Paper No.
62-MD-24

Evaluating Design Factors Affecting Costs and Reliability of Systems And Assemblies

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The purpose of this contribution is to provide a few important aids to the task of getting better results sooner in the design process, in system and assembly selection. Because of the relationship and the similar need for getting better "time" results, it also is included. The paper shows that the use of the special value engineering technology at the inception of most system or involved assembly design projects results in greater reliability, shorter design time, and lower costs.

Just what are the techniques and approaches which operate to bring the seemingly opposite forces of time, reliability, and cost into one unidirectional force?

To accomplish this triple purpose, we must have a mechanism which will produce more reliable, lower-cost solutions in less time. Stated another way, we must have a mechanism which will minimize the work spent on solution areas which will result in complicated and costly solutions consuming much design time.

The form of design logic which I will present works to accomplish that objective while the use of the value engineering technology with it assures its success.

In making today's design choices, excepting for the few areas of total newness in research and development projects, there are definitely now two controlling sets of criteria...

...design to meet suitable functional specifications.

...design to meet suitable economic specifications.

What function objectives are to be realized?
What economic objectives are to be realized?

STEP I

Precisely what are the functions required from the system or assembly?

Under what conditions of life, vibration, corrosive environment, weight, noise, shock, pressure, and so on, must each function and each supporting function be performed?

What departures from or improvements upon past performance are desired?

What other performance factors?

STEP II

Precisely what over-all cost is required?

What maximum installation cost? Operation cost? Maintenance cost? And other costs?

STEP III

The designer prepares to reject as quickly approaches which do not meet these cost factors as he will those which do not meet the performance and reliability factors.

The systems designer has traditionally now made one of two choices. He has studied the system of design logic in which meeting performance standards is virtually assured but meeting cost objectives is in grave doubt; or he has studied the system of design logic in which cost objectives are assured but meeting performance standards is in doubt.

Until recently, it has been usually considered that the best answers result from the first approach. More recently, with the advent of the special "search" and "quick rejection" techniques of the value engineering technology, a high order of results is being secured through the use of the latter system.

A system of design logic incorporating both, which is being found of great value, is here shown as Table 1.

DISCUSSION OF DESIGN LOGIC

The logic starts with the specific functions to be accomplished by a system. There are usually from two to five differing design concepts or approaches which would arrive at the required performance. For this chart, we have chosen three.

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Contributed by the Machine Design Division for presentation at the Design Engineering Conference and Show, Chicago, Ill., April)-May 3, 1962, of The American Society of Mechanical Engineers. Manuscript received at ASME Headquarters, April 5, 1962.

Written discussion on this paper will be accepted up to June 4, 1962. Paper No. 62-MD-24.

Table 1 Form of Design Logic Useful When Economic Objectives As Well As Performance Objectives Must Be Met

	Choice of Systems Design Approach	Choice of Assemblies Products, & Materials	Choice of Mfg. Processes & Arrangements	Resulting Cost
			1-1-1	$400,000
		1-1	1-1-2	
			1-1-3	
			1-2-1	
	1	1-2	1-2-2	
			1-2-3	
			1-3-1	
		1-3	1-3-2	
			1-3-3	
			2-1-1	$300,000
		2-1	2-1-2	
			2-1-3	
			2-2-1	
Function or Functions to be Accomplished	2	2-2	2-2-2	
			2-2-3	
			2-3-1	
		2-3	2-3-2	
			2-3-3	
			3-1-1	$200,000
		3-1	3-1-2	
			3-1-3	
			3-2-1	
	3	3-2	3-2-2	
			3-2-3	
			3-3-1	
		3-3	3-3-2	
			3-3-3	$100,000

After one of the three design concepts or approaches is selected, there are innumerable choices of assemblies, products, and materials. Again, three are chosen for illustration. After one set of assembly and component selections has been so made, there are innumerable different manufacturing processes and arrangements, make-or-buy, and other decisions which influence the product and its cost. Again, for illustration, we have used only three.

The result is that there may be, as in the example, twenty-seven differing costs of the final product and perhaps half as many differing performance levels. For systems or assemblies which are somewhat involved, the alternatives are nearer seventy-five to a hundred than the illustrated twenty-seven.

The designer is faced at this stage with an entire field of choice -- choice which will govern how time and resources will be committed in the design process.

My young son, while studying his geography and while further being fascinated by the space developments, pictured himself as standing near the North Pole and was discussing what he would see each hour as he looked in the direction of the sun. I asked him how long it would take him to go around the world if he were standing near the North Pole. I was pleased at his answer that it would depend upon which direction he went. If he chose east it would be a few feet. If he chose south it would be 25,000 miles.

I was somehow struck by the analogy between this situation and that which exists when we, as designers, choose the approach which we will take to accomplish the functions required of a system or an assembly. Expanding a little on what he said -- it was... depending upon the direction chosen, the distance around the earth would be somewhere between 25 ft and 25,000 miles. Similarly, depending upon the approach taken at the inception of the system or assembly design project, the result may readily vary by a factor of 3/1 reliability-wise, 5/1 cost-wise, and 2/1 time-wise.

