

VALUE ENGINEERING Fundamentals



E-SYSTEMS INC.

Aircraft Systems Group / Greenville Division

MORNING SESSION

AFTERNOON SESSION

TEAM MANAGER - R. N. STEMEN

TEAM MANAGER - M. F

TEAM #1

M. C. Owens
R. J. Erger III
J. R. Travathan
R. S. O'Hara
N. K. Norwood

TEAM #2

A. Krzykowski
J. C. Caldwell
G. R. White
C. R. Young
A. H. Little

TEAM #3

L. W. Rivers
L. W. Hamilton
S. A. Ibana
W. C. Jones
H. G. Taylor

TEAM #4

E. L. Wildhagen
W. A. Alford
B. G. Darnell
W. C. Reese
D. E. Roberts

TEAM #5

B. W. Green
P. D. Ethridge
D. Rucker
G. E. Clinton
J. M. Bowen

TEAM #6

B. J. Bickham
F. O. Harris
M. Rodriguez
R. G. McCasland
R. A. Hale

TEAM #7

R. E. Baum
S. T. Keysor
C. R. Smith
B. C. Dicken
G. D. Thomas

TEAM #8

R. G. Fluegel
C. R. Quigley
D. H. Britt
C. E. Bright
D. R. Becraft

TEAM #9

W. I. Ruble
S. J. Wolanski
J. K. Crain
W. H. Craig
J. H. Rhodes

TEAM #10

R. J. Gunnels
D. M. Lindsey
A. E. Swanson
G. G. Ross
R. D. Moreland

TEAM #11

C. L. Human
G. H. Ebensberger
K. A. Townsend
J. M. Cardwell
E. L. Marlowe

TEAM #12

R. M. Crossland
C. N. Day
C. L. Putnam
R. H. Carney
R. W. Carter

I. INTRODUCTION

Profit and Growth are hallmarks of all successful companies, but progressive growth creates problems affecting net profits. Minimizing the impact of these problems through leverage, where every dollar of reduced cost contributes to profit, is the objective of Value Engineering. This brochure will address the fundamental principles of Functional Analysis, the cornerstone of Value Analysis and provide a condensed guide for future reference.

Value Analysis is a systematic technique directed toward optimizing function/cost relationships in both hardware and software systems. A carefully executed sequence of steps known as the "Job Plan" is used to guide the analyst through the course of investigation beginning with problem selection. As information is collected, a more thorough understanding of the problem is developed and priorities assigned to each function. Further effort leads to alternative solutions, selection of the best alternative based on function/cost ratios, followed by planning for implementation.

Value Analysis specifically answers these four general questions:

1. WHAT IS IT?
2. WHAT DOES IT DO?
3. WHAT ELSE WILL DO THE JOB?
4. HOW MUCH WILL IT COST?

Answering these questions thoroughly and accurately is not as easy as it first appears.

II. (CONTINUED)

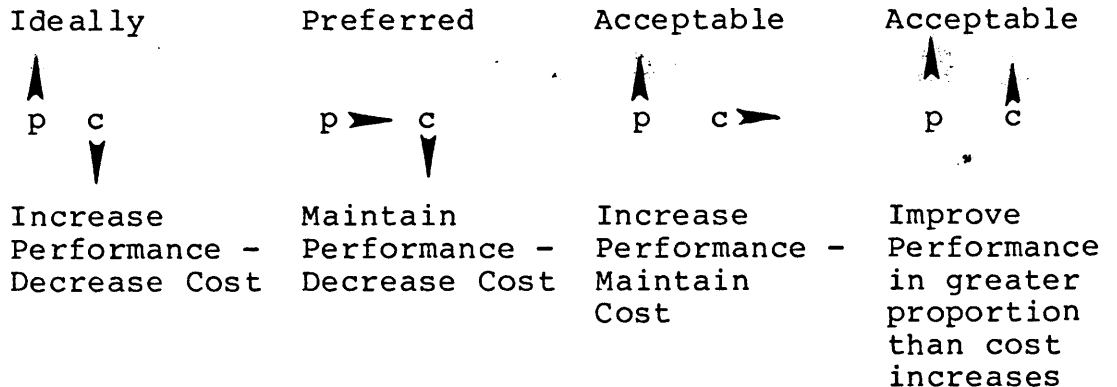
total design cost for each option. Value Analysis is still very much alive at E-Systems where, "All cost is for function".¹

III. "WE ALREADY DO VALUE ANALYSIS" COMPLEX.

The concept of Value Analysis is disarmingly simple, often believed to be nothing more than good common sense. VA is more than good common sense in that it defines a measurable target objective, follows a specific course of solution development and presents supporting justification. Above all, the VA objective is to improve product/service Value in one of four ways where Value is equivalent to a functional performance, versus cost ratio.

$$\text{Value} = \frac{\text{Functional Performance}}{\text{Cost}}$$

Four Value improvement avenues;



Two key elements in VA are Functional Analysis and Speculation, the combination of both set VA apart from other problem solving techniques. Collecting pertinent information improves the understanding of the function

1. Miles, Lawrence D., Techniques of Value Analysis and Engineering, New York, N.Y., McGraw-Hill Book Co., 1972, p. 25.

III. (CONTINUED)

and clarifies what the customer wants and is willing to pay for. Speculation is a "brainstorming" session using the verb noun definition agreed upon during Functional Analysis to direct and objectively analyze functional design alternatives. Practicing VA is possible only when a functional definition is agreed upon and alternatives generated that will satisfy the functional requirements.

IV. FUNCTION IS THE KEY

The functional design concept is truly different from the conventional design approach. It divides an assembly or process into descriptive functional segments which produce a desired output. Defining functions allows alternative solutions to be evaluated, avoiding the restrictive conventional part oriented design approach. A two word functional definition is the key to removing visualization barriers making new solutions possible.

Functional Analysis is fundamental to the VA system. Learning to define functions in a simplified two word (verb, noun) form requires a thorough understanding of requirements, specifications, and limiting design factors. Concentration and discipline are necessary while defining a function to properly describe the action which makes a product/service work or sell. Through the course of functional definition an expanded understanding of the problem is developed that allows new solutions to be considered. A verb noun definition is a thought purifying technique that requires concensus among team members, eliminates functional confusion and provides a tangible, measurable target for designers. Measurable parameters should be expressed in a unit term such as volume, weight, time, dollars, amps, foot pounds, etcetera.

IV. (CONTINUED)

An assembly or system will always consist of basic and secondary functions when defined. A basic function is the reason for the product or service existence, and is that which a product must do to work or sell. Pareto's "Law of Maldistribution" is a general rule explaining how 80 percent of the system cost can be identified with 20 percent of the components comprising the basic function. Those remaining make up the secondary functions that support the basic function. VA design changes, affecting the basic form often eliminate the need for secondary functions and provide additional opportunity for reducing costs by ensuring removal of all unnecessary functions. "All cost is for function."

The overall objective of Functional Analysis is to improve problem understanding and help the VA team to ask the right questions leading to value improvements. For this, a function must be:

- Defined in two words; verb noun
- Measurable for comparison
- Offer creative opportunities

V. JOB PLAN

The Job Plan is a formal approach that analyzes the function of items or systems to ensure overall requirements are satisfied at the lowest possible cost. It is distinctly different from simple Cost Reduction techniques that tend to reduce the cost of a function whose continuing need is largely taken for granted. E-Systems Value Analysis group uses a functionally oriented five step approach when evaluating a project, challenging the continuation of existing products or services by asking whether or not the functions performed can be met in other ways, at a lower cost.

V. (CONTINUED)

The E-Systems Job Plan sequence:

- 1.) INFORMATION
- 2.) SPECULATION
- 3.) EVALUATION
- 4.) IMPLEMENTATION
- 5.) FOLLOW-UP*

E-Systems Job Plan may differ slightly from other formal problem solving approaches yet the functional verb noun definition and alternative creation phases are evident as in all VA systems. Special emphasis is placed on the fifth step Follow-up, addressed separately from Implementation because a "check and balance" is needed to evaluate VA performance.

The INFORMATION phase includes all data collection efforts required to support a project through the Speculation phase. Research at this point identifies a problem and selects a project based on estimated net saving potential. Subjects for study are tentatively selected according to observed unnecessary cost and net

*Follow-up, sometimes called Auditing, is absolutely necessary to insure IMPLEMENTATION plans have been acted upon and projected savings verified. This last step improves the credibility of Value Analysis and strengthens confidence that VA works.

V. (CONTINUED)

savings potential after implementation. Some guidelines directing project selection are:

Pareto's "Law of Maldistribution" 80/20 rule
Material cost drivers
High rejection rates
Poor reliability maintainability
Labor cost drivers
Revised customer requirements
New Technology

A Value Analysis team consisting of five members asks two questions in the Job Plan's first step:

- 1.) What is it?
- 2.) What does it do?

A measurable verb noun functional definition must be agreed upon following these questions by all the team members before speculating on alternatives. Requiring a two word definition forces agreement among team members, creates an indepth understanding of the requirement and furnishes a simple, but specific definition necessary to create new solutions that will perform the primary function. Other information collected includes pertinent cost data, specifications, materials, supply sources and anything necessary to FUNCTIONALLY ANALYZE and define the project.

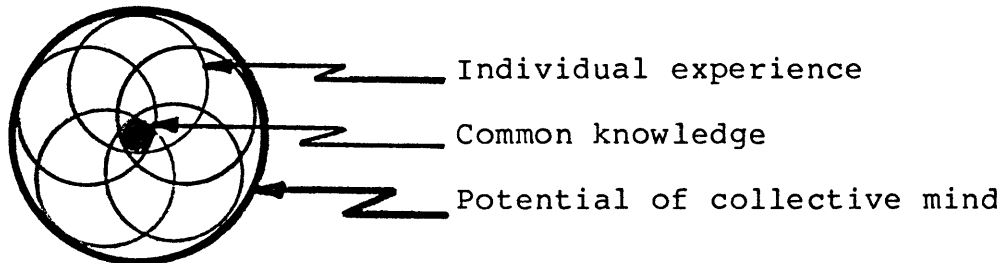
The functional verb noun definition agreed upon by the VA team in the INFORMATION phase is used to generate a large quantity of functionally acceptable alternatives in the SPECULATION phase. Removing part oriented design

V. (CONTINUED)

tendency with a simple action/task description, directs attention at satisfying the desired function without constraints. `SPECULATION answers the VA question:

3.) What else will do the job?

VA team effectiveness is optimized when five members from interdisciplinary fields are used, according to psychologists.² Each member contributes unique knowledge and experience necessary for generating large quantities of functional alternatives.



No suggestion is considered absurd during the SPECULATION Phase. Positive attitudes are promoted encouraging suggestions, judgment is deferred until the next step in the Job Plan, the EVALUATION Phase. The advantages of this philosophy demand idea quantity for the fact that an idea for a workable solution can be stimulated by an impossible suggestion. Deferred judgment cannot be stressed enough since criticism has a negative effect on creative attitudes during speculation.

Ideas generated while speculating are reviewed in the EVALUATION Phase for technical feasibility, cost and conformance to specifications. Conceptual ideas are

2. Fraser, Dr. R. A., Dynamics of VE Team Performance, 1981 Society of American Value Engineers International Conference, St. Louis, Mo., April 1981.

V. (CONTINUED)

often modified then assigned priorities on the basis of cost versus performance. Other choices are discarded in lieu of more feasible solutions.

Several methods are used to compare the optimal tradeoff alternative, one of which is the Combinex Matrix solution promoted by Carlos Fallon in his book Value Analysis³.

The IMPLEMENTATION Phase involves mapping out a strategy and schedule for putting the change into effect. Convincing key personnel with justification is the most difficult segment of the Job Plan. Resistance to change must be anticipated and plans formed to overcome delays. IMPLEMENTATION is a team effort.

FOLLOWUP is identified separately in the E-Systems Job Plan, its purpose and effect is several fold. First it ensures that everyone has fulfilled their obligation necessary to implement the recommendations or highlights problem areas. Unforeseen delays reduce potential savings because additional effort is required to clarify misunderstandings not thoroughly addressed up front in the final report. Secondly FOLLOWUP can verify implemented savings thereby improving the Value Analyst's credibility as a problem solver and contributor to company profits. Last of all FOLLOWUP often brings to attention other associated subject areas where unnecessary costs exist for future project studies.

3. Fallon, C., Value Analysis, Southport, N.C., Triangle Press, 1980, p. 133.

VII. CONCLUSION

Value Engineering is an important part of our successful operation. Its purpose is to provide quality products at the lowest reasonable cost consistent with the requirements of performance, reliability and maintainability, and schedule. When our Value Engineers suggest improvements to an existing engineering design or technique with no attendant sacrifices, we provide formal written justification as part of our implementation procedure. As a result, the product is often manufactured faster and more economically, and life cycle system costs are usually reduced.

This brochure explains VA fundamentals and presents some typical examples of costs reduced by the Value Analysis process at E-Systems. Since most of the examples shown can be applied to other projects, and most of them cause "ripple effect" cost reductions (in time, inventory, and logistics), their ultimate total cash value, however, is considerably more than the values stated.

For additional information on Value Engineering at E-Systems, please contact Bill Alford, Value Engineering Specialist at P. O. Box 1056, Greenville, Texas 75401. Mr. Alford's telephone number is 214/455-3450, Extension 4774.

GLOSSARY OF VA TERMS

Cost	A measurable quantity of spent nonrecoverable resources, e.g., time, labor, materials.
Cost Targets	Cost objectives established in conjunction with function definitions. Cost targets may also serve as a measurement tool.
Decision Support Model	A computer-based program that assists in choosing the best alternative for performing functions. This is done by analyzing the sensitivity of choice to changes in the relative importance of decision criteria and to changes in the evaluation of each alternative.
Engineering	The application of scientific principles to practical ends as in the design, construction, and operation of efficient and economical structures, equipment and systems.
Function	That action which makes an item or service work or sell.
Functional Analysis System Technique (FAST)	A systematic diagramming technique that logically identifies and visually displays the interrelationship of functions that must be performed to accomplish a specific purpose.
Function - Basic	The basic purpose(s) for which an item or service exists.
Function - Secondary	An action which supports the basic function and results from a specific design approach.

Glossary of VA Terms (Continued)

Job Plan	An organized approach for carrying out a value engineering study. It consists of five specific phases.
Phase I: Information	Tasks: (a) Select the appropriate projects. (b) Gather a complete file of information concerning the projects. (c) Define the basic and secondary functions.
Phase II: Speculation	Task: Generate as many ideas as possible for performing the necessary functions identified in Phase I.
Phase III: Evaluation	Tasks: (a) Gather and analyze data concerning ideas generated in the Speculation Phase. (b) Select one or more feasible idea(s) offering better value.
Phase IV: Implementation	Tasks: (a) Develop a plan for presenting the ideas to implementing personnel. (b) Obtain the necessary commitments for implementation.
Phase V: Followup	Tasks: (a) Verify that commitments for implementation have been fulfilled and if not, the reason(s) for delays. (b) Formally report the actual savings for comparison against projected savings.
Life-Cycle-Cost	Total system cost from conceptual R&D effort, through operation, and maintenance to disposal.
Roadblock	An action which prevents the attainment of better value.
Total Cost	To the manufacturer: All costs (material, labor, and overhead) not including profit. To the customer (buyer): Purchase price, plus operation, support, and disposal costs. (May be referred to as life-cycle-cost.)

Glossary of VA Terms (Continued)

Value	The lowest total cost to reliably perform necessary functions at the desired time and place with essential quality, often measured by comparison.
Cost Value	The monetary measure of the resources expended to obtain an item or service.
Use Value	The monetary measure of the necessary functional properties of an item or service which contribute to performance.
Value Analysis	Synonymous with value engineering.
Value Engineering	An organized effort directed at analyzing the functions of systems, equipment, supplies, and services for the purpose of achieving necessary functions at the lowest total cost consistent with necessary performance and schedule.
Worth	The sum of qualities that make something desirable.

VALUE SEMINAR

OCTOBER 25 - 29, 1982

WEDNESDAY

8:00 12:30 Review projects with respect to Speculation Phase
Speculation Phase in detail
Motivation, Creativity

B R E A K

Speculation: The Second Phase of the Job Plan (Cont'd).
Workshop Project:
Evaluative, Speculation, Alternative generation.
Introduce Evaluation Phase

11:45 4:15 C L A S S E N D S

THURSDAY

8:00 12:30 Project review with respect to evaluation
Evaluation Phase in detail
Weighing priorities
Cost Factors

B R E A K

Evaluation (Cont'd)
Combinex Method
Workshop Project
Evaluation (Cont'd)
Summarize efforts
Wrap-up

11:45 4:15 C L A S S E N D S

INTRODUCTION TO VALUE ENGINEERING¹

Value Engineering – A Managerial Tool

In simple terms value engineering (VE) is an organized, creative approach to the isolation of unnecessary costs. Through the use of its specific techniques, VE has aided in saving millions of dollars for the companies that have utilized it, and in turn, for the Department of Defense through incorporation of VE in its contract and in-house application.

Value engineering gets results. When conscientiously applied by well-trained personnel, VE historically has produced savings 300 to 400 percent greater than those achieved by other cost reduction efforts. The costs of individual components and assemblies often are reduced more than 50 percent; some have been reduced 100 percent. The eliminated costs are, of course, unnecessary – that is, unnecessary to the function being performed. Reductions do not cheapen the product (by definition, VE must maintain all the necessary performance factors of the item). In fact, many performance characteristics often are not only maintained, but also are improved while the cost is being reduced. The intrinsic worth of VE goes far beyond the savings related to existing products or services. As people gain expertise in applying the techniques in varying situations, they learn to use VE, not just in the traditional second look, but at the very inception of ideas. This is the point at which VE makes its greatest contribution. Unfortunately, it is also hardest to measure results at this stage.

Despite its name, which might suggest exclusive concern with design or manufacturing engineering, VE achieves its optimum results as a management technique. Since it reduces cost not only in products but in supporting services as well, VE affects all company functions. Bypassing traditional functional boundaries, it draws on the collective knowledge of all employees. It helps many individuals do a better job. Most important of all, it is oriented primarily toward furthering two top management goals: individual motivation and control of operating costs.

Today's most effective VE programs owe their success to top management support. True, VE programs can be launched without management's encouragement – or even, in some cases, without its knowledge. But if the program is to develop a high percentage of potential savings, there must be a general awareness that it carries a strong management priority.

¹ Copyright © 1964, 1978, by Harbridge House, Inc.

