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Value Control for System Design

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Summary

Value and cost are created and therefore controlled by the designer. Design decisions made so as to achieve the proper balance of costs and performance will yield the greatest utility value to a system.

Good value may be achieved by developing a cost model and a performance requirements model in detail sufficient to permit trade-offs to be made by the individual designer.

Introduction

If cost were no object or limitation, cost control would still be essential to achieving success in any major undertaking. Back in the 1930's, two groups of engineers ventured into the "unknowns" of dirigible design and created the R-100 and R-101. The well financed R-100 was a tragic failure. The fund limited R-101 was a success. Neville Schute, the author of "On the Beach," was one of the project managers of the R-101. He tells in his book, "Slide Rule" why this was so.[1] Some of the lessons we should draw from this experience follow.

1. Money is the control to steer projects so as to get meaningful results.

2. Too much money means too many cooks.

3. Limiting funds often will prevent effort that contributes only to confusion.

4. Cost limits help prevent technical decisions being made on a political basis.

5. An unrealistic limitation of funds can completely ruin a program.

Cost control _is_ essential. If we wish to control costs, we usually go to the controller, project manager or financial manager. This is logical. We do this because we think his job description requires that he control cost. However, he can't control costs any more than a meteorologist controls the weather. He does:

1. estimate costs,

2. account for costs,

3. monitor cost,

4. report on costs,

5. allocate funds,

6. negotiate price,

7. establish cost targets,

8. influence people who control cost.

Managers do not control costs. The man who defines what is required, who writes the specifications for the system, or hardware, and specifies tolerances creates cost. System and hardware designers control costs. Other functions such as Finance, Manufacturing and Purchasing can have some effect on cost by doing a more or less efficient job, but fundamentally, management must fund, the factory must make, and Purchasing must buy what has been designed.

Fortunately, designers (the system creators) are more easily influenced than the creator of weather. Some financial people doubt this.

Who is responsible for costs? The man who controls it? Not at all. Managers are responsible. This is how they got to be managers. They had enough guts to accept the responsibility, knowing they have no direct control, but also knowing how to use their influence. There is no paradox here. The captain of an ocean liner doesn't steer the ship. He establishes the destination or target and provides the helmsman with the tools and information to get the ship where he wants it. Navigation is a science. Setting dollar targets is still in the realm of primitive art. This paper relates to making this art less primitive.

Value - Cost - Dollars

Value - Cost - and Dollars are not synonymous. The value of systems or parts of systems is their relative contribution to meeting an objective. In the case of space systems, we have several kinds of value: the Prestige, Knowledge and Military Value to a nation carrying out the space mission, or the contributing Utility value of each element of this system to achieve overall objective.

Value - Contribution to - Prestige, Knowledge, Utility, etc.

Costs are the resources consumed to get value.

Cost can be measured in dollars.

The Rule of the Game

Sufficient Performance (to meet Objective) with least expenditure of resources. This is Maximum Value. We follow this rule to achieve cost effectiveness.[2] Cost effectiveness is like happiness. The United States Constitution permits us to pursue it -- no guarantees of ever achieving it.

The manager's objective is not only cost control but also value control. He can get cost control by making cost targets a design requirement. He can get value control if the targets are properly set.

Cost Targets

Figure 1 shows the process for determining system values. The process starts when someone decides that there is a need for a system to do something. A cost effectiveness study is made. This is sometimes done off the top of the head, sometimes by an extensive study. Basically, this consists of selecting many methods or systems to do the job, then evaluate which method will be most effective in accomplishing the task. For example, if we want to take pictures of the surface of the moon, we can:

1. Take pictures through a telescope (not very effective - low cost).

2. Ranger type program (effective enough - cost is within reason).

3. Send Team of Professional Photographers to Moon (very effective - cost high).

In order to make a cost effectiveness evaluation, it is necessary to estimate to cost of each major component or service and its cost. We usually break out the component or service by the function they perform. In so doing, we establish a cost-function relationship.

Not only must a function be performed, but it is necessary to define how effectively it must be done. If we do it with insufficient effectiveness, we fail our mission. If we over-design, we may be degrading value. We may be expending resources unnecessarily.

Two Elements of Utility Value

We must make two kinds of decisions.

1. What functions must be performed, and how much money should be allocated.

2. How well should these functions be performed to achieve maximum value.

Let's examine the function cost element. In order to plan a job, it is usual to define the job by the bits and pieces that make up the whole job.[3] This can be in the form of a work breakdown structure or Parts List arranged like a family tree, Figure 2. Figure 3 shows such a breakout on a tabular form. The target cost is the cost of all items to get a function, for example, Black Box 1 consists of expenditures in engineering, fabrication, purchasing, test, etc. The target cost is the total of all of these. The engineer must design to meet all the costs, or chaos can result. If for example the engineer's task is to design Signal Gate Modules, his engineering target might be $1,000, but 1,000 modules are to be used in a computer. A decision could be made to "play it safe" and buy 1% rather than 5% resistors, which would do the job. The cost difference is multiplied by the number of resistors per module times 1,000 modules. This can and has many times in the past consumed many thousands of dollars that could have been used better elsewhere.

