COST-EFFECTIVENESS ANALYSIS: AN APPRECIATION

E. S. Quade

October 1965

P-3248

COST-EFFECTIVENESS ANALYSIS: AN APPRECIATION

E. S. Quade*
The RAND Corporation
Santa Monica, California

This paper attempts to clarify the nature and scope of cost-effectiveness analysis and to point out its proper role as an aid to decisionmaking. It discusses, in the context of national security problems, the reliability and limitations of such analyses and ways to improve its quality.

Introduction

Cost-effectiveness is not a catchword to suggest we are doing something new, for the need to consider cost in relation to effectiveness must have occurred to the earliest planners. What is novel, however, is the marvelous refinement of methods for relating cost to performance that has taken place in the last few years and the acceptance of these methods at high policy levels where they are often proposed as a panacea for all the ills of intricate decisionmaking.

Definitions

What is a cost-effectiveness analysis? Broadly defined (too broadly for my taste) it is any analytic study designed to assist a decisionmaker identify a preferred choice from among possible alternatives. In a military context, typical analyses might tackle such questions as the extent to which aircraft should be repaired at a depot rather than on the base; the possible characteristics of a new strategic bomber and whether one should be developed or not; whether tactical air wings or carrier task forces should be substituted for U.S. ground divisions in Europe; or whether we should modify the test ban treaty now that the Chinese Communists have nuclear weapons and, if so, how. One stage of each such analysis involves a comparison of alternative courses of action in terms of their costs and their effectiveness in attaining some specific objective. This is cost-effectiveness analysis, narrowly defined. Usually this comparison takes the form of an attempt to minimize the cost implications subject to some mission requirement (which in broad problems is not likely to be measurable in dollar terms) or, conversely, to maximize some physical measure of performance subject to a budget constraint.

Since such comparisons receive the lion's share of attention by the participants, the entire study is often called a cost-effectiveness analysis. But this name emphasizes just one aspect of the study. For advice on broad questions of policy such as those related to national defense (where cost-effectiveness has been most extensively used), facets of the problem other than the comparison of alternatives may be of great significance. Among these are: the specification of sensible objectives, the determination of a satisfactory way to measure performance, the influence of considerations that can't be quantified, or the discovery of better alternatives.

Let me try to illustrate this last point with a homely example.

Suppose a family has decided to buy a television set. Not only is their objective fairly clear, but, if they have paid due attention to the advertisements, their alternatives are well-defined. The situation is then one for cost-effectiveness analysis. The only significant questions the family need answer concern the differences among the available sets in performance and cost. With a little care, making proper allowance for financing, depreciation, and maintenance, they can estimate, say, the five year procurement and operating cost of any particular set and do so with a feeling that they are well inside the ball park. They will discover, of course, that finding a standard for measuring the performance of the various sets is somewhat more difficult. For one thing, it may have many aspects--color quality, the option for remote control, portability, screen size, and so forth. But, ordinarily, one consideration--perhaps color--determines a price class. On this basis, one can look at color sets, compare costs against color quality, and determine a best buy.

Now suppose the family finds they have more money to spend and thus decide to increase their standard of living--a decision similar to one to strengthen the U.S. defense posture by increasing the military budget. This is a situation calling for a broader analysis. They first need to investigate their goals or objectives and look into the full range of alternatives--a new car, a piano, a trip to Europe. They then must find ways to measure how well these alternatives accomplish their goals and establish criteria for choice among them. Because the alternatives are so dissimilar, determining what they want to do is the major problem; how to do it and how to determine what it costs is a comparatively minor one.

In brief, to handle a broad problem adequately a study must look at the entire problem and look at it in its proper context. Characteristically, such an analysis will involve a systematic investigation of the decisionmaker's objectives and of the relevant criteria; a comparison--quantitative where possible--of the costs, effectiveness, risks, and timing associated with the alternative policies or strategies for achieving each objective; and an attempt to formulate better alternatives if those examined are found wanting. Although I prefer the

---

*Any views expressed in this paper are those of the author. They should not be interpreted as reflecting the views of The RAND Corporation or the official opinion or policy of any of its governmental or private research sponsors. Papers are reproduced by The RAND Corporation as a courtesy to members of its staff.

name "systems analysis" for the broader analysis, in what follows I'll use the term cost-effectiveness for the full range, broad and narrow, of analytic approaches to aid a decisionmaker with problems of choice.