A Brief History of Value Engineering

Shortly after World War II, a group headed by Lawrence D. Miles originated and perfected the techniques of VE¹ at the General Electric Company. These techniques gradually spread to all GE divisions – including those developing and manufacturing military products – as well as other companies. Originally, VE techniques were used mainly in the GE purchasing departments, many of which had full-time value analysts. Other functions, such as design and manufacturing engineering, cost accounting, and marketing, were included gradually. Eventually, it became evident that broader dissemination of the VE concepts would be advantageous, so formal workshop training sessions were introduced in 1952.

From the original application to long-run production consumer items, VE progressed into short-run, batch-produced military hardware. Then it progressed into other areas such as process industries and procedures. The Department of Defense incorporated the formal use of VE in its contracts and within its own internal operations, again requiring application to a new set of requirements. The latest entry is the construction field, where VE has been called "the biggest new idea to hit construction since CPM." Again, the government sponsored it and became the catalyst for this field through the Corps of Engineers and General Services Administration.

Value engineers traditionally have acted as coordinators and liaison men between functional departments. Some companies, however, now train their value engineers very intensively and use them on a full-time basis on a series of projects. Others use their value engineers primarily to train people in all operating departments, then utilize those trained men to solve specific problems. The question of how best to utilize their skills is one of the basic policy decisions required when setting up a VE program. Today the techniques of VE are proven, and the challenge has shifted to the human elements. Now it is up to those who utilize VE to become expert in its techniques and to apply them effectively. Since VE does utilize cross-function discipline requiring knowledge of both the technical and business aspects of management, many organizations are now using VE assignments as training for future project managers.

The "My Organization Is Already Doing VE" Complex

Miles's original report stated that value engineering is primarily a 75 percent human problem and a 25 percent technical problem; this statement has been verified many times. One of the most significant obstacles to the successful

¹The original term was "value analysis." "Value analysis" was coined by Henry Winne, vice president of engineering for General Electric, because he felt that no matter where the techniques were applied, they basically were concerned with analyzing value. The Navy adopted the term "value engineering," and since then the DOD has standardized upon VE. Other terms, such as "value improvement" and "value control," have been used, but all these are, for practical purposes, synonyms.

implementation of VE is a widespread conviction that, "My organization is already doing VE, but not under this fancy new name." As long as people erroneously conclude that they are applying VE, they will not be receptive to a true VE effort nor will they support one. Several reasons for this erroneous conclusion are:

- (i) VE techniques sound deceptively simple when described, and although they can be understood quickly and easily with proper guidance, experience has proven that difficulty arises in their actual application. It is in the application of VE that simplicity rapidly disappears. This situation can be compared to a person's concluding that he shoots par golf because he has read a well-written book on the subject.
- (ii) Some people feel that, since VE offers an effective and intelligent way to perform a job and since they are performing their job as effectively and intelligently as they know how, they automatically are incorporating VE in their work.
- (iii) Rather than being a simple technique, VE is a series of organized techniques, some of which have been borrowed from other disciplines such as industrial engineering, operations research, procurement, management sciences, and design. Sometimes an individual, realizing that he performs one or a few of these techniques, concludes that he is using VE when, in fact, he is taking advantage of only one small aspect and overlooking a large percentage of the available benefits.
- (iv) Some people are afraid to admit to their management that they haven't already been taking advantage of VE and its related benefits.

To a degree these are logical reasons. The logic breaks down, however, when the person fails to compare the VE approach to what actually is happening in his organization. A series of key questions can provide a basic analysis:

- (i) Are you systematically searching for high-potential projects to improve cost, performance, and schedule?
- (ii) Are you using a functional (not item) approach to design and project analysis?
- (iii) Do you bring pertinent personnel from various functional areas (for example, manufacturing, engineering, procurement, marketing, product assurance, and finance) together at strategic points during product evaluation?
- (iv) Do you concentrate on overall cost instead of just the initial cost of the item or service?

- (v) Do you have a planned, organized, step-by-step procedure to define the true problem, to develop and select alternative solutions, and to implement the ideas?
- (vi) Do you have an organized reporting procedure to inform management (and the customer) of results and to provide a data bank for future efforts?
- (vii) Do your present projects return a minimum of \$5 savings for every \$1 invested?

If, in fact, all the questions above cannot be answered affirmatively, the full potential of a VE program is not being realized.

Summary

The application of VE methodology to its associated benefits has shown an orderly growth in both industry and the government since its early days. Today the biggest challenge is overcoming uninformed human attitudes toward its application. This problem can be overcome only through intensive education in what VE really is and how it works.

A WORD ABOUT VALUE¹

Value is a relative, not an absolute, concept. Being subject to measurement by different standards, at different times and places, under different conditions, it eludes exact definition. There are, however, two different approaches to a better understanding of the meaning of value: first, an examination of some proposed methods for measuring value and, second, a look at different kinds of value.

Measuring Value

Labor Added

Attempts have been made to equate value to the amount of labor added to an object's or substance's original state or condition. Thus coal is of no value underground; it must be mined, processed, and shipped to the consumer before it is useful. Its value can then be measured by the amount of labor necessary to furnish it to the consumer. While this concept of "value added" has enjoyed wide acceptance among economists, it is insufficient for our purposes. After all, an equivalent weight of sand delivered to the power station might represent as much labor added as a ton of coal. But what would be its value in keeping steam pressure up in the boiler? And who would contend that a house foundation dug by hand shovels, and hence requiring many hours of labor, has greater value than the same foundation dug by power shovel? Rework of a rejected product to correct deficiencies adds labor, but this may actually decrease its value to the customer. Clearly, then, this measurement of value is inadequate for industrial uses.

Cost Is Value

Another proposed criterion for the measurement of value has been cost. This approach is a primary principle of the accounting profession. Since financial organizations normally keep cost records in industry, the same principle has been carried over to manufacturing operations. In general, it seems reasonable that the higher the cost, the greater the value – but a fallacy clearly exists. The costs of an inefficient producer are higher than those of an efficient producer, and this surely does not indicate that the inefficient producer's output has more value. If anything, there may be an inverse relationship between cost and value!

Value Equals Utility

Similar difficulties arise when one attempts to equate value with utility or with exchange value. Paradoxical relationships can be found immediately. The comparison of iron and gold is informative. Iron is one of the most

¹ Copyright ©1964, 1982, by Harbridge House, Inc.

useful materials. It has been the key engineering metal of the industrial revolution. Its utility value probably exceeds that of all other metals. Gold was once used in coinage. It is used in jewelry and occasionally as a protective coating. Despite its low utility value it has a high exchange value. Such anomalies clearly illustrate the fallacy of basing value on exchange or utility.

Kinds of Value

Total economic value is compounded of four kinds of value:

- **Use value** or power to serve a need.
- **Esteem value** or power to cause a desire to possess.
- **Cost Value** or resources expended to produce or obtain.
- **Exchange value** or power to procure other things in its place.

A prestige car and a compact car have the same use value – they provide transportation. Many people desire a prestige car more than a compact car; for them, it reflects a higher esteem value. (How much higher, of course, varies with individuals and their circumstances.) The amount of energy we are willing to expend to secure a prestige car is a measure of its cost value. What we can trade for it (jewelry, stocks and bonds, cash, and so on) indicates its exchange value. Particular brands or models of prestige cars introduce additional variations in value. But note that one kind of value has remained constant: the use value of the car (providing transportation). This value can be measured.

Therefore, when the value engineer talks of "value," he is referring to use value, an objective type of value, rather than to the other three types, all of which are subjective. We fully recognize the importance of esteem value in selling products – and, in fact, for a complete value engineering/analysis study, the customer's estimate of the worth of features he/she desires is important.

No Absolute Value

Value is not absolute; no product has permanent inherent value. Value is established by comparing two items that perform a similar or identical function. Consequently, use value can be defined as "the lowest cost for furnishing the desired function or service" or "the lowest cost for which a function or service may be obtained."

Any concept of value naturally must provide for the customer's desires and needs, which will vary widely from product to product, and, even for the same product, often will vary from customer to customer. One customer may be interested primarily in purchase price; another sees total cost (including maintenance) as paramount; and a third is most concerned with appearance. From the customer's point of view, value becomes the lowest cost at which he/she can reliably obtain the functions as he/she defines them. This, of course, implies that the product or service is available where needed at the proper time. Logically,

satisfying the customer's needs may involve extra cost, as in the case of an item that is delaying an entire program. In such a situation, it may well prove more profitable in the long run to incur special expenses to expedite that item than to minimize its cost.

Maintaining Quality and Reliability

In the past, conventional cost reduction techniques have focused on the item itself rather than on its function. Substitution of materials and reduction of the amount of material used have, as might be expected, often resulted in cheapening a product; thus, conscientious attempts to reduce costs often have diminished not only esteem value, but use value as well. In other words, the product's quality and reliability have been lessened.

By its very definition, successful value engineering never reduces a product's quality or reliability - or any other requirement - below the level required to meet the needs of the customer successfully over an adequate time period. Although a VE study could indicate, occasionally, that the quality level maintained on an item is unnecessarily high and could be reduced to save associated unnecessary costs, a careful analysis would be required to ensure that quality is not reduced below the minimum acceptable level.

On the other hand, a VE study (of electronic devices, for example) could show a need for increased quality or reliability. Although this action would increase the first cost of the product, it would materially lower ultimate costs by reducing maintenance, postponing replacement, and permitting lower inventories.

Summary Definition

In summary, we propose this definition, which combines all the concepts discussed above:

VALUE IS THE LOWEST TOTAL COST TO RELIABLY
PERFORM A FUNCTION AT THE DESIRED TIME AND
PLACE WITH THE ESSENTIAL QUALITY.

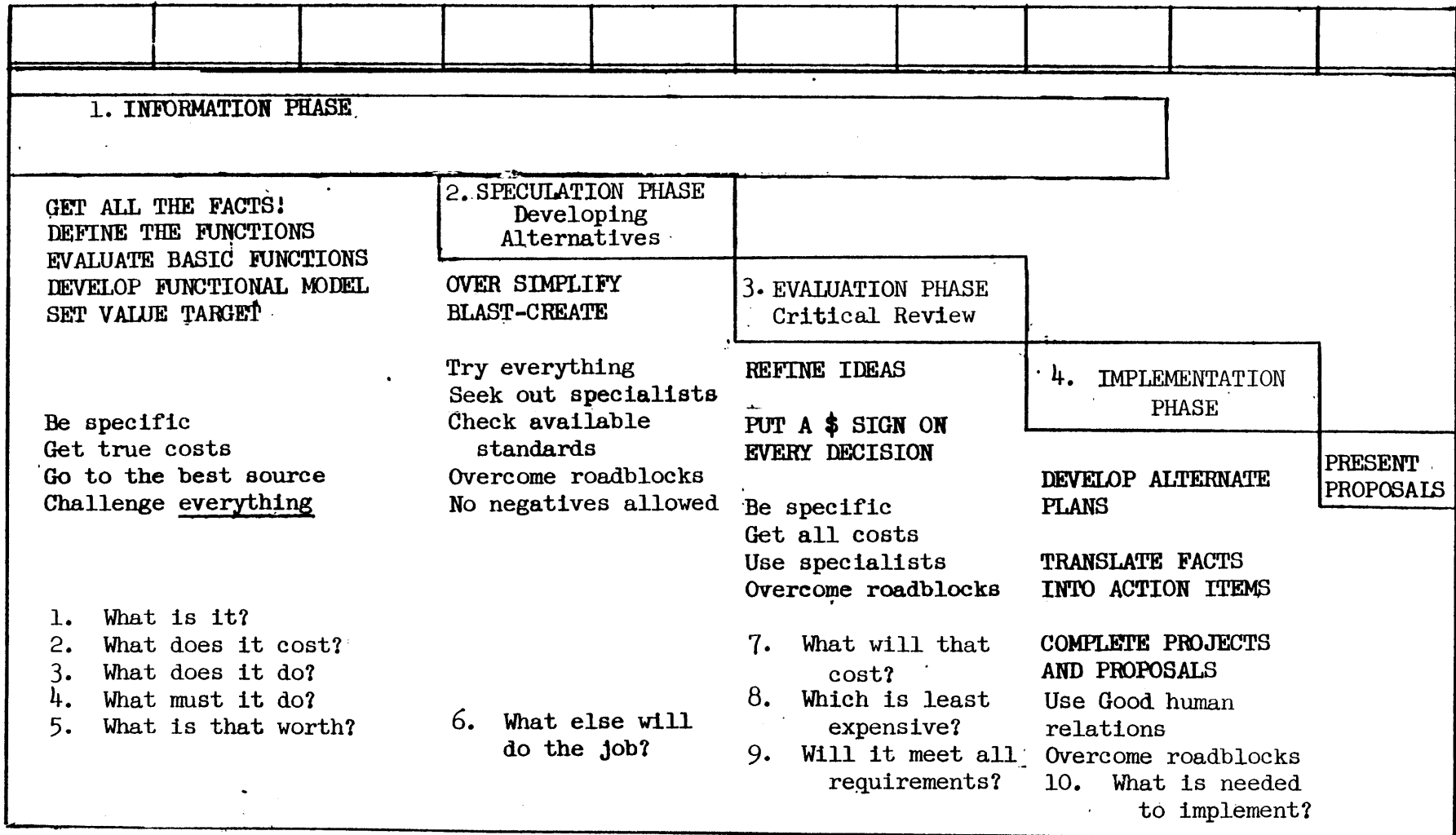
GLOSSARY OF VE TERMS

Cost Targets	Cost objectives established in conjunction with function definitions. Cost targets may also serve as a measurement tool.
Decision Support Model	A computer-based program that assists in choosing the best alternative for performing functions. This is done by analyzing the sensitivity of choice to changes in the relative importance of decision criteria and to changes in the evaluation of each alternative.
Function	That action which makes an item or service work or sell.
Functional Analysis System Technique (FAST)	A systematic diagramming technique that logically identifies and visually displays the interrelationship of functions that must be performed to accomplish a specific purpose.
Function - Basic	The basic purpose(s) for which an item or service exists.
Function - Secondary	An action which supports the basic function and results from a specific design approach.
Job Plan	An organized approach for carrying out a value engineering study. It consists of four specific phases.
Phase I: Information	Tasks: (a) Select the appropriate projects. (b) Gather a complete file of information concerning the projects. (c) Define the basic and secondary functions.
Phase II: Speculation	Task: Generate as many ideas as possible for performing the necessary functions identified in Phase I.
Phase III: Evaluation	Tasks: (a) Gather and analyze data concerning ideas generated in the Speculation Phase. (b) Select one or more feasible idea(s) offering better value.
Phase IV: Implementation	Tasks: (a) Develop a plan for presenting the ideas to implementing personnel. (b) Obtain the necessary commitments for implementation.

Life-Cycle Cost	Synonomous with customer total cost.
Product Analyzer Model	A computertized program that establishes functional worth via the establishment of Basic Functional Value Standards based on engineering formulae.
Roadblock	An action which prevents the attainment of better value.
Total Cost	<p>To the supplier (seller): All costs (material, labor, and overhead) not including profit.</p> <p>To the customer (buyer): Supplier costs and profits, plus operation and support costs. [May be referred to as life-cycle cost.]</p>
Value	The lowest total cost to reliably perform necessary functions at the desired time and place with essential quality.
Cost Value	The monetary measure of the resources expended to obtain an item or service.
Esteem Value	The monetary measure of the properties of an item or service which contribute to desirability but not to required functional performance.
Exchange Value	The ability to obtain other items or services in trade.
Use Value	The monetary measure of the necessary functional properties of an item or service which contribute to performance.
Value Analysis	Synonomous with value engineering.
Value Engineering	An organized effort directed at analyzing the functions of systems, equipment, supplies, and services for the purpose of achieving necessary functions at the lowest total cost consistent with necessary performance and schedule.
Value Improvement	The improved function-to-cost ratio resulting from applying the value engineering methodology to all phases of a product or service.

VALUE ENGINEERING

JOB PLAN SCHEDULE



Issued By: Harbridge House, Inc.
 Boston, Mass.

THE VALUE ENGINEERING JOB PLAN¹

by

**Harbridge House, Inc.
Boston, Massachusetts**

¹ Copyright © 1965, 1981, Harbridge House, Inc.

Prepared by Harbridge House, Inc. This material is intended for teaching purposes only.

INTRODUCTION

Value Engineering (VE) is an organized effort directed at analyzing the functions of systems, equipment, supplies, and services for the purpose of achieving necessary functions at the lowest total consistent with necessary performance and schedule.

To achieve maximum results, VE effort must be conducted on a systematic basis. The VE profession has developed such an approach – the Value Engineering Job Plan – which is a variation of the classical scientific method related to problem definition, analysis, and solution.

A variety of VE job plans, employing from four to seven different phases, is being used by different organizations. Regardless of the number of phases and the varying terminology utilized in each, all the VE job plans are directed toward the same goal: to provide necessary functions at the lowest total cost. The number of phases is relatively unimportant, but it is important to select a plan and learn how to use it effectively.

We will utilize a plan consisting of the following four specific phases:

- I. Information Phase
- II. Speculation Phase
- III. Evaluation Phase
- IV. Implementation Phase

During the Information Phase, the VE team performs four tasks. First, it selects appropriate projects. Second, it gathers a complete file of information concerning the projects. Third, it defines basic and secondary functions. Fourth, it determines functional worth.

During Phase II, the Speculation Phase, the VE team generates as many ideas as possible for performing the necessary functions identified in Phase I.

During the Evaluation Phase, Phase III, the VE team gathers and analyzes data concerning ideas generated in the Speculation Phase and selects one or more feasible ideas offering better value.

During Phase IV, the Implementation Phase, the value engineering team develops a plan for presenting the ideas to implementing personnel and obtains the necessary commitments for implementation. Value engineering personnel may also be assigned the responsibility by management to coordinate the implementation process.

SECTION I. INFORMATION PHASE

During this initial phase of a VE study, the team has four principal tasks.

- (i) Select appropriate projects.
- (ii) Gather a complete file of information concerning the projects.
- (iii) Define basic and secondary functions.
- (iv) Establish functional worth

A. Select Appropriate Projects

It is necessary to select an appropriate project to obtain good results from a VE study. Normally, the objective in selecting projects is to isolate areas which offer the greatest dollar savings in return for the investment in study and implementation costs. The return on investment in VE normally ranges from 500 to 1,000 percent – that is, for every \$1 invested in VE, \$5 to \$10 traditionally has been returned in savings. One method of project selection exhibiting high potential is based on Pareto's law of maldistribution, better known as the "80/20 rule," which means that usually 20 percent of the parts of a product or service account for 80 percent of the total cost. This law involves the assumption that a project involving a large dollar volume offers high savings potential.