A cost target for gate modules would prevent such a decision. Obvious, isn't it? Do your engineers work to similar cost targets?

A complete cost model or matrix will provide cost visibility. This is a practical way to identify unnecessary cost. Just knowing what the costs are in detail will reduce them 10%.[4]

Figure 3 is a plan or result of how many dollars are expended to accomplish a function by whom and at what expenditure of dollars or resources. This is a Cost Model.

The second element of utility value is performance. Performance requirements are not the same as performance objectives. We certainly want in a piece of equipment the most range, the highest data rate, the least weight, and infinite reliability.[5] We do not necessarily require the ultimate in all these things, or is it possible to get them. Performance requirements are a compromise, and we must decide how much we want of each of the "goodies." We can do this by the use of human judgment or trade-off studies.

For example, as shown in Figure 4, a trade-off for a typical system may show that the acquisition cost increases as effectiveness increases, while the operational cost of the system decreases with increased effectiveness. For the particular system plotted in Figure 4, the portion of the curve of total cost between points A and B represents the optimum cost/effectiveness ratio.

When a multiple incentive contract is written, we define in dollars the relative value to the user of all of the major performance characteristics. Figure 5 is a typical example. The incentive structure is derived by:

1. People who know the problem and use their built-in integrator (the human brain is an accurate and efficient device) and make a judgment.

2. By trade-off studies.

3. A combination of both.

This division can be looked at in two ways:

1. It may be an expression to relative value of each factor to each other.

2. It may be an expression of the relative difficulty to achieve each desirable characteristic that contributes to the ultimate objective. This is reward for overcoming obstacles. Motivating money.

We are interested in the first for design information. The second is a business arrangement. If the contract terms represent the second form, we must re-allocate on the basis of relative value.

If we extract from Figure 5 (a hypothetical contract) the weight incentive, we would look at it as follows. Figure 6 is an expression of the utility value of weight of the product in pounds and says the user is willing to pay plus or minus $200,000, depending on the weight of the final product. We can of course turn this around and intelligently establish such a utility curve in order to determine the incentive arrangement in the first place.[5,6]

Curves for the performance contribution can be established for each desirable performance characteristic. These curves include the target for the performance objectives of the system. They are derived by human judgment aided by mathematical tools. Papers showing these mathematical techniques are numerous and some are listed in the references.

In conclusion, I will quote to you an excerpt from an address by Kingman Brewster, Jr., President of Yale University to the 1964 Graduating Class.

> "The expert may explain why things happen, may even predict what will happen if all the assumptions can be held in place. But for all his science he cannot tell you how to make those decisions which require the weighing of competing claims and aspirations and values.
>
> When the whirring of computers and the chatter of committees are done, someone decides whether to advance or retreat, to hire, to fire, to expand or contract, to fish or cut bait, to reward or penalize, to buy or sell, to bluff or call a bluff.
>
> Do not expect the refinement of specialization to solve the ultimate problems which all experts deposit on the doorstep of wisdom."

List of References

1. Neville Schute, "Slide Rule."

2. Robert Hines and Ervin Leshner, "Relationship of Value Engineering and Cost Effectiveness." JOURNAL OF VALUE ENGINEERING, August 15, 1964.

3. PERT Cost

4. Lawrence D. Miles, "Techniques of Value Analysis and Engineering." McGraw-Hill 1961

5. Carlos Fallon, "Production Men, Product Decisions and Product Value." ASTME Technical Paper No. SP65-05 - 1964.

6. E. R. Lower, "Application of Value and Utilities to Decision-Making in Design." JOURNAL OF VALUE ENGINEERING, May 15, 1964.

FIG. 1

THE PROCESS OF DETERMINING SYSTEM VALUES

SPACE OR MILITARY NEED DEFINED

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SELECTION OF ALTERNATE WAYS TO MEET NEED

↓

COST EFFECTIVENESS STUDY TO SELECT BEST OF ALTERNATES

MAJOR PRODUCTS OF C.E. STUDY

1. EACH MAJOR SYSTEM COMPONENT DEFINED
2. FUNCTION OF MAJOR COMPONENTS DEFINED
3. COST OF MAJOR COMPONENTS ESTIMATED
4. SYSTEM PERFORMANCE REQUIREMENTS ESTABLISHED

