SYSTEMS ANALYSIS TECHNIQUES FOR
PLANNING-PROGRAMMING-BUDGETING

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March 1966
INTRODUCTION

Broadly speaking, any orderly analytic study designed to help a decisionmaker identify a preferred course of action from among possible alternatives might be termed a systems analysis. As commonly used in the defense community, the phrase "systems analysis" refers to formal inquiries intended to advise a decisionmaker on the policy choices involved in such matters as weapon development, force posture design, or the determination of strategic objectives. A typical analysis might tackle the question of what might be the possible characteristics of a new strategic bomber and whether one should be developed; whether tactical air wings, carrier task forces, or neither could 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. Systems analysis represents an approach to, or way of looking at, complex problems of choice under uncertainty that should have utility in the planning-programming-budgeting (PPB) process. Our purpose is to discuss the question of extending military systems analysis to the civilian activities of the government, to point out some of the limitations of analysis in this role, and to call attention to techniques that seem likely to be particularly useful. I will interpret the term "technique" broadly enough to range from proven mathematical algorithms to certain broad principles that seem to be often associated with successful analysis.

Some fifteen years ago a similar extension raised quite some doubt. When weapons system analysts (particularly those at The RAND Corporation) began to include the formulation of national security policy and strategy as part of their field of interest, experienced "military analysts" in the Pentagon and elsewhere were not encouraging. They held that the tools, techniques, and concepts of operations analysis, as practiced in World War II, or of weapons system optimization and selection—in which analysts had been reasonably successful—would not carry over, that strategy and policy planning were arts and would remain so.

Fortunately, these skeptics were only partially right. It is true that additional concepts and methodologies significantly different from those of earlier analysis had to be developed. But there has been substantial progress, and the years since 1961 have seen a marked increase in the extent to which analyses of policy and strategy have influenced decisionmakers on the broadest issues of national defense.

Today's contemplated extension to PPB is long overdue and possibly even more radical. Systems analysis has barely entered the domain of the social sciences. Here, in urban planning, in education, in welfare, and in other nonmilitary
activities, as Olaf Helmer remarks in his perceptive essay
"... we are faced with an abundance of challenges: how to keep the peace, how to alleviate the hardships of social change, how to provide food and comfort for the inaffluent, how to improve the social institutions and the values of the affluent, how to cope with revolutionary innovations, and so on." [1]

Since systems analysis represents an approach to, or way of looking at, any problem of choice under uncertainty, it should be able to help with these problems.

Actually, systematic analysis of routine operations is widespread throughout the civil government as well as in commerce, industry, and the military. Here analysis takes its most mathematical form—and, in a certain sense, its most fruitful role. For example, it may help to determine how Post Office pick-up trucks should be routed to collect mail from deposit boxes, or whether computers should be rented or purchased to handle warehouse inventories, or what type of all-weather landing system should be installed in new commercial aircraft. Such problems are typically an attempt to increase the efficiency of a man-machine system in a situation where it is clear what "more efficient" means. The analysis can often be reduced to the application of a well-understood mathematical discipline such as linear programming or queuing theory to a generic "model," which, by a specification of its parameters, can be made to fit a wide variety of operations. An "optimum" solution is then obtained by means of a systematic computational routine. The queuing model, for example, is relevant to many aspects of the operations of the Post Office, airports, service facilities, maintenance shops, and so on. In many instances such models may actually tell the client what his decision or plan ought to be. Analysis of this type is usually called operations research or management science rather than systems analysis, however.

