The Application of Value Engineering to Highway Projects and Programs

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A challenge universally faced by all highway agencies is that of needs exceeding the funds made available to deal with them. In a developing nation, the imbalance of needs to funding translates into an inability to maintain and upgrade existing highways or construct new highways to provide access for its citizens, deliver social and human services, and develop its economy. In a developed nation, this imbalance will result in the maintenance and expansion of an existing system being inadequate to meet even current demand.

Highway program budgets are generally large, even in the poorest of nations, when compared with other domestic non-defense programs. Consequently, highway resources are often viewed as virtually limitless. But, every highway administrator is painfully aware that the resources available to his program are finite and must be husbanded. To keep highway project and program costs within available funding, they are frequently forced to turn to eliminating or drastically reducing the scope of projects or entire programs.

But, there is an alternative, an effective means of controlling expenditures by identifying unneeded and unwanted costs while preserving the essential elements of projects and programs. This process is called value engineering (VE), and it has been applied successfully for over 40 years by industry as an engineering and management tool for cost control and increasing profit margins, while assuring that essential product functions are maintained. This paper provides an overview of VE and its application to highways.

WHAT IS VALUE ENGINEERING?

Value engineering is the systematic application of recognized techniques which identify the function of a product or service, establish a value for that function, and provide the necessary function reliably at the lowest life-cycle cost. In the highway context, products and services include not only the structural elements of highways, but also the processes, equipment, and supplies used in their development, from concept through operation and maintenance. In all instances, the required function should be achieved at the lowest life-cycle cost consistent with requirements for performance, maintainability, safety, and esthetics.

Developed in 1947 by Lawrence D. Miles, a General Electric staff engineer, VE is widely recognized in manufacturing and industry throughout the world, but its application to public works, particularly highways, has been largely limited to the United States and just recently the Republic of Indonesia.

The process is carried out by a multi-disciplinary team of technical experts following a set of procedures referred to as the VE job plan. The job plan consists
of eight phases: selection, investigation, speculation, evaluation, development, presentation, implementation, and audit.

**SELECTION PHASE**

The selection phase identifies which projects will be studied. Value engineering analysis is not free, therefore careful selection of study candidates must be done to assure maximum return on the investment of agency resources. Projects which are good candidates for VE study are ones that:

1. substantially exceed initial cost estimates;
2. have complex designs;
3. require critical or high cost materials;
4. are difficult to construct or fabricate;
5. have questionable justification;
6. have record seeking design;
7. appear too costly to build or maintain; or
8. have major structures or interchanges.

An effective tool for identifying value study candidates is Pareto’s law of distribution. Pareto’s law is based upon the principle that approximately 20 percent of the elements in a construction project or program will account for about 80 percent of its total cost. An example would be a highway agency with an annual construction program of 100 projects. The total cost of the 20 most expensive projects will equal about 80 percent of the total cost of all 100 projects in the program.

**INVESTIGATION PHASE**

The investigation phase is the first of five phases performed by the VE study team. It is also the foundation upon which the remainder of the study will be carried out. Three activities are performed during the investigation phase:

1. all relevant information regarding the project and its major elements is obtained;
2. the functions of the project as a whole and its major elements are determined; and
3. the cost and worth of the functions of the major elements are determined, and the functions with the greatest potential for value improvement are identified.

Function analysis is a technique which sets VE apart from other cost reduction efforts. It asks the questions, “What must this project or project element do or accomplish” and “What else does this project or project element do?” The types of functions can be categorized as utility, aesthetic, esteem, and unwanted. In highway applications, as with most public works projects, the utility function is paramount with the aesthetic and esteem functions being secondary. The function is defined in the simplest terms, a verb and a noun. For example, the basic utility function of a pencil is “make marks.” This is also the basic function of an expensive, gold-plated pen; it is the secondary aesthetic and esteem functions which are responsible for most of the high cost of the fine pen. The basic function of a bridge is to “cross obstacle.” If it is designed to be the longest, highest, etc., structure, then the esteem function may also be adding cost to the project. The heat generated by a light bulb or the disposal of excess excavation are examples of
unwanted functions. Both are costly, but neither contribute to the performance of the basic functions of the light bulb or highway.

