# THE FORMAL REQUIREMENTS OF A SCIENCE

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# The Formal Requirements of a Science

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We are living in a crisis of the scientizing of society. In one field after another science is supplanting common sense. I recently had occasion to sit in a weapons planning meeting. As I looked around me I realized that all but two or three present were civilian scientists and technicians. The military officer in his own most vital field of work had been supplanted. Today an officer must be trained as a scientist if he is to deal effectively with strategy and weaponry, and many of them do go on for Ph.D.'s.

This has happened in many fields. It has happened in medicine (see Figure 1). There was a time when the medicine man was of minimal use. Most of what he "knew" was false. He was as likely to kill you as make you well. Then in the last three centuries science began to take over. At first the role of the scientist was to test remedies already known to practitioners. Did aqua puncture help or hurt? Was a given folk drug useful or not? Was the night air harmful? Was it better to stay in bed? These common sense practitional ideas had to be subjected to rigorous observation. In that way science was making a contribution even though common sense was still providing most of the proposals. By now, however, medicine has entered the last phase where the practitioner can no longer understand the discipline unless he is a scientist himself. It takes just as long to train an M.D. as to train a Ph.D. It requires just as high an I.Q., just as much

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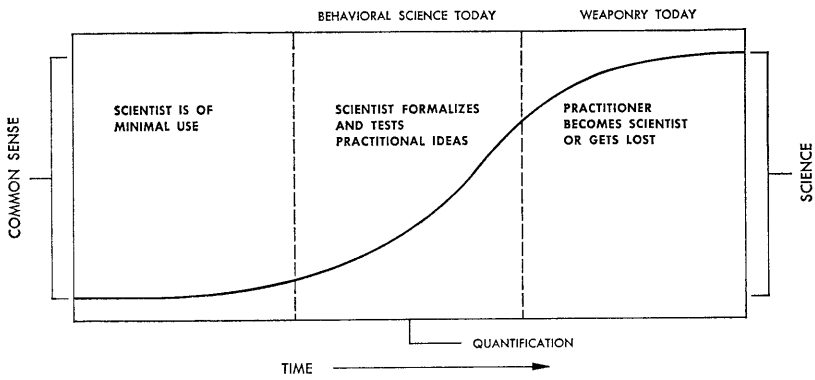
FIGURE 1. SCIENCE SUPPLANTS COMMON SENSE




experience in the laboratory, and just as much scientific knowledge. Yet the M.D. is a practitioner, not a scientist. He is not necessarily adding to our knowledge of nature. He is not discovering laws. But nonetheless he has to be just as knowledgeable of science as a scientist himself. If he is not trained as a scientist he is lost.

Like medicine, like weapons planning, so, too, marketing is not and will not become a science as such. It is an applied discipline, a profession, a practice, an engineering discipline. It uses science to answer practical questions.

In that respect it is becoming evermore scientific. We see the signs of this in the inevitable conflict between the scientist and the old-fashioned practitioner in marketing. Army officers have not given up their strategic planning function to civilian scientists without pain, nor did medicine men give in to physicians, nor Kshatriyas to Brahmins without conflict. So, too, in marketing today the researcher who comes in offering the magic of Operations Research (OR) or of statistics is only partly welcome. He is a threat to the experienced marketer.

The marketer is right in seeing him as a threat. There is no doubt that sooner or later the technician will take over from the marketer who tries to operate solely on common sense. Yet the marketer who feels threatened cannot dispense with the researcher. Often the marketer commissions research because he knows he needs it. When he listens to the results, they are vaguely disturbing but he doesn't quite know what to do. He thanks the scientist for an interesting study and says, "Come back some time, I'll phone you when I'm ready." As a temporary expedient that may succeed, for marketing is still in that

second stage of Figure 1 where the scientist is not yet ready to take over, where most of what he is testing are the practitioner's good ideas, and where the clever practitioner may still often turn out to be a lot more effective than the researcher. But it is only a matter of time before the power of research techniques will make it impossible to be a marketer without a scientific training as thorough as that of the researcher himself.

Nonetheless, I repeat, marketing is not a science but an engineering discipline. Coming from M.I.T. I am very sensitive to the confusion of these two things. A science is a set of laws, the basic form of which is: If A, then B. If a body is allowed to fall freely it will accelerate at a certain rate. If a brown-eyed individual is mated with a blue-eyed one there will be a certain proportion of brown-eyed and blue-eyed descendants.

An engineering discipline answers a different kind of question. It answers "how to" questions. It uses scientific knowledge, just as the doctor — who is a health engineer — needs scientific knowledge in order to prescribe how to get better. So, too, the bridge builder needs to know the laws of Newtonian physics to prescribe *how to* construct a bridge. But his central problem is the *how to* problem.

The difference between an engineering and a pure science is not one of its value. My engineering colleagues at M.I.T. are very sensitive to the fact that our mass media have made a hero of the scientist only. When they praise an engineer they call him a scientist. The engineers are rightly offended, for much of what is great in our civilization is its fantastic power in development and applications. Building a rocket that will go to the moon is not a scientific accomplishment, though to do it takes as much scientific training as it does to be a pure scientist. It is a massive accomplishment in logistics, quality control, systems planning, and product development. The cities, the roads, the industries which are the hallmarks of our great civilization, are themselves the work of engineers based on science. They are not works of science as such.

So when I say that marketing is not and will not be a science but that it is rapidly becoming an engineering discipline which can only be effectively practiced by men highly trained in science that is no derogation to the marketer.

Unfortunately social scientists so called — and they are usually social engineers — have an inferiority complex on this point. They want to be scientists just like the physicists whose prestige they would

like to share. They see themselves as some day becoming "social physicists" as they get around to discovering broad principles of elegant simplicity. In practice, however, they don't work like physicists. They work like system engineers. They try to predict what will happen at a particular time and place on the basis of analysis of very complex systems. They make predictions to which they attach such words as "there is a tendency." That is to say their predictions are stochastic rather than definite. They concern themselves with problems more often than with universal theories. Just as the doctor is concerned with disease, they are concerned with crime, delinquency, war, unemployment, group relations, etc.

So in practice they are acting as engineers but they talk all the time about discovering eternal truths. How likely are they to succeed? Let us consider an analogy. Which is a more intellectually challenging game, chess or roulette? I am sure most of you would say, chess. But chess is really a much simpler game. The few available moves are so well determined that one can catalogue them for several steps in advance and give the reasons why they will occur. You wouldn't even try to analyze the complex factors which determine where a roulette wheel will land on the next spin. To do so would require a room full of oscilloscopes and other equipment, masses of computations; an investment, in short, that no reasonable person would make in the game. We abandon the attempt to play roulette intellectually well because it is so hard that it is not worth the effort. Chess is sufficiently easy to entice us into trying to be rational.

The social sciences are harder than the natural sciences in the same sense that roulette is harder than chess. There are so many variables in operation that we often abandon the attempt to analyze them and fall back instead on intuition. To predict mathematically where a bouncing ball will go is not easy but it is child's play compared to predicting a vacillating customer. The social sciences, in short, are concerned with systems so complex that we will probably never be able to explain them by a few as yet undiscovered basic insights. The job will always remain one of massive systems analysis.

The only alternative to such massive systems analysis is the lazy alternative of the roulette player who leaves most of his money at home so as to reduce his risk and then plunges on the basis of gambler's intuition. We often proceed in that way in dealing with major social problems. Almost any discussion of marketing strategy will somewhere contain the statement that in addition to the various considerations

carefully measured there are also psychological and social intangibles which are essentially unpredictable. We spend millions of dollars advertising or promoting a new product and fall back in the last analysis on the hunches of the key decision makers.

That may often be the best way to proceed. If one doesn't have the mechanisms for large-scale systems observation and analysis there is nothing better to do. But that is a short-run view. Increasingly, as science takes over, some marketers will make use of the better tools becoming available and begin to change again from treating the market as roulette into treating it as chess.

There is a technique emerging for doing exactly that with complex systems. The technique for putting together the numerous calculations of the operations analyst and the numerous detailed but qualitative insights of the social researcher so as to predict outcomes of complex real world situations is simulation. It is a major break-through for the social sciences, for it offers a way of simultaneously considering the vast number of variables which interacts in real social situations. Figure 2 presents a list of some of the areas in which social simulations have been successfully carried out on computers. Economic simulations have been used to analyze particular markets (e.g., by Cohen for the hide-leather industry, or by Hoggatt and Balderston for the lumber market). They have also been used to simulate whole economies. Edward Holland is now in Venezuela heading a team, financed by the Alliance for Progress at the University of Caracas. They are applying his computer simulation to the economy of Venezuela to help that country assess the consequences over one or two decades of alternative foreign trade or investment policies.

