87-3 RRF

VALUE ENGINEERING

For Bus Maintenance Facilities

Program Digest

U.S. Department of Transportation

Urban Mass Transportation Administration

UMTA-MA-06-0120-87-2
DOT-TSC-UMTA-87-3

VALUE ENGINEERING

For Bus Maintenance Facilities

Program Digest

April 1987

U.S. Department of Transportation

Urban Mass Transportation Administration

CONTENTS

Overview

Value Engineering (VE) is a procedure used to reduce the total cost of performing a required function, without sacrificing quality or safety. The concept of VE is over 40 years old, and during its early years was primarily used in manufacturing industries. About 20 years ago, however, its precepts began to be applied to building construction. A number of government agencies, as well as private industry, have successfully used VE to obtain significant cost savings in the design and construction of buildings, bridges, sewage treatment plants and other related projects.

Until recently, VE had not been utilized in the transit industry except as an incentive in a small number of construction contracts. However, VE has a vast potential for reducing both capital and operational costs of transit maintenance facilities. To demonstrate this potential, the Urban Mass Transport istration (UMTA) recently s demonstration projects wh applied to the design of trans and maintenance facilities. presents a synopsis of the application of VE and a doc the two projects. It is ho information will encourage tr to consider incorporating co ments for a VE study whene and construction of a new facility is contemplated.

Definition of Value Engineering

Value Engineering systematic, investigative studying a product, system, order to identify and analyz that it has been designed to costs to be incurred by con utilizing the product as

Value Engineering has vast but largely untapped potential for reducing both cycle costs of transit maintenance facilities.

calculated, and alternative designs are generated in order to determine the most cost-effective method of performing the identified functions, consistent with requirements for quality, reliability, maintainability and safety. The VE approach is a creative, multi-disciplined team effort aimed at eliminating or modifying design features that add unnecessary cost without contributing to the overall function of the product, system, or facility being studied. It takes into account the total life cycle cost of producing and operating a product or facility over its useful life.

Contrary to common misconception, Value Engineering is not a design review intended to correct design omissions or check design calculations, nor is it a process for cutting costs by sacrificing necessary attributes of the design. It should also be noted that VE is not automatically performed by all designers.

History of Value Engineering

Value Engineering i concept; in fact, the origins of to the early 1940s, althoug applied in the construction about the last 20 years. Afte of World War II, Larry Miles at the General Electric C shortages of raw materials d applications were forcing d engineers to look for altern performing existing functi different materials and/or des cases he noticed that althoug designs were changed, th products still performed t functions, often more effectiv cost. Upon investigating t some of these redesigned pr often learned that the old simply the result of custom, ceptions and unfounded assum

Although developed during World War II, Value Engineering was not a construction industry until the 1960s.

Miles and his boss, Harry Erlicher, a GE vice-president, began to work on methods for motivating engineers and designers to break away from their usual, habit-oriented ways of solving design problems. During the years after the war, while he was responsible for leading cost reduction efforts on GE products, Miles developed the functional analysis method to stimulate creative thought and identify unnecessarily expensive aspects in product and process designs. This idea of cost reduction at GE was subsequently expanded to include analysis of the overall value of a product, and to involve various other departments in product-study efforts. Thus the program became known as Value Analysis and for the first time began incorporating a multi-disciplined team approach.

During the early 1950s, word of the success of the GE program came to the attention of the U.S. Navy. After observing the GE program first-hand, the Navy's Bureau of Ships initiated a value analysis program at a number of its shipyards. However, whereas GE used the program to analyze an existing produc
approach was to apply the con
Analysis during the enginee
ship design, thus prompting
name to be changed to Valu
The other armed services soo
Navy's lead and developed V
their own, in which the
involved their suppliers and c

In the mid-1960s, the
Engineers introduced VE
struction industry in the for
clauses in construction contr
ber of other Government ag
ing NASA and GSA, also be
incentives to their constructi
the early 1970s, GSA impos
ment for VE studies durin
phase of construction projec
adopted a voluntary VE pro
that became mandatory a ye
wastewater treatment projec
cost more than $10 million
other Government agencie
many firms in the private se
VE to achieve savings of mil
on many types of constructio

1. Implementing a Value Engineering Study

The implementation of a VE study for a facility project involves a number of steps that must be followed in order to make the effort effective and worthwhile. These include insuring that the study is done at the appropriate stage in the facility design cycle, and arranging for the selection and assembly of a team of professionals to perform the study. In most cases, however, a VE consultant is used to manage the entire VE study effort, so that the contracting agency's main concern is the selection of a qualified consultant.

The Value Engineering Consultant

The ideal choice for a VE consultant is an independent source who has not previously been associated with the design of the facility being studied. The consultant should be certified by the Society of American Value Engineers (SAVE) and have experience in conducting VE studies for the construction industry, good technical capability and a reasonable pricing structure.

Prior to the study, consultant responsibilities include: 1) assembling all relevant design information and distributing it to the VE team members for their review, 2) selecting a site for the study/workshop, and 3) analyzing and validating the preliminary cost estimates.

