rather than write a report after the study is completed, the forms completed during the study are transcribed, and only an executive summary is written. The forms are designed to be understandable to the untrained reader. An oral presentation to all the stakeholders is also a good idea, although the proposals should first be reviewed by the project manager.

3.0 Development of VE Job Plan for Small Transportation Projects

The following outline is the Job Plan, from Pre-Study to Presentation, proposed for Small Transportation Projects.

I. Pre-study

A. Collect data and documents

B. Define study goals

C. Complete project summary form

D. Prepare cost model

E. Select team

II. Investigation Phase (function analysis)

A. Present project to team – briefings, site visit

B. Identify and classify functions

C. Determine cost and worth of functions

D. Identify opportunities for value improvement

III. Speculation Phase (brainstorming)

A. Generate alternatives

B. Consider areas identified in guidelines

IV. Evaluation Phase

A. Develop criteria for judging ideas (including standard criteria)

B. Develop a weighted criteria matrix

C. Evaluate ideas by each criterion separately

D. Evaluate ideas by criteria matrix

E. Select ideas for development

V. Development Phase

A. Produce one-page (maximum) description of alternative

B. Produce sketch and/or backup data for alternative

C. Produce preliminary estimate of savings, life-cycle costs

D. Summarize proposed alternatives in a table

VI. Presentation Phase

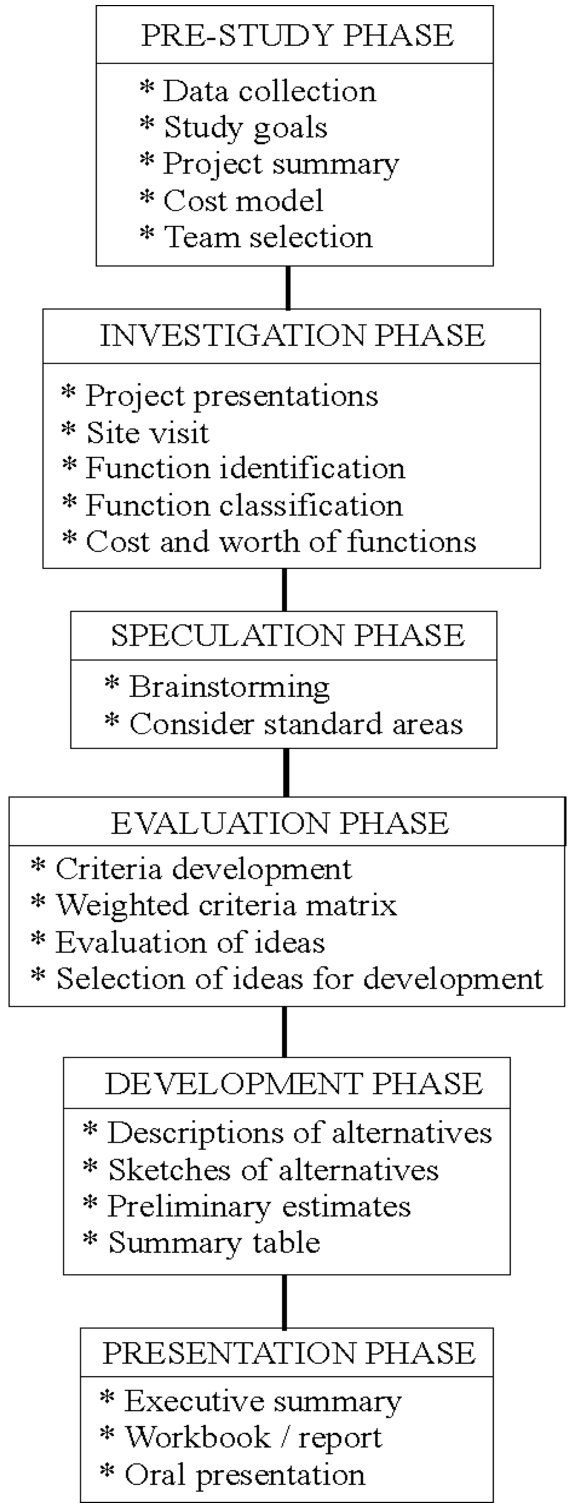
A. Write executive summary for study report

B. Transcribe forms and put together final workbook

C. After proposal review, give oral presentation to stakeholders

Figure V-5 also illustrates the Job Plan.

Figure V-5*: Proposed Job Plan for Small Transportation Project VE Studies*



4.0 Development of VE Workbook for Small Transportation Projects

The *VE Workbook for Small Transportation Projects*, which appears in **Appendix C**, contains fifteen forms for use in conducting a VE study. These forms are based on those used by the California, Virginia, and Utah DOTs (see **Section V.4.1**). The purpose of the forms is to provide guidance for VE analysis in a format that is easy to understand and use. A hard copy of the blank workbook forms has been produced, as well as a Microsoft Excel file that is user-friendly for data entry.

4.1 Workbook Forms

The following forms, with instructions for completing each form, are included in the *VE Workbook for Small Transportation Projects*:

Pre-Study Phase:

- "Approval Authority / Information Sources" lists authorizing persons, data sources, and VE team members.
- "Study Identification and Summary" includes a project description, major project elements, route conditions and other relevant projects, study dates, and study goals.
- "Cost Model" contains the cost estimate, a Pareto analysis, and chart of costs.

Investigation Phase:

- "Team Member Notes" provide spaces for notes about the project presentations and site visit.
- "Function Analysis" is used for function identification, classification, and determination of cost and worth.

- “Cost/Function Analysis” is used to analyze the relative cost and worth of each function.

Speculation Phase:

- “Speculation Phase (Brainstorming)” provides space to list ideas generated during brainstorming sessions.

Evaluation Phase:

- “Evaluative Criteria and Matrix” contains the evaluative criteria chosen for the study, a criteria matrix for analyzing the relative importance of each criterion, and any comments or discussion of the criteria.
- “Evaluation” is completed for each function. Ideas are listed and judged by each criterion individually, and the weighted criteria matrix is used to calculate a score for each idea. Advantages and disadvantages are also summarized.

Development Phase: (one set for each recommendation that is to be developed)

- “Benefits” describes the advantages and disadvantages of the recommendation, in terms of each of the evaluative criteria.
- “Sketches” provides space for sketches.
- “Estimate” is used to estimate initial savings of the proposed design.
- “LCC Cost” is used to estimate differences in life cycle costs between the original and proposed designs.
- “Summary” includes a description of the original design and the proposed design, along with a brief discussion and cost summary.

Presentation Phase:

- "Proposal Summary" summarizes all the recommendations and their estimated savings.
- Instructions are included for writing the Executive Summary.

The state DOT forms that were used as a basis for this workbook appear in **Appendix B**.

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[1] Caltrans, *Value Analysis Team Guide*, 1999, pp. 7-51

[2] NJDOT, *Value Engineering Unit Procedures Manual*, 1997, Section V.a.

[3] UDOT, *Value Engineering Manual of Instruction*, pp. 38-39

[4] UDOT, *Value Engineering Manual of Instruction*, p. 60

[5] UDOT, *Value Engineering Manual of Instruction*, p. 66

[6] UDOT, *Value Engineering Manual of Instruction*, p. 76

[7] UDOT, *Value Engineering Manual of Instruction*, p. 77

[8] SAVE, 1997, p. 5

[9] *FHWA VE Regulation* Section 627.1

VI. Implementation & Audit Phases

After the presentation of the VE results is complete, more work is necessary behind the scenes. This section of the report discusses the Implementation and Audit phases as practiced in several DOTs and how they can be incorporated into a small transportation project VE study.

1.0 State DOT Practices

The Implementation Phase consists of the review of VE proposals, their approval or rejection, and their incorporation into the project. In the Audit Phase, information about the study is recorded for tracking and statistical analysis. The activities in these phases are similar among DOTs, but their documentation varies.

