VALUE ENGINEERING
IN HIGHWAY CONSTRUCTION

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[EDITOR'S NOTE: Due to the 1978 coal strike and energy crisis, Road School was rescheduled from March 7-9 at Purdue University, West Lafayette, to April 18-19 at the Indianapolis Convention Center. Because of this rescheduling the author of the following paper was unable to present it at Road School, as originally planned, but has given permission for its publication in these proceedings.]

FUNCTIONAL ANALYSIS—VALUE ENGINEERING (VE)

Value engineering, contrary to popular misconception, is not synonymous with cost reduction and is not a design-cheapening process. Rather, it is the analysis of design, oriented toward the functions which are required or that must be performed. For this reason, I and many of my value-oriented conferers, prefer the term “functional analysis” for this methodology. This also avoids the possible implication that other types of engineering and analysis do not produce good value in design.

The formal definition for the function analysis methodology is: An organized effort directed at analyzing functions for the purpose of achieving required functions at the lowest total cost of effective ownership.

FUNCTIONAL ANALYSIS FOR FIGHTING SPIRALING COSTS

You, as persons involved in the design and construction of America's roads and highways, no doubt, are most aware of construction cost trends and have many and varied explanations as to why this price spiral. Leaving the reasons to the philosophers, political scientists, and economists, the problem is appropriately pictured in a graph of Construction Cost Trends as it appears periodically in Engineering News Record.
(Fig. 1). The seriousness of the problem is indicated by the trend line now being almost asymptotic to the cost index axis.

The problem then becomes, “How can we in the construction industry combat these spiraling and almost runaway cost trends?” One of the better tools to help owners, designers, construction managers, and contractors in combating this problem is analysis by function (functional analysis).

**Figure 1.**

INDEX OF CONSTRUCTION COSTS*
(Cost indices based on 1913 = 100)

*Based on figures from Engineering News Record.
HOW FUNCTIONAL ANALYSIS LEADS TO BETTER ENGINEERING DECISIONS

How does function analysis lead to better engineering decisions? Its logic, being function oriented, leads to an enlarged scope of understanding by asking the questions:

1. What does it do?
2. What must it do?
3. How else can we perform the required functions?

This leads away from the traditional design-oriented logic which asks, “How do we make it (this design) cheaper?” and leads to a functional fixedness.

THE FIVE-PHASE JOB PLAN—FUNCTIONAL APPROACH TO PROBLEM SOLVING

The power of this functional approach to problem solving is the Job Plan (Fig. 2). This step-wise approach guarantees that the function-oriented methodology is followed. Ideally, a team of persons will be selected to provide the experience and training parameters dictated by the specific problem.

In the Information Phase, a diagram of functions is developed to array the functions in a logical sequence. This sequence is known as the Function Analysis System Technique and produces a FAST diagram which conforms to the How?-Why? logic of abstraction. (Fig. 3) This leads to a common understanding among the team members of the scope and magnitude of the problem. Costs may be allocated to the various functions of the diagram so that a valid judgment may be made as to where high-dollar costs are located. Once these are determined, the question, “How else can we perform a specific function?” leads to numerous alternatives and sometimes unique solutions to the functional problem.

AN EXAMPLE OF FUNCTIONAL ANALYSIS

At a function analysis seminar conducted in January 1978 at the University of Wisconsin, one of the projects studied was a highway bridge across the Plover River (Fig. 4). This was a three-span four-lane crossing with a pedestrian walkway. The FAST diagram developed by the team shows how the costs were allocated in the present design (Fig. 5). Remember that the diagram is a powerful communication tool which provides a common reference or focus for designers, contractors, and owners.
## Figure 2

### THE FIVE-PHASE JOB PLAN

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
<th>Phase IV</th>
<th>Phase V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INFORMATION</strong></td>
<td><strong>SPECULATION</strong></td>
<td><strong>ANALYSIS</strong></td>
<td><strong>DEVELOPMENT</strong></td>
<td><strong>PRESENTATION</strong></td>
</tr>
<tr>
<td>Questions</td>
<td>Questions</td>
<td>Questions</td>
<td>Questions</td>
<td>Questions</td>
</tr>
<tr>
<td>What is it?</td>
<td>What else will the job do?</td>
<td>What does each cost?</td>
<td>Will it work?</td>
<td>Make presentations</td>
</tr>
<tr>
<td>What does it do?</td>
<td>How does it perform the basic function(s)?</td>
<td>Will it meet all the requirements?</td>
<td>Will it meet all the problems?</td>
<td>Written proposal</td>
</tr>
<tr>
<td>What must it do?</td>
<td>What is performance of basic function(s) worth?</td>
<td>What do I do now?</td>
<td>What is needed?</td>
<td>Oral w/illustrations</td>
</tr>
<tr>
<td>What does it cost?</td>
<td></td>
<td>What is the savings?</td>
<td>Who has to approve it?</td>
<td>(brief and pertinent)</td>
</tr>
<tr>
<td>What is performance of basic function(s) worth?</td>
<td></td>
<td></td>
<td></td>
<td>Present problem</td>
</tr>
<tr>
<td>Techniques</td>
<td>Techniques</td>
<td>Techniques</td>
<td>Techniques</td>
<td>Explain advantages and disadvantages</td>
</tr>
<tr>
<td>Use good human relations</td>
<td>Use good human relations</td>
<td>Use good human relations</td>
<td>Use good human relations</td>
<td>Present facts quickly, concisely</td>
</tr>
<tr>
<td>Get all the facts</td>
<td>Eliminate!</td>
<td>Evaluate by comparison</td>
<td>Oversimplify</td>
<td>convincingly</td>
</tr>
<tr>
<td>Get information from the best sources</td>
<td>Try everything</td>
<td>Refine ideas</td>
<td>Blast-create</td>
<td>Explain implementation problems</td>
</tr>
<tr>
<td>Obtain complete information</td>
<td>Oversimplify</td>
<td>Use services of experts</td>
<td>Oversimplify</td>
<td>Suggest further meetings</td>
</tr>
<tr>
<td>Define the function(s)</td>
<td>Modify and refine</td>
<td>Use your own judgment</td>
<td>Use creative techniques (brainstorm)</td>
<td>Follow up!</td>
</tr>
<tr>
<td>Perform functional evaluation</td>
<td>Use creative techniques (brainstorm)</td>
<td>Select first choice</td>
<td>Use creative techniques (brainstorm)</td>
<td>Remove roadblocks</td>
</tr>
</tbody>
</table>