After the 80/20 rule is applied to select a broad category of projects, further refinement is needed to assure maximum rate of return. This can be accomplished by examining potential savings, VE study and implementation costs, and probability of implementation in the following relationship:

$$\frac{\text{Potential Savings}}{\text{VE Study and Implementation Costs}} \times \text{Probability of Implementation} = \text{Potential Rate of Return}$$

Potential savings equal present costs minus estimated cost after completion of the study. Study and implementation costs represent necessary investments, and probability of implementation (ranging from 0 to 1) deals with the human aspects of the anticipated study. Table 1 illustrates application of the formula. For example, if after review of a particular item, large savings with low study costs are anticipated but it is obvious that the individual who has the authority to accept or reject a change will probably reject it no matter how good it is, obviously the study should not be undertaken. These project selection techniques permit the value engineer to concentrate on high potential projects first and on lower potential studies only if time permits.

Table 1

Potential Project	Potential Savings (Yearly)	Estimated Study and Implementation Costs	Probability of Implementation	Potential Rate of Return
A	\$25,000	\$2,000	0.6	7.5
B	8,500	3,000	0.8	2.3
C	14,000	7,000	0.9	1.8
D	13,000	1,000	0.7	9.1

Occasionally, selection criteria other than those already mentioned can be used effectively. Such selection may be based on criteria other than (although related to) high cost. They may involve items having a high reject rate or machining difficulty, excessive weight or production lead time, or low reliability or difficult maintainability. Other relationships based on a close correlation of cost to another parameter may also be used, for example, cost per pound, cost per dimension, cost per unit volume of containing capacity, and so on. In some cases management may specify projects based on its own particular criteria.

Customer desires are also very important in project selection. Accomplishment of a function is being offered to the customer through a product, and if this product does not reflect his desires, its salability will be curtailed. For example, it may be found during development that the weight of a new product is excessive - leading to a VE study to reduce weight.

B. Gather a Complete File of Information Concerning the Projects

The success of a VE study depends on having a complete file of adequate and accurate information. Since a "complete file of information" means anything and everything there is to know about the project being analyzed, study teams are often dismayed at the volume of data and the amount of work confronting them. The rounding up of data is a tall order, but it is absolutely necessary to consult all the available sources to get the complete facts.

1. Questioning

The team begins information gathering by questioning every aspect of the project. The following questions, among others, would be asked: Who is responsible for the project? What is it? What does it do? What must it do? What does it cost? What is it made from? How is it made? What are the environmental conditions under which it is used? Who makes it? Who can make it? What is the current and expected demand? How and at what cost is it shipped? Installed?

Serviced? Repaired? Replaced? Much of this analysis will be used as an integral part of the third step of the Information Phase – defining functions.

2. Sources of Information

Obviously, many sources of information must be used to obtain meaningful answers to proposed questions.

a. **Primary Sources.** Whenever possible the team should go to primary sources first. Primary sources include (i) those who recognized the opportunity to fulfill a customer desire with the product or service (for example, marketing), (ii) the engineer who originally designed the product or service, (iii) the original drawings and specifications, (iv) the product engineer or group that designed the manufacturing process, (v) the cost department that costed it out, (vi) the manufacturing department, and (vii) the purchasing department.

In addition, the team should observe the product or service in action. Very often consumers using the item and those desiring it can make important contributions to the study.

b. **Secondary Sources.** Vendors are an important secondary source of information. They are closely related to the purchasing function and will usually cooperate in hopes that their product will be recommended for future purposes. Team members should talk to present suppliers as well as other vendors who can provide products or services that will perform needed functions. They should be included in the early stages of the problem – for example, in the Speculation Phase – and should be given free rein. Vendors who are specialists may be prejudiced, however, so the team must maintain a questioning and creative attitude at all times. For example, in the case of a fastening problem, the team might question a supplier of nuts and bolts. Although he probably knows much more about nuts and bolts than the team does and may be the source of some good ideas, he may be unwilling to admit that an adhesive or some other type of product can do a better job than the nuts and bolts he sells.

Literature – such as sales brochures and other promotional pieces, standards, patent data, test results, failure reports, trade journal articles, and so forth – provides a practically endless source of useful information. It must be used carefully, however, since much of it is promotional in nature and can, therefore, be misleading. Strong claims, colorful adjectives, and vague terms such as "high strength," "low cost," and "good resistance" are suspect. Any claims that are made require quantitative proof. Unretouched photos, case histories, shop prints, and so forth, are reassuring, but the team should always maintain a questioning attitude.

c. **General Sources and Organization.** Professional value engineers save time and make information gathering easier by keeping checklists of unusual sources. They are continuously on the alert for places where information is available or where it might be available if needed. Accurate source records are maintained and used. In fact, some large VE organizations assign a value engineer full-time to this endeavor.

Any relevant information may be important – no matter how unorganized or unrelated it may seem at first, it may prove useful later. All information should be gathered before an attempt is made to organize it. After it is organized it should be assembled, studied, and digested. In sum, the value engineer should try to become more knowledgeable about the project than anyone else in the world.

C. Define Basic and Secondary Functions

After the project has been selected and the data required for analysis collected, the next step is to investigate the problem thoroughly through functional analysis. Functional analysis is the unique aspect of VE and is the most important concept in the Job Plan. Although VE is concerned with analyzing functions for the purpose of achieving necessary functions at the lowest total cost, the concept of functional analysis – so essential to all design thinking – is the most widely misunderstood and misused VE technique.

Functional analysis is concerned with locating unnecessary costs and determining the true value of the product or service. Of course, a detailed functional analysis is undertaken only after it has been absolutely ascertained that the item under study cannot be eliminated completely and that the study is, therefore, essential. The entire item can be eliminated if no basic function can be determined when the function of the entire system, component, and so forth, is defined.

A function is that action which makes an item or service work or sell – in other words, an item's function is why the customer buys the product. An item is a means to the end of providing a function, not the end itself. In using the functional approach, the VE team is constantly returned to the basic reason for the design and manufacture – the ultimate use – of an item.

The customer buys a product or service because it will provide a function that satisfies his need at a cost he is willing to incur. If, as is almost always the case, he wishes to minimize the function's total cost to him, the customer must look beyond the price of an item and consider its other costs – preparation, secondary operations, handling, quality, service, and so forth. Therefore, for successful cost reduction, a "function" must be carefully defined from the aspect of total life cycle so that its associated costs can be assigned properly.

1. Verb-Noun Description

Preliminary attempts to define the functions of an item often involve several concepts that seem to need extensive description. Although extensive description conceivably could indicate the functions satisfactorily, it is neither concise nor workable enough for successful analysis. In VE, function definition is a specific discipline, which at first may seem confining, but does actually facilitate analysis.

A function is always expressed by a verb and a noun – the verb tells what the item does, the noun tells what the item does it to. This two-word description has several advantages:

- (i) The description pinpoints the function and is not cluttered with superfluous information, thereby forcing the planner to decide what data are fundamental and should be retained and what are unimportant and should be rejected. This facilitates concentration on the exact requirements when alternatives for providing the function are developed during the Speculation Phase of the Job Plan.
- (ii) Possible alternative solutions for providing the functions are not unduly restricted. This is helpful in the Speculation Phase of the Job Plan when the effort should not be limited to a narrow range of possible alternatives. The longer the list of ideas for providing the necessary functions, the greater the probability that the list will contain the lowest cost method.
- (iii) Functions that repeat in a design can easily be identified and often eliminated.

Function must be expressed, or explained, in a measurable parameter in order to obtain a value for it later in the analysis. The nouns can be either measurable or nonmeasurable, but nonmeasurable nouns must be explained so that they can be translated into a measurable element and later evaluated. A few examples should clarify these points.

Example One

Work Function	Measurable	Explanation	Dimension
Verb	Noun		
Support	Weight	Transformer (to baseplate)	500 lbs.

Example Two

Work Function	Nonmeasurable	Explanation	Dimension
Verb	Noun		
Support	Transformer	To baseplate	500 lbs.

The results of these two examples are identical so it is merely a question of which is the easier to use. Example Two immediately identifies the item in question. If ten functions - each supporting weight - had been identified, the weight being supported would still have to be explained before the analysis could proceed. Although the word "weight" does indicate that functions repeat, this knowledge can be obtained in the dimension column by looking for all the pound items, pound-per-square-inch items, volt items, gallons-per-minute items, and so forth.

Examples One and Two are mechanical examples, but the same analytical approach can be applied to electrical problems.

Example Three

Work Function	Measurable	Explanation	Dimension
Verb	Noun		
Resist	Current	Between the positive and negative terminals of the battery	3.85 ohms

Example Four

Work Function	Nonmeasurable	Explanation	Dimension
Verb	Noun		
Transfer	Energy	Electricity	4 watts

Again we see that function definitions can be expressed either with measurable or nonmeasurable nouns.

Returning to our definition for a moment, we find that it includes sell functions as well as work functions. Although we are concentrating on work functions, Example Five illustrates what is involved in defining a sell function.

Example Five

Sell Function	Nonmeasurable
Verb	Noun
Increase	Prestige

2. Classification of Functions

The most difficult part of functional analysis is the classification of functions as either basic or secondary. The following definitions are useful in this classification process:

- (i) Basic Function - the basic purpose or purposes for which an item or service exists. This function must remain to do the job. A product may have more than one basic function. Engineers trained in VE strive to design parts that will accomplish several basic functions to reduce the total number of parts in an assembly, thus simplifying design and lowering costs.

- (ii) Secondary Function – an action that supports the basic function and results from a specific design approach. Secondary functions exist primarily because of the method the designer has used to achieve a basic function; if the design can be changed, the need for secondary functions may be modified or even eliminated.

It is important to remember that, although items often possess secondary functions when evaluated as parts of the total assembly, they also have one or more basic functions of their own when studied as individual items. Paint, for instance, normally has the basic function of "providing protection," which can be measured in terms of retarding corrosive action, providing longer life, providing fungus proofing, and so on. Paint may also have the secondary function of providing an attractive appearance. There are instances where these functions are reversed – for example, an anodized part is painted so that it matches the rest of the equipment. Here "provide appearance" is the basic function; the protective quality of the paint is secondary, or even totally unnecessary, since the part has already been protected by anodizing.

The distinction between what is needed (basic functions that possess value) and what is not needed (secondary functions that have no value) is vital to a successful VE study – elimination of unnecessary costs is dependent upon it.

D. Establish Functional Worth

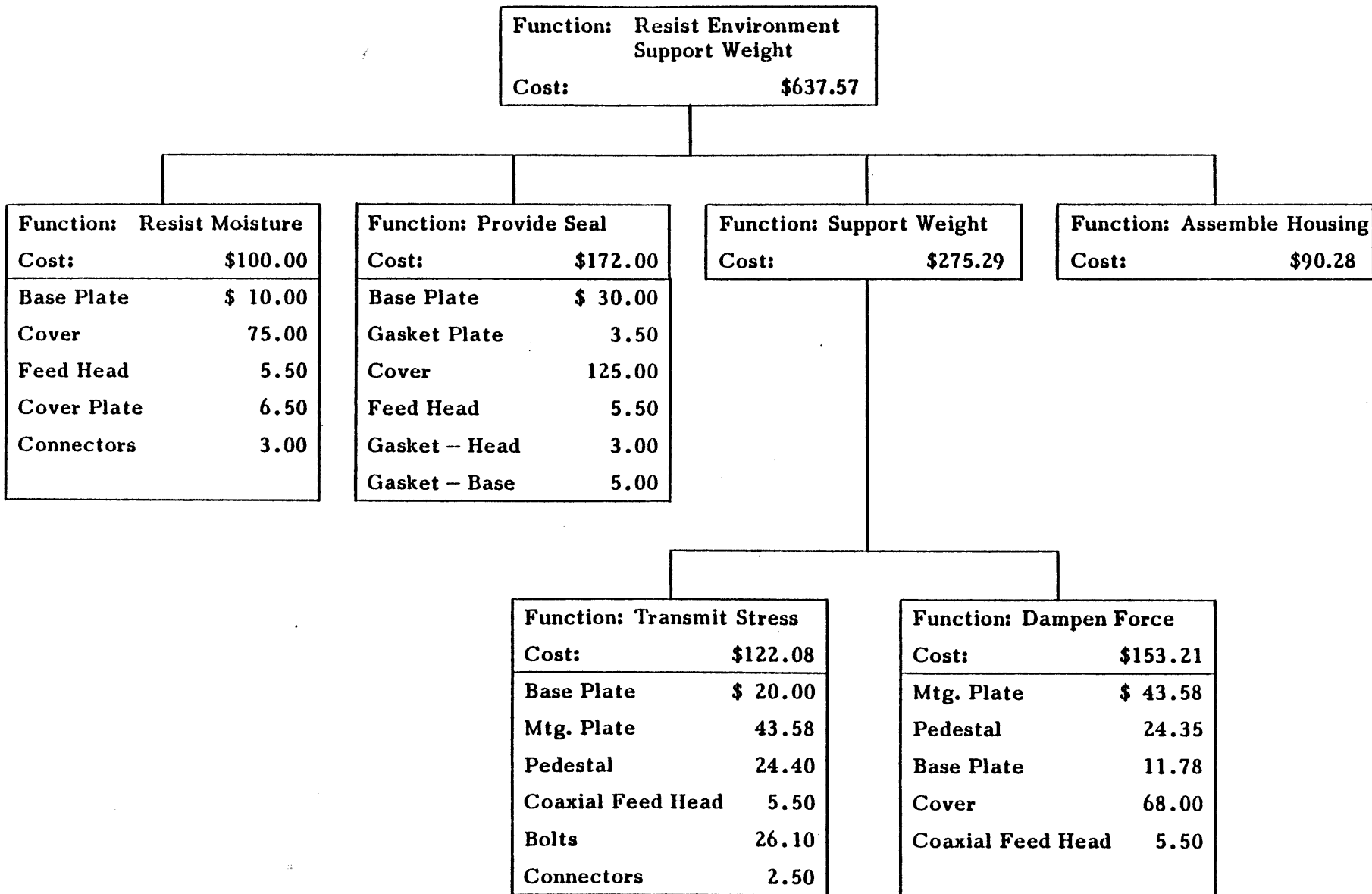
The determination of functional worth is an important step in the Value Engineering Job Plan approach. It is the basis for ascertaining where the most productive efforts should be applied for the remainder of the VE study. Several techniques have been developed by practitioners for this step ranging from very simple approaches to those requiring the development of historical algorithms of functional worth.

1. Functional Model

A functional model develops the hierarchy of functions within a product or service. In its simplest form, parts and cost are assigned to each function. For the more comprehensive studies the model can have performance characteristics assigned to each function, such as weight, reliability, and power consumption. While this technique does not establish functional worth per se, it does illustrate where costs are occurring to achieve required functions and often depicts excessive costs to achieve them. It thus meets the objective of illustrating highest potential VE study areas.

A functional model of a housing assembly illustrates the first form (see Exhibit I). The VE team recognized the complexity of the current approach to achieve the functions required in its environment. The "support weight" function, which in turn is composed of two lower tier functions, "transmit stress" and "dampen force," required too many parts and it, in their judgment, was not worth \$275.29 plus the associated assembly costs to support the weight of the electrical components inside the housing. The result was the team created a simplified design which eliminated the need for the pedestal, coaxial feed head, two gaskets,

**EXHIBIT I
HOUSING ASSEMBLY FUNCTIONAL MODEL**



Note: When a single part (base plate, cover, coaxial feed head, etc.) contributed to more than one function the part cost was

two connectors, and the cover plate. The cover itself was also greatly simplified from a casting to a hydro-formed cover.

Exhibit II illustrates a partial functional model for the control mechanism of an engine on a piece of space equipment. In this case, the weight allowances were a critical design factor with strongest delivery requirements a contractual feature. This model further illustrates why functional models have become a major management tool:

- (i) It clearly defines all functions that must be performed.
- (ii) It clearly shows the relationships of one designer's functional responsibilities to another.
- (iii) It assigns operational parameters to functions and thereby permits controlled trade-offs if required.
- (iv) It provides a mechanism to allocate and control costs.

Thus a technique originally concerned, and still very useful to determine appropriate emphasis for VE study effort, has been capitalized on and expanded to become general management techniques. As one executive at RCA stated, "This is the best tool I've yet seen to assure management that all the requirements are being performed and that the relations of one function to another are being controlled."

2. Tentative Alternatives

A technique developed in the early days of value engineering, and still widely used today, is comparing the function defined to the simplest method or product that can be imagined. For example, the function of "sealing pressure" on a fuel transfer mechanism can be compared to a simple canning gasket costing about five cents. A double throw switch could be compared to a simple spring mousetrap with a couple of terminals added for approximately one dollar. Rarely would these alternatives provide an actual solution but they do set cost goals. It has been proven many times over that much better final results will be achieved by starting with a base minimal alternative and adding to it to achieve required results, rather than starting with a higher cost approach and attempting to remove cost from it. The disadvantage of this technique is that it tends to have the VE team enter the speculation phase of the Value Engineering Job Plan before they have completed the information phase, and they therefore may not do a comprehensive job on either phase. So, care must be taken with this technique to allow it to be optimally used.

