OC-M-70-269

DD/S 70-1716

27 APR 1970

MEMORANDUM FOR: Deputy Director for Support

SUBJECT : An Increased Role for the Younger Officer

REFERENCE : DD/S 70-1632, dtd 21 April 1970
SUBJ: Management Advisory Group Paper:
"An Increased Role for the Younger Officer"

1. There is no question that the talents, ideas and enthusiasm of our younger officers can and should be fully used, both to our benefit and their development. We have been doing this to an increasing extent within the Office of Communications on both a formal and informal basis. I am of the opinion we can expand the opportunity to participate still further.

2. At the present time we are using the young officers in our Career Development Program several ways. First as a forum for exploring various aspects of our communications responsibilities, particularly in the management fields. The Chief of our Management and Training Staff conducts these informal sessions periodically and has informed me that they are extremely worth-while. I have personally attended such sessions and have been impressed with the enthusiasm of these young professionals and their eagerness to participate. Secondly, as part of their overall training, they have been given assignments to review specific projects, programs, or procedures and originate new proposals and ideas. I am attaching one such document prepared in early 1968 for your perusal. It is entitled, "A Working Guide To Cost Analysis".

3. We are, on a selective basis, assigning promising young officers to positions where they can be broadened, and at the same time make positive contributions. These assignments cut across the board in OC. One such position is on my immediate staff and the incumbent is rotated at about 12 month intervals to make maximum use of the opportunities this assignment affords. The position includes the responsibility for reviewing and recommending action to be taken on all suggestion awards received by the Office.

4. We have been using several of our younger professionals as a bridge between senior management and the employee. While this approach represents the informal organization at work, I have found this channel to be most successful in determining new approaches to problems and as a communications channel between myself and the younger engineers and professionals. For
25X1 example, [redacted] in his early thirties is a natural "bridge" between the D/CO and the young engineers.

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5. We have used junior officers on our promotion panels very effectively. I would conservatively estimate that 200 young professionals participate on these panels each year under the guidance of more senior officers.

6. Other activities within OC which would permit us to make greater use of younger officers include, but are not restricted to, the following:

A. Suggestion Awards Panel: As indicated above, responsibility for Suggestion Awards rests with a mid-career level communications officer now. I plan to expand membership on this panel by two additional young officers.

B. Career Development Advisory Panel: I believe there are many aspects in the career development field which could be addressed by a group which includes the younger officers. Career Training programs, assessment testing, evaluations and evaluation criteria are but a few. I plan to establish such a panel under the guidance of our Career Management and Training Staff.

C. Honor & Merit Awards and QSI Panel: A significant number of recommendations for awards and Quality Step Increases are received by OC each month. I propose to establish a panel with the responsibility for reviewing and processing these recommendations. Participation by young officers would challenge their judgement and permit them to contribute directly in the recognition of their contemporaries. I would suggest that a similar panel might be appropriate at the DD/S level.

D. Administrative Support Panel: I am of the opinion that a panel, constituted to review the "why", "what" and "how" we are doing in the multi-faceted field of administration would be extremely desirable. Here is a natural group for younger officers to participate and contribute. I am having our Chief, Administrative Staff explore the possible organization and responsibilities of this panel as well as its relationship to the Branches within the Staff.

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7. I expect to have the above panels in operation within the next 90 days. Time will be required to establish working procedures prior to implementation and to determine panel membership.

8. While I agree with the MAG, that not all young officers can be a part of the decision processes, the steps we propose to take will expand the existing opportunities for their participation and contribution. I am optimistic that the steps set forth, and others we shall consider, will result in both immediate and long range benefits to this Office and the Directorate.

[redacted] 25X1

Director of Communications

Attachment:
  Working Guide

# A WORKING GUIDE TO COST ANALYSIS

Approved For Release 2003/05/27 : CIA-RDP84-00780R003400060038-0

## INTRODUCTION

This paper was written for use by personnel who are engaged in the comparison and evaluation of proposed staff communications systems. It attempts to outline the purpose and techniques of cost effectiveness analyses as they were developed in the Department of Defense and as they are now used throughout the government. The thoughts in the paper are a synopsis of the best thoughts of several authors, including a former Secretary of Defense, a former Assistant Secretary of Defense, and a former president of the RAND Corporation.

The material in this paper is by no means a "recipe" for doing cost-effectiveness studies, although a sample format is included in the appendix. Two questions are answered, in a very general, narrative way: (1) What is a cost-effectiveness study? and (2) How is it done? Because the rules are unwritten and very flexible, Question (2) is answered more by example than by attempting to build a rigid, step-by-step procedure. A knowledge of cost-effectiveness techniques implies familiarity with a concept, rather than a methodical system of solution.