What is the designer, in making choice of the system approach and the assembly and product approach -- which so heavily govern the end results of the design process -- to use for criteria?

EVALUATE THE FUNCTION IN DOLLARS

A significant contribution in establishing proper cost objectives, in developing proper confidence in them, and in achieving them is provided by the process of "evaluation of a function" in dollars which is a contribution of the new technology of value engineering.

In this process, when each function and each subfunction has been clearly understood, it is assigned a value in dollars on the premise that "the value of a function, in dollars is the lowest cost which would reliably produce it."

Techniques of value engineering provide procedures for accomplishing this.

In this process, the function or group of functions to be evaluated are brought into a value system where meaningful cost comparisons are made. After one set of alternatives stands out as being the lowest over-all cost which could be made to reliably provide all of the functions and which would meet the cost objectives, it becomes the basis for the "value of the function in dollars." The cost of this alternative is, at least pro-tem, considered to be the value of the function in dollars. In a moment we will show how this drastically reduces the exploration and decision area in the design logic causing the work, time, and money to be spent in solving the problems of the alternatives which will have the lowest cost, most simplicity, and best reliability. However, first an example of evaluating a function will further clarify.

Gasoline Tanks for U. S. Navy Landing Crafts

The function is to reliably contain 200 gal of gasoline in the landing craft. The noncombat life is 8 years. The thinking process to evaluate this function is...

...what is the appropriate cost for housing 200 gal of gasoline?

...use four 50-gal standard drums $25

...use one standard 250-gal oil tank made for domestic use $30

However, some environmental treatment and perhaps some extra connections would be required. Therefore, add........................ $[illegible]

...to arrive at a tentative $50 evaluation on the gasoline-containing function.

As a result of applying the technique here... $80 gasoline containers were adopted to replace the $520 special alloy tank previously designed and used in the absence of this technique. Because at this time the mechanism of evaluating the function proceeded before other decisions were made, the saving to the taxpayers on the 1000 tanks was $440, 000... the difference between $520, 000 and $80, 000.

MODIFY CHART

In the example shown in Table 1, the function evaluation process established a value of 150, 000 on the function group.

What has now happened?

1 - Systems approaches 1 and 2 are immediately eliminated from consideration as resulting cost would be too high.

2 - Systems approach 3 is selected.

3 - Assembly and product application choice 3-1, and all above, are promptly eliminated.

4 - Assembly and product choices 3-2 and 3-3 are selected.

5 - Manufacturing processes choice 3-2-1, and all above it, are eliminated.

6 - Manufacturing process choices 3-2-2, 3-2-3, 3-3-1, 3-3-2, and 3-3-3 remain. The useful design logic is now shown in Table 2.

WORK AREA IS NARROWED

Choices are few, resources and time will not be scattered. The blueprint for start of successful solution is at hand.

To the designer more skilled in meeting hard performance objectives than hard economic objectives, it appears that the design job has been made infinitely more difficult by the elimination of approaches 1 and 2 with all of their function-producing capabilities. In practice, however, a wide range of significant benefits have already been brought into the design project:

1 The problem has now been reduced to one containing only one unknown; that is, reliable performance of the required functions. Any solution within this framework will meet the required cost.

2 The whole field which would formerly require study and selection has been reduced to one fifth so that in far less time, thorough studies may be made within this useful framework.

3 Since these are approaches for accomplishing the functions at low cost, the constructions and processes and arrangements are forced to be essentially simple, producing greater reliability. The opportunity to use highly complex subsystems, assemblies, and procedures is, by the nature of the solution logic, denied to the designer.

4 Intense problem-solving technique will be concentrated in the few "performance and reliability gaps." Experience shows that this concentration does produce solutions

Table 2 Form of Design Logic Useful When Economic Objectives As Well As Performance Objectives Must Be Met

	Choice of Systems Design Approach	Choice of Assemblies Products, & Materials	Choice of Mfg. Processes & Arrangements	Resulting Cost
			xxxxxxxxxxxx	$400,000
		xxxxxxxxxxxx	xxxxxxxxxxxx	
			xxxxxxxxxxxx	
			xxxxxxxxxxxx	
	xxxxxxxxxxxx	xxxxxxxxxxxx	xxxxxxxxxxxx	
			xxxxxxxxxxxx	$350,000
			xxxxxxxxxxxx	
		xxxxxxxxxxxx	xxxxxxxxxxxx	
			xxxxxxxxxxxx	
			xxxxxxxxxxxx	$300,000
		xxxxxxxxxxxx	xxxxxxxxxxxx	
			xxxxxxxxxxxx	
Function or)			xxxxxxxxxxxx	
Functions to)	xxxxxxxxxxxx	xxxxxxxxxxxx	xxxxxxxxxxxx	
be Accom-)			xxxxxxxxxxxx	$250,000
plished)				
			xxxxxxxxxxxx	
		xxxxxxxxxxxx	xxxxxxxxxxxx	
			xxxxxxxxxxxx	
			xxxxxxxxxxxx	$200,000
		xxxxxxxxxxxx	xxxxxxxxxxxx	
			xxxxxxxxxxxx	
			xxxxxxxxxxxx	
	3	3-2	3-2-2	$150,000
			3-2-3	
			3-3-1	
		3-3	3-3-2	
			3-3-3	$100,000

which bring with them simplicity, effectiveness and reliability. An example will illustrate.