*The list of references appears at the end.
There are, however, other decisions or problems, civilian as well as military, where computational techniques can help only with subproblems. Typical decisions of this latter type might be the determination of how much of the Federal budget should be allocated to economic development and what fraction of that should be spent on South America, or whether the needs of interstate transportation are better served by improved high speed rail transport or by higher performance highway turnpikes, or if there is some legislative action that might end the growth of juvenile delinquency. Such problems will normally involve more than the efficient allocation of resources among alternative uses; they are not "solvable" in the same sense as efficiency problems in which one can maximize some "pay-off" function that clearly expresses what one is trying to accomplish. Here rather, the objectives or goals of the action to be taken must be determined first. Decision problems associated with program budgeting are mainly of this type—where the difficulty lies in deciding what ought to be done as well as in how to do it, where it is not clear what "more efficient" means, and where many of the factors in the problem elude quantification. The final program recommendation will thus remain in part a matter of faith and judgment. Studies to help with these problems are systems analyses rather than operations research.*

Every systems analysis involves, at one stage, a comparison of alternative courses of action in terms of their costs and their effectiveness in attaining a specified objective. Usually this comparison takes the form of an attempt to designate the alternative that will minimize the costs, subject to some fixed performance requirement (something like reduce unemployment to less than 2% in two years or add a certain number of miles to

*For a further discussion of this distinction, see [2].
the interstate highway system), or conversely, it is an attempt to maximize some physical measure of performance subject to a budget constraint. Such evaluations are called cost-effectiveness analyses.* Since they often receive the lion's share of attention, the entire study also is frequently called a cost-effectiveness analysis. But this label puts too much emphasis on just one aspect of the decision process. In analyses designed to furnish broad policy advice other facets of the problem are of greater significance than the comparison of alternatives: the specification of sensible objectives, the determination of a satisfactory way to measure performance, the influence of considerations that cannot be quantified, or the design of better alternatives.

THE ESSENCE OF THE METHOD

What is there about the 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 urban redevelopment or welfare planning, where there is no accepted theoretical foundation, advice obtained from experts working individually or as a committee must depend largely on judgment and intuition. So must the advice from systems analysis. But the virtue of such analysis is that it permits the judgment and intuition of the experts in relevant fields to be combined systematically and efficiently. The essence of the method is to construct and operate within a "model," a simplified abstraction of the real situation appropriate to the question. Such a model, which may take such varied forms as a computer simulation, an operational game, or even a purely verbal "scenario," introduces a precise structure and terminology that serve primarily as an effective

*Or, alternatively, cost-utility and cost-benefit analyses.
means of communication, enabling the participants in the
study to exercise their judgment and intuition in a con-
crete context and in proper relation to others. Moreover,
through feedback from the model (the results of computation,
the countermoves in the game, or the critique of the
scenario), the experts have a chance to revise early
judgments and thus arrive at a clearer understanding of
the problem and its context, and perhaps of their subject
matter.*

THE PROCESS OF ANALYSIS

The fundamental importance of the model is seen in
its relation to the other elements of analysis.** There
are five all told, and each is present in every analysis
of choice and should always be explicitly identified.

1. The objective (or objectives). Systems analysis
is undertaken primarily to help choose a policy or course
of action. The first and most important task of the
analyst is to discover what the decisionmaker's objectives
are (or should be) and then how to measure the extent to
which these objectives are, in fact, attained by various
choices. This done, strategies, policies, or possible

*C. J. Hitch in Ref. [3], p. 23, states "Systems
analyses should be looked upon not as the antithesis of
judgment but as a framework which permits the judgment of
experts in numerous subfields to be utilized--to yield
results which transcend any individual judgment. This is
its aim and opportunity."

** Olaf Helmer in Ref. [1], p. 7, puts it this way:
"The advantage of employing a model lies in forcing
the analyst to make explicit what elements of a situation
he is taking into consideration and in imposing upon him
the discipline of clarifying the concepts he is using.
The model thus serves the important purpose of establish-
ing unambiguous intersubjective communication about the
subject matter at hand. Whatever intrinsic uncertainties
may becloud the area of investigation, they are thus less
likely to be further compounded by uncertainties due to
disparate subjective interpretations."
actions can be examined, compared, and recommended on the basis of how well and how cheaply they can accomplish these objectives.

2. **The alternatives.** The alternatives are the means by which it is hoped the objectives can be attained. They may be policies or strategies or specific actions or instrumentalities and they need not be obvious substitutes for each other or perform the same specific function. Thus, education, antipoverty measures, police protection, and slum clearance may all be alternatives in combating juvenile delinquency.