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# CHAPTER I

# BACKGROUND INFORMATION

## 1.1 PLANNING - PROGRAMMING - BUDGETING

On 25 August 1965, President Johnson directed the implementation of the Planning-Programming-Budgeting System (PPBS) of fiscal control among all agencies and departments of the United States Government. The system had been introduced into the Department of Defense by Secretary McNamara in 1961 and was generally regarded as efficient, effective, and a great improvement over previous Defense planning and budgetary practices. President Johnson believed that the same methods were applicable to the entire government and would correct the obvious deficiencies of the federal budgeting system then in use.

The old concept of budget planning entailed submission, by each agency, of a proposed list of expenditures for the coming year. The expenditures were listed in "line item" form, i.e., personnel, maintenance, construction, R&D, procurement, etc., effectively obscuring the overall goals or programs of each agency. The old system also failed to inspire creative long-term planning and allowed wasteful duplication of effort between "competing" agencies. And, finally, it failed to allow top officials sufficient time to review, evaluate, and make decisions. Because of the human proclivity for procrastination, annual budget submissions were one-shot affairs involving "go, no-go" decisions as well as hasty cost estimates.

PPBS is designed to eliminate the shortcomings of the old budgetary system by strengthening the weak link between planning and budgeting. Under PPBS, all agencies are required to submit a 5-year plan to the Bureau of the Budget (BOB) annually. The 5-Year Program Call is broken down by program category rather than by budgetary line item. In addition to a description of current andproposed programs, the Program Call includes the financial and manpower schedules for the next five years. As the proposed program initiation date approaches, the system may be modified, expanded or deleted by changing it in the annual Combined Program Call. Access to the long-range goals of all agencies has allowed the BOB to formulate a clearer set of national objectives and reduce the duplication of effort between agencies.

PPBS is a tool used primarily in the top levels of government; however, the effects of the system reach deeply into every agency. The Combined Program Call must describe each proposed system, the alternatives, and some sound and logical evidence showing the greater effectiveness and efficiency of the chosen proposal. This last requirement represents many man-hours of labor doing cost-effectiveness studies, which is the subject of this paper.

## 1.2 DEFINITION OF TERMS

The terms "cost-effectiveness study", "cost-benefit analyses", "cost-utility analyses", "systems analyses", and "operations research" are used synonmously throughout the government to denote the dialectic process used by all government agencies to give the U. S. citizen the most for his tax dollar. Although the terms actually have slightly different meanings, they all denote the quantitative comparison of inputs (costs) and outputs (gains) of alternative systems designed to accomplish the same task. "Operations research" was coined by the tactical planners of World War II as they used the system to determine optimum troop developments in the pursuit of rather flexible goals. In a non-military context, the term alludes to the optimization of a single system described by many variable parameters, and is closely akin to the "systems analyses" used at the higher levels of government. Operations research and systems analyses surpass cost-benefit analyses in scope because the former include constant system revision (and occasional restatement of objectives) in search of the optimum, while cost-benefit analyses generally denote efficiency, effectiveness, and economy comparisons between a fixed number of proposed systems. The terms cost-effectiveness, cost-utility, and cost-benefit are almost exactly synonomous; cost-effectiveness and cost-utility are generally applied to government systems because the "benefits" are not as readily apparent as are the profits of industry. As mentioned, the various terms are used interchangeably by all but the strict economist, and they will be used interchangeably in this paper.

## 1.3 THE PURPOSE OF COST-EFFECTIVENESS STUDIES

PPBS and especially the cost-effectiveness approach to decision making is an extremely controversial subject among government managers. The technique is praised by many and condemned by others. Among the latter group is Admiral H. G. Rickover, who emphatically disagreed with Secretary McNamara's decision, on a cost-effectiveness basis, to continue production of conventionally-fueled aircraft carriers rather than use nuclear power. The basis of Rickover's argument was his contention that a cost-effectiveness study has little validity because it ignores intangible factors, or at least over-emphasizes numerical data. Such criticism comes from many sources and is often justified. However, there are two points dealing with the limitations of cost-effectiveness studies which partially refute Rickover's argument: (1) According to the people who established such procedures in the Department of Defense, a cost-effectiveness study is incomplete until the pertinent intangibles have been outlined and discussed as thoroughly as the quantitative parameters; and, (2) The primary purpose of a cost-effectiveness study is to sharpen the intuition and judgment of the decision-maker. The study is but one factor which should be considered. Many decisions have been made which are non-cost-effective on paper but are extremely political-effective in practice. Regardless of its true worth, a well-done cost-effectiveness analyses of a proposed system (and its alternatives) will be a big help in selling the system to PPBS and BOB officials.

