THE LIMITATIONS OF A COST-EFFECTIVENESS APPROACH TO MILITARY DECISION-MAKING

E. S. Quade

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

The analysis of weapons and strategies for future wars presents a new kind of problem, different from earlier military planning, not necessarily in any deep logical or philosophical sense, but in a practical sense. The rapid rate of change in weapons and their almost exponential increase in complexity tends to draw more attention to costs and thus less to the political and military considerations long paramount in such planning. This has brought increased, and in the opinion of many people, excessive reliance on the cost–effectiveness study as an aid to military decision–making.

Quantitative estimates of costs and effectiveness are essential to an intelligent discussion of national security. As Alain Enthoven** puts it:

> "National security policy decisions are based on the interaction of values, on the one hand, and the costs and effectiveness of military forces and weapon systems on the other. The latter are largely, though not exclusively, quantitative matters. And this is my next main point: the quantitative aspects of national security policy problems are of the first order of

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**Paper presented by Dr. Alain C. Enthoven, Deputy Assistant Secretary of Defense at the Third International Operations Research Conference in Oslo, July 1963.

> importance. Defense policy involves numbers of ships, men, divisions, missiles, bombers, and dollars. The significance of these forces for achieving our broad objectives is a quantitative matter. This is not to imply that all relevant factors can be quantified. Rather, it is to say that only in rare and exceptional cases is it possible to do a sensible job of formulating national defense policy without careful consideration of the relevant numbers."

How are these relevant numbers to be obtained? To quote from Charles J. Hitch:*

> "The selection of weapon systems, the design of forces, and the choice of the level of the national defense effort have always been essentially artistic, rather than scientific. I wish today that I could tell you that we have found a way to change all that—but I cannot. These things still involve far more art than science, but we are beginning to take advantage of a different art form.
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> This art form could be identified by several names: the most formal is probably operations research, or operations analysis. Among the conventional disciplines, it is probably most closely connected to modern economics. Perhaps it is best described as "quantitative common sense."
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> The aim of this art is to assist the decision-maker by furnishing him, insofar as possible, with quantitative estimations of the cost and effectiveness of each of the various alternative courses which he could choose. The distinguishing feature is that these estimations are based not on opinions, or on simple extrapolations of earlier doctrines, but on quantitative analyses."

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*Address by Mr. Charles J. Hitch, Assistant Secretary of Defense (Comptroller), before the U. S. Army Operations Research Symposium at Duke University, Durham, North Carolina, March 26, 1962.

The "relevant numbers" are usually obtained by means of a cost–effectiveness evaluation of force postures or weapons systems. This gives us for each set of specific assumptions—about the political and economic state of the world, the actions of the enemy, the outcome of various technological investigations, etc.—a more or less objective appraisal of, say, the effectiveness for a fixed cost of these forces or weapons toward the attainment of given goals.

Cost–effectiveness analysis may be viewed as one form of a broader approach to problems of decision, usually called system analysis.* The purpose of such analysis is to suggest a course of action by systematically examining the objectives, costs, effectiveness, and risks of alternative policies or strategies—and designing additional ones if those examined are found wanting. It represents an approach to, or way of looking at, complex problems of choice under uncertainty, such as those associated with national defense.

To form a basis for recommendations, any military systems analysis must at the very least give adequate consideration to:

1. the objectives both of the nation as a whole and of the forces that are to implement these national objectives;

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*The difference between cost–effectiveness analysis, operations research, and systems analysis is a matter of emphasis. There is no clear line of demarcation; the differences are a matter of degree. If the emphasis is on finding significant differences in the costs or resource requirements among the available alternatives for carrying out some specified task, the analysis is generally referred to as a cost–effectiveness analysis. A cost–effectiveness analysis typically stresses the determination of an adequate but least cost scheme, sometimes accepting as inputs the objective of the system or strategy and the list of alternatives. The operations–research analyst is usually trying to use mathematics, or logical analysis, to help a client improve his efficiency in a situation in which everyone has a fairly good idea of what "more efficient" means. The systems analyst, on the other hand, is likely to be forced to deal with problems in which the difficulty lies in deciding what ought to be done, not simply in how to do it. The system analysis thus puts greater attention on the suitability of the task and the augmentation of alternatives.