3. **The costs.** The choice of a particular alternative for accomplishing the objectives implies that certain specific resources can no longer be used for other purposes. These are the costs. For a future time period, most costs can be measured in money, but their true measure is in terms of the opportunities they preclude. Thus, if the goal is to lower traffic fatalities, the irritation and delay caused to motorists by schemes that lower automobile speed in a particular location must be considered as costs, for such irritation and delay may cause more speeding elsewhere.

4. **A model (or models).** A model is a simplified, stylized representation of the real world that abstracts the cause-and-effect relationships essential to the question studied. The means of representation may range from a set of mathematical equations or a computer program to a purely verbal description of the situation, in which intuition alone is used to predict the consequences of various choices. In systems analysis (or any analysis of choice), the role of the model (or models, for it may be inappropriate or absurd to attempt to incorporate all the aspects of a problem in a single formulation) is to estimate for each alternative the costs that would be incurred and the extent to which the objectives would be attained.
5. A criterion. A criterion is a rule or standard by which to rank the alternatives in order of desirability. It provides a means for weighing cost against effectiveness.

The process of analysis takes place in three overlapping stages. In the first, the formulation stage, the issues are clarified, the extent of the inquiry limited, and the elements identified. In the second, the search stage, information is gathered and alternatives generated. The third stage is evaluation.

To start the process of evaluation or comparison (see Fig. 1), the various alternatives (which may have to be discovered or invented as part of the analysis) are examined by means of the models. The models tell us what consequences or outcomes can be expected to follow from each alternative; that is, what the costs are and the extent to which each objective is attained. A criterion can then be used to weigh the costs against performance, and thus the alternatives can be arranged in the order of preference.

Unfortunately, things are seldom tidy: Too often the objectives are multiple, conflicting, and obscure; alternatives are not adequate to attain the objectives; the measures of effectiveness do not really measure the extent to which the objectives are attained; the predictions from the model are full of uncertainties; and other criteria that look almost as plausible as the one chosen may lead to a different order of preference. When this happens, we must take another approach. A single attempt or pass at a problem is seldom enough. (See Fig. 2.) The key to successful analysis is a continuous cycle of formulating the problem, selecting objectives, designing alternatives, collecting data, building models, weighing cost against performance, testing for sensitivity,
The Promising
ALTERNATIVES

A_{10}
A_7
A_2
A_6
A_5
A_9
A_8
A_1
A_3
A_4

Reliability
Maintenance
Manpower
Supply
Communications

THE MODELS

EFFECTIVENESS (+'s)

COST (-'s)

THE CRITERION

The ALTERNATIVES in order of Preference

A_1
A_2
A_3
A_4
A_5
A_6
A_7
A_8
A_9
A_{10}

Fig. 1—The structure of analysis
Fig. 2—The key to analysis
questioning assumptions and data, re-examining the objectives, opening new alternatives, building better models, and so on, until satisfaction is obtained or time or money force a cutoff.

In brief a systems analysis attempts to look at the entire problem and look at it in its proper context. Characteristically, it will involve a systematic investigation of the decisionmaker's objectives and of the relevant criteria; a comparison--quantitative insofar as possible--of the cost, effectiveness, risk, and timing associated with each alternative policy or strategy for achieving the objectives; and an attempt to design better alternatives and select other goals if those examined are found wanting.

Note that there is nothing really new about the procedures I have just sketched. They have been used, more or less successfully, by managers throughout government and industry since ancient times. The need for considering cost relative to performance must have occurred to the earliest planner. Systems analysis is thus not a catchword to suggest we are doing something new; at most, we are doing something better. What may be novel though, is that this sort of analysis is an attempt to look at the entire problem systematically with emphasis on explicitness, on quantification, and on the recognition of uncertainty. Also novel are the schemes or models used to explore the consequences of various choices and to eliminate inferior action in situations where the relationships cannot be represented adequately by a mathematical model.