*As the dashed lines indicate, information gathering may continue throughout almost all phases of the job plan, and analysis may continue well into the development phase.*
After successful application of the Speculative and Analysis Phases of the Job Plan, this function analysis lead to the development of a proposed design using precast concrete double tees in lieu of the original AASHTO, Type II precast concrete beams. The function “convey traffic” included the bridge superstructure. Analysis of the costs included in this function determined that a large amount was involved in forming. Knowing where the costs were, led to the questioning of how these costs might be reduced or eliminated. The use of precast tees deleted the need for the bottom forms and shoring necessary to pour the bridge deck in the original design (Fig. 6). Note how this change permitted a sizeable savings in performance of the “convey traffic” function. Total savings from this analysis was $80,558 or 14.3% of the original design’s cost (Fig. 7). All required functions can still be performed equally as well by the proposed design alternative.
SKETCH OF PRESENT DESIGN

"PRESENT" FINISHED GRADE

50-YR FLOOD LEVEL

PRESENT GRADE

"PRESENT" BRIDGE

"PRESENT" EMBANKMENT

"PRESENT" PROFILE

DOUBLE HAND-RAIL

PARAPET

52' ROADWAY (4 LANES)

6' SIDEWALK

AASHTO, TYPE II P.C.C. BEAMS

"PRESENT" DECK CROSS-SEC.

COST = $600K

Figure 4.
DESCRIPTION OF PROPOSED DESIGN

"PROPOSED" DECK CROSS-SEC.

Figure 6.
PLOVER RIVER BRIDGE

Design Objectives
- Preserve Stream
- Maintain Environment

Why?
- Protect People: $12,264 (2.2%)
- Protect Vehicles: $36,480 (6.5%)
- Prevent Erosion: $16,885 (3.0%)
- Improve Appearance: $6,838 (1.2%)

How?
- Primary Function: Discharge Traffic: $72,897 (12.9%)
  - Furnish Approach: $174,384 (30.9%)
- Secondary Function: Convey Traffic: $72,462 (12.8%)
  - "At The Same Time As" Functions: $171,710 (30.4%)

Figure 7.
CONTRACTOR AND OWNER SHARE SAVINGS

It seems that we may have been discussing this problem from a purely design standpoint. How, then, do the contractor and owner figure in the total picture?

The contractor has entry into the program through the Value Engineering Incentive Clause of his contract. Paraphrased, this clause of the General Provisions states: “Mr. Contractor, if you determine that in any portion of your contract the basic function may be performed at least as well by another method, submit your Value Engineering Change Proposal (VECP). If approved, the owner will share with you in accordance with the sharing arrangement, of this contract clause.”

Generally, the sharing arrangement is 50/50. I urge those persons responsible for preparing contract documents to consider the addition of a Value Engineering Incentive Clause to your contracts. The track record of the VECP’s received under such clauses is a two-thirds approval rate. It costs nothing to include the Value Engineering Incentive Clause. The incentive clause avails the owner of the opportunity to effect construction savings and life cycle cost savings in accordance with the contractor’s functional analysis and actual in-the-field experience.

RETURNS, USING VE CONSULTANTS, BETTER THAN 10 TO 1

In addition to the incentive clause another functional analysis approach is open to the owner. He may choose to fund function analysis studies by his AE or a VE consultant. The expected minimum return from such studies is ten to one. The study done by the five-man team on the Plover River bridge represents approximately 80 man-hours of effort and equals a savings of $1,000 plus per man-hour.

VE WORKSHOPS AND UNIVERSITY COURSES

As with most endeavors, the key to performance is training. Perhaps the best method of developing the necessary understanding and skills is the 40-hour function analysis workshop. Such are offered by some universities and technical societies and approved by the Society of American Value Engineers (SAVE). Approximately one-half of the time in these workshops is devoted to function analysis of live project designs. A few of our universities now offer accredited courses in Value Engineering while numerous others are investigating the addition of such courses to their curriculum. Suffice it to say, the function analysis methodology is a powerful tool in which the skills and understanding of
the practitioner increase greatly through practical application and experience.

**VE COULD SAVE MILLIONS IN FUTURE HIGHWAY CONSTRUCTION**

To develop a perspective of the potential for function analysis in future highway and road construction, I wish to only remind you of the millions of dollars of construction that will be generated by the necessary replacement of America's older bridges within the next few years. Large as it might be, this one facet represents but a small portion of the future overall highway and road construction picture. I submit that it is to the interest of all, be they municipal, county, or state officials, designers, construction managers, contractors, or merely concerned tax payers, to value improve highway construction. Certainly one of the most powerful tools now available for achieving this function is functional analysis (value engineering).