1.1 Caltrans

The Caltrans *Value Analysis Report Guide* describes the documentation of the implementation process. A draft version of the Value Analysis study results is submitted to the Caltrans Project Development Team (PDT) and other stakeholders, who are asked to individually "record their assessment of each alternative" using a "VA Alternative Implementation" form (see Figure VI-1). The stakeholders then meet with the District VA Coordinator and the VA Team Leader to reach a consensus on the "disposition" (approval, conditional approval, or rejection) of each alternative. The results of this meeting are summarized in a "Summary of VA Alternatives" form (see Figure VI-2). The information from the Implementation Phase documentation is stored in the VA database for future use and reporting, such as the VA Annual Report.

Figure VI-1: *Caltrans VA Alternative Implementation form*

VA ALTERNATIVE IMPLEMENTATION DRAFT ***Benicia-Martinez Bridge Approaches***	**Caltrans**
Title: Reduce Levels in North Interchange	**Alt. Number:** CBN-5
STAKEHOLDER RESPONSES	**DISPOSITION**
Technical Feasibility: *Indicate how the technical feasibility of the VA alternative was evaluated*	☐ **Accept** ☐ **Conditionally Accept** ☐ **Reject**
Implementable Portions: *Identify which portions of the VA alternative can be implemented, and which require further study*	**Implemented Savings:**
Validated Cost Savings: *Describe how the estimated cost savings of the VA alternative were verified*	**Stakeholders:** **Project Development Team:**
Schedule Impact: *Give significant schedule impacts of the VA alternative*	**VA Coordinator:** **VA Team Leader:**
Safety Impact: *Reduction in accident rates*	**VA Team Members:**
Traffic Operations Impact: *Improvement in level of service*	**Other:**
Issue Resolution: *What different issues were resolved*	
Stakeholder/Partner Consensus: *How stakeholder/partner consensus was enhanced*	**Prepared by:**
Other Benefits: *Any other non-financial benefits*	**Date:**

Example

Value Analysis Report Guide
Revised 06/23/99 4.11

Figure VI-2: *Caltrans Summary of VA Alternatives form*

SUMMARY OF VA ALTERNATIVES

Benicia-Martinez Bridge Approaches

FINAL

TVI International

Alternative Number	Name	Potential Savings*	Implemented Savings*	Disposition	Comments
	CONNECT BRIDGE SOUTH				
4.0	Realign New Mococo Overhang Bridge to East	$4,152,000	$4,152,000	A	Implemented for $4,152,000 savings. Environmental mitigation of sensitive habitat required. Staging simplified to avoid overlap of bridge structures.
5.0	Move Toll Plaza on South Side Slightly North	$2,556,000	(LCC)	ca	Requires environmental review prior to acceptance.
6.0	Extend Mococo Bridge South to Eliminate Polystyrene Fill	$163,000		R	Extending the bridge would cost more and delay the project. The fill was part of the design.
7.0	MSE Wall at South Approach	$4,304,000		R	Right-of-way already purchased and MSE not appropriate wall type for 60-foot high walls; requires pile foundation.
	IMPROVE ACCESS				
8.0	Northbound 780 to Existing Bridge; Bike Path to North Bridge	$17,141,000		R	This will delay the entire project for a few years.
	COLLECT TOLLS				
9.0	Relocate Toll Plaza to North Side of New Bridge	$3,995,000		R	Not feasible – was looked at before.

*All savings are initial cost savings only, unless noted as LCC savings.

A = Accepted **CA = Conditionally Accepted** **R = Rejected** *4.7*

1.2 NJDOT

After the VE Proposals are submitted to the NJDOT Project Manager, a memo is also submitted that describes the recommendations and cost savings and provides an area for the Project Manager to accept, reject, or conditionally accept each recommendation. Either the Project Manager or the VE Unit documents the approval of recommendations via a memo in the project file.

NJDOT tracks projects with quarterly and yearly reports. The quarterly report includes project name, status, project manager, VE personnel, and VE status; the yearly report follows the FHWA VE Year End Report format (including number of studies, their costs, number of proposals, number of approved proposals, and savings) and also includes summary sheets of all VE proposals.

1.3 UDOT

The UDOT *Value Engineering Manual* points out that the implementation phase includes three steps: "(A) Develop an implementation plan, (B) execute the plan, and (C) monitor the plan to completion." It also notes that :

> The fastest way to achieve implementation of a idea is to effectively utilize the knowledge gained by those who originated it. Whenever possible, the VE team should be required to prepare initial drafts of documents necessary to revise handbooks, specifications, change orders, drawings and contract requirements. Such drafts will help to assure proper translation of the idea into action, and will serve as a baseline from which to monitor progress.

Implementation may include amending contracts, revising specifications and/or drawings, revising the project estimate and schedule, and allocating resources to make recommended changes.

The Audit Phase includes the following activities:

1. Obtain copies of all completed implementation actions.
2. Compare actual results with original expectations to verify the accomplishment.
3. Submit reports on cost savings or other improvements to management.
4. Distribute information to all interested parties and other highway agencies.
5. Review the project to identify any problems that arose, and recommend corrective action for the next project.
6. Initiate recommendations for potential VE study ideas identified during the study just completed.
7. Screen all contributors to the VE study for possible recognition, and initiate recommendations to management.
8. Determine the effect on maintenance and other life cycle costs.

1.4 VDOT

Information about VDOT’s implementation and audit phases was not available at the time of this report.

1.5 WSDOT

Recommendations from the WSDOT VE Team are evaluated by “the appropriate managers of the Department.” An implementation plan is then prepared, including the approval and comments of the managers and a schedule for implementing the recommendations. The Audit Phase consists of establishing a record system and compiling statistics as requested by management.

2.0 Implementation & Auditing for Small Transportation Projects

Three forms have been included in the *VE Workbook* for the Implementation and Audit Phases. The implementation forms are based closely on the Caltrans forms. “Review by Stakeholders” provides space for stakeholders' comments and approval, and “Summary of Approved Recommendations” is a table of recommendations, their approval status, and estimated and implemented savings. The auditing form, “Tracking Data,” is simply a listing of data that may be included in a VE study results database. These forms will be useful in developing review procedures and a VE database.

VII. Conclusions & Recommendations

1.0 Summary of Report

Many DOTs could benefit from an efficient, easy-to-follow process for conducting a VE study on transportation projects. In particular, there appears to be limited use of VE on small projects, probably due in part to the feeling that VE requires a large investment of resources. The goal of this thesis work was to develop a methodology for conducting VE studies on small transportation projects that is characterized by conformance with accepted VE practice and FHWA guidelines for mandated studies, efficient use of personnel, and ease of use. Specific objectives included (1) researching and analyzing recent and current use of VE on transportation-related projects, (2) developing project selection criteria, (3) proposing a VE study methodology, and (4) addressing the implementation and audit phases of the VE study. Each of these objectives were met and documented in this report. The resulting workbook (see **Appendix C**) contains a proposed methodology that covers the entire VE process, from project selection to auditing of the completed project.

The level of fulfillment of the overall goal can only be measured by actual testing of the workbook/methodology. Since that testing had not yet occurred at the time of this report, the success of the work remains to be assessed, and constructive feedback is welcomed.

2.0 Application of Thesis

This thesis focused on small transportation projects, which include non-transit transportation facilities with an estimated cost of under $10 million. The "VE Workbook for Small Transportation Projects" may be used for studies on any size projects, but it is specifically designed for smaller projects, where the cost of a study needs to be kept to a minimum. A number of projects should fit the cost criteria ($1-$10 million) and go through the selection process each year, yielding multiple studies. For example, Table VII-1 shows projects that appeared in the *1997 Regional Transportation Plan* for the Montachusett Region of Massachusetts (one of thirteen regions in the state). Notice that most of the projects listed in the table are bridge projects or pavement reconstruction/resurfacing. VE studies of both categories of projects have yielded savings in the past, as discussed in **Chapter III**, and it is likely that these would be good candidates for studies. Bridge projects, in particular, are good sources of VE savings because of their complexity.