## 1.4 CONCEPTUAL APPROACHES

Exactly how are the relative merits of two or more systems compared on a cost-effectiveness basis? Many well-intentioned people say that the optimum system will maximize the benefits (effectiveness) available and minimize the costs incurred. A little thought shows that such a criterion is impossible; maximum effectiveness is inconceivably large and minimum cost is zero. To put it another way: It is often possible to find a new system B which will do more at less cost than the old system A; however, it is always possible to find a third system C which will do more than either A or B, and a fourth system D which will cost less than A, B, or C. A systems analyst attempting to simultaneously maximize benefits and minimize costs will soon realize that he must place some constraints on his criteria.

The generally accepted method of cost-effective choice requires that the analyst determine the system which will maximize the benefits obtained <u>minus</u> the cost incurred. In the business world, benefits and costs are usually expressed exclusively in terms of dollars, and the objective of the cost-effectiveness study becomes the maximization of profit. The government, however, does not make a monetary profit - it provides a service to the taxpayer. As such, the benefits and costs of a system are incommensurable, and the merit of X capabilities minus 100 million dollars compared with the merit of Y capabilities minus 50 million dollars is meaningless.

A seemingly logical modification of the base criterion outlined in the previous paragraph overcomes the measurements problem but has limited application. An analyst using this conceptual approach postulates that the optimum system is the one having the highest benefit-to-cost ratio, assuming that all benefits are commensurable or that one benefit carries much more weight than the others. Such an assumption may or may not be valid. The ratio approach in its entirety is valid only when the absolute magnitude of cost or benefit is immaterial. It assumes that a system costing X dollars and having Y capabilities is the exact equal of a system costing 2X dollars and having 2Y capabilities. In the real world, quantitative requirements and budget dollars available are very much factors to be considered, and the ratio approach has little value unless definite constraints are specified. Fixing the level of cost or benefits reduces the ratio approach to one of the two procedures which will be the subject of the remainder of this paper. The first approach requires that all alternative systems achieve or surpass certain specified goals (outputs); whichever system requires the least input is the optimum solution. The second approach is used when the inputs (budget dollars) are specified; the optimum system is the one yielding the greatest return.

# CHAPTER II

# FIXED REQUIREMENTS, COST-ANALYSES OF ALTERNATIVES

## 2.1 ESTABLISHING REQUIREMENTS

In the "fixed requirements" approach, the analyst works with a pre-determined level of utility to be obtained in the accomplishment of some given objective, and his task is to determine the alternative (or feasible combination of alternatives) likely to achieve the specified level of utility at the lowest economic cost. Very often, the level of utility will be specified by higher authority and the analyses reduces to a comparison of alternative system costs. On the other hand, an exact level of utility is difficult to specify when the proposed system is only a concept, and the analyst may find himself working against a vague set of long-range objectives. If such is the case, the largest part of the analyst's job may be transforming "goals" into a firm set of quantitative requirements.

The first part of the formal study is, logically, a clear, concise, and quantitative statement of the attributes required of all alternatives. Any correspondence between the specified requirements and organizational objectives at all levels should be emphasized. Again, the requirements must be specific and, if at all possible, quantitative. An adverse indication of how well the requirements are written may be obtained by counting the number of superlatives used. "Most", "least", "best", "highest" and other glorious but useless words have no place in the requirements section of a fixed-utility cost-effectiveness study.

The search for quantitative requirements is complicated by a need for accuracy. The choice and level of a requirement is fundamental - if it is incorrectly specified, the whole analyses is addressed to the wrong question. Consider the effect of over-estimating required system capacity: The truly cost-effective system (under actual conditions) may well be eliminated from the proposed list of alternatives with no cost analyses whatever. The danger of incorrectly specifying a requirement is greater when one of the alternatives is a brain child or favorite of the analyst; he may unconsciously "hedge" the requirements in favor of his project.[1]

Another facet of the specifications problem is the time dependency of many requirements, especially those dealing with expanding system capacities. If the required system capacity is expected to increase continuously throughout the years, any system designed to meet the requirement at the end of the time span will automatically meet the requirement during the preceding years. However, the most economical alternative may very well be the one which meets the requirement on a year-to-year basis by incrementally expanding the system capacity. If the system lends itself to such incremental expansion, a year-by-year forecast of the increasing requirements is basic to the study. Such predictions may be based on intuition, long-range plans, or past history, depending on the type of system and the depth of the analyses. If the alternatives are compact, unitized systems, incremental expansion is precluded and the design goal must be the capacity requirements predicted for the end of the time span. Although the surplus capacity created during the first few years of its useful life is wasted, the unitized system may still be most economical.