During the study, the consultant is responsible for 1) conducting the workshop in conformance with the guidelines of the Society of American Value Engineers, 2) coordinating communications between the VE team and design staff when required, 3) ensuring that change proposals are realistic and cost effective, and 4) preparing the draft VE report on all proposed changes for post-study review by ager personnel.

Subsequently, the V should be prepared to furni information as required implementation of the accepte

The Value Enginee Study Team

The VE study is perfor week-long workshop by a mu team of professionals specifica for this purpose. Personnel electrical, mechanical, civil/s construction engineers, as we ists in architecture, cost, management and transit bus Most if not all of the partici have a minimum of 40 hours o and experience in VE worksh efficient use is made of the tim the study.

Timing of a Value Engineering Study

The importance of timi study cannot be overemphasize 1 indicates, the standards imposed on and by the contra and the decisions made by consultants, have the greate the life cycle costs of a facility. be seen in Figure 2, Value E highest potential for net cos during the early stages of a fa In addition, when a study i during the early stages o schedule delays, whether imp study itself or by the implemen recommended changes, are mi

Experience shows that t to do a VE study is when t approximately 30 percent comp this time, the design has sufficiently developed to aff

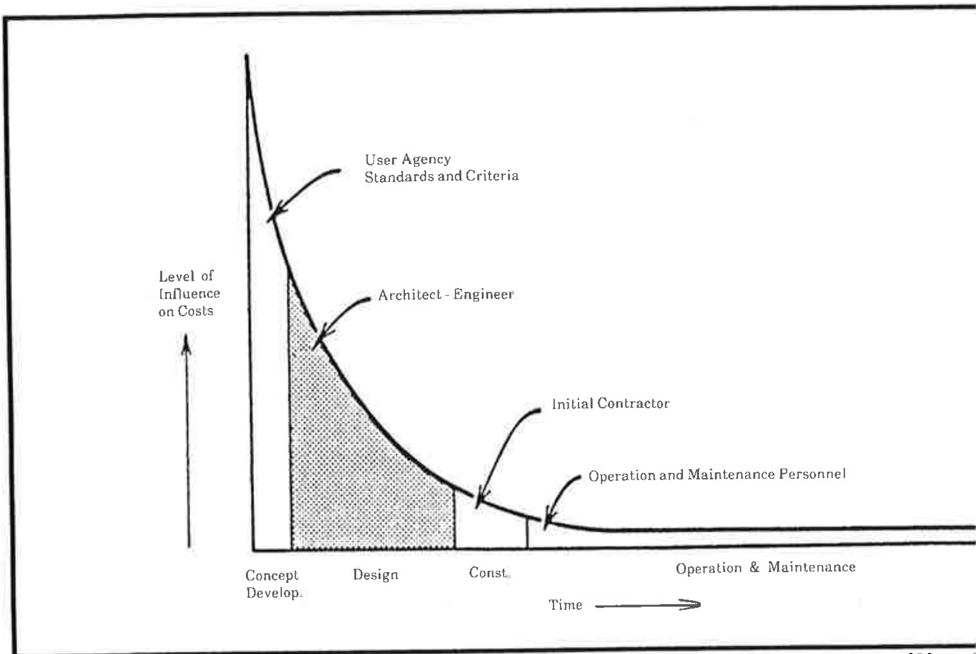


Figure 1. Relative Influence of Major Decision Makers on Total Facility C

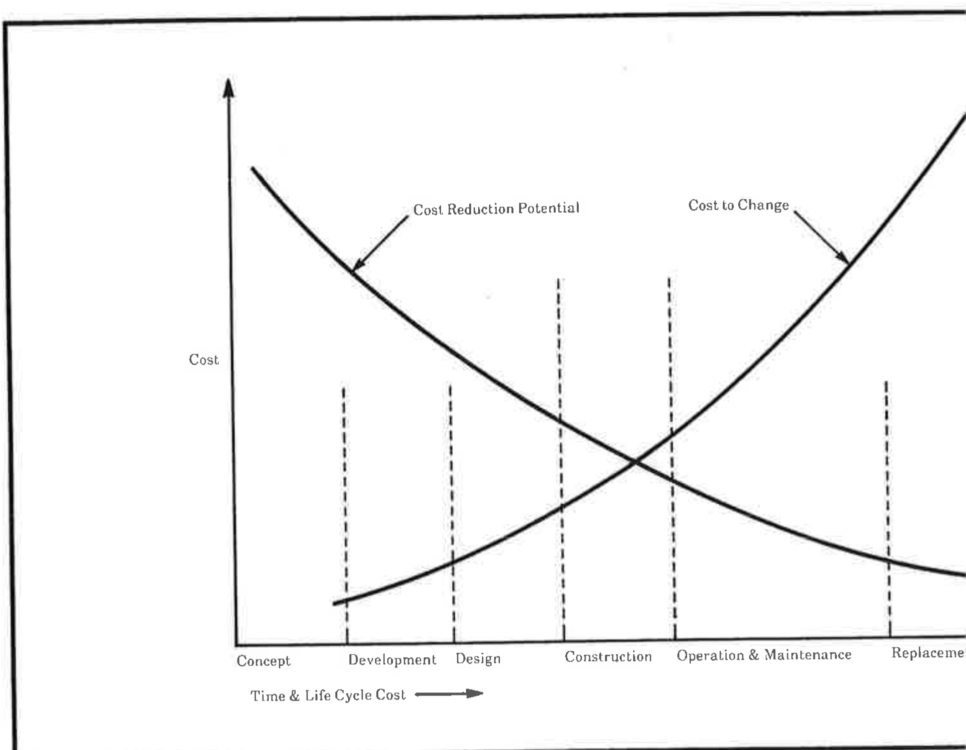


Figure 2. There Is a Direct Relation Between Timing and the Cost Reduc Potential of a Value Engineering Study

information for a study. Conversly, a study performed on a more complete design at a later stage would result in considerably reduced net cost savings due to the progressively higher costs of implementing VE changes as the project proceeds.

