STATEMENT BY F. C. TURNER, DIRECTOR OF PUBLIC ROADS, FEDERAL HIGHWAY ADMINISTRATION, DEPARTMENT OF TRANSPORTATION, BEFORE THE U.S. SENATE COMMITTEE ON PUBLIC WORKS, AUGUST 2, 1967

By definition "VALUE ENGINEERING probes into the functional requirement to determine if an alternate configuration can accomplish the required function at less cost."

While the term is relatively new, it simply describes what has been covered under terms such as "engineering economics" for many years. The function to which it applies has been one of the most important of those performed by the Bureau of Public Roads since its organization.

Value engineering or cost effectiveness as applied to the Federal-aid highway program relates to efforts directed toward determining whether alternate highway engineering plans and designs can provide equal or better service at less cost.

The probing into functional requirements to determine if an alternate configuration can accomplish the required function at less cost is perhaps the most fundamental area of responsibility exercised by the Bureau's staff. This also includes the obverse of the proposition, wherein we try to determine how added values can be bought for no increase in cost, and whether an increase in price will buy a finished road sufficiently increased in service qualities as to justify the added expenditure of public funds.

These kinds of value engineering judgments are fundamental routine in all aspects of every project proposal submitted by State highway departments to the Bureau for approval, beginning with the earliest stages of system selection and route locations.

For instance, in determining route locations we require a study of all feasible alternate alignments, and this involves identification of all significant differences among them. Each comparison of route location alternates includes consideration of many determinants including:

National defense
Economic activity
Employment
Recreation
Fire protection
Esthetics
Public utilities
Safety
Residential character and location
Religious institutions and practices
Rights and freedoms of individuals
Conduct and financing of government
Conservation
Property values
Replacement housing
Education, and disruption of school district operations
Specific numbers of families and businesses displaced
Engineering, right-of-way and construction costs for proposed highway facilities and other transportation facilities
Use of highways and other transportation facilities, and user costs
Operation of highway facilities and other transportation facilities during construction and following completion

The extent of the consideration of each determinate varies with the nature and magnitude of the proposed highway project and with the characteristics of the area in which it is located.

In the area of social values there is currently the largest difference of opinion as to the range of numerical values to assign to various factors. But we are engaged in considerable research which seeks to quantify these values also, so as to permit the intelligent application of value engineering here as well as in the area of the physical features of a highway system.

In evaluating the relative merits of alternate route locations, and alternate design solutions on a particular location, use is made of the most advanced techniques so far developed in the field of aerial surveying and its related disciplines. Using photogrammetric instruments and electronic computer applications the engineer is capable of making rapid cost determination on many alternate combinations of horizontal and vertical roadway alinement. With these techniques engineering judgments can be reached on optimum values of varying cost factors, quantities can be balanced and minimized, and the time required for design reduced greatly. The whole process is value engineering at its best.

In developing the design configuration for freeway interchanges, both rural and urban, alternate studies are made of the geometric layout and the location of the interchange area to assure that the required traffic service is provided at the minimum cost commensurate with the engineering and sociologic values involved. Direction of travel, distance of travel, value of real estate, displacement of people and of business ventures--are all given proper consideration in arriving at the solution to be adopted for construction plans. No single factor determines the answer, and the judgment made is based on public interest values.

Highway pavement design and the selection of surface type is made after evaluation of the many variables involved in this determination. The type and thickness of the surface, the base course, and the subbase to be placed on top of the subgrade material are decisions made after study of the total costs involved for the pavement structure to be made up of these three layers.

The cost varies with the location of the highway since the availability of acceptable aggregates and the character of the subgrade soils on which the highway is located changes greatly in the different parts of the country.

The number and size of vehicles to be carried on the highway determine the surface and base structure needed to assure a satisfactory pavement life. Where the subgrade soils provide good support, as in an area of gravelly soils, the depth of pavement layers is reduced and the cost of the pavement structure minimized. In these areas the surface course alone is not required to provide the load carrying capability that would be required where subgrade soils lacked good supporting characteristics.

A portland cement concrete surface course may be selected where good concrete aggregates are available and the high supporting value of this type surface can be utilized to reduce the thickness of base course and subbase material otherwise required. On the other hand, an asphaltic concrete surface could show a greater economic advantage in areas where excellent subgrade material permit a more flexible surface type and a reduced total structure number.