The Essence of the Method

What is there about an analytic approach that makes it better or more useful than other ways to furnish advice--than, say, an expert or a committee? In areas such as defense planning, where there is no accepted theoretical foundation, advice obtained from experts working individually or as a committee depends largely on judgment and intuition. So does the advice from cost-effectiveness analysis. But the virtue of analysis is that it permits the judgment and intuition of experts in many fields to be combined systematically and efficiently to yield results that can transcend those of any individual or committee. The essence of the method is to construct and operate within a "model"--a simplified, stylized representation of the real world which abstracts the cause and effect relationships essential to the question being studied. Such a model--which may take such varied forms as a set of mathematical equations or a computer program, a war game, or even a purely verbal scenario--introduces a precise structure and terminology that serve primarily as a means of communication, enabling the participants in the study to make their judgments in a concrete context and with proper reference to the judgment of others. Moreover, through feedback--the results of computation, the countermoves in the war game, or the critique of the scenario--the model helps the experts to revise their earlier judgments and thus to arrive at a clearer understanding of the problem and its context.

The central importance of the model (or the models, for it may be inappropriate or absurd to attempt to incorporate all aspects of a problem in a single formulation) can be seen most readily, perhaps, by looking at its role in the choice of alternatives.

Having formulated and researched the problem --that is, clarified the issues, limited the extent of the inquiry, searched out the necessary data and relationships, discovered what objectives the decisionmaker is, or should be, trying to attain, and how to measure the extent to which they are, in fact, attained, and built various models--the process is somewhat as follows. (See chart.) To begin, the various alternatives or means by which one can hope to attain the objectives (which may have to be discovered or invented as part of the analysis) are examined by means of the models. These models tell us what we can expect from each particular alternative with respect to such things as attrition, reliability, and so forth, and what the costs are. The measure of effectiveness then tells us the extent to which each objective is attained. A criterion or rule of choice can then be used to weigh the costs against performance and thus arrange the alternatives in order of preference.

This process may be difficult to carry out. For instance, consider the estimation of total system reliability. Often this is represented by the mean time between failures (MTBF), calculated by taking the reciprocal of the sum of the reciprocals of the subsystem MTBF's. The exponential distribution is then used to obtain the probability that no system failure will occur in a time period. This simple scheme involves at least four tacit assumptions:

- o The time between failures is exponentially distributed,
- o Failures of subsystems are independent,
- o A subsystem failure implies a system failure,
- o Subsystems are utilized equally in time.

Ideally, the equations which express reliability should account for subsystem failure rates, redundancies, dependencies, and utilization. While complicated, this is not beyond the capabilities of a computer. But the estimates of the subsystem failure rates themselves depend on partial measurements and intuitive judgments of the influence of temperature, humidity, dust, shock, stress, vibration, operating cycle, and the environment. The end result may be that predictions from the reliability model are highly uncertain.

In fact, things are seldom tidy. Too often alternatives are not adequate to attain the objectives; measures of effectiveness do not really measure the extent to which the objectives are attained; the predictions from other models, as well as from the reliability model, are full of uncertainties; and other criteria which look almost as attractive as the one chosen may lead to a different order of preference. When this happens, no one is happy and we must take another approach. Dissent and discussion force modification of original ideas about objectives and alternatives are redesigned. The key to successful analysis is a continuous cycle of formulating the problem, selecting the objectives, designing better alternatives, collecting data, building new models, weighing cost against performance, questioning assumptions and data, reexamining the objectives, opening new alternatives, and so on until satisfaction is obtained or time or money forces a cutoff.

The Limitations

Analysis of this type is not only difficult to do well but even when well done there are many limitations. Some of these are due to limitations inherent in all analysis of choice. Others are due to the difficulties encountered in coping with such things as the varying times at which alternatives become available or uncertainty about the enemy. Still others are flaws or errors which, hopefully, will disappear as we learn to do better and more thorough analyses. The most dangerous source of defects, however, is an attention bias. It is frequently caused by the cherished beliefs or unconscious adherence to a "party line" that all organizations foster to some extent.