Note that there is nothing in these procedures that guarantees the advice from the analysis to be good. They do not preclude the possibility that we are addressing the wrong problem or have allowed our personal biases to bar a better solution from consideration. When a study is a
poor one it is rarely because the computer wasn't powerful enough or because the methods of optimization were not sufficiently sophisticated, but because it had the wrong objective or poor criteria. There are some characteristics of a study, however, that seem to be associated with good analysis. Let me identify some of these.

PRINCIPLES OF GOOD ANALYSIS

1. It is all-important to tackle the "right" problem. A large part of the investigators' effort must be invested in thinking about the problem, exploring its proper breadth, and trying to discover the appropriate objectives and to search out good criteria for choice. If we have not chosen the best set of alternatives to compare we will not discover the best solution. But if we have chosen the wrong objective then we might find a solution to the wrong problem. Getting an accurate answer to the wrong question is likely to be far less helpful than an incomplete answer to the right question.

2. The analysis must be systems oriented. Rather than isolating a part of the problem by neglecting its interactions with other parts, an effort should be made to extend the boundaries of the inquiry as far as required for the problem at hand, to find what interdependencies are important, and to study the entire complex system. This should be done even if it requires the use of purely intuitive judgment.

An interdisciplinary team of persons having a variety of knowledge and skills is helpful here. This is not so merely because a complex problem is likely to involve many diverse factors that cannot be handled by a single discipline. More importantly, a problem looks different to, say, an economist, an engineer, a political scientist, or a professional bureaucrat, and their different approaches may contribute to finding a solution.
3. The presence of uncertainty should be recognized, and an attempt made to take it into account. Most important decisions are fraught with uncertainty. In planning urban redevelopment we are uncertain about city growth patterns, about the extent to which freeways or rapid transit systems will be used, about costs, about tax revenues, about the demand for services. For many of these things, there is no way to say with confidence that a given estimate is correct. The analyst attempts to identify these uncertainties and evaluate their impact. Often he can say the value of a parameter will be more than A but less than B. Sometimes it is possible to indicate how the uncertainty can be reduced by further testing and how long that will take. Most important, the analysis should determine the effect of uncertainty on the answers. This is done by a sensitivity analysis that shows how the answers change in response to changes in assumptions and estimates. 

The study report should include the presentation of a contingency table showing the effectiveness and cost associated with each significant alternative for various future environments and for each set of assumptions about the uncertainties.

4. The analysis attempts to discover new alternatives as well as to improve the obvious ones. The invention of new alternatives can be much more valuable than an exhaustive comparison of given alternatives, none of which may be very satisfactory.

5. While in problems of public policy or national security, the scientific method of controlled repeated experiment cannot be used, the analysis should strive to attain the standards traditional to science. These are (1) intersubjectivity: results obtained by processes that can be duplicated by others to attain the same results; (2) explicitness: use of calculations, assumptions, data, and judgments that are subject to checking, criticism,

*See, for example, Ref. [4], pp. 12-14.
and disagreement; and (3) objectivity: conclusions do not depend on personalities, reputations, or vested interests; where possible these conclusions should be in quantitative and experimental terms.

THE MODELS

As mentioned earlier, systems analysis is flexible in the models it uses. Indeed, it has to be. Mathematics and computing machines, while extremely useful, are limited in the aid they can give in broad policy questions. If the important aspects of the problem can be completely formulated mathematically or represented numerically, techniques such as dynamic programming, game theory, queuing theory, or computer simulation may be the means of providing the best solution. But in most policy analyses, computations and computers are often more valuable for the aid they provide to intuition and understanding, rather than for the results they supply.

While a computer can solve only the problems that the analyst knows conceptually how to solve himself, it can help with many others. The objection that one cannot use results which depend on many uncertain parameters represents a lack of understanding of how systems analysis can help a decisionmaker. For a study to be useful it must indicate the relative merit of the various alternatives and identify the critical parameters. The great advantage of a computerized model is that it gives the analyst the capability to do numerous excursions, parametric investigations, and sensitivity analyses and thus to investigate the ranking of alternatives under a host of assumptions. This may be of more practical value to the decisionmaker than the ability to say that a given alternative will have such and such a rank with high confidence in a very narrowly defined situation.