The many combinations of costs and materials involved are considered as the nature of the subgrade changes and, in the end, a surface type selection is made after considering the relative value and relative cost of several solutions.

Continuously reinforced concrete pavements are considered as a design solution where, due to the density of traffic to be served, the added cost of this surface type can be offset by the marked reduction in maintenance which it requires.

The highway engineer follows a similar study of many alternates when he selects the bridge type to be used for the drainage structures required on the highway facility. Bridges consisting of girders, arches, and trusses may be designed from various classes of structural steel. Concrete girders, concrete arches, prestressed concrete slabs, aluminum bridges--all are involved in the analyses to be made. The relative value of each type changes with the length of span involved and width of roadway required. The depth beneath the surface to adequate foundation soils is a major determinant which must be considered in bridge type selection.

The economics of bridges changes with the area of the country, the availability of materials, and the skilled workmen available. Based on all variables and a proper evaluation of their relative merit a bridge type is selected which reflects the best choice in the public interest.

In all of the engineering and economic analyses which must be made we utilize the results from research studies and experimentation, and the professional competence and experience of engineers gained through a half century or more of highway construction. Studies relating to the operating characteristics of vehicles on varying curvature of highways; the gradients to be used; the design speeds to be adopted; the lateral clearances required for safety--all are factors on which an engineering judgment is made. The ultimate judgment makes use of the results of research and the accumulated experience of the profession in arriving at a design value which will reflect an optimum service factor when weighed against the cost involved.

But value engineering does not stop here. We handle about 7 to 10 thousand new projects each year and attempt to apply value engineering, good management, common sense or whatever you want to term it to all of these in many ways.

Value engineering or cost effectiveness savings frequently result from Public Roads review of location and construction plans for Federal-aid highway projects. This is an area in which Public Roads' staff has long been active.

You may recall that Sec. 106 of Title 23, U.S.C., Highway, provides in part that ". . . the State highway department shall submit to the Secretary for his approval as soon as practicable after program approval, such surveys, plans, specifications and estimates for each proposed project included in an approval program as the Secretary may require. The Secretary shall act upon such surveys, plans, specifications and estimates as soon as possible after the same have been submitted . . .".

In accord with this legislative provision, a detailed review of project plans, specifications and estimates is made by Public Roads engineers as a step in the approval of Federal-aid highway projects, both rural and urban. Reviews made during the development stage frequently result in changes in proposed route locations or in plans and specifications as initially submitted by the States which reduce the estimated cost of right-of-way acquisition or construction without sacrifice of service or safety considerations.

The reported savings resulting from Public Roads value engineering reviews are substantial, totaling over $180 million in fiscal 1966.

The value engineering or cost effectiveness savings result in either a production increase or cost reduction, depending upon whether the projects are financed from primary, secondary and urban (ABC) funds or from Interstate funds. The distinction is as follows:

1. Production Increase

Savings realized in connection with ABC projects remain available to the States and are applied toward additional construction. Since the end product is additional miles of improved highways, the increase in output is described as "production increase".

2. Cost Reduction

The Interstate System of highways is limited by law to 41,000 miles; therefore, savings realized in connection with Interstate projects do not result in increasing the miles of highway. However, these savings do result in reducing the cost of completing the Interstate System. The savings therefore are described as "cost reduction."

The value engineering savings reported during fiscal 1966 were distributed to these two categories as follows:

Production increase, ABC projects	-	$ 29,000,000
Cost reduction, Interstate projects	-	151,000,000
Total		$180,000,000

Value engineering or cost effectiveness savings are of two kinds, namely, (1) right-of-way, and (2) engineering or technical. The 1966 fiscal year savings were distributed as follows:

Right-of-Way	-	$ 19,000,000
Engineering or technical	-	161,000,000
Total		$180,000,000

There are many situations where our Public Roads reviews result in identifiable savings, some large and some small. Representative examples are as follows:

1. On one project, rest areas initially were proposed for each side of an interstate highway. No ideal sites were available and those selected by the State would have been quite costly and would have required rest area traffic to cross truck climbing lanes. Bureau of Public Roads' engineers suggested an alternate location within an existing split diamond interchange. This suggestion allows rest area traffic to enter and exit the expressway on existing ramps, and one large rest area serves both directions of travel. Included in the numerous advantages to this new arrangement are monetary savings of approximately $250,000.