The Value Engineering Study/Workshop

The VE workshop is conducted in accordance with a step-by-step procedure called the Value Engineering Job Plan. The plan provides a systematic approach and structure for the review process, a feature that differentiates VE from all other review techniques. The VE Job Plan is essentially divided into the five phases shown in Figure 3.

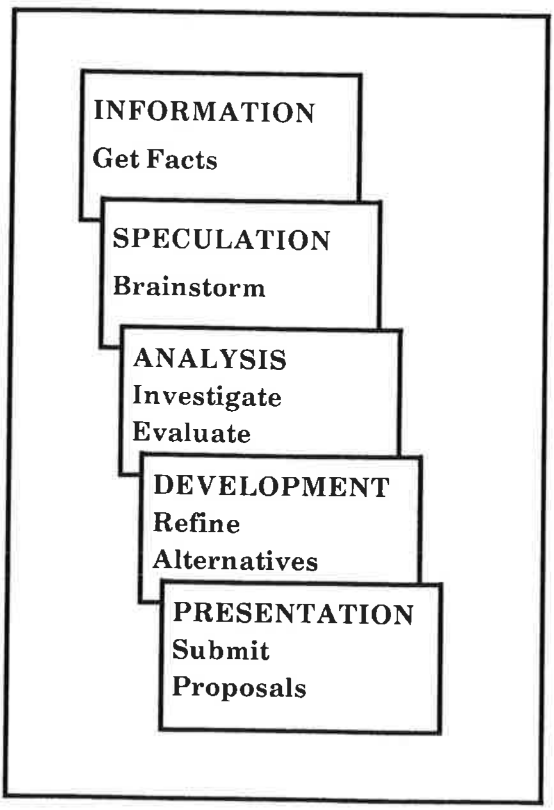


Figure 3. Value Engineering Job Plan

Information Phase

During this phase, w
begins prior to the start of t
the VE team obtains as muc
as possible on the background
as well as on the project itsel
to design drawings, specificat
estimates, such details as de
imposed constraints, site
utilities availability, utility r
and maintenance and operati
need to be examined.

As part of this phase, or
of the workshop a presentatio
members of the designer's st
study team detailing the prog
the design up to that point. W
this is followed by a site visit
team members prior to their a
the location chosen for the wor

The information phase
with a review and validatio
information provided, a calcu
cycle costs and the construc
models. The next step involve
analysis whereby the basic a
functions of the project ar
defined. Both the cost and "w
function are then identified t
areas of high cost and low
design, thus indicating th
features with the greatest pote
savings through VE. In the m
studies on transit mainte
operation facilities, the areas w
savings potential are usual
building and grounds layouts,
methods and materials, and
procedures.

Speculation Phase

Having thus selected the
design on which to focus thei
VE study team proceeds to the
or creative phase. During thi
the study, the team members

and together to generate a list of alternative methods of performing the functions involved in the targeted areas of the design. No idea evaluation is done at this time. Rather, the team members are given the freedom to draw from the full range of their knowledge and experience. A number of techniques, such as free association and organized tabulation, are used to enhance the creativity of the study team members.

Analysis Phase

Once the speculative phase is concluded, usually at the end of a set period of time, the analysis phase is begun. Each of the generated ideas is evaluated against both functional and cost-reduction requirements, as well as for its feasibility and potential for acceptance by the transit agency. In this way, all of the less promising alternatives are screened out, leaving a small number to be developed into full-fledged proposals.

Development Phase

In this phase, a revised design is developed for each proposed change. A sketch is drawn up, life cycle costs for both the original and the proposed design are calculated, and the advantages and disadvantages of the alternative are listed. Standard references are used, suppliers are contacted, and consultations are held with transit agency and design firm personnel, if required, to ensure that the proposed changes are based on the best and most up-to-date information available.

Presentation Phase

This final phase of the
takes place at the end of the
meeting involving the V
consultant/coordinator, desi
bers of the transit authority
of the design staff is conve
presentation is given by the
by the VE team member
outlining the details of the de
for each of the recommende
Written copies of all proposal
for preliminary review b
authority and their design fir

Post VE Study

Within two weeks, the
submits a draft VE Study
transit agency review board
includes the project bac
description, the scope and
analyses, a summary of
recommendations, details of
with estimated costs
implementation and life
expected savings (including
and operational cost savings
documentation.

After final decisions h
by the review board on adopt
of the various proposals, the
is prepared. Included in the
a summary of accepted p
revised capital and implem
as well as a list of rejected pr
reasons for rejection.