***Table VII-1**: Montachusett Region Planned Projects*[1]

Community	Project	Funding Category	Cost ($)	FY
Templeton	Rt 202 - Resurfacing & related work	Non-Federal Aid	3,000,000	97
Templeton	Petersham Rd (Rt 101) - Resurfacing & related work	Non-Federal Aid	1,500,000	97
Sterling/ Westminster	Redemption Rock Tr/Worcester Rd (Rt 140) - Resurfacing & related work	Non-Federal Aid	1,500,000	97
Gardner/ Westminster	East Broadway/State Rd West (Rt 2A) - Resurfacing & related work	Non-Federal Aid	1,178,463	97
Royalston	Rt 68 - Bridge #R-12-15 over Millers River	Bridge	1,161,000	97
Ayer/Groton	Ayer/Dunstable Rail Trail - Construction of trail	Enhancement	1,000,000	97
Fitchburg	Fifth St - Bridge #F-04-19 over B&M Railroad	Bridge	6,000,000	98
Athol	Main St (Rt 2A) - Bridge #A-15-06 over Millers River	Bridge	2,000,000	98
Leominster	Mechanic St - Bridge #L-08-03 over North Nashua River	Bridge	1,300,000	98
Winchendon	Glenallen St (Rt 202) - Resurfacing & related work	Non-Federal Aid	1,200,000	98
Athol	Chestnut Hill Ave (Rt 32) - Bridge #A-15-09 over Millers River	Non-Federal Aid	1,000,000	98
Fitchburg/ Leominster/ Westminster	Rt 2 - Reconstruction	Natl Highway System	9,600,000	99
Lancaster	Harvard St at Rt 2 - Interchange & full depth reconstruction	Natl Highway System	4,800,000	99

3.0 General Recommendations

Some general points should be kept in mind when applying the process described in this report and the accompanying workbook. This information also appears in the "Introduction" section of the workbook.

3.1 The VE Team and Project Manager

One of the FHWA criteria for VE studies is a multidisciplinary team that is otherwise not involved with the project.[2] For consistency, this requirement should also be applied to studies of small projects. The VE team should consist of four to six members, including one trained leader and representatives of several disciplines. For most studies, traffic, environmental, and design engineers should be included. Team members must not be otherwise involved with the project design.

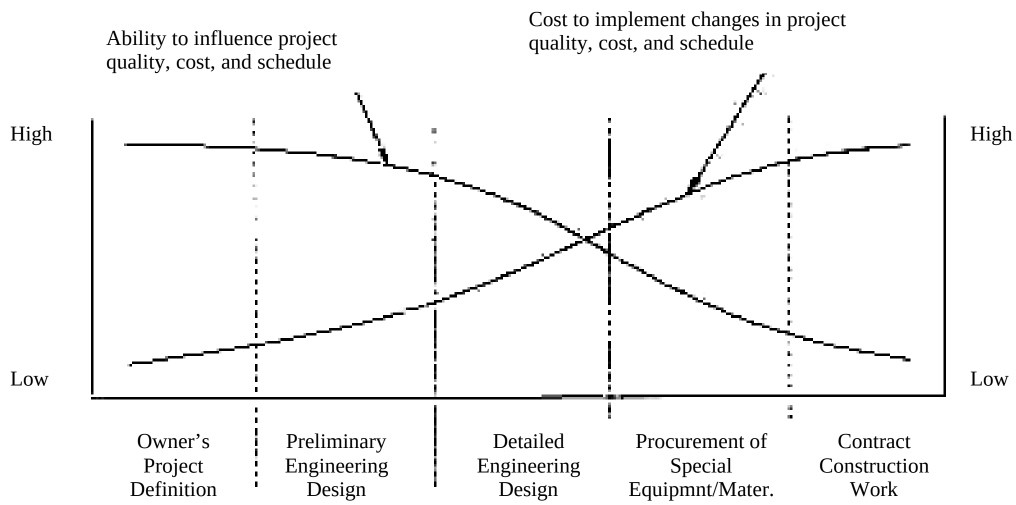
The project manager has a number of responsibilities in the VE study. He/she initiates the study, provides necessary information and documentation, and arranges for project briefings and site visits. After the study, the project manager also reviews proposals, approves them for further investigation, and is responsible for implementing them and tracking their impacts.

3.2 Timing and Schedule

After a preliminary estimate has been developed by the designer, a project should be evaluated for VE potential in accordance with the selection criteria. If the project ranks high in VE potential, a study should be scheduled to start after completion of the preliminary design. The pre-study phase may take place before preliminary design is complete. The earlier in the process the study takes place, the higher the savings that are generally realized. This is consistent with the classic “influence curve,” shown in Figure VII-1, which illustrates the importance of making project changes during the early phases of a project.

The team portion of the study should take no longer than five days, including one day for a site visit and project briefings. Investigation, Speculation, Evaluation, and Development phases should generally occupy one-half to one day each.

Figure VII-1*: The Influence Curve*[3]



3.3 Additional Recommendations

The management of a state DOT needs to provide general policies that encourage VE studies and implementation of proposals. In addition to the VE study procedures (represented by the *VE Workbook*), some other procedures must be established. Review and approval procedures are needed; these will be determined by the individual agency, but should be as efficient as possible to encourage inclusion of VE studies in projects.

The forms in the *Workbook* will be useful in carrying out these procedures. After approval of selected proposals, one or more team members may be consulted for assistance in a more detailed design or presentation.

Tracking is also vital to the success of the VE program. Adequate data must be collected during the implementation of proposals, such as proposals approved, proposals implemented, estimated costs and savings, and actual costs and savings. Again, the form provided in the *Workbook* will be helpful in recording the data, which should be kept in a database for use in reports and future studies.

4.0 Suggestions for Future Study

During the course of this thesis work, the author noticed several topics that seem worthy of future study.

- VE by contractors, or VECPs (Value Engineering Change Proposals): This thesis focused solely on VE during the design process, which is, in the opinion of the FHWA and this author, the most effective time to use these techniques. However, many states allow and encourage VECPs instead of or in addition to a formal VE study. Future research could examine how VECPs should be incorporated into small transportation projects.
- Implementation of VE recommendations: As discussed in **Section II.3.0**, potential savings are not valuable unless they are implemented. Most published articles and VE databases highlight only the successes rather than the rejected alternatives. Research into the factors that encourage and discourage the adoption of VE

recommendations would be useful to agencies attempting to establish or improve their VE programs.

- Larger-scale database analysis: Unfortunately, it is rare to find a truly thorough VE database among state DOTs, partly because the FHWA and the DOTs themselves are most interested in overall statistics. However, as **Section III.2.0** illustrates, an in-depth analysis of projects and recommendations can be revealing, since it highlights the effectiveness (from a cost standpoint) of studies of various types of projects. Such information can be used in making decisions about which projects to study and in comparing individual studies. Thus, research in this area could be quite valuable.

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[1] Montachusett Regional Planning Commission (MRPC), 1997, pp. 180-182

[2] FHWA, *Federal-Aid Policy Guide*, Par. 5

[3] Oberlender, 1993, p. 21

References

Allen, Deborah Longhi. *Value Engineering Study of Guardrail and Impact Attenuator Repair*. Publication No. FHWA-TS-87-226. FHWA: Washington, DC, 1987.

American Association of State Highway and Transportation Officials (AASHTO). *AASHTO Guidelines For Establishing and Maintaining a Value Engineering Program*. Draft version, March 1999.

Anderson, Steven (UDOT). E-mail interview. 2 June 1999.

American Society of Civil Engineers (ASCE). "Steel Girder Bridge Sets Record Length." *Civil Engineering* Vol. 54, No.5, May 1984: 38-40.

---. News item: "Deck Modules Speed Work, Cut Bridge Rehab Cost." *Civil Engineering* Vol. 62, No.5, May 1992: 10-12.

Basha, Ismail M. and Ahmed A. Gab-Allah. "Value Engineering in Egyptian Bridge Construction." *Journal of Construction Engineering and Management* Vol. 117, No. 3 (1991): 393-401.

Blais, Ernest J. *Value Engineering Study of Crack and Joint Sealing*. Publication No. FHWA-TS-84-221. FHWA: Washington, DC, 1984.

Carter, Jimmie and J. Jerry Kaufman. *Value Engineering Study of Bridge Deck Maintenance, Repair, and Protection*. Publication No. FHWA-TS-90-041. FHWA: Washington, DC, 1990.