3. Basic Material Value

A technique to assign worth of functions that has become increasingly popular is to ascertain the primary material cost associated with the function. Again, while that cost would rarely be achieved in the finished product it does provide a target to shoot toward. The concept is that any costs, in addition to that

**EXHIBIT II
CONTROL ENGINE FUNCTIONAL MODEL (Partial)**

1.0

Function:	Control Descent Engine
Hardware:	DEC ASM
Cost:	\$125,100
Weight:	7 ± .5 lbs.
Delivery:	17 weeks

1.1

1.2

1.3

1.4

Function:	Control Pitch Attitude
Hardware:	Cont. Asm.
Cost:	\$33,500
Weight:	2.10 lbs.
Delivery:	14 weeks

Function:	Control Yaw Attitude
Hardware:	Cont. Asm.
Cost:	\$56,300
Weight:	2.50 lbs.
Delivery:	16 weeks

Function:	Control Throttle
Hardware:	Input-0-4200 Output-0-100 D.C.
Cost:	\$32,500
Weight:	1.80 lbs.
Delivery:	14 weeks

Function:	House Components
Hardware:	8 x 5 x 1½ pack
Cost:	\$2,800
Weight:	.40 lbs.
Delivery:	17 weeks

Function:	
Hardware:	
Cost:	
Weight:	
Delivery:	

Function:	
Hardware:	
Cost:	
Weight:	
Delivery:	

Function:	
Hardware:	
Cost:	
Weight:	
Delivery:	

Function:	
Hardware:	
Cost:	
Weight:	
Delivery:	

EXHIBIT II (Cont'd)

1.1

Function:	Control Pitch Att.
Hardware:	Control ASM
Cost:	\$33,500
Weight:	2.10 lbs.
Delivery:	14 weeks

1.1.1

1.1.2

1.1.3 [x2]

1.1.4 [x2]

Function:	Receive Signal Distribute Signal
Hardware:	Signal Box
Cost:	\$1,800
Weight:	.30 lbs.
Delivery:	12 weeks

Function:	Prevent Noise
Hardware:	<u>±</u> Pitch
Cost:	\$4,500
Weight:	.35 lbs.
Delivery:	6 weeks

Function:	Activate Switch Motor Field
Hardware:	Saturating Circ. Amp.
Cost:	\$6,200
Weight:	.30 lbs.
Delivery:	13 weeks

Function:	Activate Bridge Elec. Circuit
Hardware:	Saturating Circ. Amp.
Cost:	see 1.1.3
Weight:	.40 lbs.
Delivery:	12 weeks

1.1.5

1.1.6 [x2]

1.1.7

1.1.8

Function:	Prevent Start Yaw Gimbel Motor
Hardware:	Field Power
Cost:	\$4,800
Weight:	.20 lbs.
Delivery:	9 weeks

Function:	Output Signal
Hardware:	Electric Bridge Circ.
Cost:	\$3,400
Weight:	.25 lbs.
Delivery:	13 weeks

Function:	Indicate Signal
Hardware:	Verify and Comp. Circ.
Cost:	\$2,400
Weight:	.20 lbs.
Delivery:	11 weeks

Function:	House Com- ponents
Hardware:	Chassis
Cost:	\$1,200
Weight:	.10 lbs.
Delivery:	14 weeks

prime material, occur as a penalty of processing due to the design utilized. Therefore, alternative ways to reduce or eliminate the penalties will be developed. This approach is often called a "forcing" technique. For example, the metal within a bronze casting may cost \$10, but the cost of the casting itself may be several times that due to the tolerances stipulated and other production procedures. If the function of the casting was defined as "contain pressure" then the objective would be to develop alternative ways to contain that pressure for \$10. Likewise, the function "transmitting fluid," costing several dollars under a present design, might involve primary tubing material costs of less than \$1.

4. Function Standards

Several organizations with long-established value engineering/analysis programs have attempted, with varying degrees of success, to develop historical function value standards. For example, the function "conduct current" would have a cost history by ranges of current, and under different conditions and tolerances. Graphs would be created for easy reference. Similarly, "support weight" graphs would be developed for ranges of weight. The approach is similar to developing parametric cost estimates by product, hardware, or systems, but functions become the parameter. Again, it should be emphasized that this source of data is normally unique to an industrial organization and could only be expected to be available under a long-term, established value engineering program.

Summary

All the individual techniques to establish functional worth are attempts to ascertain where the most opportunity for improvement exists. Thus, one ground rule is often used—secondary functions have no value. Practically speaking, this often works because secondary functions are defined as those that exist only to support basic functions and are normally a consequence of the current design and manufacturing approach. Therefore, if an alternative approach is developed to achieve the basic function any secondary function may disappear. By assigning value only to basic functions the value engineer is forced to concentrate on necessary functions and not initially spend time trying to improve something that may well be eliminated later in the study.

E. Summary

The Information Phase of the Job Plan involves four major tasks:

- (i) Select appropriate projects—project selection is important to the results of the study. Normally, the objective in selecting projects is to isolate areas that seem to offer the greatest dollar savings in return for investment in study and implementation costs. Other objectives, such as decreasing rejection rate, reducing weight, or increasing reliability, may also form the basis for selection.
- (ii) Gather a complete file of information concerning the projects—adequacy and accuracy of information will either make or

break the analysis to be performed. Every aspect of the project must be questioned. Information should be obtained from the most reliable sources. The value engineer performing the study should be more knowledgeable about the project than anyone else in the world.

- (iii) Define basic and secondary functions – VE is concerned with analyzing functions for the purpose of achieving necessary functions at the lowest total cost. By concentrating on the function of an item rather than on the item itself, the designer is constantly returned to the basic reason for which an item is required, designs are simplified, and costs are kept to a minimum. A function is that action which makes an item or service work or sell and is expressed by two words, a verb and a noun. There are two classes of function, basic and secondary.
- (iv) Establish function worth – the objective is to determine the optimal areas for productive study. Techniques include developing functional models, estimating basic material costs, comparison to simplest alternatives, and developing function standards.

Appendix A provides a checklist of typical questions to be asked during the Information Phase.

SECTION II. SPECULATION PHASE

The objective of this phase is to generate as many ideas as possible for performing the necessary functions identified in the Information Phase. Speculation should be a creative type of effort, totally unconstrained by tradition, habit, or the "How has it been done before?" attitude – far removed from everyday "Think" sessions. Whether the ideas are good or bad, feasible or not feasible, is not important in this phase of the Job Plan. The sole aim of speculation is to initiate as many alternatives as possible; comparisons and judgments are made later, during the Evaluation Phase.

There are two keys to successful speculation. The first relates to function. The purpose of speculation is not to conceive of ways to make a product or perform a specific service, but to develop ways of performing necessary functions. Therefore, it is impossible to speculate successfully unless the basic function has been clearly established.

Creativity is the second key to successful speculation. Creativity is a mental process in which past experience is combined and recombined to form new combinations. From the standpoint of VE, it is hoped that one of the new combinations will perform a particular function at less total cost than was previously attainable. In other words, the term "creativity" is used to define a process of finding a new solution to a well-defined problem. The problem itself may be either old or new to you. For example, if a member of an aboriginal tribe in the heart of New Guinea were to invent glue in order to make things stick to each other, this would be a highly creative act because the solution would be new to him. On the other hand, solving a sales organizational problem at one division by using another division organizational plan is not being creative – it's merely applying an old solution to a problem. To be successful, it's necessary to depart from ordinary patterns – from typical solutions – from habits. Admittedly, habits are difficult to break, but a number of techniques have been developed for this purpose. Two of the most effective techniques are "brainstorming" and checklists.

A. Brainstorming

Brainstorming is a strategy by which a problem is massively attacked by dozens of ideas for performing necessary functions for possible solutions. The attack can be carried out by one person or by several people as long as it is done vigorously and imaginatively. The VE team takes each of the basic functions described during the Information Phase and develops as many ideas as possible to perform the same function. At this point the item itself and everything reminiscent of it (blueprints, brochures, pictures, and so forth) should be set aside. The only thing to keep in mind is the two-word functional definition.

Brainstorming requires a free flow of ideas. To ensure such a flow, four basic ground rules should be established for any brainstorming session:

- (i) Judicial thinking (judgment) is not allowed – in other words, the purpose of the session is to generate quantities of ideas – not to

discuss or evaluate them. No idea is too fantastic, nor should anyone be allowed to laugh at an idea. Roadblocks have absolutely no place in a brainstorming session. During the Speculation Phase no one must judge any of the ideas presented.

- (ii) Hitchhiking is encouraged – that is, VE team members are encouraged to pick up ideas that others generate and expand on them. Two or more ideas can be joined into still another idea. To encourage this process the ideas are generally written down on a blackboard as they are generated for all to see.
- (iii) Quantity is desired – the greater the number of ideas, the greater likelihood of good ones emerging.
- (iv) Wild ideas are encouraged – no boundaries or limitations whatsoever must be imposed on the thinking. The wildest ideas themselves often have merit, or, by hitchhiking, they may lead to valuable alternatives. At the very least they may help to rechannel the creative thought process.

Generally speaking, anywhere from 25 to 50 ideas will be generated during a relatively short brainstorming session – all of which must be recorded. And although many of these ideas may turn out to be impractical, some of them will prove worthwhile. If only one useful idea turns up, the effort has been worthwhile. The idea may prove to be worth a million dollars – all for a few minutes of stretching the imagination.

B. Checklists

The checklist as illustrated in Appendix B is a series of statements covering areas that may not have been developed during the initial brainstorming. Since sometimes brainstorming develops or expands around one particular approach to providing a function, a checklist may open up new possible approaches and make future brainstorming more effective. In fact, a checklist can often double the number of ideas for performing a function.

One concept that should always be considered – and is too often overlooked – during brainstorming is that of eliminating the item entirely. For example, if the item in question is part of an assembly, the assembly should be visualized without this component. Will the assembly still function? If the answer is yes, the elimination will permit 100 percent savings. It is assumed that unnecessary functions were identified in the Information Phase and that only necessary functions are being considered here.

The other checklist statements are also designed to trigger similar types of speculation. Some of the checklist statements obviously don't apply to every type of product or service; and the list can, of course, be expanded as imagination dictates, but the existing list will help to increase creativity.

C. Summary

The objective of the Speculation Phase is to generate as many ideas as possible for performing the necessary functions. There are two keys to successful speculation. The first is to concentrate on performing necessary functions, not on ways to make a product or provide a service; and the second is to apply creativity to produce ideas - the end product of the Speculation Phase. Two effective techniques for improving creativity are brainstorming and the use of checklists.

SECTION III. EVALUATION PHASE

After all the ideas generated in the Speculation Phase have been recorded, judgment is applied. The objectives of the Evaluation Phase are (i) to gather and analyze data concerning ideas generated in the Speculation Phase and (ii) to select one or more feasible ideas offering better value.

A. Gathering and Analyzing Data Concerning Ideas Generated in the Speculation Phase

Since the objective of VE is to provide necessary functions at the lowest total cost consistent with necessary performance and schedule, the first task of this phase is to gather and analyze data on all the ideas so that the value engineer and other decision makers can select one or more ideas offering better value. To facilitate evaluation, data gathering and analysis are divided into two major categories - rough and fine. Enough data should be gathered initially to support a valid decision as to whether the idea will meet the necessary cost, performance, and schedule requirements. If it is obvious, however, that the needed requirements can't be met, the idea is termed not feasible for this particular study - although it may be possible for future applications. For example, 30 ideas for performing a function enter the Evaluation Phase. A rough cost estimate indicates that ten of these approaches would cost more than the present method (or more than the customer is willing to pay); rough performance calculations show that an additional ten ideas can't meet necessary requirements; and rough time estimates eliminate development of four of the remaining ten ideas. Thus it appears that only six of the original 30 ideas are feasible for this particular situation. (However, the discarded ideas may be developed in the future.) Detailed cost, performance, and schedule data for these six feasible ideas are then gathered and analyzed.

1. Detailed Cost Data

The primary goal of VE is to achieve true cost reductions. Therefore, only by performing detailed and accurate costing can valid comparisons of feasible ideas and realistic estimates of potential savings be made. Although it is not appropriate to discuss here the details of costing methods and techniques, it should be noted that a detailed cost analysis generally involves at least the following five steps:

- (i) Estimate the number of units that will be affected if a VE change is made.
- (ii) Estimate the variable costs of manufacturing the alternative product (direct labor, direct materials, variable overhead or burden, and so forth).
- (iii) Estimate the fixed costs of manufacturing the alternative product (special tooling, new equipment, fixed overhead, and so forth).

- (iv) Estimate all costs necessary to implement the change, for example, retraining personnel, developing new work methods, redesigning, testing, and installing the equipment or procedure.
- (v) Estimate the costs of operating and supporting, once in use, the product or service resulting from the new idea.

These estimates are used to develop fixed and variable costs, implementation costs, and operation and support costs – all of which constitute the total cost for utilizing the idea. This cost can then be compared to the total cost of the existing approach, or, in the situation where VE is applied to fulfill a need before a product or service exists, the ideas can be ranked in relation to total costs. Developing meaningful cost estimates is difficult even when the estimator is familiar with the ideas involved or when the products are relatively simple. Research indicates that estimates made by untrained persons vary greatly – often in a range of 10 to 1.

2. Analyzing Specific Costs

Attempts are constantly being made to simplify this entire cost estimating process. For example, a number of cost ratios and cost estimating techniques have been developed that permit comparison of the costs of products currently performing certain functions with the costs of possible alternatives.

Industrial accounting systems are frequently unable to break out the costs of specific items or processes, even though these costs are required for effective value studies. Accounting systems are often developed for total costing, not individual costing. Further, standard cost systems will not give actual costs needed for a VE analysis.

Several techniques can be helpful, however. One common approach is to figure cost per element. This refers to the process of breaking down total cost into its elements (direct materials, direct engineering labor, direct fabrication labor, manufacturing burden, test, general and administrative expense, and so forth) and then evaluating each element just as you would in any type of cost analysis. A breakdown like this often points up one cost element that's drastically out of line for a product. And this area, of course, is the one on which you concentrate.

There are many other ways of analyzing costs for VE purposes, each of which offers some special advantage. For example, you can often identify unnecessarily high cost areas by calculating the cost by component and process. Here, you break down the total manufacturing cost for an end item into costs for components, subassemblies, and assemblies. Process analysis is then used to evaluate the manufacturing process for each of these, from raw material to finished part, in an attempt to isolate the most worthwhile areas for VE analysis.

Another comparative technique that can be applied to almost all products is a cost-per-pound analysis. An example from one of our past seminars

will serve as an illustration. During project analysis, one VE team discovered that grey iron castings were costing over 50 cents per pound as compared to the normal cost of about 30 cents per pound. When they asked the vendor why, they found that certain nonfunctional design characteristics dictated expensive pouring and mold design. By altering these specifications, they were able to obtain quotations averaging only 34 cents per pound. This, of course, was much more in line with the target.

Cost per dimension, cost per property (such as area, volume, tensile strength, conductivity, and so forth), and cost per time period or quantity are other comparison techniques.

3. Detailed Performance Data

Although previous rough performance estimates have shown that the idea is feasible, performance capabilities of the idea must be substantiated through appropriate detailed design and testing. Such data will also be helpful to answer questions that are inevitably raised in the Implementation Phase of the Job Plan.

4. Detailed Schedule Data

Rough scheduling estimates of feasible ideas must also be refined. This refining process will necessitate collecting additional data to firmly support accurate time estimates.

B. Select One or More Feasible Ideas Offering Better Value

After detailed cost, performance, and schedule data have been developed for several feasible ideas, one or more of these ideas must be selected for recommended implementation. The decision maker should be offered two or three alternatives - while one of the ideas will offer the lowest total cost, other ideas may offer total costs in the low range and at the same time offer greater performance and/or shorter schedules. Then, too, if two or three sound proposals are offered, a higher probability of acceptance is insured. If, on the other hand, only one approach is proposed to the decision maker and he decides to reject it, the prior VE effort may have been wasted. Another factor to be considered in selecting feasible ideas to be presented to the decision maker is his probable attitude toward cost, performance, and schedule. Anticipating his reactions beforehand will increase the chance of the idea or ideas being accepted.

C. Summary

The Evaluation Phase involves the judging of ideas generated in the Speculation Phase. This phase requires gathering and analyzing cost, performance, and schedule data and then selecting one or more feasible ideas offering better value.

SECTION IV. IMPLEMENTATION PHASE

The fourth and last phase of the Value Engineering Job Plan - Implementation - follows the selection of one or more ideas offering better value. Two major tasks are involved:

- (i) Develop a plan for presenting the ideas to implementing personnel.
- (ii) Obtain the necessary commitments for implementation.

A. Develop a Plan for Presenting the Ideas to Implementing Personnel

A successful plan involves two major considerations: to whom and how the idea should be sold.

1. To Whom

An idea is useless unless implemented. Since it takes people to implement ideas, those who have the authority to accept or reject the idea (or influence those who do) are of particular importance. Everyone who is directly or indirectly concerned with the basic project may have to be consulted and won over before the project can be implemented. In most cases the person who is (or was) responsible for the entire project should be considered first. If his O.K. can be obtained the battle is at least half won. In addition to the person responsible for the project there are other people whose opinions should be considered: the engineer who has direct authority over the technical aspects of the project; quality control and reliability people who will often be interested, particularly if a previous product provided a high level of performance that the VE study found to be unnecessary; marketing personnel interested because of the effect changes may have on customer acceptance; and finance and accounting personnel who will be closely monitoring VE study cost and potential savings.

2. How

Once the decision makers are located, they must be convinced that a change is beneficial. Of course, the time to begin the "how" of selling is during project selection - in other words, if the decision makers need and desire a VE study, there will be a much higher probability of implementation than if the selection and conduct of the study took place in secret with the results sprung on the decision makers at the end. The people who can accept or reject a change are, and must be made to feel they are, an important part of the study from the beginning. Developing a plan for presenting ideas to implementing personnel involves a myriad of factors. In a sense, everything done during the VE study will help to sell (or to kill) the proposal. A successful plan would consider at least three major areas: the report, roadblocks, and selling techniques.

a. **The Report.** A report is normally a clear, accurate, and timely combination of oral and written information. The people for whom the report is being prepared should be a major consideration during preparation. Normally, the report should include the following:

- A brief description of the project studied.
- A summary of the problem.
- The results of the functional analysis showing existing and proposed designs (sketches, blueprints, and so on).
- Technical data that support the proposed ideas, including test information.
- Cost analysis of the existing and proposed designs and all associated data, quotations, suggestions, and so on.
- Acknowledgments of those who made contributions – such as consultants, vendors, and other company personnel.
- Recommended ideas with a summary statement explaining the advantages of accepting the ideas. If disadvantages are involved, means to overcome the disadvantages should be delineated.

Impressive potential dollar savings often are not enough to get the proposal accepted. The report must be presented convincingly, and the person giving the report must be obviously confident of the outcome. To ensure that all data in the report are accurate, all phases of the Job Plan should be reviewed.

b. **Roadblocks.** Many people feel that changes in the established order of things involve a risk and are, therefore, a potential threat to them. Such people may set up roadblocks to the attainment of better value that must be cleared away. Following are a few examples of roadblocks:

- It's been done this way for 15 years – why change?
- I know it won't work.
- That's Joe's problem, not mine.
- We can't help it – it's policy.
- We don't have enough time.
- I'll take it under consideration.
- We have no test money.