2. The UMTA Value Engineering Program

Part of the mission of the Urban Mass Transportation Administration (UMTA) is to assist urban mass transit agencies in providing safe, fast, attractive service as efficiently and economically as possible. One method of accomplishing this is to provide funding in the form of capital grants to be used for construction or rehabilitation of rail and bus storage and maintenance facilities. Under the Urban Mass Transportation Act of 1964, UMTA provides funding for 80 percent of the capital costs of construction projects undertaken by state and local transportation authorities. For the fiscal years 1965-1981, UMTA provided approximately $1.5 billion for construction and rehabilitation of bus maintenance facilities. In fiscal year 1981 alone, over $860 million was obligated for transit bus projects.

Program Objective and Approach

Regulations of the Urban Mass Transportation Administration require that these grant funds be spent prudently and with maximum effectiveness. The Value Engineering Program
to introduce and evaluate the
the design and construct
maintenance facilities as
reducing both initial and rec
associated with the constructi
and maintenance of bus ga
program includes technical a
planning VE studies, provi
contracts as a part of ca
programs, and impact ass
changes due to VE. In order to
the kinds of benefits derived fr
Value Engineering during the
maintenance facilities, two de
projects were recently unde
have resulted in significant pot
and life cycle cost savings. S
these projects are given below,
number of specific examples
proposals.

Details on all of the V
described in each case study
in final report form. Copies o
can be obtained from:

Urban Mass Transportat
Administration
Office of Bus and Paratr
Systems (URT-22)
400 7th Street, S.W.
Washington, D.C. 20590
Att: Vincent R. DeMarc
(202) 366-4035

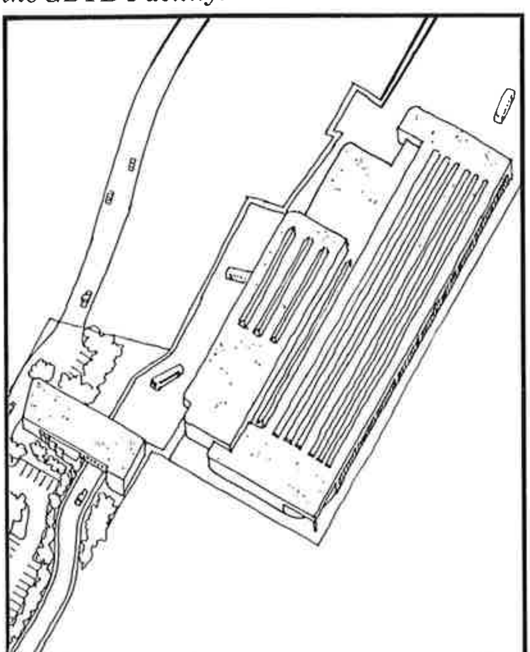
3. Program Results

Case Study No. 1: Greater Bridgeport Transit District (GBTD)

The project involved in this study consisted of a single story, 83,600 sq. ft. bus storage and maintenance building, and a 1-1/2 story, 8,000 sq. ft. operations building, to be constructed on a 6.5 acre, 2-level site . The facility had an estimated construction cost of $8.7M and is designed for the maintenance and storage of 70 buses.

The study team was assembled by the VE consultant from Hanscomb Associates of Atlanta, GA. It consisted of a construction engineer and a cost analyst from Hanscomb; an architect; mechanical, electrical and civil engineers from private industry; and a retired former Director of Maintenance for a large metropolitan transit agency. All members had previous

This sketch shows the original design for the GBTD Facility.



experience in VE workshops
number of GBTD personnel
manager of capital projects,
dent of Transportation and
Maintenance, were in atten
out the workshop.

For purposes of calcu
this study, the following ass
made:

1) Discount Rate - 1(
annually
2) Building Life - 25
3) Inflation Factor -
Dollars (0% escala
4) Equivalence Met
ization

A total of 40 potent
ideas was generated duri
stages of the VE study. Fron
selected for developmen
proposals (Table 1), of w
accepted by GBTD for im
These accepted proposals w
generate total life cycle cost
than $2M, including almost
costs out of the total estimat
cost of $8.7M.

Following are details
VE proposals selected for i
by GBTD.

1. Trombe Wall Pro

As designed, the
included a thermal mas
"Trombe" wall on the south
the building, adjacent to t
area (Figure 4). Fans and
provided to circulate heate
wall's solar collection cavity
of the storage area in winter
it outside during the summe

The VE team propos
this Trombe wall bec
uneconomically high initial

TABLE 1
GREATER BRIDGEPORT TRANSIT DISTRICT
RECOMMENDED VE PROPOSALS

1. Change enclosed, heated storage area to shed roof and windscreen design.
2. Use fuel aisle in lieu of fuel-in-place concept.
3. Replace Trombe wall with standard wall construction
4. Relocate and reconfigure operations building.
5. Change to fluorescent lighting in maintenance areas.
6. Reduce lighting level in storage area.
7. Use combined block and metal panels in lieu of precast panels for maintenance and storage building walls.
8. Use asphalt for all paved except storage.
9. Revise design of roof fran storage area.
10. Use existing concrete sla for asphalt parking lot.
11. Revise roof design to elim multi-level sections.
12. Consolidate air-condition in maintenance building.
13. Eliminate one row of bus bays.
14. Use overhead lines for ele phone service in lieu of underground cabling.
15. Use construction manage firm in lieu of general cor