Dell'Isola, Alphonse. *Value Engineering: Practical Applications*. R.S. Means Company, Inc: Kingston, MA, 1997.

Federal Highway Administration (FHWA), USDOT. "FY 1998 Annual Federal-aid Value Engineering Summary Report."

---. *Federal-Aid Policy Guide*. 1998.

---. *FHWA VE Regulation*. 23 CFR Part 627, "Value Engineering."

---. *Value Engineering Textbook*. NHI Course No. 13405, *Value Engineering for Highways*. Publication No. FHWA-HI-88-047. FHWA: Washington, DC, 1996.

GangaRao, Hota V.S., Richard Ward, and Victor Howser. "Value Engineering Approach to Low-Volume Road Bridge Selection." *Journal of Structural Engineering* Vol. 114, No. 9 (1988): 1962-77.

Garrett, Ron (VDOT). Email. 24 Aug 1999.

Hudson, James W. *Value Engineering Study of Curbs and Drainage*. Publication No. FHWA-TS-90-040. FHWA: Washington, DC, 1990.

Hunter, E.S. and Vincent J. Tabor. "Value Engineering Cuts Highway Costs." *Civil Engineering* Vol. 51, No. 10, Oct. 1981: 45-47.

Ingerman, H.L. *et al*. *Value Engineering Study of Traffic Striping*. Publication No. FHWA-TS-79-219. FHWA: Washington, DC, 1979.

Ludwig, Charly (Caltrans). Telephone interview. 23 Aug 1999.

McLaughlin, Steve (MassHighway). Telephone interview. 14 July 1999.

Montachusett Regional Planning Commission. *1997 Regional Transportation Plan*.

New Jersey Department of Transportation (NJDOT) Bureau of Quality Management Services. *Value Engineering Unit Procedures Manual*. August, 1997.

Oberlender, Garold D. *Project Management for Engineering and Construction*. McGraw-Hill, Inc.: New York, 1993.

Office of Management and Budget (OMB), Executive Office of the President. Circular No. A-131. Washington, DC, 1993.

Powell, Dana R. *et al*. *Value Engineering Study of Highway Shoulder Maintenance*. Publication No. FHWA-TS-77-210. FHWA: Washington, DC, 1977.

SAVE International. *Value Methodology Standard*. SAVE International: 1997.

State of California Department of Transportation (Caltrans) and TVI International. *Value Analysis Team Guide*. June, 1999.

State of California Department of Transportation (Caltrans). *Value Analysis Annual Report, FY 1997/1998.*

United States Department of Transportation (USDOT). Order No. DOT 1395.1A. 1992.

Utah Department of Transportation (UDOT) Engineering Services. *Value Engineering Manual of Instruction*.

Utah Department of Transportation (UDOT). *Value Engineering for Highways Study Workbook.* December, 1992.

Virginia Department of Transportation (VDOT). *VE Annual Report, FY 97/98*.

---. *VE Virginia*. Commonwealth of Virginia: Richmond, VA, 1997.

---. *Value Engineering for the Virginia Department of Transportation Study Report*. Project # 0275-007-102, P101. April, 1999.

Washington State Department of Transportation (WSDOT). "Value Engineering in the Washington State Department of Transportation." www.wsdot.state.wa.us. June, 1999.

APPENDIX A: CALTRANS VE STUDY DATA

This section contains more detail about the Caltrans VE studies discussed in **Section III.2.0**, including information about the projects and recommendations from Caltrans data and several analysis/summary tables generated by the author.

Project Name	Project Cost (after VE)	Type of Project	Other Type of Project	Project Category	Project Category 2
Failed Brow Log	$2,500,000	Roadway Repair	Drainage	Roadway	Roadside
West Bank Road	$786,000	New Road		Roadway	
Rush Creek Bridge Rehab	$1,406,000	Bridge Rehab		Bridge	
South Bonnyview	$2,727,000	Interchange		Interchange	
Miller's Curve	$4,077,000	New Road	?	Roadway	
State Route 70 Spring Garden Overhead	$2,553,000	Bridge Rehab	Roadway Realignment	Bridge	Roadway
Shasta Drainage	$300,000	Drainage		Roadside	
Pink House Curve	$5,669,000	New Road		Roadway	
Crystal Creek Curves	$3,720,000	New Road		Roadway	
Noise Abatement Walls, Sheldon Rd to Calvine Rd	$919,000	Noise Abatement		Roadside	
Kings Beach, stab slopes	$3,390,000	Slopes		Roadside	
Wdn Rdwy & L Trn Chan	$3,072,000	Roadway Widening	Paving	Roadway	
AC Overlay, Widen to 40' and...	$4,625,000	Roadway Widening	Bridge	Roadway	Bridge
Fiberoptics Communication	$2,560,000	ITS		Other	
SR-78 and Ash Street	$1,687,000	Roadway Realignment		Roadway	
Passing lane on SR 94 east of Jamul	$2,649,000	Roadway Widening		Roadway	

Project Name	Date of Study Completion	Type of Recommendation	Recommendation Category	Cost Savings

Failed Brow Log	5/25/94	Change in scope	Scope	$2,400,000
West Bank Road	5/10/94	Change in alignment	Design	$95,000
Rush Creek Bridge Rehab	7/28/97	Modify existing structure	Design	$1,533,000
South Bonnyview	12/11/92	Construct in stages	Scope	$8,800,000
Miller's Curve	6/3/93	Unknown	Unknown	$2,800,000
State Route 70 Spring Garden Overhead	3/27/97	Change in alignment	Design	$4,207,000
Shasta Drainage	12/8/93	Change in scope	Scope	$1,254,000
Pink House Curve	9/24/92	Change in alignment	Design	$1,600,000
Crystal Creek Curves	3/23/88	Change in method	Materials & Methods	$250,000
		Reduce width	Design	$128,000
Noise Abatement Walls, Sheldon Rd to Calvine Rd	10/12/94	Change in scope	Scope	$700,000
Kings Beach, stab slopes	6/13/96	Change in method	Materials & Methods	$348,000
Wdn Rdwy & L Trn Chan	10/27/93	Change in materials	Materials & Methods	$170,000
AC Overlay, Widen to 40' and...	8/28/96	Replace existing structure	Design	$95,000
		Use existing ROW	Right-of-Way	$496,000
Fiberoptics Communication System	12/27/96	Change in method	Materials & Methods	$310,000
SR-78 and Ash Street	5/14/98	Use existing ROW	Right-of-Way	$343,500
	5/14/98	Change in scope	Scope	$22,000
Passing lane on SR 94 east of Jamul	2/5/97	Use existing ROW	Right-of-Way	$15,000

	2/5/97	Relocate utilities	Design	$125,000

Project Name	Brief Description of Recommendation
Failed Brow Log	Downscope proposed project to providing for some minor drainage, horizontal drains, a paved ditch and placement of a guardrail retaining wall.
West Bank Road	Modified alignment to provide reduced excavation, balance earthwork quantities, improved geometrics, increased horizontal curve speed, and minor reductions in riparian habitat effects,
Rush Creek Bridge Rehab	Rehab existing bridge; increase bridge width, upgrade bridge and approach railings, jack bridge to provide proper super-elevation. Improve approach curve to the north and add concrete roack slope protection.
South Bonnyview	Construct the interchange project in stages over the next 15-25 years. The first stage consists of widening the existing overcrossing, installing signals, and widening offramps.
Miller's Curve	Build VE Alternative J.
State Route 70 Spring Garden Overhead	Realign SR70 and elevate it to reduce road icing problems.
Shasta Drainage	After devising parameters for analyzing the condition of existing pipes and inspecting each pipe in the field, the Team decided that only 4 of the 11 pipes in the project limits should be rehabilitated.
Pink House Curve	Alternate (double creek crossing) provides 50 MPH design speed, no design exceptions, minimum grading (not requiring offsite disposal area), and no required relocation of people and housing.
Crystal Creek Curves	Presplitting rock cut clopes and using a modified roack catchment area. Reduce bridge width over Willow Creek from 32 to 24 feet.
Noise Abatement Walls, Sheldon Rd to Calvine Rd	3 sound walls were under consideration. For one, survey the property owners and if no interest, no build.
Kings Beach, stab slopes	3 related recommendations: Use rock under RSP, flatten slopes, reduce shoulder cutout section from full width to half width, and roughen the slopes to reduce amount of erosion control needed.
Wdn Rdwy & L Trn Chan	Use asphalt rubber hot mix overlay.