Appendix C is a comprehensive checklist of the 101 ideas of negative thinkers. Roadblocks may be encountered during all phases of VE - from information gathering to implementation. One way to overcome them is to be prepared with facts, but a better approach is to keep them from being set up in the first place. A few suggestions on how to avoid roadblocks follow:

- (i) The decision makers should be acquainted with the nature and goals of the task from the very beginning of the VE effort to allay fears and ensure cooperation.
- (ii) From the very beginning, the job should be as much of a team effort as possible. Recognition of contributors throughout the progress of the study will be effective in this respect.
- (iii) From the beginning of the task, the chain of command and the personalities of the people worked with should be respected.
- (iv) The reactions of the small minority who may consider the VE efforts a challenge to their work, an intrusion, or a threat to their jobs should be anticipated.
- (v) All suggestions, recommendations, and requests should be as clear as possible.
- (vi) In selling proposals, care should be taken to avoid proposing changes and conclusions that imply criticism of individuals. Above all, before changes that affect jobs and assignments are recommended, all personnel details should be discussed with appropriate managers.

c. **Selling Techniques.** Selling the proposed ideas is facilitated by presenting a meaningful report and minimizing roadblocks throughout the study. However, implementing an idea is not easy; often it will be necessary to enlist the aid of others or even have them do it for you. There's an adage that states, "The type of person who can have ideas seldom has the ability to sell them." The value engineer must guard against becoming so enthusiastic about an idea that he overlooks disadvantages and the feelings of others, and in turn becomes a roadblock himself. Mr. Eric Webster of England has developed ten thought-provoking suggestions for selling ideas:

- (i) "Don't assume that people want ideas because they say they do." What they usually want is something that looks like an idea but isn't - something that will please everybody without actually changing anything. Real ideas involve change, which is usually unwelcome until it is over, by which time it's history and therefore respectable.
- (ii) "Don't think other people think the way you think." If they did, they'd probably have had the idea you are now trying to describe. Unless you're very careful, what you say and what they see in

their minds will differ so much you'll never get through to them. The idea they turn down won't be yours but their idea of your idea, which may be a very different thing.

- (iii) "Decide whether you want to get the idea accepted or whether you want to get the credit." The two propositions are often mutually exclusive. Sometimes you may get action on an idea. Sometimes you may get the credit for it. Seldom will you get both.
- (iv) "Arrange for someone else to have your idea." Pick the most powerful man of the group you are trying to influence. This is like fly-fishing. You'll have to cast the problem pretty skillfully to get a bite. Once he's got the bait and has surfaced with the right solution, strike immediately! Utter some faintly doubting remark. When he starts defending what is now his idea to you and the group, he's hooked. Now allow yourself to be won around step by step to his point of view. He will begin to think highly of you. You will find life is much healthier and happier if you get the reputation of never having an idea yourself but being a good appreciator of other people's ideas, and always, mysteriously, present when they happen!
- (v) "Be casual." Clinical detachment is a big help. As long as you don't seem to care whether your idea is accepted or not, you've reduced the joy people can take in shooting it down. If you can actually move on to pointing out snags and getting others to iron them out, you're halfway home. But, remember, if you show even the mildest spasm at some particularly crass obstructionism, you'll instantly be flushed from cover with the whole pack in exultant pursuit.
- (vi) "Don't confuse them." Your task is difficult. Don't make it impossible. Don't show them more than one idea at once or they'll panic. But there is an exception:
- (vii) "Sometimes it pays to throw out decoy ideas." Some irredentist ideamen habitually score success by putting up decoy ideas to be shot down like clay pigeons. This requires a nice sense of reaction and timing. Only when the bloodlust of the audience has been assuaged is the real idea brought forward.
- (viii) "Don't overstress originality." The more original your idea, the less you should stress the fact. Make it seem as innocuous as possible. Mention similar-sounding ideas that have worked. Give your audience plenty of chance to get used to the thought.
- (ix) "Make your idea watertight" - but don't suppose this will make it unsinkable!

- (x) "Give it a warm emotional appeal." Get some well-hated person to oppose it. Mention the possibility of a competitor getting in first with it.

In addition to being amusing, Webster's suggestions for overcoming resistance to change are very helpful and practical in developing a plan for presenting the ideas to implementing personnel.

B. Obtain the Necessary Commitments for Implementation

After a plan for implementing the proposal has been developed, the proposal must be sold. Each seller will, of course, develop his own approach to presentations, but, in any case, the approach must be clear, accurate, and simple.

Implementation is an extremely important aspect of the Job Plan; it must be followed up to ensure that action has been taken - many proposals have died a slow death because they have been "taken under consideration" for months by decision makers. The objective of VE is to provide necessary functions at lowest total cost - this objective can be met only with implemented proposals and not with dangling ideas.

C. Summary

The two major objectives of the Implementation Phase are to develop a plan for presenting the ideas to implementing personnel and to obtain necessary commitments for implementation. A successful implementation plan involves two important considerations; to whom the idea must be sold and how the idea should be sold. Follow-up ensures that implementation action has been taken.

GENERAL SUMMARY

The Value Engineering Job Plan is an organized approach for carrying out a VE study. It consists of four specific phases: Information, Speculation, Evaluation, and Implementation. We have indicated that these phases are distinct - in other words, that they are easily distinguished from one another and flow in sequence; but in fact, this is not completely true. Certain tasks defined as taking place within one phase or another actually occur throughout the entire VE effort. Take information gathering as an example. Admittedly, the Information Phase is used to gather information. Ideally, the Speculation and Evaluation Phases will be entered with all the background information needed to successfully value engineer the project, but like most ideal situations, this hardly ever happens. It's always necessary to gather additional information at the time evaluation is taking place. The Job Plan sequence may also be altered during the Evaluation Phase. Decisions reached during this phase can retrigger the entire VE Job Plan cycle: information gathering, defining functions, more speculation, additional evaluation, and so on. Regardless of the recycling, however, a sequence that should not be altered is that of defining the problem before striving to solve it. In other words, functions should be described in verb-noun form before speculation takes place.

The Value Engineering Job Plan and its elements are more easily described than carried out. A successful VE effort is a highly demanding undertaking requiring close teamwork, unusual creativity, a pioneering approach, and dynamic sales and follow-up effort. But also, through application, the Job Plan becomes a systematic way of thinking that can be utilized in any activity - final results will be greatly improved and return on investment of time and money greatly increased.

(Appendix A through C appended.)

**APPENDIX A
CHECKLIST OF TYPICAL QUESTIONS FOR
THE INFORMATION PHASE**

A. Questions Pertaining to the Overall Project

- What is the problem?
- What is the cause of the problem?
- Why is this problem being considered for study?
- Is this the most urgent problem to be studied now? Why?
- Will satisfactory results yield the greatest rate of return? How will this be determined?
- Can the entire scope of the problem be defined? Where should the study begin and end?

B. Questions Pertaining to Specific Areas

1. Marketing

- Who is the contracting officer?
- What is the actual or estimated volume under this contract?
- What is the estimated future potential?
- What is the estimated market life?
- What selling obstacles have been associated with this product?
- At what price can this item be sold currently?
- What is the profit on the current sales price?
- What is the cost of competitive equipment?
- Can we obtain a sample?
- Is interchangeability required? Why?
- Do we have patent protection?
- What are the good points of the competition unit? (Cost? Size? Weight? Reliability? Maintenance?)
- Who are the customers?
- What are the customer requirements (operational space, spares, and so on)?
- What reports are required?
- What effect would changes have on the costs of manuals and publications?
- What are the penalties on changes?

- What do you recommend for investigation, change, or improvement?
- Are any special codes involved (building codes, NEMA, industry standards, and so on)?

2. Engineering

- Who is the responsible engineer?
- What is the basic function of the item?
- Can the item be eliminated?
- Is it a standard item?
- Is interchangeability required?
- Is the item used in other assemblies? (Same part number?)
- Where does it fit in the system? Size? Weight?
- Are there any limitations in regard to space? Appearance? Performance? Environment? Material? Tolerance? Life?
- What was the date of the original design? Of revisions?
- What other designs were considered?
- What other designs were tried? Which failed? Which succeeded? Why?
- What new developments and/or changes are being considered?
- What are the latest specifications and requirements?
- Are outlines, schematics, products, manuals, or drawings available?
- Are any changes planned for the future?
- In your opinion, can it be done at less cost? How?

3. Manufacturing

- Are capabilities now available for producing this item?
- Have we ever made this item?
- Is there an inventory to use up?
- What basic machining arts are performed (drilling, milling, shaping, turning, press work, or grinding)?
- What production methods or forms are used?

Sand casting	Impact extruding
Permanent mold casting	Spinning
Press forging	Molding of plastics
Cold heading	Precision investment casting
Sectioning tubing	Drop forging

Powder metallurgy
 Plaster mold casting
 Die casting
 Upset forging

Stamping, forming
 Extruding and cutting
 Screw-machine work
 Welding or brazing parts

- Are the following available?

Assembly charts
 Bills of materials
 Operation process charts

Flow diagrams
 Planning cards
 Product flow process charts

- What are the bottlenecks?
- What are the high scrap operations?
- What are the standard manufacturing procedures?

4. Procurement

- Is this item available as a standard product?
- Is there a quantity price break?
- Are we authorized to take a price break?
- Who is the supplier?
- Who else has been considered?
- What are the procurement policies?
- What factors determine vendor selection?
- What do similar items cost?
- What is the cost of a quotation?
- Who decides on "make" or "buy"? How?

5. Costs

- What are the material costs?
- What are the labor costs?
- What are the fixed overhead costs?
- What are the variable overhead costs?
- What are the costs of scrap? Rework? Inspection?
- What level of cost should we use? Shop costs? Manufacturing costs? Total cost?
- What is the cost system?
- How are costs controlled?
- Are there special costs such as tooling? Dies?
- Are there assorted transportation costs?

**APPENDIX B
SPECULATION PHASE CHECKLIST**

General

- Can the item be eliminated?
- Can the assembly be oversimplified to determine basic requirements?
- Can specification requirements be eliminated?
- Can a standard part be used?
- Can the present design be purchased at a lower cost?
- Would a modified standard part reduce cost?
- Do we need the present shape?
- Is the design a result of custom, tradition, or opinion?
- Are features that improve appearance justified?
- Is there a less costly part that will satisfy the function?
- Can a less expensive material be used?
- Is it overdesigned for necessary performance characteristics?
- Can surface coatings be revised?
- Can the use of expensive materials be eliminated?
- Can alternative manufacturing methods be employed? . . . such as:

powder metallurgy
stamping
plastic molding
spinning
extruding
drawing
brazing
die casting
tubing
forging

electric forming
plastic casting
investment casting
epoxy binding
steel rule dies
explosive forming
hot heading
cold heading
spot welding

- Can two or more parts be combined into one?
- Will newly developed fasteners speed assembly?
- Is the minimum number of hardware sizes used?

Machining

- Is the tooling cost and method reasonable for quantity?
- Would a coarser finish be adequate?
- Are tolerances reasonable?
- Can a freer machining material be used?
- Can parts be standardized to permit special tooling?

APPENDIX C
CHECKLIST OF 101 IDEAS FOR NEGATIVE THINKERS

- | | |
|---|---|
| 1. I agree, but . . . | 30. Impracticable. |
| 2. We've tried that too, but . . . | 31. Too radical. |
| 3. We did it this way. | 32. Too complicated. |
| 4. Our procedures won't permit it. | 33. It isn't progressive. |
| 5. It won't work. | 34. Too theoretical. |
| 6. It's not in the budget. | 35. Too difficult. |
| 7. Where does the money come from? | 36. Unsound. |
| 8. You can't do that. | 37. Not feasible. |
| 9. You should know better. | 38. Impossible. |
| 10. Who thought of that? | 39. The production department won't accept it. |
| 11. I think it stinks. | 40. The field will think we are crazy. |
| 12. I can't give you the money to go ahead without further thought. | 41. Personnel aren't ready for this. |
| 13. Costs too much. | 42. Engineering won't approve it. |
| 14. Too big (or too small) for us. | 43. Our problems are unique. |
| 15. We've tried that before, and it didn't work. | 44. The men won't go for it. |
| 16. We're not ready for that. | 45. You'd never be able to sell that to management. |
| 17. We have the best system already. | 46. Boss won't like it. |
| 18. We don't do things that way. | 47. Can't see it. |
| 19. Everybody does it this way. | 48. Too much trouble to get started. |
| 20. I'm the boss here. | 49. Doesn't conform to our policy. |
| 21. It's policy. | 50. We don't have the manpower. |
| 22. Too academic in its approach. | 51. Who is going to do it? |
| 23. Not timely. | 52. Takes too much time. |
| 24. It's a gimmick. | 53. Too much work. |
| 25. Not for us. | 54. It's never been done before. |
| 26. Too hard to administer. | 55. It will not apply to our problem. |
| 27. No good. | |
| 28. Plain stupid. | |
| 29. Worthless. | |

APPENDIX C (Cont'd)

56. Don't move too fast.
57. It's new.
58. It will set a precedent.
59. We don't want to do this now.
60. We can't do it here.
61. It's too much trouble.
62. We have too many new projects.
63. Not enough background.
64. Why can't we do it another way?
65. Not convincing.
66. Stretches imagination too much.
67. Against good judgment.
68. We know all this.
69. Haven't we got something just as good now?
70. Why should we change now?
71. The thinking is purely on the surface - get some depth to it.
72. We don't need it.
73. Let's wait and see later.
74. Don't be ridiculous.
75. That's not our responsibility.
76. We don't have time for that.
77. It will make present equipment obsolete.
78. We don't have enough volume.
79. It's not practical for operating people.
80. It's too hard to maintain.
81. We've never done it before.
82. Not permitted by specifications.
83. That will take two years to test.
84. Not in accordance with standard plans.
85. Let's shelve it for the time being.
86. Let's form a committee.
87. It won't work in this case.
88. It's not standard stock.
89. Cost doesn't matter.
90. What about the directive?
91. It won't last.
92. We can't be sure.
93. Why change it - it works?
94. We haven't tested it yet.
95. I don't care how long it has been used commercially.
96. How do we know it works?
97. I'm too busy to decide now.
98. We haven't enough facts.
99. Not invented here.
100. But, on the Panama Canal job we . . .
101. No, no, no!

THE EYEBOLT CASE¹

The equipment, a small weather detection system, must be shipped on a company flatbed truck. Cables that attach to an anchor assembly are looped over the equipment. The anchor assembly screws into the floor bed of the truck, which has holes previously drilled and tapped (3/8-16) running along the outside edges of the bed. These holes go completely through the floor bed. The contractor cannot alter the truck in any manner.

The engineer has stated, "Since we never know the exact positioning of an equipment on the truck, and since it is an irregularly shaped object, we never know at what angle the cable and hook will come at the anchors. Therefore, we have designed the swivel feature into the anchor assembly to be able to accept the cable from any angle. Each anchor assembly must carry a 1,000-pound load."

The contract calls for 10 systems, one system per truck. There are 6 cables used per system (12 anchors).

¹Copyright © 1965, 1981, Harbridge House, Inc.

Prepared by Harbridge House, Inc. This material is intended for teaching purposes only.

PARTS LIST

	Code	Material	Labor
Eyebolt - 2143	OV/MS	\$1.59	\$.80
Ring - 2144	M/S	.44	.72
Stud - 2145	M/S	.92	7.04
Nut Self Lock - 6654	O/V	.08	—
Screw (3) - 7655	O/V	.08	—
Lock Washers (3)	O/V	.08	—
Assembly		<u> </u>	<u>.65</u>
		\$3.19	\$9.21

Note: Labor Rate - Machine Shop: \$8.00 per hour

Labor Rate - Assembly: \$7.00 per hour

PLANNING CARD

Part - 2145 - Stud

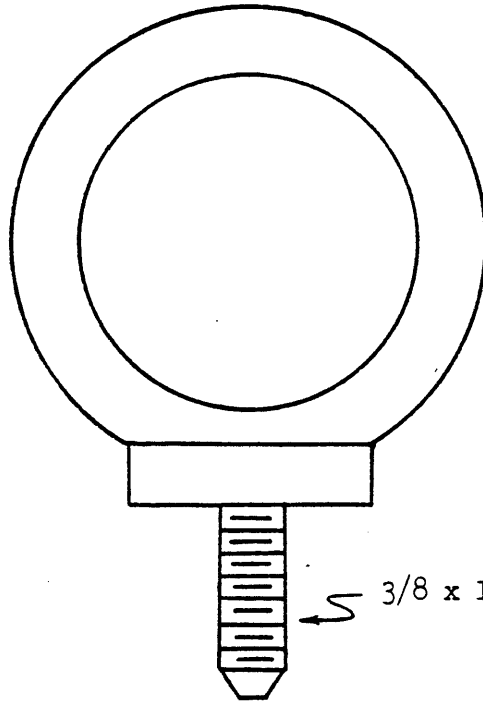
Oper. #	Station	Description	S/U	RP/100
1	42	S/U, face, bore, knurl	2.08	160.00
2	42	S/U, turn to 3/8 dia., thread 3/8 - 16	2.08	372.00
3	42	Cut 1 length		28.00
4	51	S/U, drill and tap 1/4 - 20 (3)	2.00	144.00

Part - 2143 - Eyebolt

Oper. #	Station	Description	S/U	RP/100
1	42	S/U, cut 1 length, thread 3/8 - 16	2.08	80.00

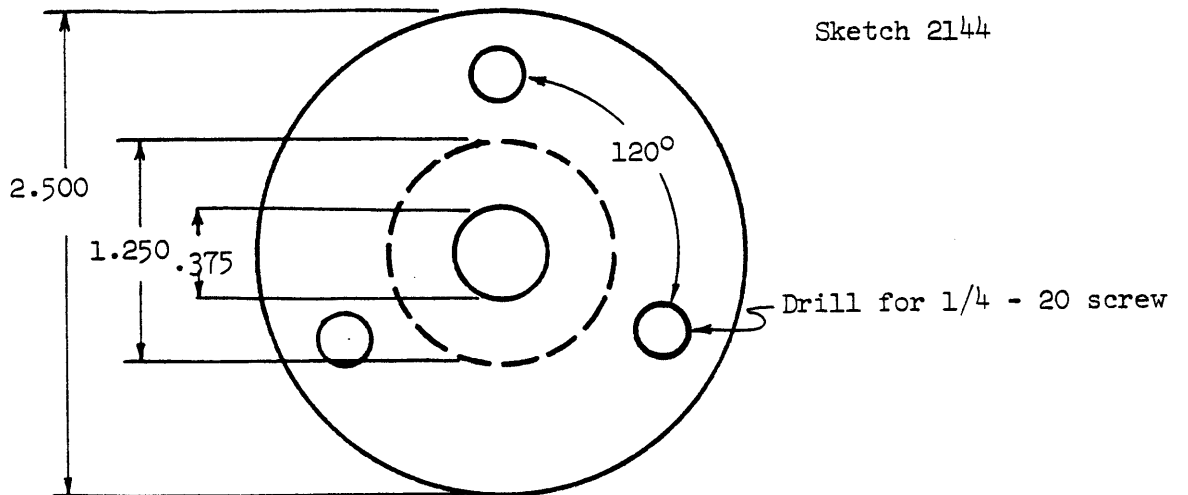
Part - 2144 - Ring

Oper. #	Station	Description	S/U	RP/100
1	42	S/U, face, bore cutout	2.08	160.00
2	42	S/U, cut 1 length	1.84	60.00
3	51	Drill holes - 1/4" (3)	2.00	68.00