The schedule for installation and operation of a new system may be another major consideration. Many proposed systems are designed to replace existing systems which are being obsoleted by newer and more economical state-of-the-art components. One requirement of all such systems is that there be no interruption of service during system change-over. Because of this, a complex system must be phased in a subsystem at a time, and should be available from the manufacturer on that basis.

Cost-effectiveness techniques may be used in an infinite number of situations, each situation requiring different effectiveness yardsticks. No one person could catalog all the output parameters which could possibly be used to describe a communications system, and the short list compiled at the

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[1]An excellent example of a hypothetical Defense Department systems analyses based on improperly specified requirements may be found in Appendix II of Tucker's A Modern Design for Defense Decision, a McNamara-Hitch-Enthoven Anthology, Industrial College of the Armed Forces, Washington, D. C., 1966. The article, entitled "An Illustrative Example of Systems Analyses", was prepared for instructional use at the United States Military Academy at West Point and is well worth reading for any potential systems analyst.

end of this chapter is intended only as a reminder and guide.

## 2.2 DETERMINING SUITABLE ALTERNATIVES

Once the analyst has determined what his final system is required to do, he must make a search for candidates. Usually, one particular system has already been studied and may have generated the request for a cost-effectiveness study. Also, most new systems are replacements for existing systems and must be proven more cost-effective than the original system. If the effectiveness of the original system (after modification) will meet the new requirements, it should be considered the baseline alternative. Many analyses will contain only these two - the original and a proposal, while other studies compare a large number of alternative systems or a single system having continuously variable input parameters. The "tradeoffs" possible in this latter type of analysis effectively create an infinite number of alternatives. The great problem in choosing alternatives to compare is to be sure that all alternatives have been included, since the optimum system may well be a combination of two or more original alternatives. Frequently, the analyst lacks the imagination to mix alternatives at the beginning of the analysis and the optimum solution is not even considered until he is well into the problem. The invention of better systems in this fashion has been lauded as one of the principal payoffs of systems analyses.

Although consideration of any proposal as a system alternative should be ipso facto evidence of requirements met, the outputs of some systems must be calculated and shown in the analyses, simply to prove the eligibility of the system to the reader. However, maximum output is not a criterion in the fixed-utility approach and no effort need be wasted detailing system outputs if it is evident that the stated requirements are met.

## 2.3 THE COST ANALYSES

The cost analyses portions of a cost-effectiveness study do not necessarily involve money. During wartime, many resources are put on a "critical materials" list and become valuable because of their scarcity; their dollar values are essentially meaningless. Another "cost" which is occasionally used in an analysis without reference to money is manhours of labor. A fixed-utility cost-effectiveness study using labor as its only cost becomes a time-and-motion study. However, a system using both critical materials and manhours of labor as costs cannot be analyzed until a common denominator is found for the inputs. Although far from perfect, the almost unlimited possibilities of substitution in our economy make dollar costs a satisfactory measure in most cases. In any long-range program involving R&D and procurement, dollar measurements are far superior to any practical alternative.

Before a comparison of alternative system costs can be made, the analyst must determine the most useful and informative cost breakdown. As mentioned previously, complex systems are generally installed over a span of years, and the yearly costs are of prime importance in budget planning. For this reason, a year-by-year cost analysis over the time span of the study is required. Care must be exercised in choosing the time span, also, since R&D and procurement costs are much higher during the first years of a new system. If system costs are not projected far enough into the future, the overall economy of a new system in comparison with an existing system may not be evident.

The actual category of cost may follow along either an objective or a functional approach. In those systems which are phased in a function at a time, both breakdowns may be required. An objective breakdown is required for budgetary purposes, since Congress is always interested in the money spent on R&D, procurement, installations, training, equipment replacement, personnel, etc. A functional breakdown is an extension of the "PPBS" concept to lower levels of planning. It is particularly applicable to complex systems containing several subsystems which are procurred and installed in successive stages. The cost breakdown by function allows the system engineer to eliminate those functions which can be performed more economically by the existing system or a third alternative, providing that all proposals follow the same functional breakdown. It also provides some indication of the effect of program revision or cancellation at a later date.

One mistake that is frequently made in cost analyses is the inclusion of "sunk" costs in the total cost of an alternative. Sunk costs are those which are non-recoverable regardless of which alternative is chosen. The cost of a "feasibility study" prior to the selection of a new system represents money spent and not retrievable, regardless of how feasible the proposed system turns out to be. Another example of sunk costs is the R&D expenses of equipment originally developed for another system. Any cost which still exists after all proposals have been discarded cannot be considered attributable to any particular alternative.