The type of model appropriate to a problem depends on the problem and what we know or think we know about it.

For example, suppose we are concerned with long-range economic forecasting or decisions about the development of a national economy. The type of model to use will depend on the particular economy and on the kind of
questions that must be answered. If the questions were about the United States, the model might be mathematical and possibly programmed for a computer because of its size and complexity. (By a mathematical model I mean one in which the relationships between the variables and parameters are represented by mathematical equations.) In the case of the United States, because of the vast amount of data available in the form of economic and demographic time series regarding just about every conceivable aspect of economic life, numerous mathematical and computer models have been formulated and used with more or less success.

If we are not able to abstract the situation to a series of equations or a mathematical model, some other way to represent the consequences that follow from particular choices must be found. Simulation may work. Here, instead of describing the situation directly, each element making up the real situation may be simulated by a physical object or, most often, by a digital computer using sets of random numbers, and its behavior analyzed by operating with the representation. For example, we might use computer simulation to study the economy of some Latin American country. The distinction between a computer simulation and the use of a computer to analyze a mathematical model is often a fuzzy one, but the fundamental difference is that in simulation the overall behavior of the model is studied through a case-by-case approach.

For studying the economy of a newly emerging nation such as is found in Africa, where the situation is even more poorly structured and where we have little firm knowledge of existing facts and relationships, a possible approach would be through the direct involvement of experts who have knowledge of the problem.

Ordinarily, we would like to have the judgment of more than one expert, even though their advice usually
differs. There are several ways to try for a consensus; the traditional way has been to assemble the experts in one place, to let them discuss the problem freely, and to require that they arrive at a joint answer. They could also be put to work individually, letting others seek methods for the best combined use of their findings. Or they could be asked to work in a group exercise—ranging from a simple structured discussion to a sophisticated simulation or an "operational game"—to obtain judgments from the group as a whole.

This latter approach is a laboratory simulation involving roleplaying by human subjects who simulate real-world decisionmakers. To study the economy of an underdeveloped country the various sectors of the economy might be simulated by specialized experts [5]. They would be expected, in acting out their roles, not so much to play a competitive game against one another, but to use their intuition as experts to simulate as best they could the attitudes and consequent decisions of their real-life counterparts. For instance, a player simulating a goods producing sector of the economy might, within constraints, shut down or expand manufacturing facilities, modernize, change raw material and labor inputs, vary prices and so on. There would also need to be government players who could introduce new fiscal or monetary policies and regulations (taxes, subsidies, tariffs, price ceilings, etc.) as well as social and political innovations with only indirect economic implications (social security, education, appeals to patriotism, universal military service, etc.). In laying down the rules governing the players' options and constraints and the actions taken within these rules, expert judgment is essential. It is also clear that for this problem political and sociological experts will be needed, as well as economists.
There is, of course, no guarantee that the projections obtained from such a model would be reliable. But the participating experts might gain a great deal of insight. Here the game structure—again a model—furnishes the participants with an artificial, simulated environment within which they can jointly and simultaneously experiment, acquiring through feedback the insights necessary to make successful predictions within the gaming context and thus indirectly about the real world.

Another useful technique is one that military systems analysts call "scenario writing." This is an effort to show how, starting with the present, a future state might evolve out of the present one. The idea is to show how this might happen plausibly by exhibiting a reasonable chain of events. A scenario is thus a primitive model. A collection of scenarios provides an insight on how future trends can depend on factors under our control and suggests policy options to us.

Another type of group action, somewhat less structured than the operational game, attempts to improve the panel or committee approach by subjecting the views of individual experts to each other's criticism without actual confrontation and its possible psychological shortcomings. In this approach, called the Delphi method, direct debate is replaced by the interchange of information and opinion through a carefully designed sequence of questionnaires. At each successive interrogation, the participants are given new refined information, and opinion feedback is derived by computing consensus from the earlier part of the program. The process continues until either a consensus is reached, or the conflicting views are documented fully [6] [7].