Simulations of individual behavior have largely dealt with the thinking process under the heading of artificial intelligence. Simon, Shaw, and Newall have produced computer programs that can prove theorems in geometry and perform other operations like those of a human mind.

More to the point for today's symposium are social simulations, i.e., simulations of the complex systems produced by the interactions of groups of human beings.

Any computer process starts with a set of binary words in memory and then proceeds to modify them as instructed in the program. Social simulation may be defined by two requirements:

1. A major sub-set of the initial material placed in memory consists of words, each of which describes characteristics of a person.

2. A number of the important operations called for by the program express social science propositions.

The first requirement alone might be met by a simulation of a tank battle in which the population of drivers move their vehicles to points on a grid that result in varying probabilities of kills and misses. The computer program in this case records the physical fact of being alive or dead, not the social changes which interest us. In social simulations the program incorporates sets of propositions representing what we know in the social sciences.

Such social simulations have been tried in a number of fields as indicated in Figure 2. McPhee, Abelson, and I have worked exten-

FIGURE 2

ECONOMIC SIMULATIONS

Cohen
Hogatt, Balderston
Kuehn
Orcutt, Greenberger
Holland, Gillespie

SIMULATIONS OF INDIVIDUAL BEHAVIOR
(Artificial Intelligence)

Simon, Newell, Shaw

SIMULATIONS OF SOCIAL SYSTEMS

*Marketing*

Media-Mix (Simulmatics)
Dynamark (James Coleman)
Community Controversy (Abelson)

*Other Fields*

McPhee
Urban Redevelopment
Personnel
Nation–State System (Benson) (Abt)
Information Diffusion
Decisions and Planning (Shubik)

sively in the field of election simulation. McPhee has also developed a number of ingenious simulations concerning popular culture, fads, and other mass phenomena. Simulations are extensively used today in planning urban redevelopment and traffic movements. The flow of personnel in large corporations from recruitment to retirement constitutes a usefully simulable system. So does the balance of power among nation states or the spread of ideas, whether they'd be agricultural innovations, party preferences, or views on fluoridation — all of which have been simulated.

But our subject today is marketing. I would like to develop the application of simulation to that field.

Computer simulations can reproduce any sort of system. It may be a system of winds and clouds making the weather; of vehicles and routes making a traffic jam; of commodities and warehouses making an inventory problem. It may be a system of TV programs, magazines, and newspapers making a media schedule. It may be a system of human beings and stores making a consumer market. All these systems can be simulated.

What one needs is a system on whose pieces we have some data and some working hypotheses — but too complex, as a system, to figure out by hand arithmetic.

Marketing and advertising research provide us with some excellent examples. Let us consider the situation pre-computer. The most valuable instrument available was the sample survey. With it one can measure how many people of any given type buy any given product, know any given claim, or are exposed to any given vehicle. The result is essentially a rating. It may be a separate rating for men and women, a separate rating for young and old. But it is still a snapshot; a rating of how many do X at moment Y.

What is it that such a static picture fails to tell us? It fails to follow through how people behave with that exposure, and how they change over time. An exposure is an exposure in most advertising statistics, and that just isn't so. A person's receptiveness changes after he has already been exposed, or as he tries the product. The customer has a natural history between the start of a campaign and the final result of his becoming a regular customer or not.

It takes a complex model to follow through such sequences of change from the beginning to a predictable steady state.

One of the most commonly used types of models are Markov chains. They are very powerful mathematically but have one great

defect for social science applications. In their basic form they assume that what I do tomorrow depends above all on where I am today. They pay no attention to how I got there. And human beings don't behave that way. Unfortunately human beings have memories. What brand of orange juice I buy tomorrow depends not only on what brand I buy today but also on what I recall buying and using from a thousand yesterdays. So more complex analyses than simple Markov chains are needed, though modified Markov chains are very useful.

Simulation provides for such more complex analyses. Let me give you two examples — two examples drawn from simulations actually done for clients of the Simulmatics Corp., though, of course, disguised. The first of these is a Media-Mix simulation, the second a Dynamark simulation.

The purpose of the Media-Mix simulation is to analyze who is being reached over a long period of time by a complex advertising campaign. Rating type statistics will tell who is being reached single medium by single medium, but what of duplication among them? Rating type statistics will tell who is being reached in a single issue audience, but how does it cumulate over a year? To estimate the answers to those questions we turn to Media-Mix simulation.

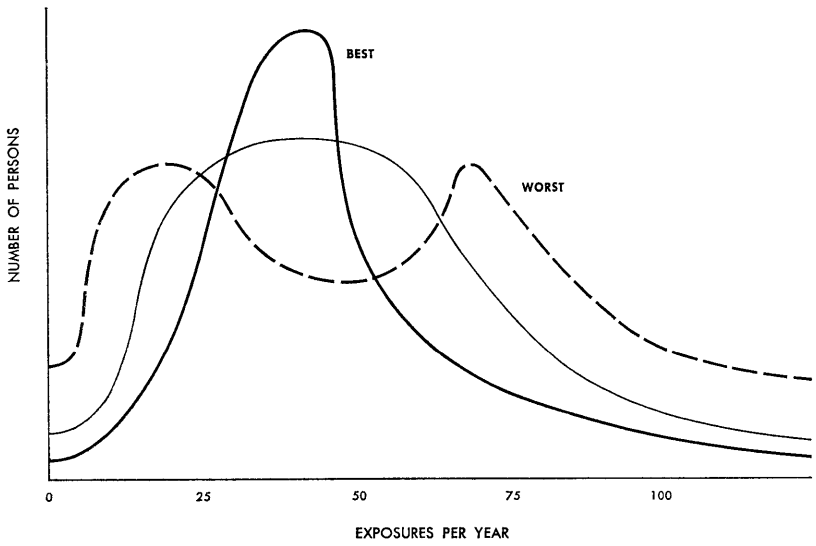
The principle of the simulation is easy, its implementation very complex.

We started by describing 3,000 hypothetical individuals, a cross section of the American public, on a computer tape. On another tape media output is described. These are brought together. Each time a person happens to be exposed to a medium, that fact is recorded. In effect, we play out the day-to-day patterns of TV viewing, newspaper and magazine reading, and other media behavior of the American people.

A lot of data had to be assembled for recording on the tapes. For each individual of the 3,000 we have what amounts to a thumbnail biography: his job, age, sex, residence, income, family size; the newspaper he reads, the magazines he reads, his preferred radio station, his preferred TV programs, the times of day he is available to watch and listen, and so on.

All this information leads to a calculation for each individual for each day. For example, what are his chances of looking at a TV program at a given time. Having established that probability we run a so-called Monte Carlo device and determine whether he was viewing. These exposures are thus cumulated for the entire sample population, for all media for the whole year.

FIGURE 3




Almost any large advertising campaign will ultimately reach almost all of the American public. But of what use is it to reach a person once or twice a year? What is needed is a sustained level of reach. For a given product suppose the median level of reach is about 40 times a year. That might be very adequate; but two campaigns might both allow a medium of 40 times a year, yet be of very different efficiency because of the nature of the distribution. One campaign might expose almost everyone between 25 and 65 times a year and that would be good. Another campaign might expose many people once, twice, or three times, only a few people at an efficient level such as around 40 times, and many other people 100 or more times.

In Figure 3 we look at results for three campaigns. Each of these is the campaign of one of our major companies all in the same convenience goods field. Note how different in efficiency the different campaigns are, yet all buy many rating points or circulation millions.

In retrospect one can see how even a skilled company can make the mistake represented by the bimodal curve. They have latched on to a small number of popular shows and media and use those repeatedly. Some people happen to be their fans and subscribers, and those people are exposed to them often. Other people have other tastes and get exposed only occasionally.

What the distribution pattern of exposures by frequency is for a given advertising campaign over time is not something easy to calculate. It is now, therefore, usually left to chance as buys are made in terms of gross exposures. Media-Mix simulation now allows one to achieve a new element of sophistication in advertising campaign analysis and Media-Mix II will allow that to be done as a routine operation.

I turn now to a second example of a marketing simulation. This example is James Coleman's Dynamark simulation which is applied to panel data for the purpose of distinguishing the impact in the market situation of advertising, promotion, consumer habits, etc. It addresses itself to such questions as:

1. What were the effects of your product's *advertising* in relation to other influences, such as promotion, on the purchasing of your product? Should your advertising be increased or decreased?
2. What were the effects of *promotion* actions by your brand in relation to other effects? Should this promotion effort be increased or decreased?
3. What were the effects of various *copy strategies?* Which were most effective?
4. Does attitude change precede or follow purchase? How does this result differ among various groups of purchasers as related to their brand loyalty, or as related to their purchase volume?
5. How does advertising affect the adoption of a brand as a "usual brand"? What effect does this, in turn, have on purchase?
6. How does promotion lead to purchase, and from there to the adoption of the brand as a "usual brand"?
7. How do purchase habits for various brands relate to each other? (Where are your product's purchasers coming from, or going to?)
8. What are the relative effects of different copy on attitudes towards each brand, and on *purchasing* of these brands?
9. Which competing brands are most vulnerable? Which can your brand attract buyers from, and how? Is this from loyal buyers of other brands, occasional buyers, or switchers?

Our model can be described by considering individuals in one of four possible positions in relation to each brand. We use just two attributes in this example for simplicity of illustration:

| | | |
|---|---|---|
| Attribute 1 | + | favorable attitude toward brand |
| | − | no favorable attitude toward brand |

| | | |
|---|---|---|
| Attribute 2 | + | recent purchase of the brand |
| | — | no recent purchase of the brand |

Cross-tabulation of these two attributes gives us four positions, with a person at a given interview in one of the four. Then examinations of the same people at a second interview allow us to cross-tabulate the 4 x 4 so that for each position of origin for each individual in the first interview we have a position of destination on the second interview (see Figure 4. We can then examine the extent to which each individual has been exposed to advertising and promotion and analyze to what extent this has influenced his purchase behavior.

In particular, we can examine the strength of the relationships in the structure from Figure 5.

**FIGURE 4. DYNAMARK MARKOV MATRIX**

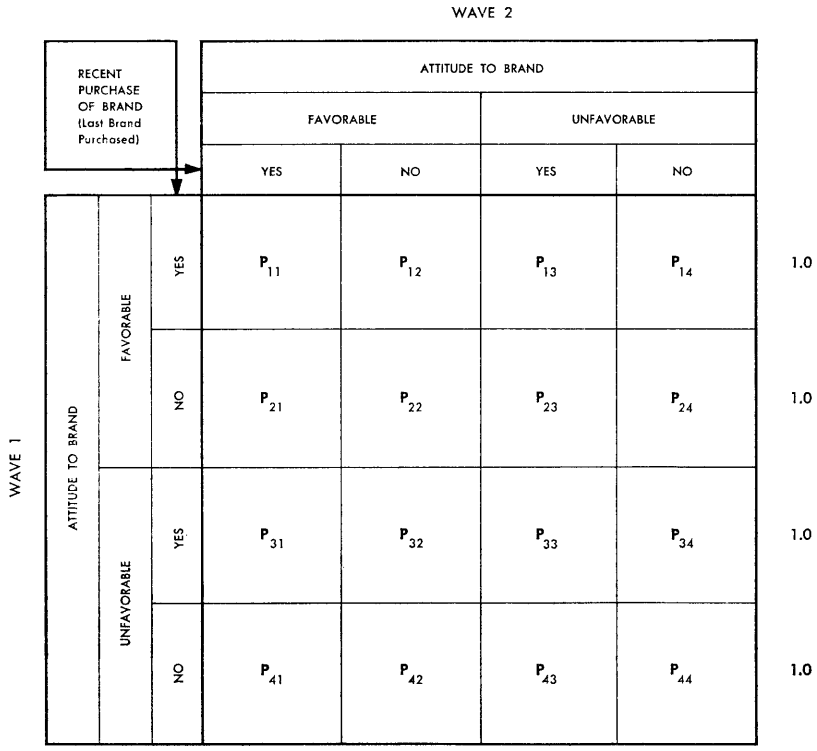
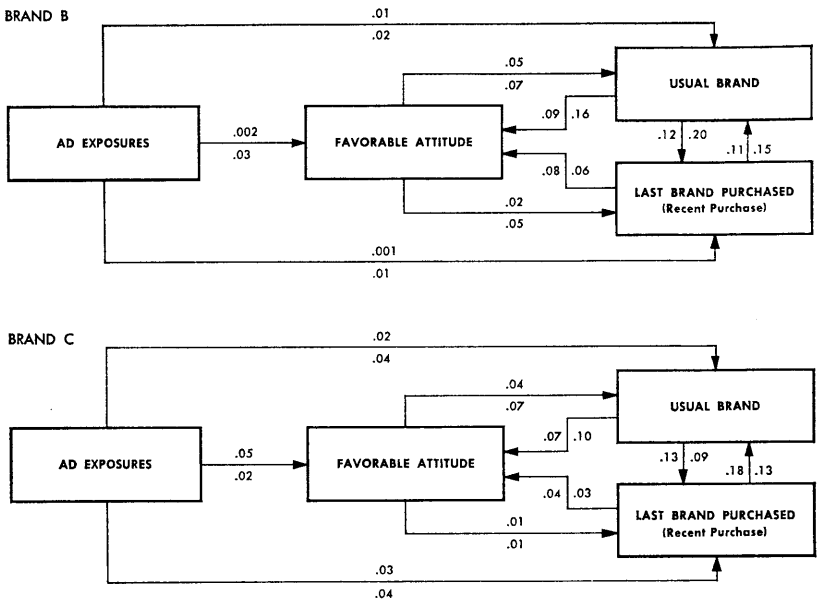


FIGURE 5




The figure shows the cause and effect relationships revealed among four variables or "attributes":

Ad Exposure
Favorable Attitude
Usual Brand (a measure of brand loyalty)
Recent Purchase (last brand purchased)

The direction of each arrow shows the direction of the causal relationship.

The figures can be interpreted as follows: Each figure is a measure of the relative strength of an increase in a given variable in causing an increase in the other variable. For example, in the figure for Brand B, the figure of .02 above the arrow going from Favorable Attitude to Recent Purchase (last brand purchased) shows that for every increase of 100 persons having a favorable attitude between the two waves of the panel, there was an increase of 2 who purchased the product recently *as a result of their favorable attitude.*

The figures *above* the arrow show the *generating* effects of each variable (or "attribute") on the other. The figures *below* each arrow are the *preserving* effects. The generating effect can be interpreted

as the effect of the given attribute in bringing about an increase in persons having the other attribute. The preserving effect can be interpreted as the effect of the attribute in *maintaining* the present level of number of persons having the other attribute.

What kinds of advice follow from such analyses? Competitor B should obviously stress improved distribution, whereas C should probably stress advertising. Advertising is indeed helping B to retain his old customers but it isn't winning him new ones. (Actions that get the product into the hands of the customers affect their attitudes very favorably, but for some reason — apparently distribution — new ones don't buy. The buyers are those who say it is their usual brand.) Competitor C, on the other hand, is clearly gaining new customers by advertising.

This analysis permits a calculation of the steady state. If this situation continues as existing at present, we can calculate what share of the market each brand will have a year hence.

These are the kinds of improved insights computer simulation can bring to the marketer.

Perhaps the most sophisticated social simulation yet developed is that of Robert Abelson of Yale and Alex Bernstein of the Simulmatics Corporation, which represents community controversies. It was first developed to analyze the public opinion processes in fluoridation referenda. It applies equally to other community controversies such as those about school bonds or to the introduction of a new product into a test market.

In a population of 500 hypothetical individuals representing a sample of a community, each has his own beliefs and predispositions about the issue, as well as his own media habits and personal contact network. In the computer words that describe each individual there are listed the arguments (from a list) that he had heard of. If he knows the issue, is it important to him, and is he for or against it? If he does not yet know of it, how is he predisposed towards it?

The simulation also allows for substantive arguments about the controversy to appear either in the mass media or in conversation. When a person is exposed to an argument it is tested for congruency with his previous beliefs or with his predispositions, and he reacts accordingly.