Another cost mentioned in the literature and frequently ignored by the analyst is the "salvage" value of the system at the end of the time span selected for the study. The salvage value is often ignored by postulating that the equipment involved will deteriorate or become obsolete at a rate which will cause the utility of the system to approach zero at the end of the study. If such is the case, the salvage value is reduced to the "used hardware" value of the equipment, which is probably negligible when compared with R&D, procurement, and annual operating costs. If the salvage value cannot be ignored, it appears as a "negative" cost of the alternative and must be subtracted from the total system cost.

The complexity of the actual cost computations depends largely on the size and complexity of the system. Some simple system alternatives may be described solely on the basis of the cost estimates found in the contractor's proposal. Larger systems, however, have constantly fluctuating requirements, and the most economical alternative may be the one which adjusts to meet the requirements on a year-to-year basis. The annual costs of such a system will generally follow the annual ooutput, and the correlation between predicted capacity requirements and input dollars must be found. The relationship between input and output is referred to as a "model" in many systems analyses texts. Depending on the complexity of the system and the depth of the analysis, the model may vary from a simple output volume/input dollars ratio to an assortment of graphical displays and mathematical formulas containing numerous parameters. Of course, the model need not be the same for all alternatives, since only the end result is fixed; the method of achieving the end results is unrestricted. Regardless of what form it takes, the model will allow the analyst to predict (1) future system costs based on future requirements and (2) the relationship between current costs and outputs.

Although the actual yearly breakdowns are required for budgetary planning, cost comparison of alternatives is difficult on that basis; the high R&D costs of a new system may be balanced by lower operating costs in the later years of the study, making the total cost less than the old system's. Because of this, the costs section of each alternative should show the actual yearly breakdown, the total cost of the system, and the average yearly cost (less salvage cost, if applicable).

## 2.4 UNCERTAINTIES AND ASSUMPTIONS

As the study progresses, the analyst is likely to find the number and range of the parameters increasing rapidly. To keep the study from hopelessly floundering, the analyst must (1) keep an outline in mind similar to the one in the appendix; and (2) stifle the ever-increasing scope of the problem by acknowledging the uncertain areas and making some educated assumptions. Of course, the reliability of the study decreases with every assumption made, but man-power and time limitations always prevent absolute accuracy. An abbreviated study abounding with reasonable assumptions is infinitely more desirable than an exact study completed too late to be useful. However, the analyst must document the uncertainties and assumptions so that the decision-maker may form his own opinion of the validity of the study. A cost-utility analysis should be complete in itself, as should any other staff study; anything that the analyst is called upon to explain about the analyses should have been included in the first place. Implicit in this statement is the requirement for mathematical clarity and completeness in explanation of the models used.

## 2.5 COMPARISON OF ALTERNATIVES

The final step in a fixed-requirement cost-effectiveness study is a qualitative discussion of the relative merit of each alternative. Previous steps in the analyses must ignore any benefits or outputs which are "above and beyond" the stated requirements, since minimum cost is the selection criterion. However, an output advantage of one alternative or an intangible benefit which could not be stated as a requirement may offset a slight cost disadvantage in the mind of the decision-maker. Again, the purpose of a cost-effectiveness study is to sharpen the intuition and judgment of the decision-maker. Although a fair and complete statement of the requirements implies recommendation of the cheapest alternative, a cost-effectiveness study is not a recommendation. It is properly found as an attachment to a formal military staff study, which does contain recommendations.

If two or three alternatives are being considered, the discussion of side benefits and intangibles may be completely written in narrative form. As the number of alternatives is increased, however, comparison becomes difficult unless a tabular presentation is used. A side-by-side comparison of costs and extra benefits, as shown in the appendix, will be very useful to the decision-maker.

# CHAPTER III

## FIXED BUDGET; UTILITY-ANALYSES OF ALTERNATIVES

### 3.1 SPECIFICATION OF BUDGET LEVEL

The second primary approach to cost-effectiveness determinations requires a knowledge of allowable system inputs (money) over the time span of the study. Money, rather than specified requirements, becomes the fixed parameter and system output is the variable parameter which must be maximized. This technique may be of some value when applied to short-range projects of limited scope, since the funds available are generally known. In long-range, far-reaching programs, the generosity of the BOB and the taxpayer X years hence is uncertain and dependent on how critically the system is needed. Since the fixed-budget approach sets no specific level of required system capacity, budget people are apt to wonder if the analyst's optimum system is required at all; or why it can't be substantially reduced in scope and cost. Although the usefulness of this method in government programs is doubtful, the procedural differences between the two approaches is slight and will be outlined here for the sake of completeness.