2. Substantial savings in right-of-way costs were realized by changing the roadway alignment of a project to avoid acquiring a large independent gasoline station. The value of the station was estimated at $275,000; whereas, the additional damages resulting from the change in the location of the roadway were estimated to be only $25,000. The net amount saved as the result was approximately $250,000.
3. Two borrow pits proposed to be used for an Interstate project could not be obtained and as a result two other locations were substituted. The quality of the material in the new pits was significantly higher than the original pits. Bureau engineers called the State's attention to the fact that the increased quality of material would permit a decrease of 3 inches in the thickness of the select material required in the project specifications. The estimated savings based on average contract prices amounted to $10,000.
4. The original design of an Interstate project required the construction of a separate structure over an existing street. Bureau engineers participated in meetings with the local county commission and planning board and suggested an alternate plan which eliminated the need for the structure. This was accomplished by closing the existing street at that location and building a frontage road which connected to another local street to maintain the traffic flow. The resulting savings were estimated to be $180,000.

5. An Interstate project was planned to include an interchange as well as a grade separation structure to serve traffic to a city. As a result of the Bureau's review of the locations, and consultations with State and city authorities, it was decided that the city could better be served by converting the planned road separation structure to a diamond interchange and eliminating the interchange originally planned. The overall savings estimated as the result of this change amounted to $141,700.

6. On a Primary project Bureau engineers suggested an alternate bridge design using a long bridge with spill-through type abutments rather than the proposed cantilever retaining wall type of abutments. As a result, the estimated cost of the bridge was reduced from $132,007 to $76,020 for a net saving of $55,987.

7. During an engineering review of a Primary project, Bureau representatives suggested that a long box culvert be rearranged to provide a greater amount of open channel and reduce the length of the culvert. The original length of 1,300 feet was reduced to about 300 feet with a resulting savings of $135,000.

8. As the result of the Bureau's review and request, two proposed projects were combined into one so that excess dirt on the north end of the first could be used to build embankments on the south end of the second project. This saved paying

for disposal of surplus excavation of one project and additional borrow material on the other. The estimated savings amounted to $1,325.

9. After review of a proposed bridge on an Interstate project the Bureau recommended a change in the channel to reduce the skew. In addition, recommendation was made to change the bridge type from I-beam to reinforced concrete slab. The result was a reduction in the depth of the superstructure which reduced roadway embankment requirements. The estimated savings was $65,000.

10. After review of the State's proposal to construct a new bridge across a river on an Interstate route and an investigation of the design on an existing bridge, recommendations were made for certain modifications in the existing structure and to continue its use rather than constructing an entirely new bridge. The difference between the estimated cost of a new bridge and the cost of modifications on the existing bridge amounted to $555,000.

The attached list identifies additional items for which savings have been reported. The list covers only a portion of such items reported during fiscal 1966 and the first half of fiscal 1967, and is not intended to be all-inclusive.

In Public Roads we are necessarily limited in our value engineering reviews by the extent to which engineering staff is available for this type of activity. As always, we make every effort to accomplish as much as possible with the staff available to us.

In concluding this discussion of value engineering, I should mention that we have authorized a procedure similar to that used by the Department of Defense wherein the contract includes a provision permitting the successful bidder to share in the savings of cost resulting from cost reduction proposals initiated and developed by the contractor for changing design plans and specifications or other contract requirements. For example, we expect to include this provision for certain contract items in a proposed project for the construction of twin multi-million dollar tunnels through the Continental Divide in Colorado.

So you can see that value engineering is our constant and day-to-day routine way of doing business with the funds which this Committee entrusts to us and the State highway departments. It is one of the many areas in which Federal-State cooperation serves to provide for better highways at less cost.

This concludes my prepared remarks. I will be glad to answer any questions the Committee members may have concerning this or other aspects of Federal-aid highway program activities.