It is important to remember that all analysis of choice falls short of scientific research. No matter how we strive to maintain standards of scientific inquiry or how closely we attempt to follow scientific methods, we cannot turn cost-effectiveness analysis into science. Its objective, in contrast to that of science, is primarily to recommend--or at least to suggest--policy, rather than merely to understand and predict. Like engineering, it seeks to use the results of science to do things well and cheaply. Yet it differs from ordinary engineering in its enormous responsibility, in sometimes being forced by the nature or urgency of a problem to substitute intuition for verifiable knowledge, in the unusual difficulty of appraising--or even discovering--a value system applicable to its problems, and in the absence of ways to test its validity.

Except for this inability to verify, cost-effectiveness analysis may still look like a purely rational approach to decisionmaking, a coldly objective, scientific method free of preconceived ideas and partisan bias and judgment and intuition. But it isn't really. Human judgment is used in designing the analysis: in deciding what alternatives to consider, what factors are relevant, what the interrelations between these factors are, and what numerical values to choose. Moreover, it is human judgment which analyzes and interprets the results of the analysis. This fact --that judgment and intuition permeate all analysis--should be remembered when we examine the results that come, with apparent high precision, from analysis.

But it is the inherent limitations of the analysis, not errors, that confine it to an advisory role. I shall single out three of them for further comment: analysis is necessarily incomplete; measures of effectiveness are inevitably approximate; and ways to predict the future are lacking.

Analysis is necessarily incomplete

Time and money costs obviously place sharp limits on how far any inquiry can be carried. Other costs are important here too. For instance, we would like to find out what the Chicoms would do if we put an end to all military aid to Southeast Asia. One way to get this information would be to stop such aid. But while the immediate dollar cost would be low, the likelihood of other costs occurring in time precludes at once this type of investigation.

Still more important, however, is the general fact that even with no limitations of time or money analysis can never treat all the considerations that may be relevant. Some are intangible. For example, how some unilateral U.S. action will affect NATO solidarity or whether Congress will accept military economies that disrupt cherished institutions such as the National Guard or radically change the pattern of domestic military spending are questions that are hard to handle objectively. Considerations of this type can, and possibly should, play as important a role in the choice of alternative force postures as any idealized war outcome calculations. But ways to measure these things even approximately don't exist today and they must be handled intuitively Other issues involve moral judgments: whether national security is better served by an increase in the budget for defense or for welfare or under what circumstances the preservation of an ally is worth the risk of general war. The analyst can apply his own judgment and intuition and that of others to these considerations (at least to those of which he is aware!), thus making them part of the study and bringing them to the attention of the decision-maker. But the man with the responsibility will rightly insist on applying his own.

Measures of effectiveness are approximate

In military cost-effectiveness comparisons, measures of effectiveness are at best reasonably satisfactory approximations for indicating the attainment of such vaguely defined objectives as deterrence or victory. Sometimes the best that can be done is to find measures which point in the right direction. Consider deterrence, for instance. It exists only in the mind--and in the enemy's mind at that. We cannot, therefore, measure directly the effectiveness of alternatives we hope will lead to deterrence, but must use instead approximations such as the potential mortalities that we might inflict or the roof cover we might destroy. Consequently, even if a comparison of two force postures indicated that one could inflict 50 per cent more casualties on the enemy than the other, we could not conclude that this posture supplies 50 per cent more deterrence. In fact, since it may be important not to look too dangerous, we find arguments that the posture which threatens the greatest number of casualities may provide the least deterrence!

Moreover, we can't be as confident about the accuracy of our estimates of effectiveness as we are about our cost estimates. It is the opinion of analysts who are studying the problem of estimating potential casualties that these estimates could easily be off by factors of three or four.

In brief, we don't know how to translate a capability to create casualties (as perceived by the enemy) into deterrence, we don't know how they will compute the casualty-producing capability of our forces, and we don't even know how to do it ourselves very accurately.

Don't misunderstand me--the determination of even the dollar costs of a military action is not simple, and to trace out all the resource implications of forces and weapons that are as yet only concepts is difficult. But once we decide what we are costing, we can do fairly well.