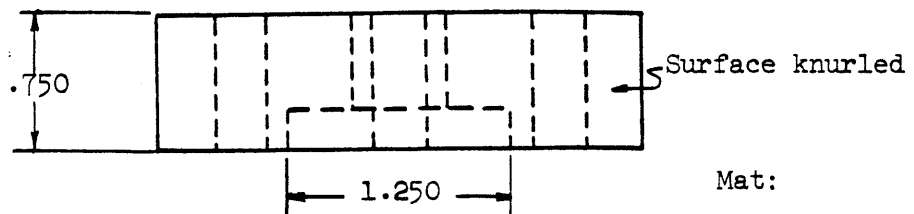


Sketch 2143

Vulcan #56
or equivalent

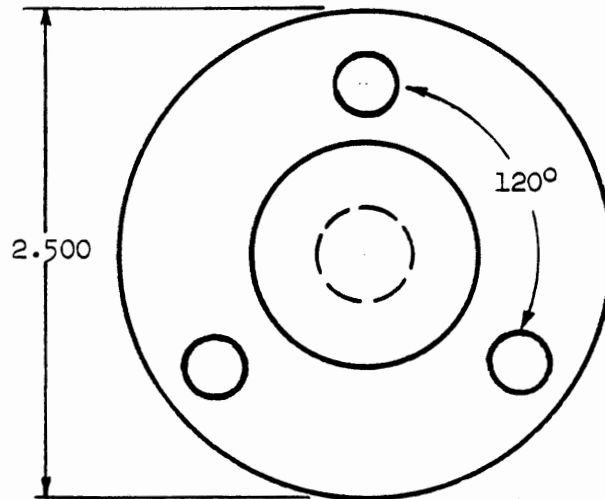


Sketch 2144

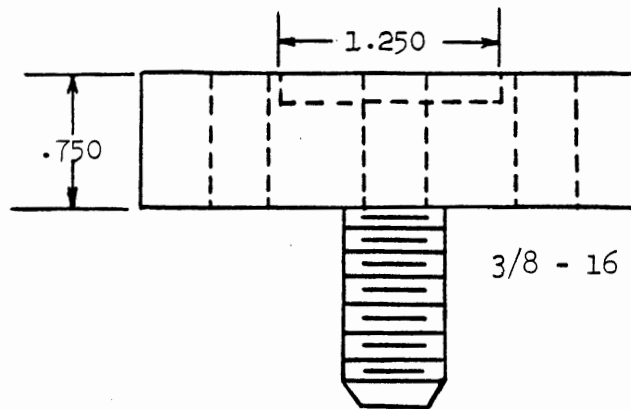


Mat:

Note: All dimensions
± .010 unless
otherwise shown



Drill and tap (3)
1/4 - 20



Surface knurled

3/8 - 16

Mat:

Note: All dimensions
± .010 unless
otherwise shown

COST ANALYSIS - EXAMPLE

This operation involves the following factors:

Material overhead	5%
IME	150%
Engineering overhead	100%
BPS - (Box, Pack, Ship)	3% of shop cost
G&A	5% of manufacturing cost
Profit	7% of total cost

Example (assume material = \$1.00, labor = \$1.00, eng. = \$1.00)

Material	\$1.00		
Material O.H.	.05		
Labor	1.00	Mfg. cost	\$5.66
IME	<u>1.50</u>	G&A	<u>.28</u>
<u>Shop Cost</u>	\$3.55	<u>Total Cost</u>	\$5.94
Engineering	1.00	Profit	<u>.41</u>
Engineering OH	1.00	<u>Sell Price</u>	\$6.35
BPS	<u>.11</u>		
<u>Mfg. Cost</u>	\$5.66		

ANCHOR ASSEMBLY

EYEBOLT

VE 4801-1

FUNCTIONAL ANALYSIS WORKSHEET

QUANTITY	COMPONENT	FUNCTION		(EXPLANATION)	DIMENSION	CLASS	LEVEL NUMBER	VALUE OR WORTH	ACTUAL COST
1/ASM	EYEBOLT	receive	hook		500 lb.	B	1	10	.59
		hold	nut			R			
		permit	swivel		360°	R			
1	RING	seats	eyebolt			R	1		.83
		seats	screws			R			
		permit	grip			R			
		resists	nut	force		R			
1	LOCKNUT	permit	swivel		360°	R	1		.02
		fastens	parts	eyebolt to ring		R			
1	STUD	fastens	ASM	to truck base	500 lb.	B	1	.05	1.99
		receives	screws	(2) - threaded		R			
		seats	ring			R			
		permit	grip			R			
3	SCREWS AND LOCKWASHERS	fastens	parts	ring to stud		R	1		.04
	ASSEMBLY COST							25	

Speculative Phase

The function is Anchor Assembly. It is a
 basic () secondary () function.

Alternative means of performing function prepared during the
 brainstorming session.

- | | |
|--|--------------------------|
| 1. <i>Nail it</i> | 21. <i>Air cushion</i> |
| 2. <i>Eliminate weight equipment</i> | 22. <i>Epoxy bonding</i> |
| 3. <i>Glue it</i> | 23. <i>Canvas canopy</i> |
| 4. <i>Screw it directly</i> | 24. |
| 5. <i>Fly equipment to site</i> | 25. |
| 6. <i>Use rope</i> | 26. |
| 7. <i>Wrap around</i> | 27. |
| 8. <i>Sell at factory-- let customer
ship it</i> | 28. |
| 9. <i>Cut hole in truck-- use hook</i> | 29. |
| 10. <i>Use seat belt</i> | 30. |
| 11. <i>Weld it</i> | 31. |
| 12. <i>Braze it</i> | 32. |
| 13. <i>Solder it</i> | 33. |
| 14. <i>Twist wire through hole & hook</i> | 34. |
| 15. <i>Melt hook and let harden</i> | 35. |
| 16. <i>Staple it</i> | 36. |
| 17. <i>Drill hole in hook-- screw
to truck</i> | 37. |
| 18. <i>Use magnets</i> | 38. |
| 19. <i>Use cellophane tape</i> | 39. |
| 20. <i>Vacuum</i> | 40. |

Analytical Sheet

<u>Idea</u>	<u>Comment</u>
1) Nail it	may be feasible, must get customer ap-
16) Staple	proval to change fastening to truck
6) Use rope	must change specification. Cost of ade-
7) Wrap around	quate rope appears excessive
14) Twist wire	could work--but must be able to guarantee tension--follow this up in detail
4) Screw directly	can't screw I-bolt direct--spec. says
17) Drill hole	must fit flush--why?--could possibly drill hole in hook and screw it into floor bed-- check this out in detail
11) Weld it	would hold--but if weld cracked during shipment, couldn't be refastened

Note

Investigation of feasible alternatives disclosed the following information:

- a) The present source of supply for the assembly was supplying the belt and hook as a special item. It wasn't a "cable" in the normal sense but rather a web belt with a take-up arrangement similar to seat belts.
- b) This present source had a standard assembly which had a right angle piece of hardware attached to it. It would be possible to procure this standard item for \$1.50 less than the present assembly with the special hook.

The team therefore decided to propose using the standard item, drill a hole in its base and insert an undercut thumbscrew. The undercut would permit swivel (see proposal sheet).

VE-4801-5
VALUE ENGINEERING SUGGESTION SHEET

SH. NO. _____

Name of Part <i>Cable Hold-down</i>		Part Used In <i>AN-MPQ-XX</i>		
Dwg. No.		Quantity/ Unit <i>System: 12</i>		
		Quantity/ Yr. <i>Contract 120</i>		
<u>Present</u>		<u>Proposed</u>		
	Material - Each	Labor - Each	Adj. Cost - Ea	Tooling
Present Costs	.79	9.23	9.16	-
Proposed Costs	.04	.05	.14	\$ 50.00
<p style="text-align: center;"><i>Contract</i> Estimated Annual Savings \$ <u>678.00 - 850.00</u></p> <p style="text-align: center;">Comments: <i>Further savings of \$90.00 is possible by procuring std. belt assembly instead of special.</i></p>				
Project Group: <i>A. B. Smith, J. W. Tasley, W. W. Callis, H. H. Ingels</i>				
Table No: <i>4</i> Date: <i>xx/xx/xx</i>				
Proposal is applicable: Immediate <input checked="" type="checkbox"/> Intermediate Long Range				

COST VISIBILITY IN PRODUCTION SUMMARY

- The price of items is based upon estimates of time and material to be used directly for the item, plus a multiple of the estimates which provides for labor and material of allocable burden support, plus a multiple of the direct and burden for G&A plus profit or fee.
- The nature of the pricing process tends to magnify any deficiencies in the estimated cost.
- The accuracy of an estimate is influenced favorably by maximum capability and experience of the estimating personnel and unfavorably by the lack of design maturity and adequate time to make the estimate.
- The learning curve is a useful method of rapidly estimating the amount that the cost of an item diminishes as production proceeds when unchanged, and the fabrication cost variations that result from changes.
- A cost model of a subject under study facilitates consideration of the elements that make the major contribution to total cost.
- The cost model should include hardware and software elements directly associated with the project.
- Cost models should present unit costs, quantity involved, and total costs projected to reflect future expenditures.

COMBINEX METHOD FOR EVALUATING VALUE ENGINEERING PROPOSALS¹

The Value Engineering Job Plan is an organized approach for carrying out a VE study. The Job Plan consists of four phases: information, speculation, evaluation, and implementation. The objective of the speculation phase is to generate as many ideas as possible for performing functions. One of the key tasks of the evaluation phase is to select one or more feasible ideas offering better value. The purpose of the Combinex Method is to provide a tool for objectively evaluating feasible ideas.

Historically, choices among alternatives resulting from VE studies have been developed by the personal judgment of team members who feel that their selection of Alternative A is better than either B or C. They have attempted to support this judgment further by supplying cost estimates. Management, however, is faced with a substantial investment of money and time coupled with associated risks of unknown designs and, consequently, has strongly desired more accurate verification of potential benefits than that provided by the pure judgment of the team or the familiar VE technique of "evaluation by comparison."

As an aid in closing this gap, Carlos Fallon (then director of purchasing research and value analysis at RCA) developed a matrix analysis approach to decision making aimed at providing a system that offers the basic benefits of mathematics-oriented analysis yet is easy to use and understand. Combinex,² as it is called by Fallon, is a system capable of combining benefits, evaluating resource mixes, and comparing potential courses of action.

A matrix, however, does not and cannot make decisions. Rather, it is extremely useful in lining up criteria upon which decisions can be based and in providing analytical bases for those decisions. It also can correlate, through a numerical system, such diverse criteria as customer needs, available resources, costs, potential returns on investment, and so on. But – and this is most important – it remains necessary for the decision makers (that is, management or appointed representatives) to use effective judgment in making the decisions and then in taking appropriate actions.

¹ Copyright ©1967, 1982, by Harbridge House, Inc.

This case has been prepared by Harbridge House, Inc., and is designed for teaching purposes only. The case does not necessarily indicate the policy or practice of any company, institution, or government agency and is not intended to illustrate either correct or incorrect, desirable or undesirable, management procedures. Where necessary, names and figures have been disguised.

² Fallon, Carlos, "Using the Combinex Method in the Measurement and Comparison of Value," proceedings of the National Electronics Conference, Volume XXI, 1965.

Task Sequence

The Combinex Method for evaluating alternatives consists of eight tasks which are listed below:

1. Select the criteria upon which decisions will be based (that is, cost, weight, delivery, reliability, and so on).
2. Assign relative weights to these criteria.
3. Set upper and lower limits for each criterion.
4. Define a standard scale.
5. Establish utility curves.
6. Develop a rating for each criterion and alternative.
7. Compute the total score for each alternative.
8. Compare and select the alternative(s) that offer the best total value.

1. Select the Criteria

In selecting the criteria to be used, the first step is becoming aware of needs, particularly customer-oriented needs that a product or service must satisfy. Such factors as length of service, maintenance, overhaul, and replacement should be considered as well as initial costs and internal design and manufacturing areas. Too often VE studies have been concluded on the basis of internal improvements rather than on the basis of customer needs. As one would expect, gathering the pertinent criteria will require input from multiple sources – engineering, finance, marketing, management, manufacturing, and the customer.

We also will find that the Combinex algorithm calls for nonnegative numbers, which means converting negative qualities to positive ones (for instance, costs into economy of production, weight into lightness of weight, and so on).

2. Assign Relative Weights to These Criteria

In the Combinex process, two steps are important to the determination of final outcome – the selection of criteria and the relative weighting of these criteria. Of these two, selection of criteria presents the fewest problems. Various management sources can decide what criteria should be used – the basic question is, How important is each criterion in relationship to the others. For instance, engineering management might state that reliability, weight, and performance are essential; manufacturing may want the decision to be based on producibility, quality, and costs; marketing may base it on appearance, cost, delivery, reliability, and so on. The essential problem remains the relative importance of the factors. Is reliability twice as important as cost? Is delivery 40 percent as important as quality? Is weight equal to appearance?

One approach to weighting of criteria is to assemble a team representing the affected areas in order to develop the relative weighting. The team may begin by assuming that all factors are equal and then adjusting them while maintaining a unit total. For illustrative purposes, let's consider that a two-way radio is being developed. The decision criteria selected by the management are reliability, shock resistance, maintainability, range, appearance, and cost. The team started with the assumption that each criterion represented one sixth of the total value and, using this as the basis for discussion, eventually agreed that in their judgment the weighting should be:

Reliability	.20
Shock Resistance	.18
Maintainability	.12
Range	.20
Appearance	.05
Cost	<u>.25</u>

Unit Total 1.00

But what, after all, is the basis of a valid decision? It must be made with equal participation from each team member. In practice, it is impossible to assemble five to seven persons for such a meeting and have them all feel equal, either in formal or informal "hierarchical order" or in personal natures. Certain individuals will be more articulate, more dominant - and their weighting suggestions consequently will be more influential. It has been said that the making of business decisions is based mainly upon eliminating personal risks and minimizing personal loss. The potential risks and losses to these people will dominate the scene. For example, if the production representative is the dominant individual, any alternative that increases factory loading will receive maximum weighting, even though factory loading is not one of the specified decision factors. In essence, then, "how much" (or relative importance) is a personally motivated decision. In actual usage, the most common practice is for the team to weight the factors individually and then calculate a single average of each team member's figures.

A second approach to weighting, called the "paired comparison method," is based on the assumption that the simplest and least emotional decision is a basic yes or no. This can be done by comparing each criterion methodically with each of the others, which involves making a large number of decisions, each based on a yes or no answer, rather than attempting to juggle several factors in one decision.

Let's go back to the two-way radio illustration mentioned above. In each decision, we would ask only, Which is more important? not, How much more important? Table 1 demonstrates a set of decisions and asks in each case only which is more important, not the degree of importance. For example, in the first decision, when asked, Which is more important, reliability or shock resistance? reliability was selected. Table 2 gives the decision totals.

TABLE 1
PAIRED COMPARISONS – TWO-WAY RADIO

<u>Decision Number</u>	<u>Which Is More Important?</u>	<u>Decision</u>
1	Reliability or Shock Resistance	Reliability
2	Reliability or Maintainability	Maintainability
3	Reliability or Range	Reliability
4	Reliability or Appearance	Reliability
5	Reliability or Cost	Cost
6	Shock Resistance or Maintainability	Maintainability
7	Shock Resistance or Range	Range
8	Shock Resistance or Appearance	Appearance
9	Shock Resistance or Cost	Cost
10	Maintainability or Range	Range
11	Maintainability or Appearance	Appearance
12	Maintainability or Cost	Cost
13	Range or Appearance	Range
14	Range or Cost	Cost
15	Appearance or Cost	Cost

TABLE 2
DECISION TOTALS - TWO-WAY RADIO

<u>Criteria</u>	<u>Decision Number & Criteria Chosen</u>															<u>n*</u>	<u>n ÷ 15**</u>	
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>			
Reliability	1		1	1													3	.200
Shock Resistance																	0	.000
Maintainability		1				1											2	.133
Range							1			1			1				3	.200
Appearance							1			1							2	.133
Cost					1				1			1		1	1		5	.334
																		<u>1.000</u>

* Total number of times each decision was chosen.

** Number of times each decision was chosen divided by total number of decisions (15).

3. Set Upper and Lower Limits for Each Criterion

Establishing the upper and lower limits for each criterion defines the range over which each alternative is measured. The example provided below uses three criteria: manufacturing cost, lightness of weight, and reliability in terms of mean time between failures (MTBF). The upper limit is set by the lesser of two conditions:

- The best we can practically achieve. For example, it was determined that a manufacturing cost of \$6.00 is the best that can be achieved with reasonable effort.

OR

- The most we can effectively use. If, for example, our two-way radio were part of a larger piece of equipment that had a reliability of 1,000 hours, it would probably not be logical to increase the upper limit above 1,000 hours although it could be achieved technically.

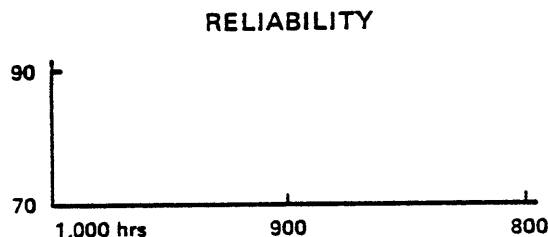
Criteria	Upper Limit (Best Practical)	Lower Limit (Least Acceptable)	Range
Manufacturing Cost	\$6.00	\$10.00	\$4.00
Lightness of Weight	40#	80#	40#
Reliability (MTBF)	1,000 hrs.	800 hrs.	200 hrs.

4. Define a Standard Scale

We need a standard scale of measure in order to compare various criteria (for example, manufacturing cost in dollars, weight in pounds, reliability in hours). In practice, many standard grading scales, such as 1 to 100 or 1 to 10 are used. One scale with which we all are familiar is the school grading scale where 70 is passing and 90 is very good. This (70 to 90) is the standard scale we will use below.

5. Establish Utility Curves

The utility curve defines the relationship between the upper and lower limits and the standard scale developed for each criteria. For example, for reliability, we know that our upper and lower limits are 1,000 hours and 800 hours, respectively, and that our standard scale is 70 to 90. This information forms the coordinates of a graph as illustrated below.



We know that if a product provides 1,000 hours of reliability it would be assigned a rating of 90 and for 800 hours the rating would be 70. The question is, What would the rating be if the reliability fell within the 1,000 to 800 range? The utility curve defines this relationship. (Five characteristic curves are illustrated in Table 3.) These curves are based on judgment concerning how important (rating value) reliability is over the range (1,000 to 800 hours). Table 4 provides utility curves for each of the three criteria used for illustrative purposes.