It should be emphasized that in many important problems it is not possible to build really quantitative models. The primary function of a model is "explanatory,"
to organize our thinking. As I have already stated, the essence of systems analysis is not mathematical techniques or procedures, and its recommendations need not follow from computation. What counts is the effort to compare alternatives systematically, in quantitative terms when possible, using a logical sequence of steps that can be retraced and verified by others.

THE VIRTUES

In spite of many limitations, the decisionmakers who have made use of systems analysis find it extremely useful. In fact, for some questions of national defense, 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. It may be essential in other areas also; one cannot experiment radically with the national economy or even change the traffic patterns in a large city without running the risk of chaos. Analysis offers an alternative to "muddling through" or to settling national problems by yielding to the strongest pressure group. It forces the devotees of a program to make explicit their lines of argument and talk about the resources their programs will require as well as the advantages they might produce.
It is easy, unfortunately, to exaggerate the degree of assistance that systems analysis can offer the policymaker. At most, it can help him understand the relevant alternatives and the key interactions by providing an estimate of the costs, risks, payoffs and the timespan associated with each course of action. It may lead him to consider new and better alternatives. It may sharpen the decisionmaker's intuition and will certainly broaden his basis for judgment, thus helping him make a better decision. But value judgments, imprecise knowledge, intuitive estimates, and uncertainties about nature and the actions of others mean that a study can do little more than assess some of the implications of choosing one alternative over another. In practically no case, therefore, should the decisionmaker expect the analysis to demonstrate that, beyond all reasonable doubt, a particular course of action is best.

THE LIMITATIONS

Every systems analysis has defects. Some of these are limitations inherent in all analysis of choice. Others are a consequence of the difficulties and complexities of the question. Still others are blunders or errors in thinking, which hopefully will disappear as we learn to do better and more complete analyses.

The alternatives to analysis also have their defects. One alternative is pure intuition. This is in no sense analytic, since no effort is made to structure the problem or to establish cause-and-effect relationships and operate on them to arrive at a solution. The intuitive 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 one hand, and systems analysis, on the other, other sources of advice can, in a
sense, be considered to employ analysis, although ordinarily a less systematic, explicit, and quantitative kind. One can turn to an expert. His opinion may, 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 explicit. Only then can others use his information to form their own considered opinions. But an expert, particularly an unbiased expert, may be hard to find.

Another way to handle 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. This is not to imply that a look by a "blue ribbon" committee into such problems as poverty or the allocation of funds for foreign aid might not be useful, but a committee's greatest utility is likely to be in the critique of analysis done by others.

However, no matter whether the advice is supplied by an expert, a committee, or a formal study group, the analysis of a problem of choice involves the same five elements and basic structure we discussed earlier.

It is important to remember that all policy analysis falls short of being 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 systems analysis into science. Such analysis is designed primarily to recommend—or at least to suggest—a course of action, rather than merely to understand and predict. Like engineering, the aim is to use the results of science to do things well and cheaply. Yet, when applied to national problems, the difference from ordinary engineering is apparent in the enormous responsibility involved in the unusual difficulty of appraising—or even
discovering—a value system applicable to the problems, and in the absence of ways to test the validity of the analysis.

Except for this inability to verify, systems analysis may still look like a purely rational approach to decision-making, a coldly objective, scientific method free from preconceived ideas and partisan bias and judgment and intuition.

It isn't, really. Judgment and intuition are used in designing the models; in deciding what alternatives to consider, what factors are relevant, what the inter-relations between these factors are, and what criteria to choose; and in interpreting the results of the analysis. This fact—that judgment and intuition permeate all analysis—should be remembered when we examine the apparently precise results that seem to come with such high precision analysis.