No satisfactory way to forecast the future exists

While it is possible to forecast events to come in the sense of mapping out possible futures, there is no satisfactory way to predict a single future in terms of which we can work out the best system or determine an optimum policy. Consequently, we must consider a range of possible futures or contingencies. In any one of these we may be able to designate a preferred course of action, but we have no way to determine one for

the entire range of possibilities. We can design a force structure for a particular war in a particular place, but we have no surefire way to work out a structure that is good for the entire spectrum of future wars in all the places they may occur.

Consequently, defense planning is rich in the kind of analysis that tells what damage could be done to the United States given a particular enemy force structure, but it is poor in the kinds of analyses that evaluate how we will actually stand in relation to the Soviets in years to come.

The Virtues

In view of its defects, is cost-effectiveness reliable? If reliability has its colloquial meaning of being a measure of whether it works or not, the answer is yes. This is certainly the opinion of the decisionmakers who have made extensive use of it. As Charles J. Hitch, then Assistant Secretary of Defense, expressed it:

> In a way, it is quite ironic that the very people who are so insistent that they want the "best and most modern" in Defense hardware, are opposed to the "best and most modern" in Defense analysis and decision-making techniques.[1]

The fact that we cannot perform cost-effectiveness analyses with anything near 100 per cent confidence of perfection is no reason to rule out their use. The real argument for their use is that they provide sounder advice than the alternatives.

These alternatives have defects too. One alternative is pure intuition. It is in no sense analytic, since no effort is made to structure the problem or to establish cause and effect relationships and use them to arrive at a solution. The process is to learn everything possible about the problem, to "live with it," and to let the subconscious provide the solution.

Between pure intuition, on the one hand, and cost-effectiveness analysis, on the other, there are other sources of advice that can, in a sense, be considered to employ analysis, although the analysis is ordinarily less systematic, explicit, and quantitative. One alternative is to turn to an expert. His opinion can, in fact, be very helpful, if it results from a reasonable and impartial examination of the facts, with due allowance for uncertainty, and if his assumptions and chain of logic are made <u>explicit</u>. For if it is explicit, others can use his information to form their own considered opinion. But an expert, particularly an unbiased expert, may be hard to find. Another way of handling a problem is to turn it over to a committee. Committees, however, are much less likely than experts to make their reasoning explicit, since their findings are usually obtained by bargaining.

The danger is <u>not</u> that analysis will give the wrong advice; it may, of course, but without analysis the chances are much higher. And for some questions analysis is essential: without calculation there is no way to discover how many missiles may be needed to destroy a target system, or how arms control may affect security. Analysis offers an alternative to "muddling through"; to waiting until one can see the problem clearly and then attempting to meet the situation. Delay can be hazardous; in the world today, there could be a crisis or a weapon that could not be handled in this way. This is not to say that every aspect of such problems can be quantified or that analysis is without limitations, but only that it is not sensible to formulate policy without careful consideration of whatever relevant numbers can be discovered.

Let me draw an analogy between the decisionmaker using a study team for advice and a medical doctor using a clinical laboratory. Suppose, for example, our doctor is trying to decide whether to send his patient to a surgeon to have his stomach resected or to treat him medically for a gastric ulcer. The doctor is influenced by:

1. The technical findings of the laboratory crews. Like the decisionmaker, he might or might not be able to carry out these investigations himself, but it would not be economic for him to do so. He depends, therefore, on laboratory reports, some of which will be on cold slips of paper without comment or nuance--numbers alone. Others from the laboratory might write paragraphs or talk to the doctor or bring x-ray plates to discuss with him.

2. Observations or analyses the doctor makes himself. Some of these he puts in the form of written notes; those he can't write out he retains in his head.

3. Impressions of the risks and possibilities of success with various treatments. Some of these impressions are from his experience, others from medical reports.

Finally, like the decisionmaker, the doctor must make a judgment based on whatever facts or analyses he has. This judgment is the ultimate synthesis the doctor makes of the numerical tests, the written out but relatively diffused notes, the unrecorded conversations with technicians, and his own introspection. It is not a mere calculation, but is made on intuitive grounds. Sometimes a factor is overriding, but on the whole he just doesn't know. He could do more analysis, sometimes even risk the patient's life in order to guard it--call for a liver puncture or other dangerous procedures--but his inquiry can never be complete. His judgment, like that of every decisionmaker, must be made with uncertainties in mind.