6. Develop a Rating for Each Criterion and Alternative

The next step is to develop a rating for alternatives based on the information developed. To illustrate, let's assume that we want to determine the best approach concerning three alternative designs (A, B, and C). The results of measuring the alternatives against the three categories are provided below.

	Economy	Weight	Reliability
Alternative A	\$6.00	70#	850 hrs.
Alternative B	\$7.50	60#	900 hrs.
Alternative C	\$9.00	40#	950 hrs.

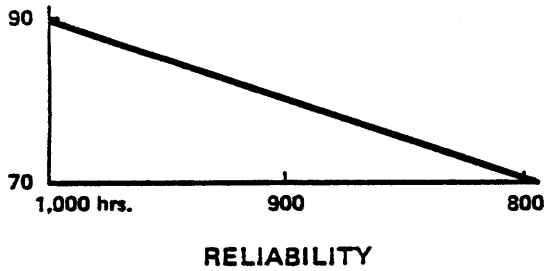
Each of the measurements is now converted to the standard scale through use of the utility curves. The development of each rating is illustrated in Table 5 and summarized below.

	Economy	Weight	Reliability
Alternative A	90.0	72.5	75.0
Alternative B	77.0	78.0	80.0
Alternative C	72.5	90.0	85.0

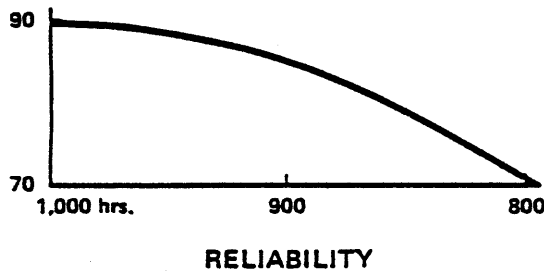
7. Compute the Total Score for Each Alternative

The total score for each alternative is computed by multiplying the assigned weighting times the rating for each criteria and summing the values. The weightings used for this example are .40 for economy, .25 for weight, and .35 for reliability. Table 6 illustrates this process using the three design alternatives discussed previously. For example, for Alternative A, the economy weighting (.40) is multiplied by the rating (90) to provide an adjusted figure of 36.0. This also is done for the weight and reliability criteria. The total score for Alternative A is determined by adding the adjusted figures ($36.0 + 18.1 + 26.3 = 80.4$).

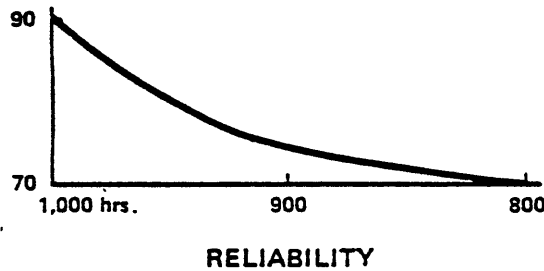
TABLE 3
CHARACTERISTIC UTILITY CURVE SHAPES
USING RELIABILITY AS A CRITERION



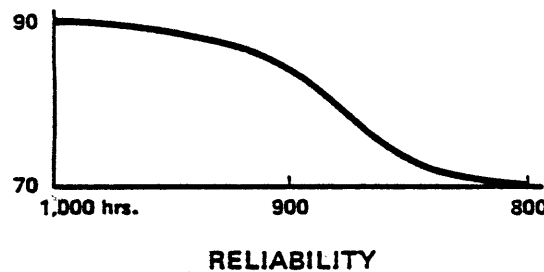
Equal increases (or decreases) in reliability result in equal changes in rating.



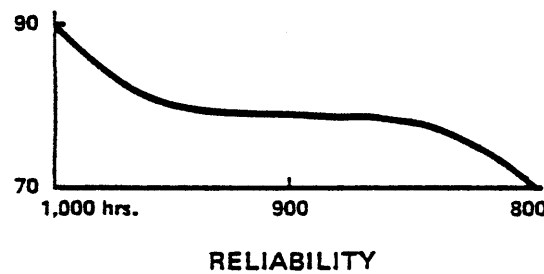
If reliability falls below 900, the rating of a particular alternative is impacted significantly.



The rating of a particular alternative changes very little until reliability is above 900 hours.



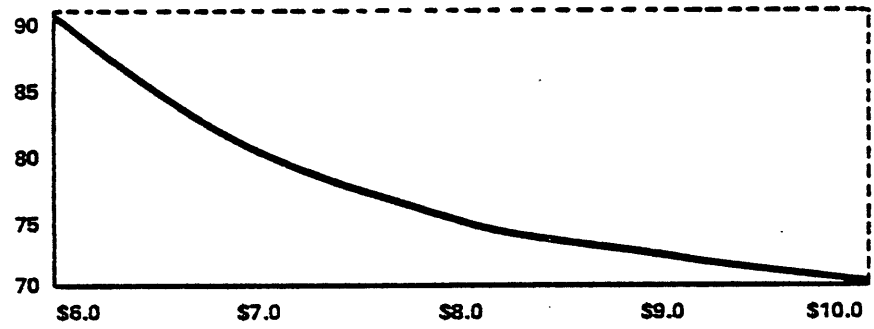
Reliability rating remains about the same until it reaches 850 hours at which time it increases significantly until it approaches 950 hours.



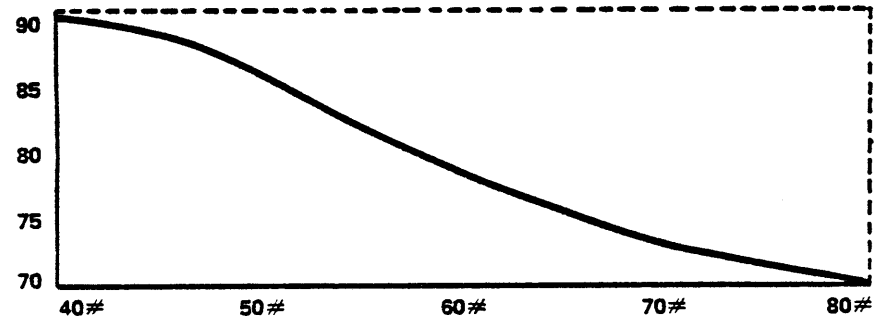
Reliability rating increases significantly to mid-range (80) at 850 hours and does not improve again until it exceeds 950 hours.

TABLE 4
UTILITY CURVES

ECONOMY OF PRODUCTION



LIGHTNESS OF WEIGHT



RELIABILITY

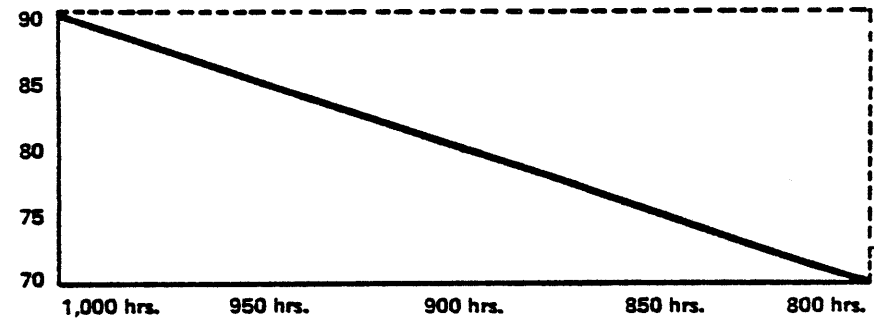


TABLE 5
RATING OF ALTERNATIVES

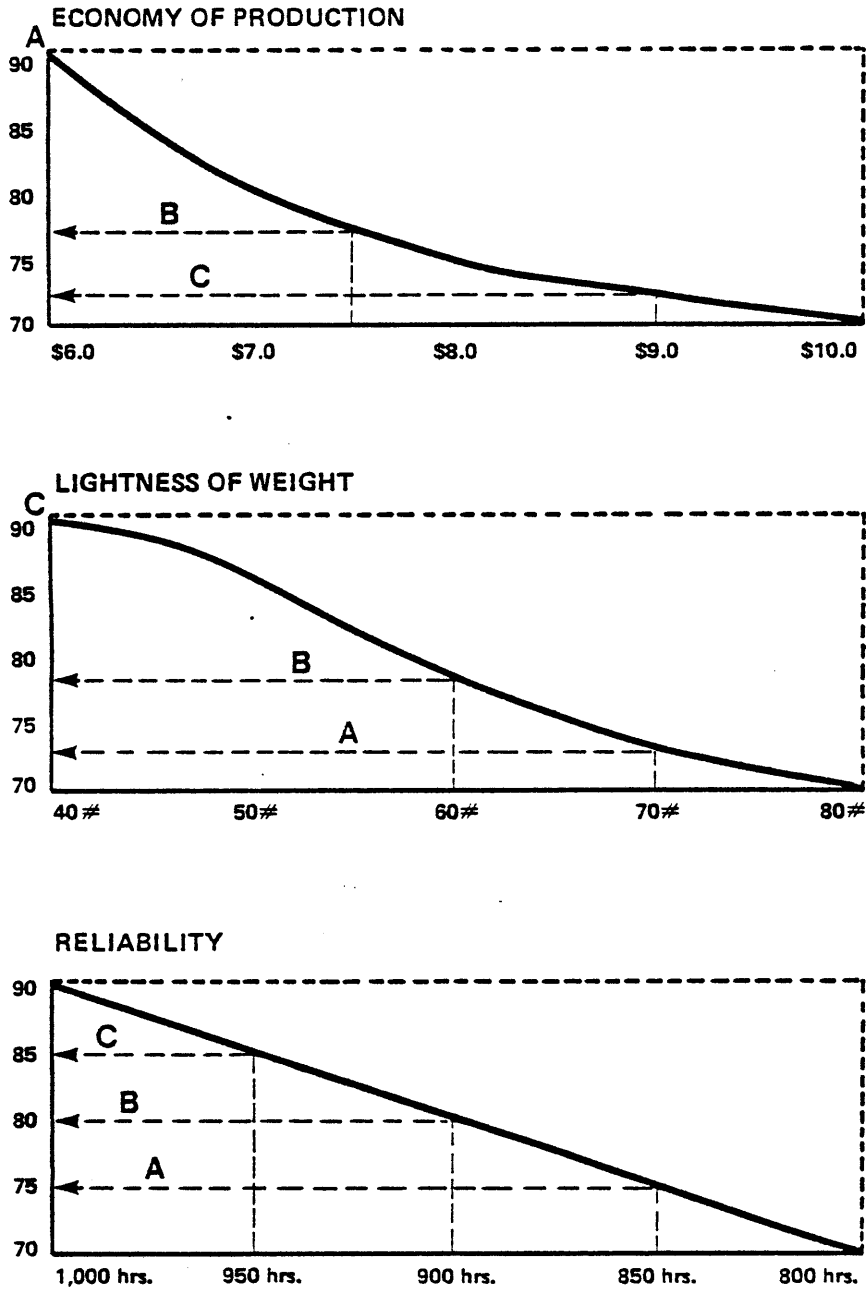


TABLE 6

Weighting ↓ Choices	Relative Weighting of Criteria			Total
	Economy	Weight	Reliability	
	.40	.25	.35	1.00
Alternative A	90.0 36.0	72.5 18.1	75.0 26.3	80.4
Alternative B	77.0 30.8	78.0 19.5	80.0 28.0	78.3
Alternative C	72.5 29.0	90.0 22.5	85.0 29.8	81.3

8. Compare and Select the Alternative(s) That Offer the Best Total Value

Alternative C is the best choice by virtue of the fact that its total score (81.3) is the highest. Alternative A (80.4) is ranked next, and Alternative B is last (78.3).

While the choice, based on the above analysis, is Alternative C, we should be able to show and to explain the procedure for arriving at this choice to the final decision makers, giving them the opportunity to reevaluate the criteria, weighting factors, utility curve shapes, and so on. When this is done, the alternative ranking may change.

Summary

Use of the Combinex Method provides an easily understood and administered process for orderly decision making. It also provides valuable insights into the decision-making process itself. The Combinex approach reveals advantages and risks of alternative positions and results in a summary of the process of reaching the decision.

APPLICATION TO THE MANUFACTURING PROCESS

In recent years a great deal of attention and focus of Value Engineering/Analysis has been applied to areas beyond hardware such as systems and procedures. Occasionally attempts have been made to apply the techniques to manufacturing processes. Unfortunately, despite management concern with costs in this area, the VE/VA study efforts have been inconsistent.

Harbridge House, through its educational workshops and specific studies with clients, has structured a variation on the traditional theme to productively study and analyze manufacturing processes utilizing the basic VE/VA technology.

The key and heart of the study approach still is the VE/VA Job Plan. However, because the situation is unique, just as applying VA to procedures requires adaptation, the application of VA to manufacturing processes requires some modifications. Exhibit I lists the prime steps within the basic VA Job Plan. The main differences between traditional product-oriented steps and process steps lie in the Information Phase – particularly in the need to define project scope, use of flowcharting, and function evaluation.

Scope

A prime difference between the manufacturing process-oriented study and the more classical product study is that in the manufacturing process area we assume that the product itself will remain basically unchanged. In a VA product study, quite frequently the product is substantially changed or even completely replaced. The essence of the changes in the process study will be material flow, work stations, different tools or fixtures, and possible changing of capital equipment such as upgrading to machine-controlled tools or even entering the field of manufacturing group technology. Of course there may be minor changes such as surface finishes or tolerance changes but these do not normally substantially affect the product itself, but are more often adapted to allow revision to the manufacturing process.

Flowcharting

Sequence flowcharting is a technique borrowed from the field of industrial engineering. The VA variation includes time and cost identification to identify high-cost areas. The VA technique of function evaluation, in relating the function with the cost, determines what part of high cost is unnecessary and thereby where the greatest opportunity for improvement lies. As with any product analysis, it has been proven many times that in manufacturing there is always a new, less costly way to do nearly everything. If a new idea to reduce costs has not been presented, that simply means an opportunity still exists. The plunge into the Speculation Phase is designed to offer the opportunity and to create those new possibilities (see Exhibit II).

EXHIBIT I
VALUE ANALYSIS JOB PLAN
MANUFACTURING PROCESS

Information Phase

- Define Scope
- Prepare Flowchart
- Define Functions
 - Determine Basic/Secondary Functions
- Prepare FAST Diagram
- Cost - Existing Process
 - FAST Diagram
- Review Scope

Questions

- What is it?
- "
- What does it do?
- "
- "
- What does it cost?
- "

Speculation Phase

- Create Ideas on Basic Function(s)

Evaluation Phase

- Select "Best" Alternatives
- Develop New Flowcharts
- Cost - New Process

Implementation Phase

- Develop Implementation Plan
- Develop Approvals
- Evaluate/Debug
- Make Final Changes
- Document

EXHIBIT II
FLOWCHART
PART A.B.C. - 100 PCS

WHO WHAT	Rec	Inven- tory	Mill Dept	Drill Dept	Insp	Matl Hand	Ship- ping			Time per Event	Cost per Event	
Receive/Inspect Parts										5.50	.44	
Inventory Parts										4.00	.32	
Receive Mfg Order										1.00	.08	
Locate Parts/Deliver to Work Station										20.00	1.60	
Mill Parts/Stack										10.90	1.74	
Deliver to Next Operation										10.00	.80	
Drill and Ream Part										9.60	1.44	
Deliver to Insp										10.00	.80	
Inspect Part										5.00	.40	
Deliver to Shipping										20.00	1.60	
										TOTAL	96.00	12.82

3

VA-0411

A. Scoping the Project

Like all variations of Value Analysis/Value Engineering, Value Analysis in the manufacturing process is function based. The primary question is "How can I alter, improve, or redesign the manufacturing process to accomplish the required functions for less cost while retaining the same performance levels?" In fact, the prime objective may be to improve quality while retaining the same cost. The analysis generally leads to new processes, systems, or procedures that perform the functions more reliably. A recent Harbridge House survey indicated that such changes resulted in improved producibility in 94% of the cases. But, as with any suggested improvements, the new ideas require a willingness to accept change and get away from what may be longtime acquired habits. VA is not a simple formula that works every time, nor one that can be achieved by simply following the numbered steps. It requires skillful application of the proven techniques.

To apply the function-based techniques in manufacturing processes requires certain ground rules and relationships that must be fully understood.

Definition of Scope

In order to solve any problem we must first define where the problem starts and stops. As with developing a functional model of a hardware system, there will be a hierarchy of functions. We must define what is included, or excluded, and what interactive and interface points are acceptable within the scope. We maintain the ground rule that we must accept everything before and after the scope of the defined problem or else we would invariably try to solve problems based on at least entire plant operations. For example, if we study a part-shaping problem as the example in this article uses, we would accept everything that happens prior to the receiving of the material and everything that happens after we put the parts into final inventory. Again, as with any other study, we recognize that problem scope limits are normally established because of time limits imposed on study teams. If broader functions could be fully investigated where the relations of all parts to the overall process could be considered, then we would expect greater accomplishments as well (see Exhibit III).

B. Definition of Functions

Value Analysis discipline states that there are only two kinds of functions — basic and secondary. Basic function is the specific work which a process is designed to accomplish. Secondary functions are all other functions that are performed during the manufacturing process and only exist because of the current process approach. For analytical purposes, the secondary functions add no value to the product, and in fact can be considered as penalties, i.e., they add cost but no value.

A process may have more than one basic function but great care must be taken to be sure that two different elements of work are being done. A single function may be accomplished in more than one step of the manufacturing process. However, most manufacturing processes themselves only have one basic function.

EXHIBIT III

Name of Study Part ABC Process

Department	Individual(s)	Position	Phone	Date
------------	---------------	----------	-------	------

Engineering

- EE.....
- ME.....
- RE.....
- SE.....
- HE.....

Other _____

Remarks:

Scope includes receipt, inventory, processing, packing

Manufacturing

- Methods....
- Test.....
- QA.....
- Fab.....
- Assy.....

Other _____

Scope does not include incoming/outgoing freight

Manufacturing steps include milling, drilling/ream, inspection

Purchasing

- Elec.....
- Mech.....

Other _____

Cost.....

PMO.....

Marketing....

Customer.....

Other _____

Daily Log....

VE.....

Again the VA discipline maintains that functions are defined in terms of a verb and a noun. To state what something does in two words can be difficult but it does force simplification of thought and creates a better understanding. Simple definitions such as "move material," "generate shape," or "inspect material" make sure that everyone clearly understands the function and enhances communications. Exhibit IV is a partial list of verbs and nouns to use when defining manufacturing processes functions. Care must also be taken not to use words that define the functions in a single method of processes. "Shape parts" would be preferred to "mill parts" because there are many potential ways to shape a part besides milling.