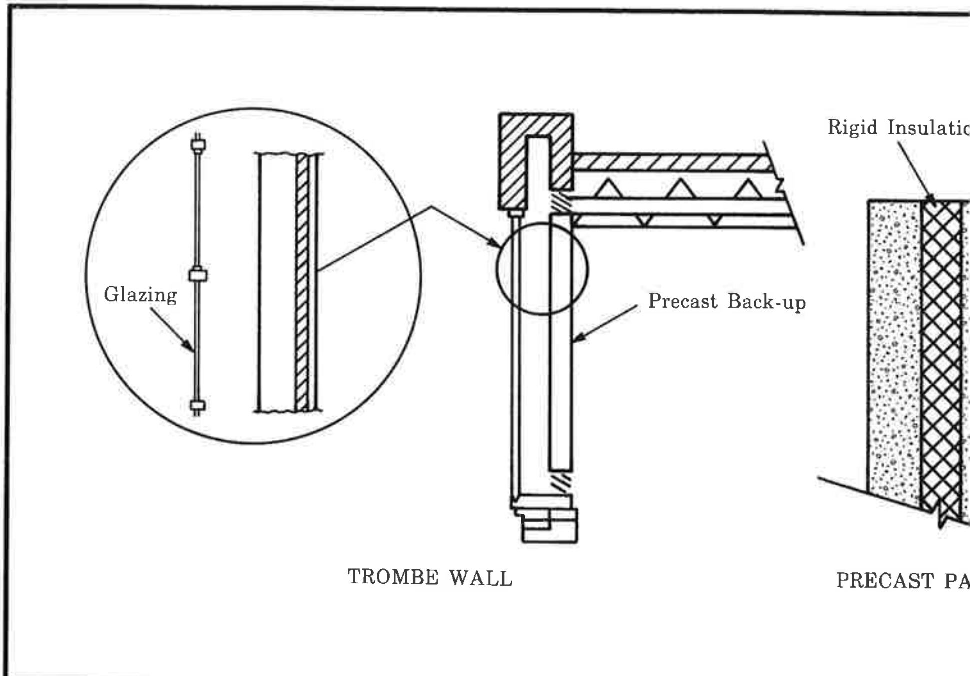


Figure 4. The Original Trombe Wall Design (with Enlargement) and, on the Proposed Precast Concrete Panel Substitute

costs and substitute precast concrete panels that are also used in other areas of the building. Implementation of this proposal was estimated to save more than $233K in initial construction costs, with even higher life cycle (25 year) operating cost savings of $265K.

2. Air Conditioning Proposal

The design for the GBTD bus maintenance and storage building contained provisions for air conditioning of certain selected offices and other rooms. These rooms were isolated in three separate areas and thus required three separate air conditioning units .

The VE study team proposed that all of the air conditioned rooms be located together so that only a single larger unit would be required (Figure 5). Although the initial cost of the larger single air conditioning unit was estimated to be approximately $4.6K higher cost of the three smaller uni in maintenance and energy single unit over the life of th estimated to be $75K. Th tation of this proposal would life cycle cost savings of mor

3. Operations Build Reconfiguration

The Operations B designed as a split level fac to the bi-level contour of the The functional areas were si partial floors under one required an internal ramp elevator for proper circu arrangement, along with façades on the north an dictated a larger building exterior surface area than is type of building.

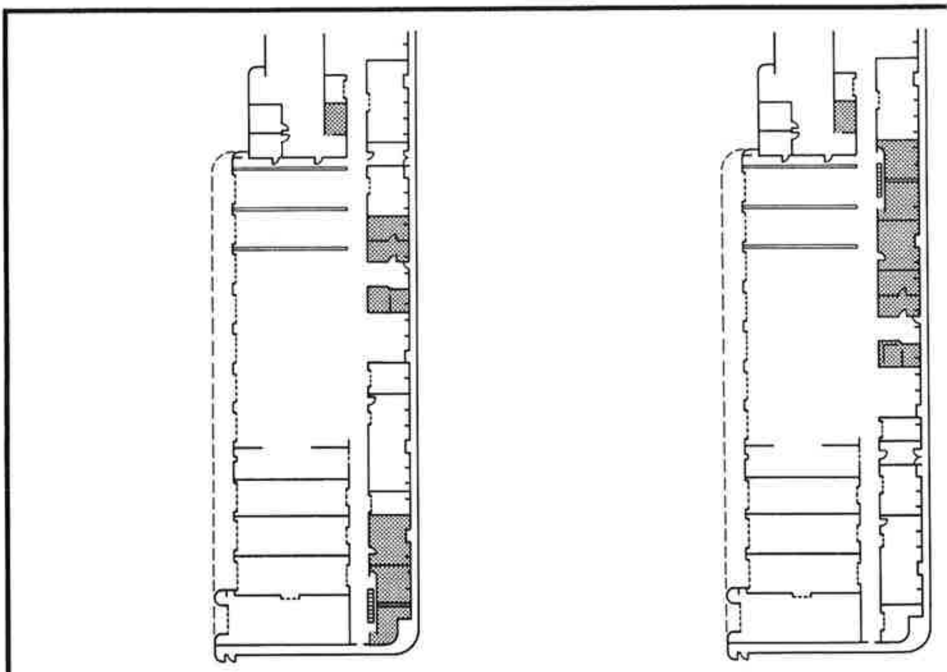


Figure 5. Shaded Areas Show the Arrangement of Air Conditioned Ro Original Plan (Left) and the VE Proposal (Right)