Cost and worth are often confused, but in VE they are very distinct. Cost is the amount of money spent to accomplish a function using the present design, and worth is the minimum amount that must be expended to accomplish the required function. Cost will always exceed worth, but when cost substantially exceeds worth, the potential for value improvement is high. Those functions with costs substantially exceeding worth are selected for further evaluation in the VE study.

The speculation phase is also a unique feature of VE as it forces creativity. In this phase, the study team speculates on different ways of performing the functions identified as having high potential for value improvement. Since the functions have been defined in the simplest terms, the team is not confined to conventional engineering solutions. Brainstorming is an effective means of stimulating team creativity and is the most frequently used method of generating ideas in VE. It is not uncommon for the study team to generate a list of 50 or more ways to perform a single function.

The evaluation phase refines the list of ideas developed during the speculation phase. Factors critical to the project such as construction cost, safety, esthetics, environmental concerns, right-of-way requirements, and anticipated maintenance costs are used to evaluate each alternative on the list. Ideas unsuitable for the project at hand are discarded, and others may be combined selectively to form new ideas. Finally, through the use of ranking techniques, the best alternative is identified for further development.

The development phase expands the best idea into a complete proposal. Construction and life-cycle costs are calculated, advantages and disadvantages are identified, sketches are drawn, checks are made to assure that all project requirements are met, and assumptions are validated. In some cases, full designs may be prepared.

The presentation phase is the last task performed by the VE study team. It usually includes the preparation of a formal report documenting the team’s recommendations and a brief oral presentation to the highway administrator or his designee and the persons responsible for making decisions on the project.

The implementation phase is the decision point for the highway administrator. The team’s recommendations are accepted as submitted or as subsequently modified. Approved proposals are incorporated in the construction plans, and design improvements and/or savings are realized.

The audit phase evaluates the performance of the implemented VE proposals and determines the actual construction and life-cycle cost savings. The information gained is used to monitor and improve the process.

APPLYING VE TO HIGHWAY PROJECTS AND PROGRAMS

Design excellence is the goal of every designer. No designer would knowingly incorporate poor value into this work, but experience has shown that highway projects are no different from buildings, military hardware, automobiles, etc. Poor value clips into the best designer’s work for the following reasons commonly attributed to highway projects:

- lack of information;
- habitual thinking;
shortage of time;
emphasis on performance at any cost;
changing technology;
misunderstood project requirements;
decisions made before the costs and/or value of alternatives are known; and
changes in conditions or project scope over time.

As highway professionals, we will recognize items on this list and their influence on our projects. This is not an indictment of our ability as engineers, but a reflection of the world we must all work in. Value engineering gives us a tool for the rational evaluation of our work and helps to preserve the design excellence for which highway engineers are so rightfully proud.

It is the early decisions that have the greatest influence on a project's life-cycle cost. Experience has also shown us that recommendations from VE studies done early in the project development process (before commitments have been made and designers have become so personally involved in the project) have a much better chance of acceptance than ones from studies done later. Logically then, the selection of projects for VE study should occur early in the project development process so that the study can be conducted when the potential for savings and acceptance is greatest. When the design of a project has advanced to about 30 percent completion, it is quite likely ready for VE review. For large improvements requiring several construction projects to complete, two or more VE studies may be appropriate: one during early design and others as the design progresses.

Nearly all highway projects are designed by several individuals or small groups working independently towards a more or less common goal. There is frequently a lack of effective communication, and information vital to two or more designers is not shared because they are not aware of its existence; misunderstandings occur; and individual design elements are maximized without consideration for the project as a whole. The multi-disciplinary team approach used in VE can overcome these communication breakdowns. Also, working as a true team, the VE study team can generate more and better ideas than as individuals working separately. This is most clearly demonstrated during the speculation phase.

Value engineering teams are normally made up of five to eight persons from varying backgrounds. Areas of highway expertise that should be considered when forming a team are geometrics, traffic, structures, hydraulics, right-of-way, environment, geotechnical, construction, cost estimating, maintenance, materials, and perhaps others. The team members' attitudes are as important as their technical backgrounds. Members should be open-minded and willing to work in a team environment. To assure objectivity, it is recommended that none of the members have direct involvement in the project being studied. Leadership is also a critical factor in the success of the study. The leader must be technically competent, experienced in the value process, and have good leadership qualities.

Gathering information for the VE study can be a difficult task. The team must be thorough but tactful. The required information will probably be spread over several offices as well. Some designers may be reluctant to provide information for a variety of reasons.

The level of development of VE recommendations can vary depending on the needs of the highway agency. Some develop the proposal to a point where an
informed decision can be made, but additional effort will be needed to implement it. Others fully develop the idea into a nearly complete design before presentation to management. Either procedure is satisfactory as long as management knows what they are getting and the team knows what is expected of them.

The real results of a VE program are not study recommendations but value actually achieved. Implementation of a VE proposal does not happen by itself. Management must accept the proposal, the approved proposal must be communicated to the designer, and the designer must incorporate the proposal into the plans. Making sure that all this happens will avoid wasted effort.

ESTABLISHING A VE PROGRAM

When the recommendation is made that an agency establish a formal VE program, a frequent response is, "We do it all of the time; we just don't call it VE." Value engineering is made up of systematic application, function analysis, creativity, and team work. It can only be done as a conscious effort. The benefits of VE can be best realized when it is applied in an organized manner to a predetermined list of projects.

Top management commitment and involvement are most important in assuring the success of a VE program; passive support is not enough. Following are some suggested actions to be taken by top management to show their active support.

1) Establish the VE organization. This includes selecting a VE coordinator, setting the size of the VE unit, and identifying the location within the agency where VE activities will be carried out.
2) Develop a written policy on VE. This is top management's declaration of intentions relative to VE. It clearly identifies who is responsible and what is expected from the VE organization and the rest of the agency.
3) Commit resources. As noted above, VE is not free. Cost is a consideration and must be considered along with savings, but just as important are the human resources required to perform studies, implement recommendations, and train personnel.
4) Demand results. Top management should expect the study teams to produce value improvement recommendations, which reflect sound engineering judgement, in a timely manner.
5) Implement recommendations. As a practical matter, all recommendations may not be used, but all should receive fair and honest consideration. Decision makers should be encouraged to accept VE recommendations unless there is a sound reason for not doing so.

Second only to top management in assuring the success of the agency's VE program is the support and cooperation of middle management. Middle managers impact project selection, designate team members, are often the persons who will be accepting VE proposals, and are responsible for implementing them.

As the focal point for the agency's VE activities, the VE coordinator is the keystone of the agency's VE program. The coordinator manages the agency's program and advises top management and other highway agency units of VE matters.
Very few highway engineers study VE as a part of their formal education so training is an essential element in an agency's VE program. Training serves three purposes:

it prepares employees to become study team members and/or leaders;

it indoctrinates them into the value process so that they may support the agency's program and lend assistance to studies; and

it helps reassure agency employees that VE is not a threat to them.

In-house training capability can be developed by any highway agency, but most United States highway agencies have elected to take advantage of the Federal Highway Administration's VE workshop or hire VE consultants to provide their training. To assure quality training, consultants should provide a value engineering workshop approved by the Society of American Value Engineers or one of their international affiliates.

CONSULTANTS

In many of the world's highway programs consulting engineers play an important part in highway design, and sometimes supervise construction. Consequently, they must be recognized in any activity that impacts design. It is quite common for design consultants to resist VE, and highway administrators will hear, "We do it all the time; we just don't call it value engineering." But, they do not do it all of the time any more than highway agencies do. Design consultants may be reluctant to see VE introduced into a project schedule because of a lack of understanding and/or the fear of losing face with their clients. Whether the design is developed in-house or by a consultant engineering firm, the same reasons for poor value exist. Consultant designed projects should receive the same attention for VE analysis as those developed by the highway agency's staff.