Again, the Value Analysis rule of "make sure there is a basic function, otherwise the process can be eliminated" holds true for manufacturing processes analysis.

The Procedure

Exhibit V, the Function Worksheet for the part shaping, provides an example of the start of the process. It answers, "What does the process do?" Also, each function is defined as basic or secondary.

A very useful technique developing by the Value Engineering fraternity for analyzing systems and processes is the Function Analysis System Technique (FAST). FAST is a diagramming technique which illustrates the specific relationships and interrelationships of all the essential functions.

At first glance, the FAST diagram appears similar to a PERT chart or manufacturing flowchart. The basic difference is that FAST diagrams are function oriented rather than activity or time oriented. Truthfully, FAST is more closely analogous to the systems engineer Functional Flow Block Diagram but adapted and expanded for manufacturing systems and processes.

The FAST diagram pictorially displays the relationships of the functions of a manufacturing process as it does the tasks it was designed to do – what is happening now, not what we would like to have happen. The diagram utilizes the verb-noun definitions described on the earlier created Functional Worksheet. The guidelines are as follows:

1. The scope of the study is enclosed within two vertical dashed lines. Higher order functions lie to the left of the left-hand scope line and assumed (lower order) functions lie to the right of the right-hand scope line.
2. The "How" and "Why" questions are asked of each function identified within problem scope. This testing assures the correct functional alignment and relationships. First the question, "How do I (verb) (noun)?" is asked. The function answer should lie to the immediate right. Every function which has a function to the immediate right should logically answer this "How" test. If it does not, the function is either defined improperly or is in the wrong sequential place.

EXHIBIT IV
MANUFACTURING PROCESSES

Partial List of Verbs

Allow	Finish	Produce
Apply	Fire	Receive
Assemble	Form	Reduce
Bend	Generate	Remove
Band	Grind	Restrict
Bake	Heat	Resist
Compress	Hold	Roll
Conduct	Hone	Route
Convey	Inspect	Saw
Cure	Increase	Shape
Cut	Insert	Shield
Decrease	Lift	Sort
Discard	Load	Spin
Drill	Mill	Stake
Drive	Modify	Support
Dry	Move	Tap
Enclose	Open	Transmit
Eliminate	Place	Transport
Extrude	Plane	Weld
Filter	Prepare	Wrap

Partial List of Nouns

Corrosion	Force	Supplies
Current	Light	Torque
Energy	Material	Voltage
Electricity	Motion	Waste
Fixtures	Power	Weight
Friction	Shape	

EXHIBIT V
WHAT DOES IT DO?

<u>Functions</u>	<u>B/S</u>	<u>Explanation</u>
1. Receive Material	R	
2. Inspect Parts	R	
3. Stack Parts	U	
4. Inventory Parts	XU	
5. Receive Order	R	Internal Manufacturing Order
6. Remove Inventory	R	
7. Deliver Material	R	To Work Station 500
8. Mill Part	B	Per Planning Sheet A101
9. Stack Part	U	
10. Deliver Part	R	To Work Station 602
11. Drill/Ream Part	B	Per Planning Sheet A101
12. Deliver Part	U	To Inspection 1330
13. Inspect Part	R	Per IS-2000
14. Deliver Part	R	To Stockroom
15. Produce Shape	H	

Then the "Why do I (verb) (noun)" test question is asked. This test works in the same way as the "How" question but in the opposite direction, right to left. The answer to "Why" should be in the function to the immediate left and be answerable "So that I can (verb) (noun)." The answer must make sense and be logical.

3. The result of the "How," "Why" testing process is the establishment of the critical path of functions within the scope of the project under study. If a function can be removed from the critical path, and the adjacent function still answers the "How" and "Why" tests, then the function is not a critical path function and should be placed elsewhere in the FAST diagram.
4. The basic function(s) will lie to the immediate right of the left scope line. All other functions will lie to the right of the basic function(s) and are considered secondary functions that are required to complete the process.
5. All other secondary functions which the process performs will be above or below the critical path functions. If a function happens at the same time or is caused by a function on the critical path, that function is placed below the critical path function. If a function happens all the time during a process, it is placed above the critical path diagram.

Constructing a FAST diagram is not an exact science. Each individual constructing a diagram of the same project may have slight differences. However, as long as the essential functions are on the critical path and the relationships are consistent, the objective has been met.

Cost-Function Relationships

One of the most important steps in the Information Phase of manufacturing processes study is obtaining good cost data and relating them to function. (For a discussion of cost, see Cost Visibility in Production, RPP11320).

After assigning actual costs to each function in the function workshop, the costs are transferred to the FAST diagram (see Exhibit VI). Then the study team is ready to either redefine the scope or solve the original problem as defined. A ratio of costs for basic versus secondary functions often provides guidance and greatest opportunity for improvement.

Conclusion

The stage is then set to move into the speculative phase of the Job Plan. The greatest opportunity has been defined. The remaining steps and phases of the Job Plan follow the pattern of other types of studies. Experience has proven that by following each step of the Job Plan the application of the principles and techniques of value analysis to manufacturing processes is effective.

EXHIBIT VI

FUNCTION ANALYSIS TECHNIQUE DIAGRAM
(FAST DIAGRAM)

GROUND RULES VIA GENERIC MODEL

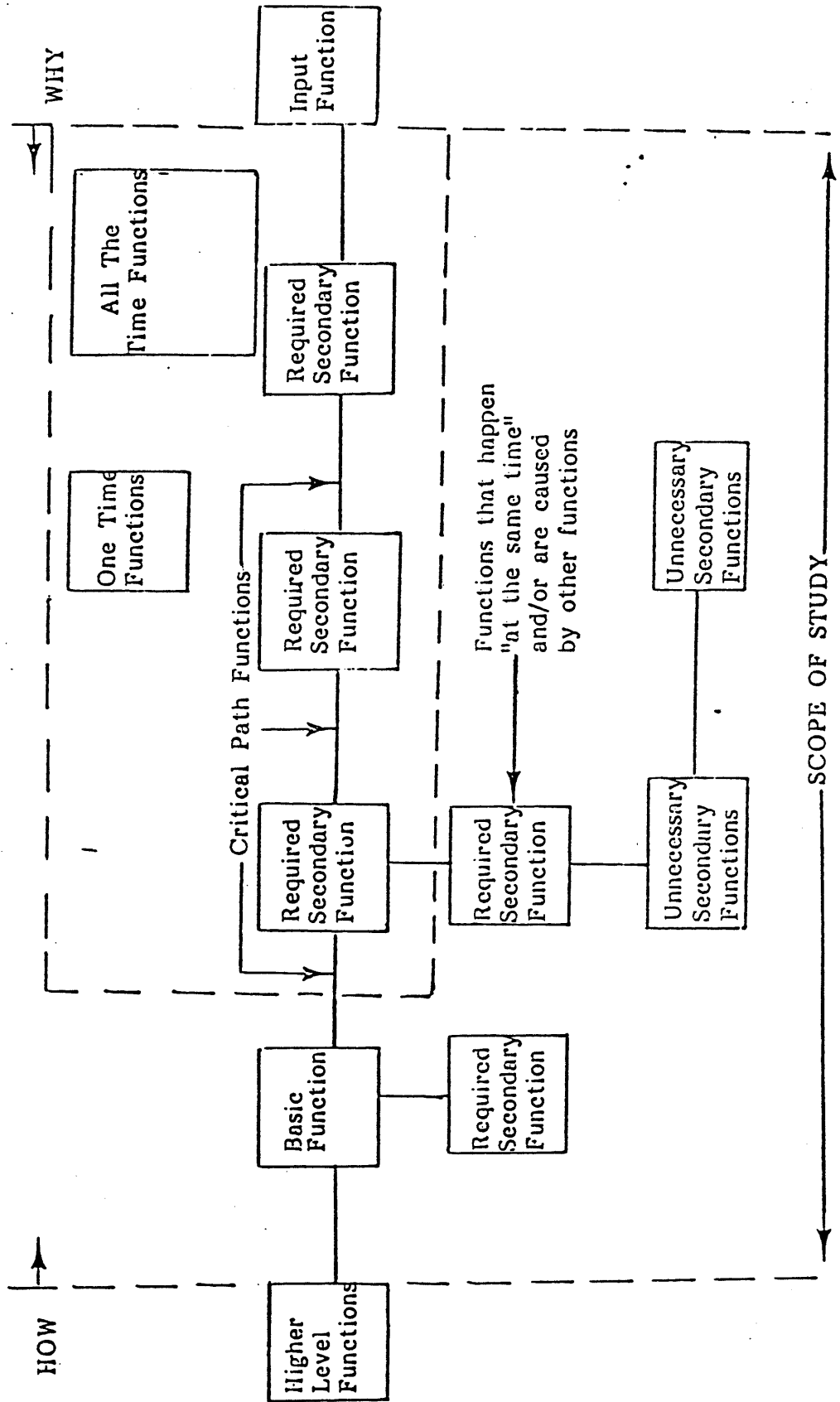


EXHIBIT VI (Cont'd)
 FUNCTIONAL ANALYSIS SYSTEM TECHNIQUE DIAGRAM
 PROCESS PART ABC - 100 PCS

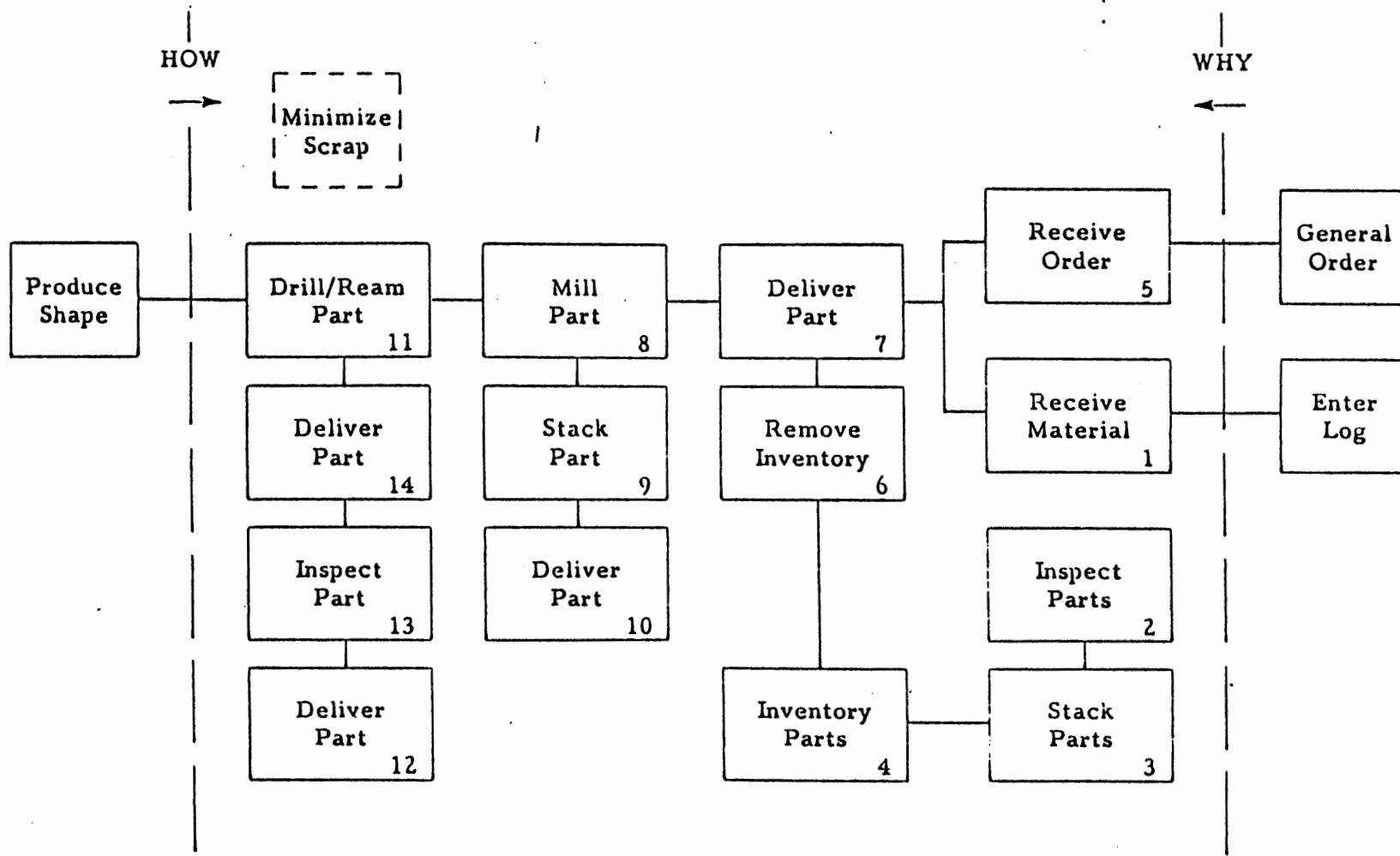
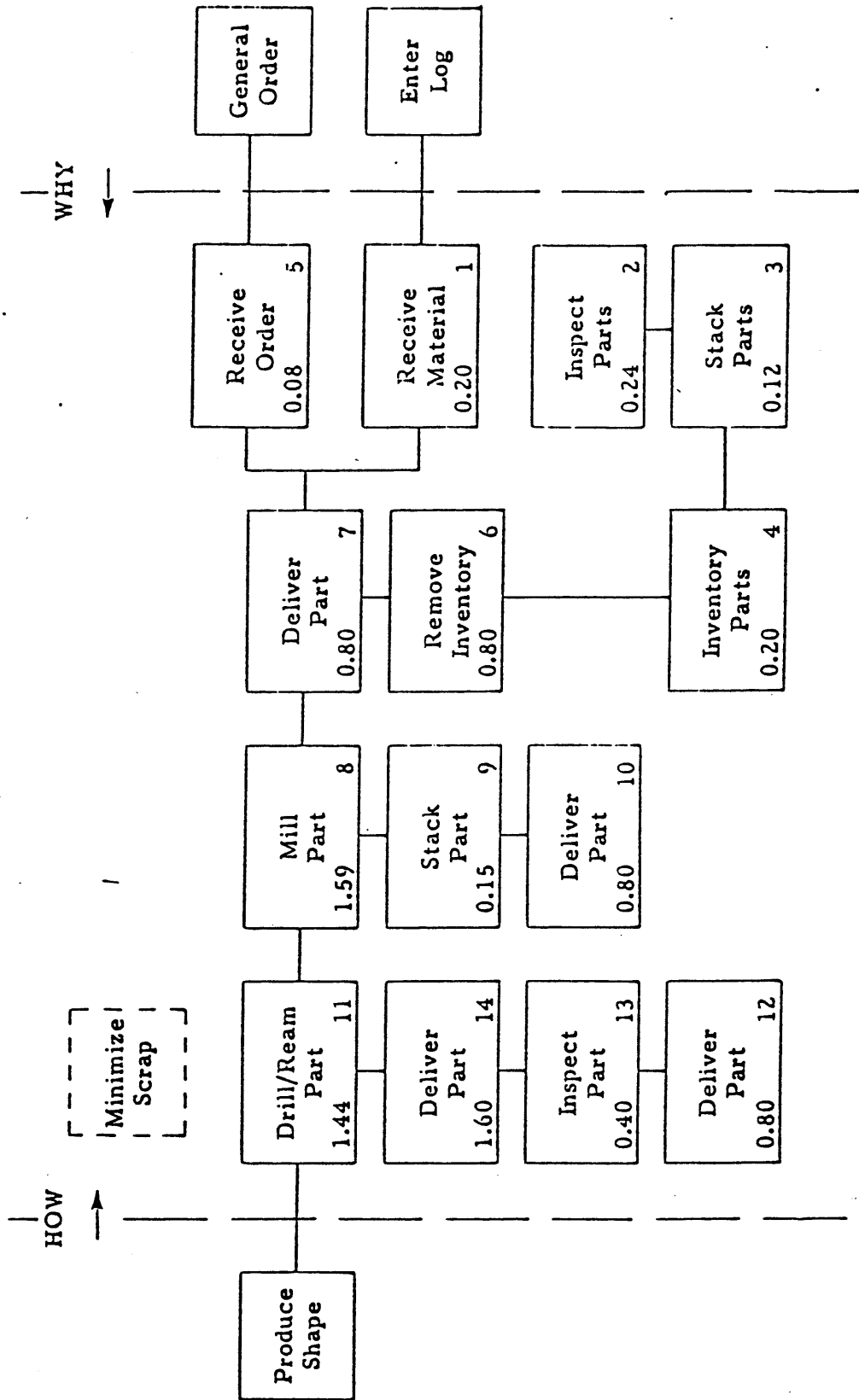


EXHIBIT VI (Cont'd)
 FUNCTIONAL ANALYSIS SYSTEM TECHNIQUE DIAGRAM
 PROCESS PART ABC - 100 PCS
 (Costed)



Name of Study _____

<u>Department</u>	<u>Individual(s)</u>	<u>Position</u>	<u>Phone</u>	<u>Date</u>
<u>Engineering</u>				
EE..... <input type="checkbox"/>	<u>Remarks:</u>			
ME..... <input type="checkbox"/>				
RE..... <input type="checkbox"/>				
SE..... <input type="checkbox"/>				
HE..... <input type="checkbox"/>				
Other _____				
<u>Manufacturing</u>				
Methods.... <input type="checkbox"/>				
Test..... <input type="checkbox"/>				
QA..... <input type="checkbox"/>				
Fab..... <input type="checkbox"/>				
Assy..... <input type="checkbox"/>				
Other _____				
<u>Purchasing</u>				
Elec..... <input type="checkbox"/>				
Mech..... <input type="checkbox"/>				
Other _____				
Cost..... <input type="checkbox"/>				
FMO..... <input type="checkbox"/>				
Marketing.... <input type="checkbox"/>				
Customer..... <input type="checkbox"/>				
Other _____				
Daily Log.... <input type="checkbox"/>				
VE..... <input type="checkbox"/>				

Idea:

Sketch and References:

Advantages:

Disadvantages:

Follow-Up Necessary:

Final Action:

Date:

VE Worksheet Number 3

VALUE ENGINEERING RECOMMENDATION

Approved: _____

Sheet Number: _____

Date: _____

Date: _____

Name of Study:

Part Used In:

Contract Number:

Quantity/Unit:

Drawing Number:

Quantity/Year:

Present Design

Proposed Alternative

Ref:

Material

Labor

Overhead

Tooling/Eng

Est. Original Costs:

Est. Alternative Costs:

Estimated Net Savings: \$ _____ per _____
 Potential Reduction: _____ %

Comments:

Team Members:

Proposal Applicable: