SCIENTIFIC AIDS TO DECISIONMAKING --
A PERSPECTIVE

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My subject today is Scientific Aids to Decisionmaking. To make clear what I mean by this, perhaps it might be worth while to examine other aids that are used by decisionmakers. By my definition, they must be unscientific. I want to start by showing how unscientific a most common aid is -- the use of committees, even committees composed of scientists.

Now, the decisionmaking problem is as old as history and the committee has been used as an aid by decisionmakers from the beginning of time. It is still customary to appoint committees and to expect them to meet and come up with recommendations.

I want to argue today for a reappraisal of this "sure-cure" technique and to suggest some more advanced methods for arriving at decisions.

To be fair, there are some situations where committees can operate effectively. For example, they are useful when diverse points of view must be sought; certainly they are invaluable for purposes of arriving at a compromise position; they can be used to postpone a decision; and committees can relieve a decisionmaker of the responsibility for a decision. But I think that most of our important problems today are much too technical and complicated for committee solution.
Now, I probably don't have to dwell too long on this matter. You all know about committees. I would like to suggest a rather unfair test -- the test of hindsight. Look back on the work of some of the committees you are familiar with and judge for yourselves. How would you evaluate their findings? How good were their recommendations? How lasting were their "solutions"?

I have tried to use hindsight on the work of a number of committees and with very few exceptions I have found their recommendations to have been wrong, or merely stop-gaps, or even dangerous. And yet some of these committees received wide public acclaim at the time their findings were announced.

How does the scientific method differ and why is it better? Well, to start with, a committee is usually handed a problem, and told to come up with a recommendation. The problem is defined in advance and is never really analyzed. Given a problem, the very first thing that is needed is a careful and objective analysis of what the problem really is -- not just a study of its outward manifestations and how to make them go away.

For example, a committee may be asked for an answer to the question, "Is Weapon System A better than Weapon System B?"; "Which is the preferred system, the intercontinental ballistic missile or the nuclear propelled manned bomber?" Perhaps the committee should be pondering, instead, the question, "What per cent of our strategic capability should be composed of A and what per cent should be composed of B?" Or is even this the right question?

Again, a committee might be asked -- was asked, in fact -- to solve
the problem of making the air defense of the United States less vulnerable to mass raids, to saturation tactics. But the real problem is not to prevent ourselves from being destroyed in some specific manner, but from being destroyed in any way whatsoever. We must therefore consider all the possible ways in which an intelligent and determined enemy can attack us.

My point here is simply the great importance -- and difficulty -- of discovering what questions we should be asking. To get a neat answer to the wrong question may be worse than to get an incomplete answer to the right question.

After the problem has been analyzed and the objective clearly defined, we have to determine what criteria we ought to use to evaluate various solutions, to see how well they satisfy our objective. This is one of the most difficult things in the whole process of analysis.

For example, in World War II bomber tactics were chosen so as to maximize the ratio of bombs on target to aircraft lost. Used with good sense this criterion led to improved decisions; used uncritically it could have resulted in foolish tactics. If, for example, you have the problem of choosing between the purchase of warehouse A and warehouse B, you are unlikely to use merely the simple criterion of maximum space per dollar cost -- for you might then find yourself buying an inexpensive warehouse of completely insufficient capacity. My example has been too simple, but in one disguise or another this criterion of maximum ratio of returns per unit investment has been responsible for considerable grief.
A more troublesome difficulty in choosing a criterion arises when our problems involve uncertainties, as they always do when we face the future. Let me illustrate. Suppose I were to offer you a choice of two lottery tickets: one is a sure thing, a certainty of winning $1,000; the other gives you one chance in ten of winning $10,000, ten times as much as the first, but with one tenth the probability of winning. Which would you choose? We cannot fix one definite criterion for choice between these two that will apply to all individuals. My homely illustration turns up, in disguise, in many important problems. Should the military risk large losses in order to chance an exceedingly favorable outcome, or, instead, choose a policy which offers low risks and modest success?

This problem of dealing with an uncertain future is one with which we at RAND are much concerned. The problems of our military analyses have been compared to the problem of the owner of a racing stable who wants to win a horse race to be run many years hence, on a track not yet built, between horses not yet born. To make matters worse, we must contemplate the possibility that when the race is finally run, we may find that the rules have been changed, the track length altered, and horses replaced by greyhounds.

My point is that, in general, criteria are treacherous, and good ones are not easily come by. Moreover, the selection of a criterion is not a problem worked on merely by "long-hairs," but is one which, like death and taxes, must be faced by all practical men.
In designing most analyses it is necessary to introduce various simplifying assumptions. The real world is very complicated and we can't handle everything that may have some impact on the problem. The simplifying assumptions have to be examined with care to be sure that enough of the real environment has been retained to represent the context adequately. When this process has been completed, you are a long way toward determining the answer you will get. The assumptions can control the results. Sometimes it doesn't matter how you process the material, once the assumptions are made.

There is another difficulty. Many problems, or some critical parts of some problems, just don't lend themselves to analytical solution. You have to use judgment. Well, what is judgment? Judgment is just experience. But here you run into another difficulty. Today most of our serious problems lie in areas where the factors involved are so technical and where the problem itself is so broad in scope that no one can honestly claim to have experience. Take the subject of national security -- or a problem of planning industrial expansion in the face of an uncertain economic future.

We must come back to the original idea of analyzing the problem. What does this mean? It means breaking the problem down into its components. There may be many parts. Some of them we can handle by analysis, using various scientific techniques. You may have to make a mathematical model of one part of the problem; you may use other devices to examine other parts. But some of the components may still defy analytic treatment. Here, because you have broken it down into narrower fields, it may be
possible to find individuals who have direct, sound experience. When this is the case, you can draw upon their individual judgment.

Now, after these components have been studied, analytical techniques exist for combining the results, for coming up with answers, conclusions, and recommendations concerning the over-all problem. And this is the way an analytical approach to decisionmaking is handled.

What committee operates in this way? Have you ever heard of one that functions in this way?

I have been trying to describe a scientific approach to solving the tough problems which face business management and government today.

There are all sorts of ways to go about this. Literally hundreds of companies have hired "operations researchers" to conduct "in-house" analyses. In addition, a new kind of management consultant firm has emerged, identified by such words as "general analysis," "systems research," "technical operations," and so on, in their corporate titles. These new advisors to business and government are usually teams of mathematicians, economists, and physical scientists. They operate quite differently from committees.

Bringing diverse skills and ingenious new analytical techniques to bear on your problems, they are still constrained to understand the problem and to define objectives, to search diligently for all available data, to make searching tests of their assumptions, and to weigh carefully the criteria with which they must evaluate their conclusions and recommendations.

Notice that I have not yet talked at all about the giant high-speed computers, often wrongly called "electronic brains," which so many people
equate with modern decisionmaking. It has become a fad, nowadays, for business to buy high-speed computers and a staff to run them, expecting that this will give them better answers to their problems. I know of one large outfit that installed such a machine in a production facility with the expectation of scheduling its manufacturing processes so as to increase profits. This was an expensive mistake, because two years later the machine was engaged chiefly in making out the payroll checks for the accounting department.

It is wrong to assume that all you need to solve your problem is an electronic computer and people who know how to operate it. The computer is just a tool -- something you can use sometimes -- a machine that can't do anything it's not told to do. I can't stress this point too strongly, because in modern scientific analyses the solutions are only as good and as sensible as the people who define the problem, state the objectives, and choose the criteria.

I don't want to minimize the importance of computers as analytical tools. Their real function is that they make possible the application of new and powerful analytic techniques which couldn't even be considered before their advent. I am referring to such new techniques as dynamic programming, linear programming, the Monte Carlo method, and so on. Very often, a component of a complex problem can be rigorously handled only by one of these powerful new analytical tools and with the aid of a big computer.

As an illustration of such a situation, I would like to describe an exciting and realistic problem -- faced by every petroleum refinery
today -- to which the techniques of linear programming are being effectively applied to help maximize profits.

The problem facing management is this: By turning valves, setting temperatures, pressures, and starting pumps, crude oil is drawn from one or several oil fields to the refinery. Like that old song about the trumpet, it goes around and around and it comes out as several kinds of pure oils -- various grades of gasolines, stove oil, diesel oil, and fuel oil. These can be marketed at varying prices. By changing the control settings the amounts of these products can be varied. This will change the cost of operating the equipment and the revenues from sales. Now, the various components are interrelated in such a complicated manner that it is not at all obvious what is the best way to operate the equipment to maximize profits. In spite of these complex interrelations, when the system is broken down into basic functions as the first step in building a model, it turns out that there are essentially only three main kinds of activities taking place: distillation, cracking, and blending.

In the distillation activity the net effect of the flash tower, heater, fractionating towers, strippers, and so on, is to separate the crude into varying amounts of pure oils. Now, crude oils drawn from different fields will break down in different ways. Hence, there must be a separate distillation activity for each type of crude. The amount of crude that can be distilled depends on which of the several pieces of equipment turns out to be the bottleneck.

The cracking process takes one of the heavier type oils and breaks it down into lighter oils. In the case of fuel oil, it will produce a
small amount of the lighter types and leave a larger amount of the heavy oil which can be recycled back into the cracker and made into a lighter oil. A separate type of activity must be set up for cracked fuel, diesel, and stove oils.

Gasoline is not a pure oil, and in the blending process several of the lighter types of pure oils are combined.

Once the flows of these three major activities have been determined on a per-barrel basis, a mathematician finds it a simple matter to set up a linear programming model with which the managers can determine the best way to run the refinery to maximize profits. It's not quite as simple as it sounds and what the managers have to work with is a complicated matrix which displays the interrelation of the various processes, products, and profits. These must be related expertly to the various economic facts at hand -- such as the cost of crudes and the market demand and prices.

In the situation which I have just described the linear programming techniques result in what may seem to be only a minor improvement over what can be achieved by experienced refinery operators: According to the informal opinion of the oil company experts, the method permits an improvement of about 1 per cent in gross profits. However, for a major producer this can easily mean an increase in profit of $10,000 a day, which represents a 5 per cent profit increase before taxes and reinvestment.

There are many other powerful tools which the scientist can bring to bear upon some of the tough analytical problems we face today. It is up to the analyst to decide where and when these tools can profitably be brought to bear on a problem to improve the answers. It is important