The first step in the fixed-utility approach was the specification of quantitative requirements. In the fixed-budget approach, the budget must be quantitatively specified by the analyst over the time span of the study. Although a logical estimate of future budget levels may require less thought than an estimate of future required system capacities, the effect of underestimating money available may be as disastrous as overestimating required capacity in the fixed-utility approach. Inaccuracy may eliminate the truly cost-effective system from consideration.

### 3.2 ALTERNATIVES

The search for suitable alternatives is similar to the process described in Chapter II. The only requirement that a candidate system must meet is that of maximum projected cost, and proof of eligibility for consideration is necessary only if the cost of an alternative is not readily apparent to the reader. The existing system, if eligible, should be considered one alternative, and the analyst should again be alert for advantageous combinations of alternatives.

## 3.3 COMPUTATION OF OUTPUT

The portion of the fixed-budget analyses which is analogous to the costing portion of the fixed-utility analyses is the determination of system output. Much the same mathematical and graphical techniques of model building used in the fixed-utility approach are applicable, since input/output relationships do not depend on the method of system analyses. Cost becomes the independent variable which must be specified; output is the dependent variable.

If the proposed system has only a single output or has one particular output which is much more important than all others, maximization of output is a straightforward matter. However, most systems have several output parameters of importance - capacity, speed, accuracy, etc., which are incommensurable and not directly related. In other words, Alternative A may provide the greatest capacity for a given budget level, Alternative B the greatest speed, and C the greatest accuracy. Unless the relative contributions of the individual parameters to the total worth of the system can be found, quantitative comparison of the alternatives is blocked. The meaning of this statement may best be demonstrated by using an example from private industry.

A factory owner is planning to redesign the assembly line and quality control divisions of his plant and has three alternative systems in mind. The costs of installation and operation is roughly the same for all three systems, and the output parameters of importance are capacity (number of assembly lines), speed (of assembly), and accuracy (percentage of produced units which are never returned due to defects).

The total worth of each alternative system may be quantitatively described by the number of perfect units which could be turned out each day if that system were selected. In this example, the mathematical relationship of the parameters to the total system worth is obvious - The number of perfect units manufactured each day is the product of the number of assembly lines, the speed of assembly in units per day, and the percentage of units which are defect-free. If this product is computed for each alternative, the factory owner may select the system which will provide the greatest return for his investment.

## 3.4 COMPARISON OF ALTERNATIVES

Unfortunately, very few systems are simple enough to be analyzed on a half sheet of paper. Normally, a nice, neat, rigorous mathematical relationship between system worth and



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the individual parameters cannot be found. Frequently, the system is so complex that the analyst cannot establish even an empirical relationship. In such a case, about the best he can do is investigate the tradeoffs in the hope of designing another alternative combining all of the good points and none of the bad points of the original alternatives. If such a system cannot be found, the analyst can at least qualitatively discuss the advantages and sacrifices involved in the choice of each alternative. The final, irrevocable choice is up to the decision-maker; but the analyst can greatly assist him with an orderly, written presentation of fact.



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# CHAPTER IV

# MISCELLANEOUS CONSIDERATIONS

## 4.1 FIXED AND VARIABLE PARAMETERS

Throughout this paper, much effort has been expended sidestepping any detailed discussion of the difference between optimization of variable systems and the selection of one cost-effective system from several unique alternatives. An attempt at clarification will be made here.

The simplest problems involve a number of separate, unrelated proposals, where the relationship between cost and output for each proposal is fixed and known. The specification of output dictates the cost of an alternative, or fixing of cost tells the analyst exactly what the output of each alternative is. Mathematical computations are straightforward and determination of the cost-effective alternative is automatic.

Consider now the factory reorganization problem in Chapter III. The factory manager arrived at his alternatives by allowing himself $10,000 costs. Previous time-and-motion studies had shown that the cost of adding another line would be $1,000, the cost of speeding up a line would be $20 per day, per line for each additional unit produced, and that quality-control costs ran about $40 for every percentage point of perfection (per cent of units produced which were not returned due to defects in manufacture). Using these costs, the plant manager had determined three alternative ways to spend his $10,000:

| | NUMBER OF ASSEMBLY LINES | SPEED (UNITS PER LINE PER DAY) | PER CENT DEFECT-FREE | COST |
|---|---|---|---|---|
| ALTER A | 1 | 250 | 100 | $10,000 |
| ALTER B | 3 | 150 | 100 | $10,000 |
| ALTER C | 5 | 100 | 75 | $10,000 |

As explained in Chapter III, the total daily output is a good indicator of system worth. Alternative B, since it turns out 450 units per day compared with 250 for A and 375 for C, is the cost-effective choice.