2. the military capabilities required to attain these objectives;
3. the technological possibilities;
4. the effectiveness of each posture, system, or plan considered;
5. the costs or resource implications of the choices;
6. the uncertainties in the above.

These things, of course, cannot be specified absolutely. They depend, for example, on such things as each other, the degree of security deemed adequate and the enemy's interpretation of our objectives and the actions we take to implement them; and they vary over time. Moreover, the entire structure is based on a set of assumptions. These assumptions, hopefully, are not arbitrary but are objective, for if action is to be taken on the basis of the analysis it is important that they, as well as the goals, be the right ones.

What are the limitations of such analysis? No categorical answer can be given, for these analyses vary greatly in thoroughness, in coverage, and in quality. As Mr. Hitch remarks further on in the speech quoted above, they certainly do not constitute anything like a panacea and in some circumstances their use may even constitute a hazard:

> ... there will always be considerations which bear on the very fundamentals of national defense which are simply not subject to any sort of rigorous, quantitative analysis. It is not even possible to draw a line between those which are and those which are not—the gamut encompasses a wealth of considerations which are more or less subject to analysis. Thus, there will necessarily be some questions which are outside the scope of our analytical technique. For this reason alone, we cannot expect a panacea. It is as if some of the digits had been left off the input keyboard of our computer. As an example, I might mention considerations of the morale

of our forces. How do you quantitatively distinguish between men who are highly motivated, and those who are demoralized? In fact, how do you quantitatively predict what it is that motivates or discourages a man? And which man? The fact that we cannot quantize such things (and there are many other similar examples) does not mean that they have no effect on the outcome of a military endeavor—it simply means that our analytical techniques cannot answer every question.

That such is the case is widely recognized, particularly by those in the military profession who have had to live with these realities. But does that mean that all analysis becomes meaningless? I think not. Every bit of the total problem that can be confidently analyzed removes one more bit of uncertainty from our process of making a choice. While I can hardly believe that any significant military problem will ever be wholly susceptible to rigorous analysis, I feel just as certain that analytical techniques can allow us to make significant choices with a very real increase in confidence.

On the second point—that such techniques constitute a potential hazard as well as a potential benefit—there is a well-known human tendency to believe the printed word. By the same token, in the design of military forces, there is a tendency to associate analysis with credibility—particularly if the magic word "computer" is mentioned. In fact, of course, the Machiavellian analyst can "prove" the most outrageous theses. But he is not the major threat—such analyses are subject to rebuttal by equally clever opponents. The real threat lies not so much in deliberate deceit as it does in our own imperfections—inadvertent omission of important factors—the pyramiding of erroneous analyses on an unsuspected fallacy—subconscious desires to substantiate one's previously committed position, and so on.

Analysis of defense problems is frequently critized as being too computer dependent and for not allowing opportunity for the exercise of judgment.

Satisfactory analysis can make extensive, but limited, use of the computer. Computers, are merely tools that can expedite the analysis, almost always extremely useful but subject themselves to certain severe limitations. For example, certain relatively

intangible factors, of great importance in national security planning and hence not negligible, are extremely difficult to quantify; loyalty, morale, resistance to change, the stability of political alliances, etc. Even the most elaborate models adapted for high-speed computers are not likely to take these factors into consideration with proper emphasis and subtlety. Practical considerations, of course, impose many simplifications on a computer representation, requiring the use of aggregate variables and the omission of many details. It frequently requires several years and many people to formulate and program an elaborate model. Thus the model is likely to be not only expensive but, more importantly, rigid. The assumptions on which a model is based inevitably call for successive corrections indicated by rapid changes in the factors which affect national security or suggested by the learning process that parallels the application of the model. The learning process is frequently hindered rather than enhanced by the use of a computer model. For it is in the nature of the process that only selected stages of the computation are readily visible to an observer while most of the intermediate steps remain hidden in the "black box" of the machine. Hence the direct influence of the variables upon one another, the knowledge of which is crucial in any intuitive reappraisal of a given theory, is generally not observable but must be inferred indirectly.

In the words of R. D. Specht, RAND analyst, speaking* about the application of modern mathematical techniques and high-speed computers to produce a neat solution from which conclusions and recommendations could be drawn:

> There are many problems in the world for which this is a sensible, even a recommended approach. There are problems impossible of solution without the use of the most powerful tools of mathematics and of computers.