It is easy, unfortunately, to exaggerate the degree of assistance that analysis can offer a policymaker. In almost every case, it can help him understand the relevant alternatives and the key interactions by providing an estimate of the costs, risks, and possible payoffs associated with each course of action. In so doing, the analysis may sharpen his intuition; it will certainly broaden his basis for judgment. This can almost always help the decisionmaker make a better decision than he would otherwise make, but the inherent limitations mean that a study can

seldon demonstrate, beyond all reasonable doubt, that a particular course of action is best.

Now what about quality control? Because cost-effectiveness analysis is to a large extent art, it is pointless to expect success to follow from a set of definite rules. Reliability and quality control are not applicable to an art and a high degree of accuracy in an absolute sense is meaningless and impossible. The only way to insure that the work is well done and used with its limitations in mind is through a thorough critique by others. For no individual can hope to be completely objective. The most we can hope for is that they be honest in identifying their bias.

The Future

And finally, what of the future? Resistance to the use of cost-effectiveness analysis to help in broad problems is gradually breaking down. Government and industry planning have always involved more art than science; what is happening is that the art form is changing from an ad hoc, seat-of-the-pants approach based on intuition to one based on analysis supported by intuition and experience. With this change the computer is becoming increasingly significant--as an automaton, a process controller, an information processor, and a decision aid. Its usefulness in serving these ends can be expected to grow. But at the same time, it is important to note that even the best computer is no more than a tool to expedite analysis. Those advocates who hold that decisions can be made today solely by consideration of computer calculations are not only premature in their belief (to say the least), but have a basic misunderstanding of how such calculations must, in fact, always be used. Even in the narrowest decisions, considerations not subject to any sort of quantitative analysis can always be present. Big decisions, therefore, cannot be the automatic consequence of a computer program, of cost-effectiveness analysis, or any application of mathematical models.

For broad studies, involving force posture and composition or the strategy to achieve foreign policy objectives, intuitive, subjective, even ad hoc study schemes must continue to be used--but supplemented to an increasing extent by cost-effectiveness analysis. And as ingredients of this analysis, along with an increasing use of the computer for those problems where it is appropriate, in recognition of the need for a better treatment of the nonquantifiable aspects, a greater use of techniques for the better employment of judgment, intuition, and experience can be expected. These techniques: war gaming, "scenario" writing, and the systematic interrogation of experts are on the way to becoming an integral part of cost-effectiveness analysis.