The VE team proposed a reconfiguration of the building as a one-story structure on a single-level area abutting the original location. The interior ramp, two stairways and the elevator could thus be eliminated, reducing the building perimeter and exterior wall areas. Although the proposed reconfiguration would impose a requirement for an exterior pedestrian ramp and stairs from the upper parking lot, it would allow for potential programmatic expansion of the building.

This reconfiguration wou
cost of the building from more
per sq. ft. to less than $83
resulting in an estimated net
savings of almost $410K. Ope
savings over the life of the bu
estimated to be more than $1
would result in a life cycle cos
almost $600K from implement
proposal.

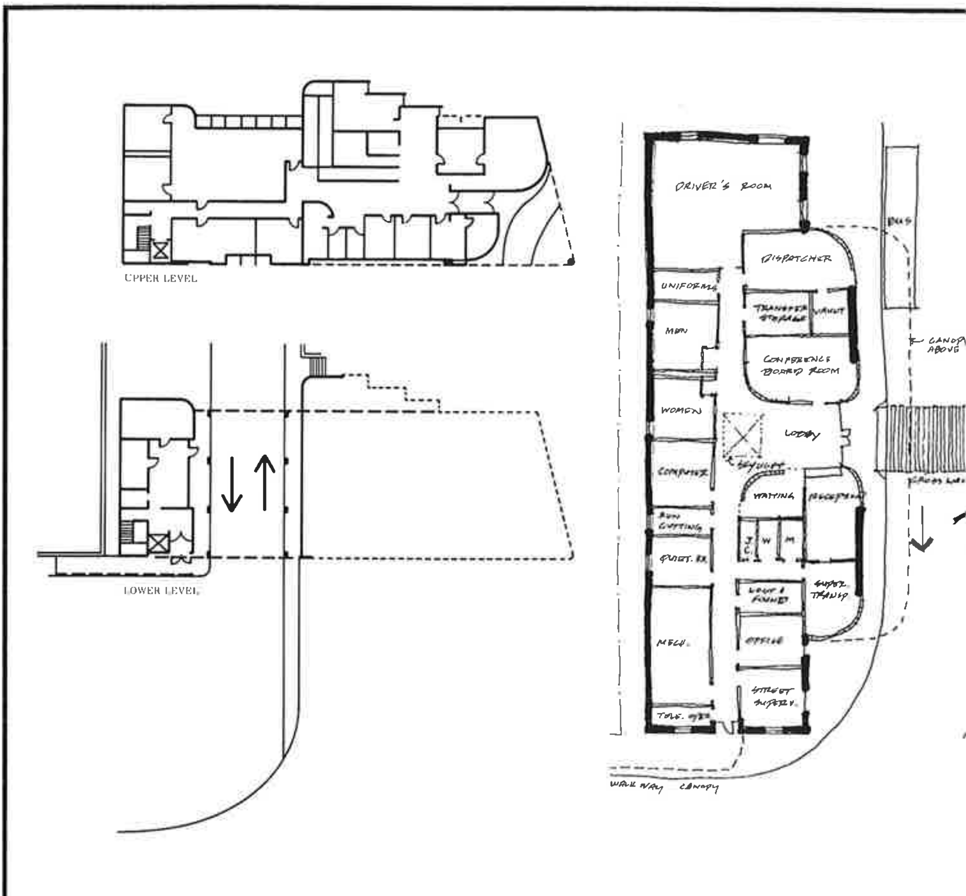


**Figure 6. The Original 1-½ Story Operations Building Design Shown at Le
Replaced with the Single-level Plan at Right**

Case Study No. 2: Washington Metropolitan Area Transit Authority (WMATA)

The subject of this VE study was a 1-1/2 story, 76,000 sq. ft. bus service and maintenance facility to be situated on a 30 acre site outside of Washington, DC, in Springfield, VA. The garage was designed to accommodate a fleet of 250 transit buses and had an initially estimated construction cost of $4.8M.

The VE study team for this project consisted of mechanical, electrical, civil and structural engineers, along with an architect and a cost specialist, all from the Detroit and Washington offices of the VE consulting firm, Smith, Hinchman and Grylls Associates, and bus maintenance and operations specialists from Fleet Maintenance Consultants, Inc. In addition, two Division Maintenance supervisors and a project engineer from WMATA were present throughout the stud make efficient use of the spa the offices of Smith, Hinchm the VE team was divided in two or three members each discipline.

For purposes of calcu this study, the following ass made:

1) Discount Rate - 10 annually
2) Building Life - 25
3) Inflation Factor - 1 Dollars (0% escala
4) Equivalence Meth Annualization

In the WMATA study, alternative ideas were initi during the speculation phase 46 were further developed i proposals (Table 2). The tota savings to be realize

A Bus Service and Maintenance Facility similar to the proposed WMATA gara Springfield, VA.