Some things that can be done by the agency to encourage the consultant's cooperation are:

inform all prospective firms that the design process will include VE in the request for proposals;

formally alert the firm in its contract that VE will be a part of the design process;

include representatives of the firm on the study teams (the firm's representatives should not be involved in the project being studied);

coordinate the scheduling of the studies with the consultant; and

include in the firm's contract appropriate payment and time for their involvement in the studies and for making changes that result from the studies.

Value engineering consultants can provide highway agencies and design consultants with assistance in VE training and studies. Their expertise in guiding VE studies assures that the job plan is followed, encourages a creative environment, and promotes objectivity. Value engineering consultants may be retained by the highway agency or the design consultant; of prime importance is the consultant's qualifications as a VE practitioner.

VALUE ENGINEERING IN HIGHWAY CONSTRUCTION

Value engineering during the construction stage of a highway project should supplement the agency's organized preconstruction VE program; it is not a
substitute for it. The potential for impacting life-cycle costs during construction is relatively small. Opportunities for value improvement are usually limited to design details as major changes in the basic design or scope of the project would seldom be implemented.

The most common application of VE in highway construction is the Value Engineering Incentive Clause (VEIC). The VEIC is a contract clause which encourages the construction contractor to develop and submit change proposals that will result in a lower contract cost but maintain essential design criteria and quality. If the contractor's change proposal is accepted by the contracting agency, savings are divided between the agency and the contractor, usually on a 50-50 basis. The VEIC should always include a provision that the contracting agency has the absolute right to reject any change proposal, and rejection cannot be the basis for a claim by the contractor.

The advantage of including the VEIC in contracts is that the contractor's unique skills and experience can be used to reduce construction cost. However, designers are sometimes reluctant to endorse the contractor's proposal. Another shortcoming of the VEIC is that the highway agency has no way of forcing the contractor to submit change proposals. Contractors may be reluctant to risk the investment of time and effort necessary to develop and submit change proposals.

Another approach to VE during construction is the Value Engineering Program Clause (VEPC). The VEPC is a contract clause which requires the construction contractor to perform VE studies on the project of selected project elements. A bid item is included in effort. Additionally, the contractor shares in the savings realized as a result of the VE studies, but at a much lower rate than with the VEIC, probably in the range of 20 percent. The construction contractor would be required to retain a recognized VE consultant or have a proven VE capability within his organization to lead the studies. The study team would be made up of the contractor's team leader, representatives of the highway agency, design consultant, construction contractor, and outside experts as necessary. Selected elements that this highway agency could identify in the contract for study might include interchanges, large structures, areas requiring special geotechnical attention, and major drainage systems.

This approach offers some special advantages: it guarantees that VE studies will be done; there is a much better chance of acceptance of study recommendations since all parties involved in the design and construction of the project are represented on the team; and the highway agency is able to target specific areas for study. The studies will require time at the beginning of the project, and the approach should be used selectively so the time invested is sure of being recovered by cost reductions and time savings later in the project. To our knowledge, this approach has never been used in the highway industry, but a similar approach has been used very successfully by the U.S. Department of Defense in the procurement of military hardware.

CONCLUSIONS

Value engineering is not free. It requires a monetary investment for salaries and fees, and an investment of time by a team of highway professionals. The team effort portion of the study seldom requires more than a week to complete. Preliminary information gathering, certain elements of development, and report
preparation may require more time. A highway administrator should reasonably expect a return on investment of 10 to one for a VE study, and returns on investment in excess of 100 to one are common. The amount of savings that can be expected is difficult to predict. Some studies may yield little or no savings while others may yield 30 percent or more. Our experience has been that an average of 5 to 10 percent savings is produced by a VE study.

A VE program provides the highway administrator with a means of controlling life-cycle costs without sacrificing project quality or arbitrarily reducing its scope, but it will not happen without the involvement and cooperation of all levels of highway management.

Value engineering is not a criticism of the designer. It is an extension of the design process which builds upon and refines the work already accomplished.

ACKNOWLEDGEMENTS

The Value Engineering Program Clause was first proposed for highway work by Harold Tufty, CVS, in 1988, while assisting the Ministry of Public Works of the Republic of Indonesia.
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