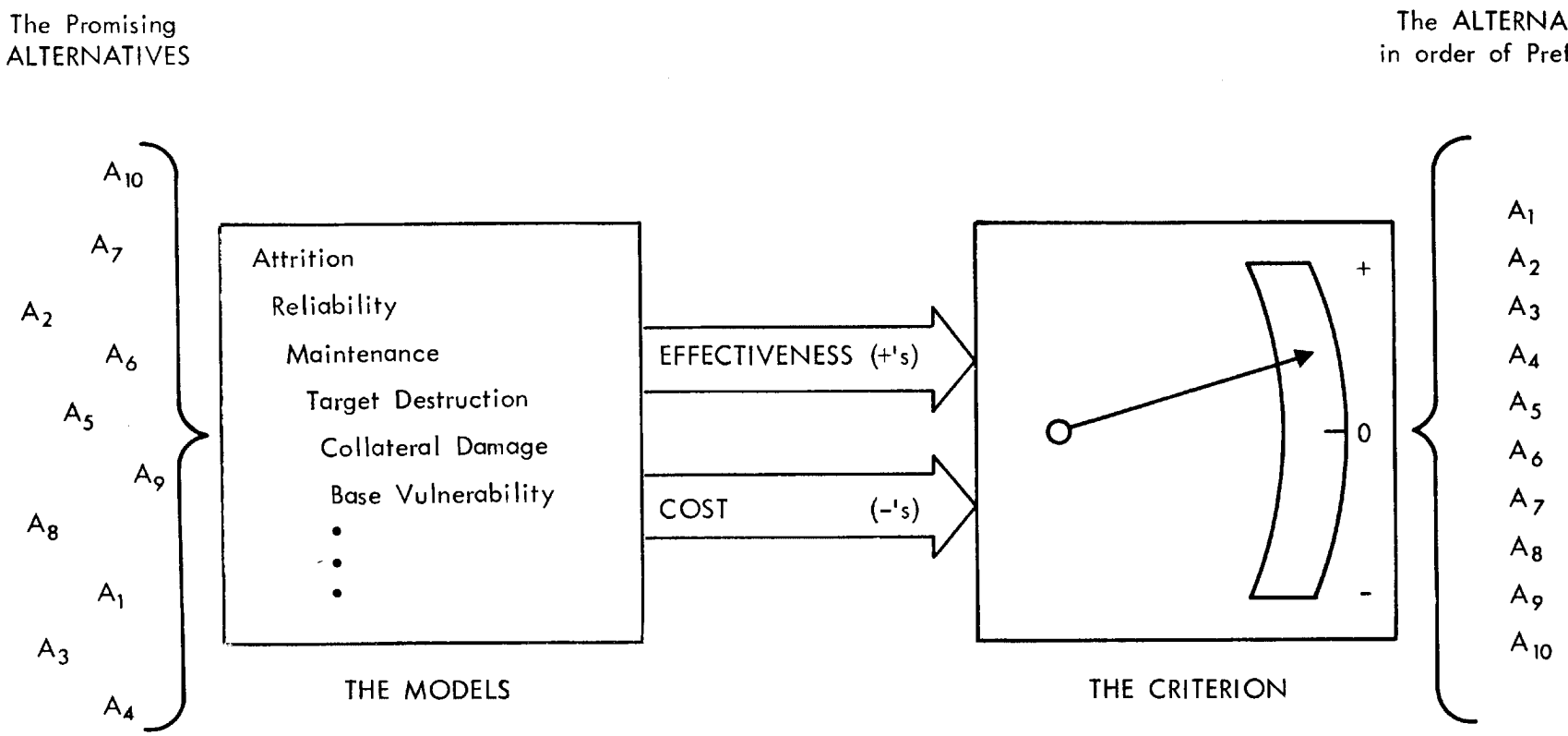
Moreover, the scope will broaden. Cost-effectiveness has barely entered the domain of the social sciences, where in urban planning, in education, in welfare, and in other nonmilitary aspects of government we are faced with an abundance of challenges: how to alleviate the hardships of social change, how to provide food and comfort for the poor, how to improve the social institutions and the values of the affluent, how to cope with revolutionary innovations, and so on. Cost-effectiveness analysis[2] can help with these problems as well as those of industry and the military.

Concluding Remarks

And now to review. A cost-effectiveness analysis is an analytic study designed to assist a decisionmaker identify a preferred choice from among possible alternatives. It is characterized by a systematic and rational approach, with assumptions made explicit, objectives and criteria clearly defined, and alternative courses of action compared in the light of their possible consequences. An effort is made to use quantitative methods but computers are not essential. What is essential is a model that enables expert intuition and judgment to be applied efficiently. The method provides its answers by processes that are accessible to critical examination, capable of duplication by others, and, more or less, readily modified as new information becomes available. And, in contrast to other aids to decisionmaking, which share the same limitations, it extracts everything possible from scientific methods, and its virtues are the virtues of those methods. At its narrowest, cost-effectiveness analysis offers a way to choose the numerical quantities related to a weapon system so that they are logically consistent with each other, with an assumed objective, and with the calculator's expectation of the future. At its broadest, it can help guide national policy. But, even within the Department of Defense, its capabilities have as yet to be fully exploited.

Bibliography

1. Hitch, Charles J., Cost/Effectiveness, Military Operations Research Symposium, Washington, D. C., April 29, 1964.
2. Helmer, Olaf, Social Technology, The RAND Corporation, P-3063, February, 1965.
3. Quade, Edward S. (ed.), Analysis for Military Decisions, Rand-McNally & Co., Chicago, 1964.



The structure of analysis