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*R. D. Specht, "RAND—A Personal View of Its History," Operations Research, Vol. 8, No. 6, November–December, 1960, pp. 836–838.

> The optimal distribution of weight and thrust between the several stages of a lunar probe, the determination of its initial trajectory—these are well-defined questions and yield to neat and orderly solution. On the other hand, the stability of the thermonuclear balance or the composition of a strategic deterrent force or the character of the next generation of tactical weapons—these are not questions that may be attacked usefully in this manner, although essential fragments of these problems may be solved analytically. A trivial reason for this is that even modern techniques of analysis are not sufficiently powerful to treat these problems without brutal simplification and idealization. The major reason, however, for the inadequacy of simple optimization procedures is the central role that uncertainty plays in this sinful but fascinating world.

The uncertainties regarding the future are formidable. Our ability to predict our own objectives ten years from now is poor, let alone our ability to predict what the enemy may choose to strive for or to do on the basis of his prediction of our objectives. Although even the crudest of computer models may serve to indicate the grossly inefficient systems or strategies, basing our choice of weapons or force posture on even highly accurate cost estimates obtained as the result of a specific set of assumptions about the future is thus a highly risky business.

By the nature of the process, judgment is inherent in the analysis.

Systems analysis, particularly of the type required for military decisions, is as Mr. Hitch remarked, still largely a form of art. An art can be taught in part, but not by means of definite fixed rules which need only be followed with exactness. Thus, in systems analysis we have to do some things that we think are right but that are not verifiable, that we cannot really justify, and that are never checked in the output of the work. Also, we must accept

as inputs many relatively intangible factors derived from human judgment, and we must present answers to be used as a basis for other judgments. Whenever possible, this judgment is supplemented by inductive and numerical reasoning, but it is only judgment nonetheless.

By definition, no judgment is known to be correct. Because systems analysis ordinarily goes beyond objective analysis, it relies heavily on considered judgment. Its standard technique of constructing an appropriate model of the situation enables judgment to be applied efficiently. The model—by introducing a precise structure and terminology—serves primarily as an effective means of communication, and thereby, through a feedback process, helps the expert to arrive at a clearer understanding of his subject matter.

Analysis can be sufficient to reach a policy conclusion only when the objectives are agreed upon by the policy makers. In defense policy in particular, and in many others as well, objectives are not, in fact, agreed upon. In these cases, the choice, while ostensibly between alternatives, is really between objectives or ends. Hence, nonanalytical methods must be used for a final reconciliation of views. The consequences computed from the model may provide guidance in deciding which objectives to compromise. Usually, it is not obvious how to do this, however, and judgment must again be applied.

No matter what may be the hopes of professional analysts, the judgment applied by the decision maker in the last phase of a study limits the influence of the previous analysis. At its best, analysis can embrace only a part of a broad-scope problem, it gets no foothold at all on many subjective elements, and before it organizes an understanding of all objective elements it becomes too complex to handle.

To obtain theoretical or empirical knowledge sufficient to make a choice among alternatives frequently requires more than analysis;

development and experimentation can rarely be replaced by paper studies and computer simulation. More is involved than the collection of information and its manipulation in mathematical models. Asking the right questions, inventing promising alternatives, skillfully interpreting the results of the computations and relating them to the many nonquantitiable factors are all part of the analytic process. They are of the utmost importance and may be much more helpful in making decisions than thousands of machine computations or a thorough knowledge of sophisticated mathematical techniques. An important point to note is that computation with models and machines is valuable not merely because results are proved by these computations, but because the computations lead to more and better analysis at the intuitive level. The question of the realism of a study is a difficult problem, one that involves far more than great complexity and careful attention to detail; these things must be consistent with our knowledge of the real world and with what we are trying to accomplish.

How then can the danger of reliance on cost—effectiveness analysis in defense decisions be summarized? One, since there are factors, fundamental to considerations of national defense, that are not subject to rigorous, quantitative, computer—based analysis, it is possible that they may be neglected, or deliberately set aside, or improperly weighted in making a decision based on such analysis. Two, because the analysis may on the surface appear so scientific and rigorous it may be attributed a validity not justified in view of the many subjective judgments involved. These dangers are present to an extent with any analysis, no matter how broad and thorough.