In its present form, the above analysis is a reasonably simple example of a problem involving one system and several cost-related parameters which may take on only discrete values. Only three mathematical computations were necessary to determine which combination of parameters yielded the greatest return. Of course, as the parameters are allowed to take on more values, the number of computations will increase greatly. A systems analyst working on this system could not be satisfied with his work unless he were free to try other values (2, 4, 6, etc.) for the number of assembly lines. Although Alternative B is the best choice of the three alternatives specified, there is no guarantee that a better combination of capacity, speed and accuracy could not be found. Digital computers, which are ideally suited to such repetitive calculations, may become necessary as the number and range of parameters is increased.

When all restrictions other than cost are removed from the above output parameters, they become continuously variable and may generally be maximized mathematically. Two algebraic equations govern the performance of the factory system above:

$$\text{Output} = x\ y\ z$$

$$\text{Cost} = \$10{,}000 = \$1{,}000\ x + \$20\ y + \$40\ z$$

where $x$ = number of assembly lines

$y$ = assembly line speed, in units produced per day

$z$ = percentage of produced units which are defect-free

If these two equations are simultaneously maximized, the maximum system output is found to be 463 units per day, which would occur if 3 1/3 (if such were possible) assembly lines producing 166 2/3 units per day, per line at an 83% defect-free rate were used. No combination of parameters will give a greater output for $10,000 or less.

## 4.2 TREATMENT OF UNCERTAINTY

As discussed in preceding chapters, every system analysis includes a number of intelligent prophecies and assumptive analytical short-cuts which require detailed explanation and justification. The introduction of such uncertainties into an analysis is a necessary evil, since future occurrences are by definition uncertain and manpower limitations prevent completely rigorous mathematical analyses. As the degree of uncertainty surrounding the mathematical model or any of the key parameters increases, the reliability of the final results decreases. This may be easily demonstrated by hypothesizing a system having ten independent parameters. If nine of the parameters are known exactly and the tenth is estimated with an 80% probability of being correct, the probability of all ten parameters being correct is also 80%. However, if each of the ten parameters is estimated and has an 80% chance of being correct, the probability of all ten parameters being correct is approximately 10% ($0.8^{10}$). If this system had been analyzed using only the one "best guess" case, the analyst would be ignoring a set of probable occurrences which has a 90% chance of occurring. Very few decision-makers would wager any money on such odds.

In the interests of accuracy and credibility, therefore, the analyst must analyze all significant and interesting contingencies. Unless a great deal of judgment is used in the selection of contingencies for analyses, the analyst may face an insurmountable pile of work. If there are two uncertain factors, each of which may take on five different values, the analyst must make $5^2$ or 25 different calculations, which is quite feasible with a hand calculator. However, ten uncertain factors which are permitted five values each represent $5^{10}$ or 9,765,625 different computations. Although electronic computers could easily do the computations, no single human being could ever compare the results. Elimination of insignificant contingencies (i.e., those contingencies having very little chance of occurring) becomes the practical problem facing the analyst.

Many chapters of many textbooks are devoted to Monte Carlo and other gaming techniques for dealing with statistical fluctuations of parameters. Such statistical computations are often complicated; they usually end up as "window dressing" which is never understood and which causes the reader to distrust the entire study. However, there are two relatively simple standard procedures for dealing with uncertainty which may be of considerable assistance to the analyst. The first of these is the <u>a Fortiori</u> argument, which follows this line of reasoning: <u>Suppose two</u> alternatives, A and B, are being considered. The analyst, using a "best guess" for one of the parameters, has shown Alternative A to be the cost-effective choice, but the uncertainty surrounding the indefinite parameter casts some doubt on the validity of his study. The analyst will then deliberately resolve the uncertainty in favor of Alternative B. If Alternative A still proves to be cost-effective, all doubt is removed from the analyst's solution. If not, the analyst is no worse off than he was before.

An extension of the <u>a Fortiori</u> argument which is used extensively in Defense Department Analyses is the sensitivity analyses. Instead of using best guesses for key parameters exhibiting a high degree of uncertainty, the analyst will use several values (high, medium, low) in an attempt to determine the sensitivity of each alternative to variations of the uncertain parameters. Only those parameters which significantly affect system output need be investigated further. A high degree of uncertainty in only one or two parameters may be handled by presenting best, worst, and most likely solutions to the decision-maker.