COST

DEVELOP WORK BREAKDOWN STRUCTURE

↓

DEVELOP COST MODEL

↓

ESTABLISH TARGETS

PERFORMANCE

ESTABLISH RELATIVE UTILITY VALUE OF EACH PERFORMANCE REQUIREMENT

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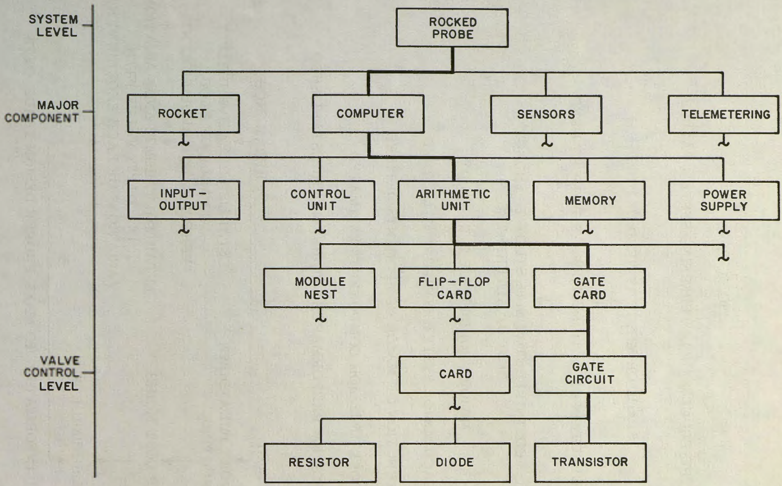
ESTABLISH TARGETS AND VARIATION IN UTILITY VALUE WITH VARIATIONS OF EACH REQUIREMENT

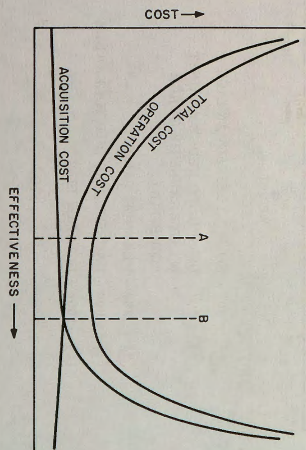
REQUIRED INFORMATION TO MAKE PROPER DESIGN TRADE OFFS


SYSTEM LEVEL
MAJOR COMPONENT
VALVE CONTROL LEVEL
ROCKED PROBE
ROCKET
COMPUTER
SENSORS
TELEMETERING
INPUT-OUTPUT
CONTROL UNIT
ARITHMETIC UNIT
MEMORY
POWER SUPPLY
MODULE NEST
FLIP-FLOP CARD
GATE CARD
CARD
GATE CIRCUIT
RESISTOR
DIODE
TRANSISTOR

LEVEL 1 2 3 4 5	ENG.	PURCH.	FAB.	TEST	ETC.	ETC.	TARGET COST
ROCKET PROBES							
COMPUTERS							
ARITH. UNIT							
NEST							
GATE							
CIR.	$1.	34.7	9.0	11.5	.8	-	47.0 M.
BLACK BOX							
ETC.							

FIG. 3
TYPICAL COST MODEL

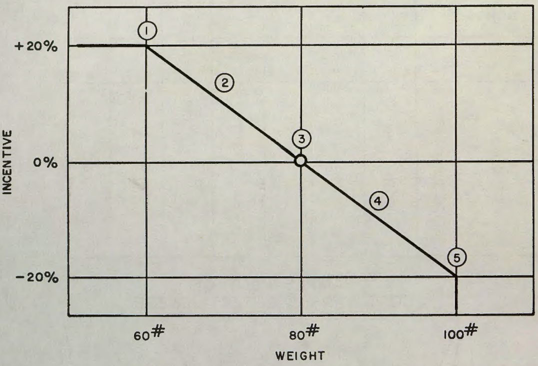
SAMPLE PLOT OF
COST VERSUS EFFECTIVENESS



TYPICAL MULTIPLE INCENTIVE STRUCTURE

TOTAL CONTRACT PRICE			\$10,000,000
INCENTIVE FEE SWING			±10%
INCENTIVE STRUCTURE			
COST	±20%		= \$200,000
SCHEDULE	+20%		= \$200,000
PERFORMANCE	±60%		
MAINTAINABILITY		+10%	= \$100,000
WEIGHT		±20%	= \$200,000
RELIABILITY		±20%	= \$200,000
VOLUME		±10%	= \$100,000

FIG. 5



NOTE

(1) 60# - NO FURTHER ADVANTAGE

(2) 70# - USEFUL TO HEDGE AGAINST WT OVERRUNS OF OTHER EQUIPMENT.

(3) 80# - PLANNED TARGET

(4) 90# - UNDESIRABLE BUT TOLERABLE

(5) 100# - USEABLE LIMIT

FIG. 6