AC Overlay, Widen to 40' and...	Replace the existing bridge with a box culvert.
	Widening within the existing 60- and 80-foot right of ways. Save money in utility relocations and right-of-way acquisitions.
Fiberoptics Communication System	Eliminate trenching, instead running along highways.
SR-78 and Ash Street	Reduce right-of-way acquisition.
	Modify the project to include Haverford Road modification and overlay for another section of SR 78. Significantly reduces disruption to traffic and community.
Passing lane on SR 94 east of Jamul	Use south side edge of pavement as south side edge of shoulder and expand roadway to the north. Eliminate need for added ROW to the south, but increases ROW needed to the north.
	Relocate all utility poles to either the north or the south and place power and communication lines on the same pole.

VA Studies Summary	
Total Number of Projects	16
Total Cost of Projects	$42,640,000
Average Cost of Projects	$2,665,000
Range of Project Cost	$300,000-$5,669,000
Average Pre-VE Cost of Projects	$4,270,719
Range of Pre-VE Project Cost	$881,000-$11,527,000
Total Number of Recommendations	21
Total Cost Savings	$25,691,500
Average Recommendation Savings	$1,223,405
Average Savings/Project	$1,605,719
Range of Recommendation Savings	$15,000-$8,800,000
Range of Savings/Project	$95,000-$8,800,000

Cost Savings Summary

	Recommendation Category			
Savings Category	Scope	Design	ROW	M&M
Bridge	0%	100%	0%	0%
Roadway	19%	49%	7%	3%
Roadside	85%	0%	0%	15%
Interchange	100%	0%	0%	0%
Other	0%	0%	0%	100%
Total	51%	30%	3%	4%

Cost Savings Summary - excluding scope changes

	Recommendation Category		
Savings Category	Design	ROW	M&M
Bridge	100%	0%	0%
Roadway	83%	12%	6%
Roadside	0%	0%	100%
Other	0%	0%	100%
Total	80%	9%	11%

Project Costs by Project Categories:

Category	*Cost*	*Percent*	*Savings*	*Percent*
Bridge	$ 8,584,000	16%	$ 6,331,000	19%
Roadway	$ 31,338,000	60%	$ 12,746,500	39%
Roadside	$ 7,109,000	14%	$ 4,702,000	14%
Interchange	$ 2,727,000	5%	$ 8,800,000	27%
Other	$ 2,560,000	5%	$ 310,000	1%

Projects by Categories:

Category	*Number*	*Percent*
Bridge	3	16%
Roadway	10	53%
Roadside	4	21%
Interchange	1	5%
Other	1	5%

Roadway Project Costs & Savings by Project Type

Type	*Cost*	*Percent*	*Savings*
New Road	$ 14,252,000	41%	$ 4,873,000
Roadway Repair	$ 2,500,000	7%	$ 2,400,000
Roadway Realignment	$ 4,240,000	12%	$ 4,572,500
Roadway Widening	$ 10,346,000	30%	$ 731,000
Paving	$ 3,072,000	9%	$ 170,000

Roadway Projects by Project Type

Type	*Number*	*Percent*
New Road	4	36%
Roadway Repair	1	9%
Roadway Realignment	2	18%
Roadway Widening	3	27%
Paving	1	9%

Adopted Savings by Recommendation Category

Category	*Number*	*Savings*	*% of Studies*	*% of Savings*
Scope	5	$13,176,000	26%	58%
Design	7	$ 7,783,000	37%	34%
Right-of-Way	3	$ 854,500	16%	4%
Materials & Methods	4	$ 1,078,000	21%	5%

Adopted Savings by Recommendation Category - excluding scope changes

Category	*Number*	*Savings*	*% of Studies*	*% of Savings*
Design	7	$ 7,783,000	50%	80%
Right-of-Way	3	$ 854,500	21%	9%
Materials & Methods	4	$ 1,078,000	29%	11%

Adopted Savings by Design Recommendation Type

Category	*Number*	*Savings*	*% of Studies*	*% of Savings*
Change in alignment	3	$ 5,902,000	43%	76%
Modify existing structure	1	$ 1,533,000	14%	20%
Replace existing structure	1	$ 95,000	14%	1%
Reduce width	1	$ 128,000	14%	2%
Relocate utilities	1	$ 125,000	14%	2%

Appendix B: Forms Used as Basis for Workbook

These forms were used as a starting point in developing the "Value Engineering Workbook for Small Transportation Projects," which appears in **Appendix B**. They include the following:

- "Approval Authority / Information Sources" - VDOT (*Value Engineering for the VDOT Study Report*, page 1.2)
- "Study Identification" - Caltrans (*Value Analysis Team Guide*, page 9)
- "Cost Model" - Caltrans (*Value Analysis Team Guide*, page 13)
- "Project Information" - Caltrans (*Value Analysis Team Guide*, page 11)
- "Function Analysis" - Caltrans (*Value Analysis Team Guide*, page 15)
- "Cost/Function Analysis" - Caltrans (*Value Analysis Team Guide*, page 19)
- "A Guideline for VE Evaluations" - NJDOT (*Value Engineering Design Unit Procedures*, page 2)
- "Speculation Phase - Brainstorming" - UDOT (*Value Engineering for Highways Study Workbook*, page VE-6)
- "Evaluative Criteria Matrix" - Caltrans (*Value Analysis Team Guide*, page 23)
- "Creative Ideas Evaluation" - Caltrans (*Value Analysis Team Guide*, page 25)
- "Development Phase" - VDOT (*Value Engineering for the VDOT Study Report*, page 2.3)
- "Value Analysis Alternative" - Caltrans (*Value Analysis Team Guide*, page 29)
- "Benefits" - Caltrans (*Value Analysis Team Guide*, page 35)
- "Sketches" - VDOT (*Value Engineering for the VDOT Study Report*, page 2.5)

- “Sketches” - Caltrans (*Value Analysis Team Guide,* page 31)
- “Cost Worksheet” - VDOT (*Value Engineering for the VDOT Study Report*, page 2.9)
- “Summary of Potential Cost Savings” - VDOT (*Value Engineering for the VDOT Study Report*, page 2.1)
- “Life Cycle Cost Analysis - Present Worth Method” - UDOT (*Value Engineering for Highways Study Workbook*, page VE-9D)
- “Executive Summary” - VDOT (*Value Engineering for the VDOT Study Report*, no page number)

APPENDIX C: WORKBOOK FOR VE ON SMALL TRANSPORTATION PROJECTS

This workbook was developed as part of the thesis work. Its purpose and application are discussed within the workbook and elsewhere in the thesis report.

VALUE ENGINEERING WORKBOOK FOR SMALL TRANSPORTATION PROJECTS

Table of Contents

INTRODUCTION: THE VE STUDY

This workbook is intended for use on small transportation projects that have the following characteristics:

(1) use of federal or state funds (from FHWA or a state DOT);

(2) non-transit transportation facilities (roadway, intersection, bridge, bikeway, etc.); and

(3) estimated cost of under $10 million (including design, right-of-way, construction, and mitigation).

The body of the workbook contains forms for each phase of the VE study and instructions for their use. These forms are also provided in Microsoft Excel 95 format. By using the forms, a VE study can be completed with little preliminary training, particularly if the team leader is experienced in VE techniques.

Appendices A and **B** contain information that will be helpful in the study process. **Appendix C** contains a form to assist in selecting projects for a VE study by assessing their VE potential. Finally, **Appendix D** contains forms to aid in implementing VE recommendations and tracking their results.

For more information regarding this document, refer to *Value Engineering for Small Transportation Projects* by Jennifer Clark (WPI Master's Thesis).