TABLE 2
WASHINGTON METROPOLITAN AREA TRANSIT AUTHOR
RECOMMENDED VE PROPOSALS

1. Revise bus lift equipment and hydraulic fluid distribution system.
2. Revise bus maintenance bay size.
3. Reduce length of inspection lane.
4. Review program requirements.
5. Revise shop equipment.
6. Relocate functions within building.
7. Relocate fare collection area.
8. Separate operations and maintenance functions in single story design.
9. Revise bus washer water reclamation system.
10. Reduce the number of spare breakers in panels.
11. Remove air curtains from emergency generator load.
12. Reduce emergency generator load.
13. Mount site lights on building.
14. Reduce the number of lighting panels.
15. Eliminate electrical panel DR.
16. Reduce the number of electric reels/cords.
17. Change lighting fixtures and reduce light levels.
18. Change lighting fixture type 5.
19. Specify alternative site lighting fixtures.
20. Revise site lighting.
21. Reduce roof span at maintenance bays.
22. Revise roof framing.
23. Reduce height of maintenence bays.
24. Eliminate roof monitors and use skylights.
25. Eliminate recesses at exterior overhead doors.
26. Eliminate stairway penthouse.
27. Use alternative metal ex system.
28. Eliminate heat recovery lanes and use direct exhau
29. Reduce fresh air ar distribution for maintenan
30. Lower design temperatu unit heaters in lieu of air service lanes.
31. Decentralize domestic system.
32. Temper bus washing wate detergent consumption.
33. Reduce number of overhe maintenance bays.
34. Relocate inspection bay HVAC system.
35 Use 90° parking for buses concrete paving.
36. Eliminate curbs and secondary entrance parking.
37. Use bituminous pave secondary entrance road.
38. Realign storm sewer main.
39. Raise elevation of bui parking area.
40. Reduce length of sanitary
41. Revise layout of employ lot.
42. Revise number and lo underground tanks.
43. Use concrete curb in lieu gutter.
44. Use granular fill in lieu of for backfill at tanks.
45. Revise design of secon access road.
46. Add oil/water separator to

implementation of these recommended proposals were projected to be more than $4M, which included $3.3M in initial costs out of the total current estimated construction cost of almost $15.5M. Were additional proposals for significant redesign to be accepted, which would add more than 9,300 sq. ft. to the area of the building, the increase in implementation and construction costs would reduce the projected initial cost savings by approximately one-half. This would still leave the total life cycle cost of the garage more than $1M below the original construction estimate.

Details on three of the VE proposals recommended to WMATA are presented below.

1. Inspection Lane Proposal

As designed, the WMATA garage provided a 220 ft.-long drive-through bay for District of Columbia safety inspections (Figure 7). The bay contained brake testing equipment, a single-post lift, a wheel alignment tester and an inspection pit. Inspectors are on site onc inspect a portion of the garag each bus is seen twice a year.

The VE team propo length of the inspection bay eliminating the pit, since shown that there is no requir during inspections. It was the shortened bay then be m interior location adjacent t area, to the end of the repair retaining the drive-throu required for the assembly-l process.

Elimination of the pi area of the inspection bay b Calculating construction cos sq. ft., a capital cost savings o annualized basis is projected and operation costs are esti per sq. ft. per yr., or $6.9K an

The total estimated (life cycle cost savings a implementing this chang amount to more than $292K.

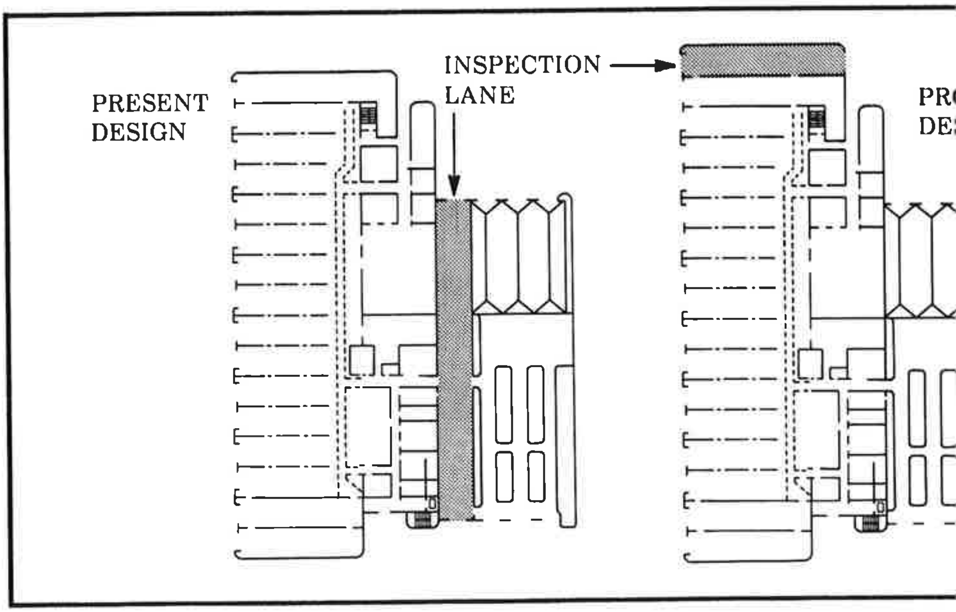


Figure 7. Proposed VE Changes at WMATA Included Reducing the Le Inspection Bay and Moving It to the End of the Repair Bay

2. Roof Monitor Proposal

The WMATA garage as designed included twelve 6 ft.-6 in. high interior roof monitors over the maintenance bay and service bay areas (Figure 8). Windows were provided in one vertical face of the monitors to admit daylight into these work areas.