Many flaws are the results of pitfalls faced by the analyst. It is all too easy for him to begin to believe his own assumptions and to attach undue significance to his calculations, especially if they involve bitter arguments and extended computations. The most dangerous pitfall or source of defects is an unconscious adherence to a "party line." This is frequently caused by a cherished belief or an attention bias. All organizations foster one to some extent; RAND, the military services, and the civilian agencies of the government are no exception. The party line is "the most important single reason for the tremendous miscalculations that are made in foreseeing and preparing for technical advances or changes in the strategic situation" [7]. Examples are plentiful: the political advisor whose aim is so fixed on maintaining peace that he completely disregards what might happen should deterrence fail; the weaponer who is so fascinated by the startling new weapons that he has
invented that he assumes the politician will allow them to be used; the union leader whose attention is so fixed on current employment that he rejects an automatic device that can spread his craft into scores of new areas. In fact, this failure to realize the vital interdependence among political purpose, diplomacy, military posture, economics, and technical feasibility is the typical flaw in most practitioners' approach to national security analysis.

There are also pitfalls for the bureaucrat who commissions a study or gives inputs to it. For instance, he may specify assumptions and limit the problem arbitrarily. When a problem is first observed in one part of an organization, there is a tendency to seek a solution completely contained in that part. An administrator is thus likely to pose his problems in such a way as to bar from consideration alternatives or criteria that do not fit into his idea of the way things should be done; for example, he may not think of using ships for some tasks now being done by aircraft. Also, to act wisely on the basis of someone else's analysis one should, at the very least, understand the important and fundamental principles involved. One danger associated with analysis is that it may be employed by an administrator who is unaware of or unwilling to accept its limitations.

Pitfalls are one thing, but the inherent limitations of analysis itself are another. These limitations confine analysis to an advisory role. Three are commented on here: 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. The very fact
that time moves on means that a correct choice at a given
time may soon be outdated by events and that goals set
down at the start may not be final. The need for report-
ing almost always forces a cutoff. Time considerations
are particularly important in military analysis, for the
decisionmaker can wait only so long for an answer. Other
costs are important here, too. For instance, we would
like to find out what the Chinese Communists 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 this would clearly be cheap in immediate dollar
costs, the likelihood of other later costs precludes this
type of investigation.

Still more important, however, is the general fact
that, even with no limitations of time and money, analysis
can never treat all the considerations that may be relevant.
Some are too intangible—for example, how some unilateral
U.S. action will affect NATO solidarity, or whether Congress
will accept economies that disrupt cherished institutions
such as the National Guard or radically change the pattern
of domestic military spending. Considerations of this
type should play as important a role in the recommendation
of alternative policies as any idealized cost-effectiveness
calculations. But ways to measure these considerations
even approximately do not exist today, and they must be
handled intuitively. Other immeasurable considerations
involve moral judgments—for example, 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 immediate advantage is worth the
compromise of fundamental principles. The analyst can
apply his and others' judgment and intuition to these
considerations, thus making them part of the study; but
bringing them to the attention of the decisionmaker, the
man with the responsibility, is extremely important.
Measures of Effectiveness Are Approximate

In military 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 that 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 the effectiveness of alternatives we hope will lead to deterrence by some scale of deterrence, but must use instead such approximations as the potential mortalities that we might inflict or the roof cover we might destroy. Consequently, even if a comparison of two systems indicated that one could inflict 50 per cent more casualties on the enemy than the other, we could not conclude that this means the system supplies 50 per cent more deterrence. In fact, since in some circumstances it may be important not to look too dangerous, we encounter arguments that the system threatening the greatest number of casualties may provide the least deterrence!

Similarly, consider the objective of U.S. government expenditures for health. A usual measure of effectiveness is the dollar value of increased labor force participation. But, this is clearly inadequate; medical services are more often in demand because of a desire to reduce the every day aches and pains of life. Moreover, we cannot be very confident about the accuracy of our estimates. For example, one recent and authoritative source estimates the yearly cost of cancer to the United States at $11 billion, while another, equally authoritative, estimates $2.6 billion [8].

No Satisfactory Way To Predict the Future Exists

While it is possible to forecast events in the sense
of mapping out possible futures, there is no satisfactory way to predict a single future for 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 such action for the entire range of possibilities. We can design a force structure for a particular war in a particular place, but we have no 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.

In spite of these limitations, it is not sensible to formulate policy or action without careful consideration of whatever relevant numbers can be discovered. In current Department of Defense practice quantitative estimates of various kinds used extensively. Many people, however, are vaguely uneasy about the particular way these estimates are made and their increasingly important role not only in military planning but elsewhere throughout the government.