Systematic quantitative analysis of military questions, because its predictions are ordinarily not verifiable and the urgency of its problems forces the substitution of intuition for verifiable knowledge, falls far short of being scientific research. But, in contrast to other aids to decision making, it wrings everything possible out of scientific methods, and its virtues are the virtues of those

methods. Furthermore, its limitations are shared by its alternatives. And if we exclude intuitive or "unbuttoned" judgment, then in a sense these alternatives are also analysis but less systematic and quantitative.

One alternative way to handle a problem is to turn it over to an "expert." An expert in an area where no one has had relevant experience is hard to find. His considered opinion can be very helpful if it is arrived at by a reasonable and impartial examination of the facts, with due allowance for uncertainty, and if it is made explicit. For if it is explicit, others have some chance of coming to their own considered opinion from the information he presents. But an expert is even more valuable if his knowledge and opinions can be used in association with other experts. The analytic approach, with its models and games, is essentially a device for providing a framework for the systematic exploitation of experts.

Another way to handle a problem is to turn it over to a committee. Now although there is no real reason why a committee should not engage in systematic analysis, this is not likely to happen. When committees are used, the problem is usually defined in advance. There is not likely to be a careful determination of what the problem really is—just a study of how to make it go away. Committees are much less likely than experts to make their reasoning explicit since the findings are usually obtained by bargaining. Then efforts are more likely to be directed toward consensus and acceptable compromise than toward originality and efficiency.

The alternatives to explicit analysis also necessarily involve models. However, the models involved there, by virtue of being hidden and implicit, run a much greater danger of being dangerously inadequate.

It may be that the frequent failure to take the broader systems-analytic approach leads to much of the criticism of cost-effectiveness analysis.

But even the best of systems analyses is subject to criticism that it is not sufficiently broad, complete, or realistic.

In summary, what can be said?

Cost-effectiveness analysis, in contrast to its alternatives, other than broader analysis, provides its answers by processes which are reproducible, accessible to critical examination, and readily modified as new information becomes available. At the very least, it can supply a means of choosing the numerical quantities related to a weapon system in such a manner that they are logically consistent with each other, with an assumed objective, and with the calculator's expectation of the future. But before quantitative analysis can be of assistance to the decision maker it must be tempered with and used alongside of experience, experiment, judgment, and intuition. Quantitative analysis alone cannot replace these but it can build a framework in which they can operate more profitably. There is no magic device which eliminates all uncertainty from decision making. The systems analyst does not believe that he can read the future or that his models will prove a sure guide to tomorrow. He does believe, however, that to solve successfully the problems of this hazardous world, it is necessary to bring to bear all the available resources of experience, of judgment, of intuition—and of analysis. With its emphasis on least cost, the cost-effectiveness study is likely to put too little attention on certain virtues of the broader approach which are particularly important for military planning.

First, systems analysis is as much concerned with determining what the problem really is, what ought to be done, and with devising new alternatives and objectives as it is with ranking known alternatives by dollar cost with respect to some given objective. And the dollars required are not always the best measure of the true cost.

Second, the analysis is systems oriented. It recognizes that anything taking place in one part of an activity, or organization, or weapon system is likely to have an effect on what goes on in the other parts. Rather than factoring out a part of the problem and isolating it, by neglecting interactions with other parts, the analysis tries to extend the boundaries of the "system" outward as far as is required by the problem, to determine which interdependences are significant, and to evaluate the combined impact.

Third, insofar as possible, the analysis strives to use the methods of science and to maintain the same traditions. The ideal is to be objective and quantitative with all calculations, assumptions, data, and judgments being made explicit and subject to duplication, checking, criticism, and disagreement.

Fourth, the analysis is carried out with the uncertainties in mind and treats them explicitly. When the uncertainties are great, usually the case in defense problems, it addresses the question as to which systems or policies have a clear advantage rather than the question as to precisely how much better one system is than another. The search is for gross differences in relative cost and effectiveness of alternative policies, and specifically for differences of a sort that have a chance of surviving any likely resolution of the uncertainties. It makes use of sensitivity testing to determine that the alternative designated as preferred will work well under many widely divergent contingencies and even give some sort of reasonably satisfactory performance under major catastrophe. For until at least this much is determined, the problem is not yet solved.