## 4.3 SPILLOVERS

Another mistake frequently made in cost-effectiveness studies is the neglect of "spillover" costs. The term "spillover" describes the effect of a new system, operation or action on the costs or benefits of a semingly unrelated system already in existence. In simpler terms, a spillover cost is a detrimental effect not anticipated by the analyst. A classic example involves the use of system analyses to determine an optimum wash-tub/rinse-tub arrangement in an Army field kitchen. Using minimization of man-hours as his criteria, the analyst had determined that a maximum number of mess-kits could be cleaned in a given time if three of the four available tubs were used for washing, and the one remaining tub was used for rinsing. After implementation of the analyst's recommendations, a hypothetical conversation with the mess sergeant was reported as follows:

> Yeah, I remember that guy. He had some screwball idea that the mission of the Army was to eliminate waiting lines. Actually I had it all figured out that two was the right number of rinse tubs. With everyone rinsing in one tub the bacteria count would get way past the critical level. But we switched to one rinse tub while he was around because the old man says he's an important scientist or something and we got to humor him. Had damn near a third of the outfit out with the bellyache before we got the character off the reservation. Then we quick switched to three rinse tubs and really made a nice line. "Nothing like a good line to get the men's legs in condition," the old man says.[2]

The above example illustrates spillover effects and how easily they may be missed by the analyst.

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[2]From A. M. Mood's Review of P. M. Morse and C. E. Kimball, Methods of Operations Research, in the Journal of the Operations Research Society of America, November 1953, p. 307.

## 4.4 SUB-OPTIMIZATIONS

The term "sub-optimization" appears frequently in the literature without definition. In the interest of completeness, a brief attempt at clarification will be made in this paper.

A large corporation or government department cannot possibly subject every facet of its-operation to simultaneous analyses; the scope of the problem would be beyond the mental capacity of any analyst. Since the validity of an analysis depends on the analyst's ability to examine all the unsolved problems of choice simultaneously, most complex systems must be optimized a sub-system at a time; hence, sub-optimization. Sub-system analyses almost necessarily follow along hierarchial lines, with many specific decisions being made at lower levels of authority and broader, but relatively few, decisions being made at the highest corporate or government levels.

During his examination of a specific alternative, the analyst may find that he must make a sub-optimization of the alternative to determine its true merit. An extension of the hypothetical assembly-line situation detailed earlier in this chapter makes a good example. Assume that the factory owner owns a second factory turning out a different but highly marketable product. The owner would like to expand his second factory, but can raise only the $10,000 with which he is planning to modernize his first factory. If he is to make maximum use of his available capital, the factory owner must choose between tow alternatives: Expansion of Factory #2, or modernization of Factory #1. However, before he can make a choice, he must perform a sub-analysis of one alternative - the modernization of Factory #1, as explained in the first section of this chapter. Determining the maximum output of Factory #1 must now be called a sub-optimization, since it involves only one alternative and is subordinate to the primary analysis.



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APPENDIX I

SAMPLE FORMAT: COST-UTILITY ANALYSES; FIXED REQUIREMENTS

1. Requirements and Background Information

   a. Message Volume
   b. Speed
   c. Reliability
   d. Accuracy
   e. Urgency

2. Description of Alternatives

   a. Existing System
   b. Alternative 1
   c. Alternative 2

3. Analyses of Existing System (Modified)

   a. Input/output relationships (model)
   b. Objective cost analysis:

| | FY69 | FY70 | FY71 | FY72 | TOTAL |
|---|---|---|---|---|---|
| (1) Research & Development | | | | | |
| (2) Procurement | | | | | |
| (3) Installations | | | | | |
| (4) Training | | | | | |
| (5) Equipment Maintenance | | | | | |
| (6) Personnel Salaries | | | | | |
| (7) Expendable Supplies | | | | | |
| (8) Other | | | | | |
| TOTAL | | | | | |

c. Functional cost analyses:

| | FY69 | FY70 | FY71 | FY72 | TOTAL |
|---|---|---|---|---|---|
| (1) Function A | | | | | |
| (2) Function B | | | | | |
| (3) Function C | | | | | |
| TOTAL | | | | | |

d. Salvage value

e. Average yearly system cost:

$$\frac{\text{Total cost - salvage value}}{\text{Time span of study (years)}}$$

f. Uncertainties encountered and assumptions made in analyses

g. "Bonus" system benefits

4. <u>Analyses of Alternative 1</u>

(Repeat Step 3 for Alternative 1)

5. <u>Analyses of Alternative 2</u>

(Repeat Step 3 for Alternative 2)

6. <u>Comparison of Alternatives</u>

a. Cost analyses:

(See next page for chart)

b. Conclusions



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Sample format (cont'd):

| | EXIST. SYSTEM | ALTER. 1 | ALTER. 2 |
|---|---|---|---|
| (1) Costs: FY 69 | | | |
| FY 70 | | | |
| FY 71 | | | |
| FY 72 | | | |
| .... | | | |
| TOTAL | | | |
| (2) Salvage Value | | | |
| (3) Average Yearly Cost | | | |
| (4) "Bonus" Benefits | | | |
| a. | | | |
| b. | | | |
| c. | | | |



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