LOWER COST AND GREATER RELIABILITY

In a recent special program, twenty-four assemblies were studied. Twenty-one had excellent reliability while three did not have the reliability desired. For the twenty-one, functions were studied and evaluated. The design logic illustrated was developed. The performance and reliability of all were kept, but enough better solutions to specific design problems involved in the lower cost brackets were developed to reduce manufacturing costs in all by significant percentages.

The three reliability problems were handled somewhat differently. Objectives were developed to "hold cost at the same level" but eliminate the problems. The men on the three assemblies used the design logic illustrated, evaluated the function, and determined that lower-cost objectives were also more appropriate on the items. Interestingly enough, as the same techniques were used on these three as the other twenty-one, the "performance gaps" were first illuminated, then eliminated. The changes brought accuracy, reliability, simplicity, and lower cost. Manufacturing cost of each of the three was lowered by five figures. Low cost and high reliability in systems are often parallels.

Low cost means accomplishing the functions the simple, reliable, effective way. High reliability means accomplishing the functions the simple, reliable, effective way.

SPECIAL TECHNIQUE TO ASSIST

It must be borne in mind that in order to design to low cost and high reliability, the designer must believe that the objectives are attainable. The basic steps, job plan, and special techniques of value engineering provide to him opportunity to develop that assurance and guide him in doing it.

This necessary assistance comes in four types.[2]

1 Identifying, classifying and evaluating functions:[2]

"Any product or service has one or more prime 'use' functions which can usually be described in a two-word definition--such as, provide light, communicate intelligence, transmit torque; 'secondary' functions--such as resist shock, allow access, operate quietly; and 'esteem' functions--such as, provide attractiveness. Value, being a relative measure, the comparison approach must be used in evaluating functions --if there is no comparison, there is no evaluation."

2 Identifying and dealing with roadblocks:[2]

"Rules and generalities stop progress as fog stops traffic. Although there is not necessarily any tangible obstruction in a fog, it is dense and unmanageable and constitutes an effective stopper, because there is no assurance that the fog shrouds no problems. Attack each 'generality'."

3 Providing search-oriented as differing from knowledge-oriented techniques:[2]

"The technique of finding, utilizing and paying for vendors' skills and knowledge yields an exceptionally high return. Only a relatively small amount of the total special knowledge bearing on any technology exists in any one place at any one time. For several reasons, designers too often do not use it. They don't know it exists. They don't know where it is. They are unsure of results before starting the search, therefore, settle for a known though more costly solution."

4 Providing "quick rejection" techniques to minimize the unnecessary use of resources on unsuitable solutions:[2]

"For nearly every function and for nearly every manufacturing situation, there exist many alternative solutions; all of which will accomplish the purpose. Proper selection depends upon meaningful costs. How is the business really affected? Without meaningful cost, decisions cannot be made to provide good value."

In the process of providing ideas, knowledge, and approaches in these performance gaps, the engineer will find the search systems and quick rejection systems of the value analysis and engineering techniques of great value.

SUMMARY OF PROCEDURE

1 Secure clearly defined performance needs.

2 Secure definite cost needs.

3 Intensely study all functions and sub-functions both as to the results to be accomplished and the conditions under which they must be accomplished.

4 Create design logic complete with...
- (a) systems design approaches
- (b) principal assembly and product selection approaches
- (c) manufacturing or equivalent approaches

5 Evaluate functions and subfunctions in dollars. Bring enough effectiveness into this task to achieve an evaluation equal to or below the cost objective.

6 Apply the function evaluation to the design logic eliminating concepts, approaches, assemblies, etc., which cannot be used. Commit resources to the remaining alternatives.

7 Identify the areas in the remaining system where lack of knowledge or lack of suitable ideas produce what we have called a "performance gap."

8 Pinpoint sufficient resources on these gaps to bring forth effective solutions.

CONCLUSION

Today's systems and assembly designer faces, on the one hand, a growing mass of knowledge of functional capabilities to be utilized, and, on the other, a growing requirement to make selections which will shorten development time, increase reliability, and lower cost. He requires both greatly improved search techniques and effective quick rejection techniques. He requires means for filling in the new and for promptly eliminating large areas of alternatives which would be found to not meet his objectives.

The mechanism of evaluating functions, then using this evaluation with the design logic illustrated, first forces vigorous creative search, then narrows choices to a practical successful minimum. It, thus, is--another potent tool in the engineer's kit.

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[2] Partial quotation from "Techniques of Value Analysis and Engineering," McGraw-Hill Book Company, New York, N. Y., 1961.