Job Plan

PRE-STUDY PHASE

* Data collection
* Study goals
* Project summary
* Cost model
* Team selection

INVESTIGATION PHASE

* Project presentations
* Site visit
* Function identification
* Function classification
* Cost and worth of functions

SPECULATION PHASE

* Brainstorming
* Consider standard areas

EVALUATION PHASE

* Criteria development
* Weighted criteria matrix
* Evaluation of ideas
* Selection of ideas for development

DEVELOPMENT PHASE

* Descriptions of alternatives
* Sketches of alternatives
* Preliminary estimates
* Summary table

PRESENTATION PHASE

* Executive summary
* Workbook / report
* Oral presentation

PRE-STUDY PHASE

This phase should be completed before the VE team is assembled for the study. While gathering information about the project to be studied, complete the three forms in this section. Distribute copies of these forms to the members of the VE team prior to the first meeting.

Form: Approval Authority / Information Sources

Purpose: Record project information.

(1) Heading: Fill in project number, project name, and VE study number.

(2) Authorizing Persons: Include Project Manager and any other people responsible for reviewing and/or authorizing recommendations. Phone, fax, and email should be included if available.

(3) Data Sources: Document all sources of data to be used in the study, with names, title if relevant, and dates. "Data type" is cost estimate, drawings, standards, etc.

(4) VE Team: Include all members of the VE Team when they are known. As much contact info as possible should be recorded.

Project # *Project:*			VE Study # Approval Authority/ Information Sources	
Authorizing Persons				
Name	Position	Phone	Fax	Email
	Project Manager			

Data Sources		
Data Type	Source	Notes

VE Team				
Name	Position/Organization	Phone	Fax	Email

Form: Study Identification and Summary

Purpose: Record project information for distribution to team members.

(1) Project Description: Include as much information as is known.

(2) Major Project Elements: Break the project up into large pieces and describe them. "Type" may be bridge, paving, road improvements, intersection improvements, bikeway, etc.

(3) Route Conditions/Other Projects: Describe conditions and/or projects (recent, current, and planned) on adjacent segments and the overall route. This applies to bike/pedways as well as roads.

(4) Study Description: Record the dates of the study. Also, list the major goals of this particular study, e.g., "reduce cost" or "generate alternatives to undesirable solution." Include other notes as needed.

Project #	VE Study #
Project:	Study Identification and Summary

Project Description

District:		Length:	
City/Town:		Design Speed:	
Type of Project:		Projected Traffic	
Street/Route:		ADT:	
Location:		Year:	
Total Cost:		Project Phase:	
Type of Funds:		Milestone:	
Scheduled Award Date:			

Major Project Elements

Type	Description

Route Conditions / Other Projects

Adjacent Segments	Overall Route

Study Description

Study Dates:	Study Goals:
Other Notes:	

Form: Cost Model

Purpose: Categorize costs and examine the sources of costs in order to understand where the costs are concentrated.

(1) Estimate: Record source and date of estimate. The costs may be at any level of detail; group them into ten to twelve categories. (Examples: right-of-way, traffic signals, paving.) List the items and their costs, along with any notes.

(2) If completing the form on a computer, sort the items according to cost (in increasing order); the percentages and Pareto analysis will fill in automatically, and the cost chart will need minor adjustments to the axes. If completing manually:

  (a) For each cost item, calculate the percent of the project cost it represents (item cost divided by total cost).

  (b) For the Pareto analysis, estimate the smallest number of items needed to make up 80% of the total cost. The easiest way to do this is start with the largest cost item and work down, adding percentages until you reach approximately 80%.

  (c) Sketch a chart of the costs, with items on the vertical axis and cost on the horizontal axis.

Project # *Project:*	VE Study # Cost Model
Source of Estimate:	Date:

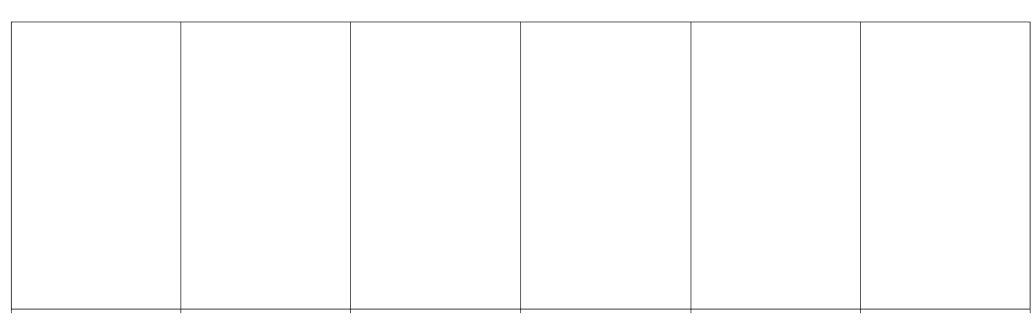
Item	Cost	% of Project	Notes
Total	$		

Pareto Analysis

% of Costs	# of Items
	1
	2
	3
	4
	5
	6

% of the costs are contained in of the items.

Cost Chart



INVESTIGATION PHASE

This phase should begin with presentations (briefings) by the project manager and designer, giving an overview of the project and the issues and concerns associated with it. A site visit should also be incorporated in the initial part of this stage. A copy of the "Team Member Notes" form should be given to each VE team member to record his or her observations during the presentations and site visit.

The other two forms guide the team through the function analysis process, which identifies functional areas with the most opportunity for value improvement. These forms should be completed as a team.

Form: Team Member Notes

Purpose: Provide a record of notes and observations for use in the study.

One form should be completed by each team member. Record notes and observations from the project briefings/presentations and the site visit. Note particularly what elements the designers or other parties are likely to be flexible about, and what elements should be left unchanged.

Project # *Project:*	VE Study # Team Member Notes
Team Member:	

Project Briefings/Presentations

Site Visit

Form: Function Analysis

Purpose: Perform function analysis to identify potential areas of savings and/or improvements

(1) Use the items from **Cost Model**.

(2) For each item, identify one or more functions the item performs. Each function consists of a verb + a noun. Also, classify each function as basic, required secondary, secondary, or unwanted. A basic function is one that is essential to the project. A required secondary function (1) is necessary for supporting a basic function, (2) must be achieved to meet codes or standards, or (3) must be included to satisfy the owner. A secondary function is not necessary and has a "worth" of zero. An unwanted function is an undesirable effect that may require mitigation.

(3) The "cost" for each item comes from the estimate on **Cost Model**. If practical, allocate the item cost among its functions.

(4) The "worth" of each function is the estimated cost of the least expensive way to fulfill that function. For example, the least expensive way to "transport water" may be a simple ditch.

(5) Record any notes about functions, costs, and worths in the "Comments" field.

(6) Identify the function(s) of the entire project. Sum the "costs" and "worths" to get the project cost and worth.

Project # *Project:*							VE Study # Function Analysis
Function = Active Verb + Measurable Noun			*Kinds: (B)asic, (S)econdary, (R)equired (S)econdary, (U)nwanted*				
Item #	Item Description	Function		Kind	Cost	Worth	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							

Project # *Project:*						VE Study # Function Analysis	
Function = Active Verb + Measurable Noun			*Kinds: (B)asic, (S)econdary, (R)equired (S)econdary, (U)nwanted*				
Item #	Item Description	Function		Kind	Cost	Worth	Comments
10							
11							
12							
ALL	Entire project						

Form: Cost/Function Analysis

Purpose: Continue the function analysis.

(1) Record functions from **Function Analysis**. Also, record their kind, cost, and worth.

(2) Calculate the percentage of the total cost and total worth that each function represents.

(3) Rank the functions in descending order. You may also want to calculate their cost/worth ratio. Based on these factors, choose the functions to consider in the speculation phase.

Project # *Project:*					VE Study # Cost/Function Analysis
Function = Active Verb + Measurable Noun *Kinds: (B)asic, (S)econdary, (R)equired (S)econdary, (U)nwanted*					
Function		Kind	Cost / % of Total	Worth / % of Total	Comments
Total					

SPECULATION PHASE

This phase consists of a team brainstorming session to generate ideas. Guidelines for brainstorming appear in *Appendix A.* A form is provided for recording the results of the session.