EXAMPLES OF VALUE ENGINEERING - COST EFFECTIVENESS SAVINGS

	Item	Estimated Savings
1.	Revision in interchange scheme eliminating need for two ramps.	$ 204,000
2.	Change in project design to avoid acquisition of a commercial property.	200,000
3.	Design changes to avoid landlocking and thereby causing heavy damages to 40 acres of commercial property.	150,000
4.	Elimination of grade-separation structure.	200,000
5.	Substitution of special borrow material for higher priced gravel borrow.	257,600
6.	Provide for an access road to avoid acquisition of right-of-way and the relocation of 50 families.	100,000
7.	Revised roadway alignment to avoid adverse soil conditions	60,000
8.	Street relocated to eliminate need for grade separation structure.	63,000
9.	Hydraulics analysis showed that the size of twin box culverts could be reduced.	10,000
10.	An 84 inch sewer was bridged rather than relocated.	183,000
11.	Relocation of railroad spur track reduced cost of constructing interchange.	800,000
12.	Two overpass structures eliminated.	2,000,000
13.	Unnecessary plant material eliminated from a 17 mile landscaping project.	90,000
14.	Use of longer prestressed concrete bridge spans reduced construction costs.	40,000
15.	Embankment with surcharge used in lieu of dual structures over area containing poor subsoils.	2,356,000
16.	Route relocation allowed a shorter structure to be used.	368,000
17.	Construction of a fill with surcharge across a creek in lieu of a fill with vertical sand drains.	1,100,000

	Item	Estimated Savings
18.	Total length of a structure over a river reduced from 6,400 feet to 5,600 feet.	$1,000,000
19.	Adjustment in grades resulted in decrease in earth excavation and overhaul.	250,000
20.	Interchange location changed to avoid large gravel deposit and active aggregate producer.	300,000
21.	Route relocation resulted in the elimination of two major stream crossings.	200,000
22.	Concrete ballast deck substituted for proposed steel ballast plate deck.	23,000
23.	Railroad crossing structure designs changed to consolidate two crossings.	423,000
24.	Design changes to reduce railroad bridge lengths and eliminate separation structures.	164,000
25.	Design changes were made to eliminate a directional interchange with backup structures in favor of a simple diamond interchange.	200,000
26.	Plans were revised to construct a single structure to carry a crossroad over an Interstate highway rather than construct dual structures to carry the Interstate over the crossroad.	100,000
27.	Additional design study resulted in the use of twin structural plate pipes rather than the originally proposed bridges.	93,845
28.	The construction of a frontage road at a cost of $6,130 reduced severance damages to property owner by $327,275.	321,145
29.	Review of a separation structure design indicated a shorter structure should be used. The bridge length was subsequently reduced by 455 feet.	283,129
30.	Design of separation structure was changed from full retaining abutments to spill-thru end slopes and shallow wing walls.	130,349

Item	Estimated Savings
31. Location and design of an interchange was changed, resulting in simplification of the design and reduction in grading quantities.	$ 300,000
32. Original plans on several projects provided for arch type drain pipes for drainage although standard round type drain pipes were adequate.	150,000
33. Interchange was redesigned to avoid acquisition of a microwave tower and electrical substation.	200,000
34. Borrow material was obtained from a drainage ditch being constructed by a local authority.	144,000
35. Changes in grade were made which reduced the embankment material requirements by 250,000 cubic yards.	87,500
36. Field review resulted in shifting the alignment of the road and thereby reducing the quantity of rock excavation.	71,500
37. Route investigation led to the development of a new route location with resulting savings in construction costs.	7,000,000
38. Road design changed to avoid encroachment on a local airport.	200,000
39. Change to heavier and stronger bridge piers to eliminate the need for expensive fender system to protect piers from barge collision damage.	264,000
40. Change to use of prestressed concrete construction on approach spans of a bridge.	100,000
41. Construction of a frontage road provided access to property and eliminated severance damages which would have been substantially higher than the cost of the frontage road.	292,000
42. Design for a stream crossing changed from a 2-cell box culvert to a rigid frame bridge crossing.	101,000
43. Bridge design change from a short bridge with high abutments to a longer bridge with spill through open abutments.	40,000
44. Adjusted grade at a crossroad resulted in lower embankments.	20,000

Item	Estimated Savings
45. Substituted chain link fence in lieu of extra excavation for control of falling rock.	$ 98,000
46. Change to treated gravel course for erosion control in lieu of rip-rap.	24,930
47. Revised structural details regarding type of girder and bridge bearings.	13,000
48. Substituted twin pipe arches for a 240-foot bridge.	161,400
49. Through design changes, a bridge was reduced in length by 100 feet.	100,000
50. As the result of lowering the grade on a project, the borrow excavation requirements were reduced by 347,000 cubic yards.	208,200