The heart of this simulation is a set of 27 psychological principles which determine what the individual's response to new information may be, once it gets through to him. He may accept it, reject it, forget

it, or change his previous belief. What he does is a function of who gave him the new information, his attitude toward them, how much he cares about the subject, and what he believed before. In short, a wide range of insights from common sense and from experimental social psychology are simultaneously brought to bear in assessing the impact of each exposure.

A test marketer would use a similar simulation to greatly reduce the time of his test operations or to extrapolate to changed and differing conditions from those which occurred in the test market. He would use the survey data he already collects to ascertain consumers' knowledge of and beliefs about claims, their media habits, their buying cycle, etc. He would simulate change in attitudes under different marketing strategies.

We have now given some examples of how scientific approaches may take over market planning. We have said that marketing itself is not *per se* a science. The closest analogy to the problems of marketing which can be found in scientific approaches in the physical world lie in the realm of environmental modification. The problems of epidemic control, of animal breeding, or of weather control are much like those of the marketer. In each case there is an action objective. In each case the achievement of the action objective requires detailed scientific knowledge, it requires not only knowledge of general laws but also accurate measurements from the place and time where control is being attempted.

New modes of environmental control are among the great breakthroughs of technology in our day. Planned genetics and weather control are likely to revolutionize our society far more than did the atom bomb. These things are coming soon. We can only pray that our society will be wise enough to manage them.

Those are not easy processes to manage. They are hard to predict precisely. No one proposition accounts for much of the variance. Many factors are operating simultaneously. But at the same time, if you understand the system, you can find ways to produce critical changes in it.

Let us consider the example of hurricane control. The Navy and Weather Bureau have been engaged in experiments in this area. Three times now they have sent planes to climb the eye of a hurricane to a selected point over 40,000 feet where cloud seeding would produce a sudden burst of rainfall and dramatic change in temperature. With that the hurricane veers off in a slightly different direction.

The analogies between hurricane control and market management are very striking. One can have only a limited effect on the system, for it has an autonomous movement of its own, but that limited effect can be quite critical. In the case of a hurricane, if one can indeed shift its path by a few degrees, one can save thousands of lives, but at the same time one is exercising the horrendous prerogative of choosing which people will be hit. A marketer, too, changes a society only in small degrees, but in so doing he is changing it profoundly.

A small difference can be critical, but even that small difference can only be achieved if you understand the whole system. One can easily overseed the cloud; one must get to precisely the right point in the structure of the storm. Indeed we do not fully understand the system. Two out of three times the results were similar, the third time it was different. Our mastery is incomplete, but whatever control we have depends upon working with the complex system that is there. So, too, the marketer can at best effect small changes in the share of the market or in the behavior of consumers. But these small changes may make companies and products live or die. And even these changes he can only effect regularly if he understands the system very well.

Furthermore a complex system sometimes insulates itself against planned changes. Virus strains develop immunity to antibiotics; the remedy that worked once may not work twice. In the same way the marketer who is also in the field of environmental control, finds the system takes account of what he does and learns to discount it. He, too, is coping with a self-protecting system.

In the field of environmental control as in marketing, predictions are seldom absolute. Research reduces uncertainty step by step, but one is always using intuition along with scientific knowledge. The animal breeder knows more and more of genetics, but it is still a matter of chance which possibility is born on a given trial. It is partly a matter of intuition which of an infinitely large number of alternatives to try.

We have used the word control to point out the analogue between scientific marketing and some scientific fields that deal with our natural environment. The marketer is a manager of hurricanes. Our use of the word control probably frightens some. There is a school of thought that man's growing control over his environment, and particularly his growing control over man, is a menace. Are we entering 1984, where the marketer by scientific means manipulates his customer?

There is, of course, a danger but it can be easily overstated. There

was danger when man discovered the atom bomb. There is a danger now that we are learning to control hurricanes. We will be faced with horrendous moral and political problems as we try to save some lives in an era when we will not be able to save them all. But the problem is a political one. The essential need is to keep the society that solves these questions open and competitive. One competitor's increased ability to control is offset by another's. Some will be using science to help the system insulate itself against the way others will be using science. Life in a scientific age will not be without its dilemmas and problems. But unless we let one party, one group, or one clique take over the management of the available controls, the gains in power which scientific understanding gives will always be relative, partial, and limited by the gains made by competitors who have other interests and views.