Form: Speculation Phase (Brainstorming)

Purpose: Record results of brainstorming session.

(1) Complete a separate form for each function. Summarize the original design in one line.

(2) Brainstorm alternative design ideas, keeping in mind the overall goals of the study. Additional guidelines for brainstorming sessions appear in *Appendix A*. During the session, record all ideas. For the final form (report), write succinct idea descriptions.

Project # *Project:*	VE Study # Speculation Phase (Brainstorming)
Function: **Original design:**	
Ideas Generated	

EVALUATION PHASE

This phase is another group activity. The two forms guide the team through the evaluation process, in which the most promising alternatives are selected for development.

Form: Evaluative Criteria and Matrix

Purpose: Define criteria (and their relative importance) for judging ideas generated by brainstorming.

(1) Choose up to seven criteria that are key to the project. Include the following: reliability, life-cycle cost, safety, quality, and environmental impact (these may be modified to apply to the specific project). Add any comments needed for clarification.

(2) Complete the criteria matrix. Compare each pair of criteria and record their relative importance. For example, if criteria E is "safety" and criteria G is "aesthetics," and safety is considered more important than aesthetics, that section of the matrix would look like this:

E	?	e
	F	?
		G

(3) Calculate the total points for each criterion. Each "greater importance" is 1 point; each "equal importance" is 1/2 point. Sum the values for the "total points."

(4) Calculate the percentage of total points assigned to each criterion.

(5) Record any notes about the criteria matrix values in the comments/discussion section.

Project # *Project:*	VE Study # Evaluative Criteria & Matrix

Evaluative Criteria

ID	Description	Comments
A		
B		
C		
D		
E		
F		
G		

Criteria Matrix

A							
	B						
		C					
			D				
				E			
					F		
						G	

	Total points	% of Total
Total		

a	= *A is of greater importance*
a/b	= *A and B are of equal importance*

Comments/Discussion

Form: Evaluation

Purpose: Judge ideas by criteria, and choose ideas to develop further.

(1) Complete one form for each function. From ideas generated (see **Speculation Phase - Brainstorming**), choose all ideas that the team considers to be feasible. List them, and assign a number or code to each.

(2) Discuss advantages and disadvantages (benefits and drawbacks) of each idea with regard to the evaluative criteria. Describe these briefly in the spaces provided.

(3) Judge the ideas by each criterion. Assign a number from 0 to 10, with 10 being the best.

(4) Calculate the total score of each idea. Multiply the value assigned for each criterion by the total points given to that criterion on **Evaluative Criteria and Matrix**, and sum the values for the "total score." (If you are entering the data into the computer, the spreadsheet should calculate the total score automatically.)

(5) Choose ideas to develop further (one or more of the top-scoring ideas).

Project # *Project:*	VE Study # Evaluation

Function:

Idea #	Idea Description	Criteria								Advantages	Disadvantages
		A	B	C	D	E	F	G	Score		

DEVELOPMENT PHASE

For this phase, a set of five forms is provided. One set should be completed for each proposed alternative. These forms help the team develop each idea into a preliminary design alternative.

Form: Development - Benefits

Purpose: Identify advantages and disadvantages of an alternative design.

(1) Complete one form for each idea/alternative.

(2) List the evaluative criteria in the spaces provided.

(3) For each criterion, discuss the advantages and disadvantages (benefits and drawbacks) of the proposed design.

Project # *Project:*	VE Study #
	Development - Benefits
Recommendation:	Recommendation # _____ Page __ of __

Advantages & Disadvantages
Criterion:
Criterion:
Criterion:
Criterion:
Criterion:
Criterion:
Criterion:

Form: Development - Sketches

Purpose: Develop idea/alternative.

(1) Complete one form for each idea/alternative.

(2) Sketch original and proposed designs (if applicable) in the spaces provided.

Project # *Project:*	VE Study #
	Development - Sketches
	Recommendation # _____
Recommendation:	Page __ of __

Form: Development - Estimate

Purpose: Estimate initial costs of idea/alternative.

(1) Complete one form for each idea/alternative.

(2) Record recommendation number, description, and page numbers.

(3) Unit cost data should come from the project estimate, if possible. Include items at whatever level of detail is appropriate to show the sources of potential savings.

Project # *Project:*				VE Study # Development - Estimate Recommendation # _____		
Recommendation:				Page __ of __		
Element			Original Design		Proposed Design	
Item	Units	Unit Cost	# Units	Total	# Units	Total
		Totals:		$		$
		Initial savings/ cost avoidance:				$

Form: Development - LCC Cost

Purpose: Estimate life-cycle cost savings of alternative.

(1) Complete one form for each idea/alternative.

(2) Record recommendation number, description, and page numbers.

(3) Record discount rate to be used and estimated economic life of the design.

(4) List one-time expenditures and annual costs that can reasonably be expected, for both the original and proposed designs.

(5) Find the PW (Present Worth) factors from the chart in *Appendix B.* Calculate the PW of each cost by multiplying the cost by its PW factor.

(6) Sum the present worths of all costs for the "total life cycle cost."

Project # *Project:*				VE Study #	
				Development - LCC Cost	
				Recommendation # _____	
Recommendation:				Page __ of __	
Discount Rate:			Economic Life:	years	
Element	PW Factor	Original Design		Proposed Design	
		Cost	PW	Cost	PW
One-time Expenditures:					
Annual Costs:					
Total Life Cycle Costs			$		$

Form: Development - Summary

Purpose: Summarize a proposed alternative.

(1) Complete one form for each idea/alternative.

(2) Briefly describe the original and proposed designs, and discuss important advantages, disadvantages, and implications.

(3) Record costs and savings from other **Development** worksheets.

Project # *Project:*	VE Study # Development - Summary Recommendation # _____ Page __ of __
Function:	

Original Design
Proposed Design
Discussion

Cost Summary	Original Design	Proposed Design	Savings/Cost Avoidance
Initial Cost			$
Other Life Cycle Costs (Present Worth)			$
Total Life Cycle Savings/Cost Avoidance:			$

PRESENTATION PHASE

This phase should be an individual effort, unless a group presentation is desired. The team leader should complete the "Proposal Summary" form and write an executive summary of the study. Then, the completed workbook should be transcribed and printed as the final report.

Form: Proposal Summary

Purpose: Present proposal information in a summary table.

(1) For each proposed alternative, record recommendation number, description, and initial costs from **Development - Summary**.

(2) Also from **Development - Summary**, calculate initial, life-cycle (O&M), and total potential savings.

(3) Sum the costs and savings.

Project # *Project:*					VE Study # Proposal Summary	
#	Description	Original Design Cost	Proposed Design Cost	Initial Savings	O&M Savings	Total Savings
Totals		$	$	$	$	$

Executive Summary

Purpose: To present a summary of the study and its results.

(1) The executive summary should be concise, confined to one page if possible.

(2) General information should include a project description (including estimated cost) and a study description (dates, goals). This information comes from **Study Identification and Summary**.

(3) Include a summary of results indicating the number of VE proposals and their estimated savings. Also, give a brief description of some or all of the recommendations.

(4) Indicate the team leader or other contact person, along with contact information (phone, fax).

Appendix A: Brainstorming

Excerpted from UDOT's Manual of Instruction for Value Engineering:

BRAINSTORMING: This creative approach is an uninhibited, conference-type, group approach, based upon the stimulation of one person's mind by another's. A typical brainstorming session consists of a group of four to eight people spontaneously producing ideas designed to solve a specific problem. The objective is to produce the greatest possible number of alternative ideas for later evaluation and development. Rules observed during brainstorming:

1. Judicial thinking must be withheld. This means controlling the natural tendency to instantaneously evaluate ideas.
2. No criticism by word of mouth, tone of voice, shrug of shoulders or other forms of body language, that indicates rejection, is permitted.
3. "Free-wheeling" is welcomed. The wilder the idea, the better; it is easier to tame down than to think up.
4. Apply the technique of "hitchhiking" or "piggybacking" which is to expand on the ideas of others by offering many variations (synergism).
5. Combination and improvement of ideas is suggested.
6. Set a goal in the number of ideas, or time, to force hard thinking.