Some skepticism may be justified, for the analytical work may not always be done competently or used with its limitations in mind. There may indeed be some dangers in relying on systems analysis, or on any similar approach to broad decisions. For one thing, since many factors fundamental to problems of Federal policy are not readily amenable to quantitative treatment, they may possibly be neglected, or deliberately set aside for later consideration and then forgotten, or improperly weighed in the
analysis itself or in the decision based on such analysis. For another, a study may, on the surface, appear so scientific and quantitative that it may be assigned a validity not justified by the many subjective judgments involved. In other words, we may be so mesmerized by the beauty and precision of the numbers that we overlook the simplifications made to achieve this precision, neglect analysis of the qualitative factors, and overemphasize the importance of idealized calculations in the decision process. But without analysis we face even greater dangers in neglect of considerations and in the assignment of improper weights!

THE FUTURE

And finally, what of the future? Resistance by the military to the use of systems analysis in broad problems of strategy has gradually broken down. Both government and military planning and strategy 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. This change may come more slowly in the nonmilitary aspects of government. For one thing, the civilian employees of the government are not so closely controlled "from the top" as those in the military; also the goals in these areas are just as vague and even more likely to be conflicting.* The requirements of the integrated Planning-Programming-Budgeting system will do much to speed the acceptance of analysis for other tasks, however.

*James R. Schlesinger [2] has a slightly different view: "Thus the mere uncovering of ways to increase efficiency is not sufficient. Even where a
With the acceptance of analysis, the computer is becoming increasingly significant—as an automaton, a process controller, an information processor, and a
decision is clear to the disinterested observer, it is difficult to persuade committed men that their programs or activities should be reduced or abandoned. The price of enthusiasm is that those who have a commitment will be "sold" on their specialty and are incapable of viewing it in cold analytical terms. This may be especially true of the military establishment, where the concepts of duty, honor, and country when particularized lead to a certain inflexibility in adjusting to technological change and the new claims of efficiency. But it is also true in the civilian world: for conservationists, foresters, water resource specialists, businessmen, union leaders, or agrarians, some aspects of their value-systems run directly counter to the claims of efficiency. The economic view strikes them all as immoral as well as misleading. (After all, is it not a value judgment on the part of economists that efficiency calculations are important?)

"Even in the case of fairly low-level decisions, if they are political, systematic quantitative analysis does not necessarily solve problems. It will not convince ardent supporters that their program is submarginal. Nevertheless, quantitative analysis remains most useful. For certain operational decisions, it either provides the decisionmaker with the justification he may desire for cutting off a project or forces him to come up with a nonnumerical rationalization. It eliminates the purely subjective approach on the part of devotees of a program and forces them to change their lines of argument. They must talk about reality rather than morality. Operational research creates a bridge to budgetary problems over which planners, who previously could assume resources were free, are forced, willingly or unwillingly, to walk."
decision aid. Its usefulness in serving these ends can be expected to grow. But at the same time, it is impor-
tant to note that even the best computer is no more than a tool to expedite analysis. 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 or of any application of mathematical models.

For broad studies, intuitive, subjective, even ad hoc study schemes must continue to be used—but supple-
mented to an increasing extent by systems analysis. The ingredients of this analysis must include not only an increasing use of computer-based models for those problems where they are appropriate, but for treatment of the nonquantifiable aspects, a greater use of techniques for better employment of judgment, intuition, and experience. These techniques—operational gaming, "scenario" writing, and the systematic interrogation of experts—are on the way to becoming an integral part of systems analysis.

CONCLUDING REMARKS

And now to review. A systems analysis is an analytic study designed to help a decisionmaker identify a preferred choice 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 pro-
vides its answer 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 therefore its virtues are the virtues of those methods. At its narrowest, systems analysis has offered 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, through providing the analytic backup for the plans, programs, and budgets of the various executive departments and establishments of the Federal Government, it can help guide national policy. But, even within the Department of Defense, its capabilities have yet to be fully exploited.
REFERENCES