Elimination of these roof monitors was proposed by the VE study team, with installation of simple skylights over each bay suggested as an alternative . Due to the large amount of steel superstructure and exterior closure materials required for the monitors, their elimination resulted in a significant (5 percent) estimated capital cost savings of $774K.

3. Fluids Storage Tanks Proposal

The original WMATA garage design provided for 12 underground storage tanks for the various fluids used at the site. The VE team proposed eliminating three of the tanks and reducing the size o follows:

- Eliminate the lead tank since there is requirement for lead
- Eliminate the mixe storage tank and s 50/50 mixture pump antifreeze tank inste
- Eliminate the eme erator fuel tank and generator to the bu tanks instead.
- Reduce the size of th tank, since gas is site and can be u primary fuel in a du boiler.

Elimination and downsi tanks, and reduction in the nu down pads from six to four, re estimated capital cost savings c

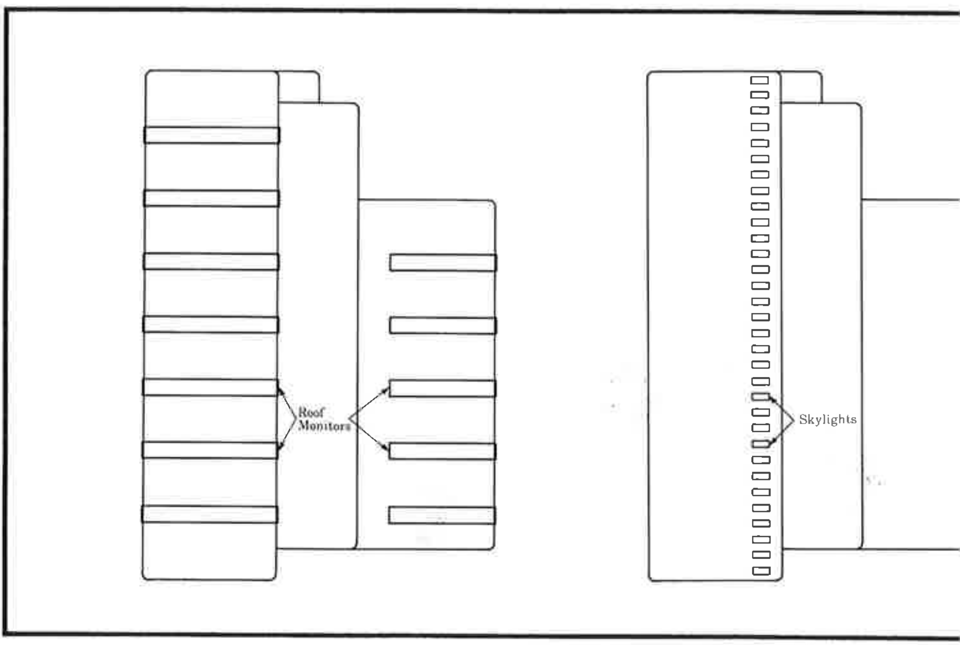


Figure 8. The VE Study Team Proposed Replacing the Original Roof Mo Shown at Right with the Skylights at Left for Estimated Savings of $774I

Bibliography

1. **Value Analysis in Design and Construction**, J.J. O'Brien, McGraw-Hill Book Co., New York, NY, 1976.
2. **Value Engineering**, A.E. Mudge, Society of American Engineers, Irving, TX, 1971.
3. **Value Engineering - A Practical Approach for Owners, Designers and Contractors**, L.W. Zimmerman and G.H. Hart, Van Nostrand Reinhold Co., New York, NY, 1982.
4. **Value Engineering Has the Potential to Reduce Mass Transit Construction Costs**, U.S. General Accounting Office, Washington, DC, 1982, GAO/RCED-83-84.
5. **Value Engineering in the Construction Industry**, A.J. Dell'Isola, Van Nostrand Reinhold Co., New York, NY, 1975.
6. **Value Engineering Re ington Metropolitan Authority Bus Garage Facility in Springfield** Hinchman & Grylls As Washington, DC, 1985.
7. **Value Engineering St Street Bus Mainte Storage Facility**, R. J. S.M. Mitchell, Greate Transit District, Bridgep UMTA-CT-06-0015085-1
8. **Value Management struction Industry**, M al., John Wiley & Sons, I NY, 1978.

This report was prepared by the Technology Sharing Office of the U.S. Department of Transportation, which periodically issues documents on a variety of transportation topics. For a list of recent publications from the Technology Sharing Office, or for additional copies of this publication, please contact:

Office of Technology Sharing
U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center — Code 151
Kendall Square
Cambridge, MA 02142

(617) 494-2486