The general procedure for brainstorming is:

1. The group has a free discussion, with the group leader only questioning and guiding and occasionally supplying problem-related information.
2. All ideas are listed so that all members of the group can see as well as

hear the ideas. The use of a flip chart and crayons, or felt tip pens, is preferable. The filled sheets can be taped to the walls so that they are constantly in view.

Adapted from NJDOT's Value Engineering Unit Procedures:

Consider the following during speculation:

- Traffic:
  - ∗ Look for traffic squeeze points upstream/downstream
  - ∗ Simplify traffic control and staging
- Roadway
  - ∗ Utilize existing versus abandoning and/or realigning
  - ∗ Widen roadway on one side versus both sides
- Structures
  - ∗ Eliminate structures
  - ∗ Reconstruct versus rehabilitate
  - ∗ Construct new parallel structure versus widening existing
  - ∗ Retaining walls/ reinforced earth walls versus fill
- Utilities
  - ∗ Avoid utility conflicts
  - ∗ Simplify utilities
- Impacts
  - ∗ Reduce/eliminate environmental impacts (historic, wetlands, waste)
  - ∗ Avoid/improve access impacts
  - ∗ Reduce/eliminate right-of-way impacts
- Other
  - ∗ Innovative versus traditional methods
  - ∗ Traffic signal versus overpass
  - ∗ Reduce drainage system

Appendix B: Present Worth Factor Chart

Years	6%	7%	8%	9%	10%	12%	14%	16%	18%	20%
1	0.943	0.935	0.926	0.917	0.909	0.893	0.877	0.862	0.847	0.833
2	0.890	0.873	0.857	0.842	0.826	0.797	0.769	0.743	0.718	0.694
3	0.840	0.816	0.794	0.772	0.751	0.712	0.675	0.641	0.609	0.579
4	0.792	0.763	0.735	0.708	0.683	0.636	0.592	0.552	0.516	0.482
5	0.747	0.713	0.681	0.650	0.621	0.567	0.519	0.476	0.437	0.402
6	0.705	0.666	0.630	0.596	0.564	0.507	0.456	0.410	0.370	0.335
7	0.665	0.623	0.583	0.547	0.513	0.452	0.400	0.354	0.314	0.279
8	0.627	0.582	0.540	0.502	0.467	0.404	0.351	0.305	0.266	0.233
9	0.592	0.544	0.500	0.460	0.424	0.361	0.308	0.263	0.225	0.194
10	0.558	0.508	0.463	0.422	0.386	0.322	0.270	0.227	0.191	0.162
11	0.527	0.475	0.429	0.388	0.350	0.287	0.237	0.195	0.162	0.135
12	0.497	0.444	0.397	0.356	0.319	0.257	0.208	0.168	0.137	0.112
13	0.469	0.415	0.368	0.326	0.290	0.229	0.182	0.145	0.116	0.093
14	0.442	0.388	0.340	0.299	0.263	0.205	0.160	0.125	0.099	0.078
15	0.417	0.362	0.315	0.275	0.239	0.183	0.140	0.108	0.084	0.065
16	0.394	0.339	0.292	0.252	0.218	0.163	0.123	0.093	0.071	0.054
17	0.371	0.317	0.270	0.231	0.198	0.146	0.108	0.080	0.060	0.045
18	0.350	0.296	0.250	0.212	0.180	0.130	0.095	0.069	0.051	0.038
19	0.331	0.277	0.232	0.194	0.164	0.116	0.083	0.060	0.043	0.031
20	0.312	0.258	0.215	0.178	0.149	0.104	0.073	0.051	0.037	0.026

Appendix C: Selection Criteria

The following form should be completed for each small transportation project. When selecting projects for VE study, use the “total criteria points” as a measure of the VE potential of each project.

Form: Selection Criteria

Purpose: Assess the VE potential of a project in order to select the most promising projects for VE studies.

(1) For each criterion, indicate if it is satisfied and note any comments.

(2) The “total criteria points” is the number of criteria satisfied.

(3) Rank VE study candidates by their total criteria points. The projects with the highest score should receive the highest priority (subject to other factors, such as schedule).

Project # *Project:*		VE Study # Selection Criteria
Criteria Satisfied?	Criteria Description	Comments
	Project cost (initial estimate) greater than $5 million	
	Project cost (initial estimate) exceeds the budget	
	Bridge work over 25% of total project cost	
	Roadway repair &/or realignment over 50% of total project cost	
	Roadside work over 25% of total project cost	
	Major changes to existing structures (new alignments, new interchanges, widening, major reconstruction)	
	Multiple construction stages, night work construction, &/or expensive construction traffic control	
	Expensive solutions (overly long material haul, non-standard items, difficult materials requirements, highly skilled labor, etc.)	
	Accelerated design (tight design schedule)	
	Statewide or districtwide impact	
	Wetland mitigation	
	Hazardous waste cleanup	
	Extensive environmental or geotechnical requirements	
	High estimated life cycle / maintenance costs	
	Total Criteria Points (14 maximum)	

Appendix D: Implementation & Auditing

IMPLEMENTATION AND AUDITING PHASES

Once the VE study has been completed, recommendations need to be reviewed, accepted, and implemented. During and after the implementation, the results also need to be tracked, or audited. The following forms will help in accomplishing these objectives.

Form: Review by Stakeholders

Purpose: To document the responses of project stakeholders to the VE recommendations.

(1) Distribute copies of the form to the stakeholders along with copies of the recommendations.

(2) Instruct stakeholders to write their comments on the form.

(3) Arrange a meeting of the stakeholders to discuss their responses and come to consensus on the status of the recommendation.

(4) Keep a copy of each stakeholder’s form with the completed VE study.

Project # *Project:*	VE Study # Review by Stakeholders
Recommendation:	Recommendation # _____
Review Status: Accept Conditionally Accept Reject	
Prepared by:	Date:

Stakeholder Responses
Technical Feasibility: *(including how the feasibility was evaluated)*
Implementable Portions: (*can be implemented without further study)*
Validated Cost Savings: *(including how the estimate was verified)*
Schedule Impact:
Safety Impact:
Traffic Operations Impact:
Issue Resolution: *(any issues that were resolved)*
Stakeholder Consensus: *(what other parties need to be consulted)*
Other Comments: *(any other benefits or concerns)*

Form: Summary of Accepted Recommendations

Purpose: To document the approval status and savings of VE recommendations.

(1) On completion of the review process, list all recommendations from the VE study along with their approval status (accepted, conditionally accepted, or rejected) and estimated potential savings.

(2) On completion of the project or as recommendations are implemented, record the actual implemented savings realized, as well as any comments to clarify savings or suggest improvements.

Project # *Project:*					VE Study # Summary of Accepted Recommendations
Recommendation #	**Description**	**Potential Savings***	**Implemented Savings***	**Approval (A,CA,R)****	**Comments**

*All savings are initial cost savings only, unless otherwise noted.
**A=Accepted, CA=Conditionally Accepted, R=Rejected

Form: Tracking Data (2 pages)

Purpose: To record data about projects and VE studies for tracking purposes, particularly for entry into a database.

Fill out all information as completely as possible. Too much information is better than too little! Fill out a form for each VE study done, and keep at least some of the information in a database if possible.

Tracking Data

Project Name: Project #: Project Dates: Project Manager: Project Location: Major Project Components: Bridge Road improvements Paving Intersection improv. Bikeway Other (_____________________________)
Study Name: Study #: Study Dates: VE Team Leader: Other VE Team Members: 1 2 3 4 5
Summary Data: Initial project cost estimate Final project cost # of recommendations # of approved recommendations Estimated value of all recommendations Estimated value of approved recommendations Implemented savings

Recommendations:	
	Name
	#
	Estimated value
	Review status
	Implemented savings
	Comments
Recommendations:	
	Name
	#
	Estimated value
	Review status
	Implemented savings
	Comments
Recommendations:	
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