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ALFRED P. SLOAN SCHOOL OF MANAGEMENT

INTRODUCTION TO MANAGEMENT SCIENCE AND MARKETIN

David B. Montgomery** and Glen L. Urban**

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This paper is a working draft of Chapter 1 in

Management Science in Marketing

by

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CHAPTER ONE

INTRODUCTION TO MANAGEMENT SCIENCE AND MARKETING

INTRODUCTION

A Marketing Dialogue in 1988

The year is 1988. The place is the office of the marketing manager of a medium size consumer products manufacturer. The participants in the following discussion are John, the marketing manager; Bill, the director of marketing science; Rod, Bill's assistant who specializes in marketing research; and Scott, the sales manager for the company. The scene opens as Bill, Rod, and Scott enter John's office.

John: Morning Bill...Rod...Scott. What's on the agenda for this morning?

Bill: We want to take a look at the prospects for our new beef substitute.

John: What do we have on that new product?

Rod: We test-marketed it late in 1986 in four cities, so we have that data from last quarter.

John: Let's see how it did.

(All four gather around the remote console video display unit. John activates the console and requests it to display the sales results from the most recent test market. The system retrieves the data from random access storage and displays it on the video device.)

John: That looks good! How does it compare to the first test?

(The console retrieves and displays the data from the first test on command from John.)

Rod: Let me check the significance of that sales increase of the most recent test over last year's test.

(Rod requests that the system test and display the likelihood that the sales increase could be a chance occurrence.)

Rod: Looks like a solid sales increase.

Bill: Good! How did the market respond to our change in price?

(Bill commands the system to display the graph of the price-quantity response based upon the most recent test data.)

John: Is that about what our other meat substitute products show?

(John calls for past price-quantity response graphs for similar products to be superimposed on the screen.)

John: Just as I suspected -- this new product is a bit more responsive to price. What's the profit estimate?

(John calls for a profit estimate from the product planning model within the system.)

John: Hmm...$5,500,000. Looks good. Is that based upon the growth model I specified to the model bank last week?

Bill: No. This is based upon the penetration progress other food substitutes have shown in the past as well as the information we have on the beef substitute from our test markets.

John: Let's see what mine would do.

(He reactivates the product planning model, this time using his growth model. The profit implications are displayed on the console.)

John: Well, my model predicts $5,000,000. That's close. Looks like my feelings are close to the statistical results.

Bill: Let's see if there's a better marketing strategy for this product. We must remember that these profit estimates are based on the preliminary plan we developed two weeks ago.

(Bill calls for the marketing mix generator to recommend a marketing program based upon the data and judgmental inputs which are available in the data bank's file on this product.)

Bill: There, we can increase profit by $700,000 if we allocate another sales call each week to the new product committees of the chain stores.

Scott: I don't think our salesmen will go along with that. They don't like to face those committees. The best I could do is convince them to make one additional call every other week.

John: What would happen in that case?

(The marketing mix generator is called with the new restriction on the number of calls.)

John: Well, the profit increase is still $500,000, so let's add that call policy recommendation to our marketing plan. I'm a little worried about our advertising appeals, though. Can we improve in that area?

Bill: Let's see what the response to advertising is.

(The video unit shows a graph of the predicted sales-advertising response function.)

Bill: If we changed from a taste appeal to a convenience appeal, what would the results be, John?

John: I think it would look like this.

(John takes a light pen and describes a new relationship on the video unit based upon his judgment of the effectiveness of the new appeal.)

Rod: Let me check something.

(Rod calls for a sample of past sales-advertising response curves of similar products using the convenience appeal.)

Rod: I think you are underestimating the response on the basis of past data.

John: Well, this product is different. How much would it cost for a test of this appeal?

(Rod calls a market research evaluation model from the console.)

Rod: It looks like a meaningful test would cost about $5,000.

Bill: Wait! Hadn't we better check to see if the differences between these two advertising response functions will lead to any differences in profit?

(The marketing mix model is called for each advertising function.)

Bill: Looks sensitive to the advertising response, all right. There's a $900,000 difference in profit.

John: I wonder what risk we'd run if we made a decison to go national with the product right now. What are the chances of a failure with this product as it stands if we include this morning's revisions to the marketing mix?

(A risk analysis model is called on the system.)

John: Looks like a 35% chance of failure. Maybe we'd best run further tests in order to reduce the risk of failure. What's next on the agenda this morning?

The dialogue presented in this section indicates the probable environment in which future marketing decisions will be made. Marketing managers will be able to call upon powerful information systems to assist them in charting the course and evaluating the results of the firm's marketing efforts. Such systems will provide the manager with advanced modeling and statistical techniques to assist him in improving his decisions. They will also provide him with the capacity to store, retrieve, and manipulate data relevant to his decision problems. Although the dialogue was depicted as occurring in 1988, recent developments in computer technology and marketing modeling techniques may make such systems a reality in the much nearer future.

Management Science and Marketing: The Present

In the period after World War II, a new methodology for analyzing management problems emerged. The methodology has been commonly referred to as operations research or management science. This methodology has produced models and quantitative techniques such as mathematical programming, PERT, and simulation. These new techniques have found a number of successful applications in production and finanace. Marketing, however, has not experienced a parallel development. Although there is evidence of accelerating interest in the management science approach to marketing, achievements in this area remain more modest than in areas such as production and finance.

A number of factors have contributed to this relative lag in management science progress in marketing. The following six factors

would seem to be the major factors in this lag:

1. Complexity of Marketing Phenomena. The modeling of market phenomena often requires greater complexity due to the fact that response to market stimuli tend to be highly non--linear, to exhibit a threshold effect (i.e., some minimum level of the stimulus is required for there to be any response at all), to have carry-over effect (e.g., response to this period's promotion will occur in future periods), and to decay with time in the absence of further stimulation. A further consideration is the fact that market response tends to be dependent upon many factors. This multivariate nature of marketing problems injects additional complexity into marketing decisions.
2. Interaction Effects in Marketing Variables. The impact of any single controllable marketing variable is difficult to determine due to interaction of the variable with the environment and with other marketing variables. For example, the impact of promotional effort may depend upon factors in the firm's environment, such as the level of economic activity, the availability of credit, and customer expectations. Interaction with other marketing variables occurs, for example, when sales results due to promotion depend upon the level of price and distribution. These interactions within the marketing mix make it difficult to uncouple the elements in the marketing mix so that they may be analyzed independently. Other management decision areas have had more success in uncoupling the component subsystems for further analysis.
3. Competition and Marketing Decisions. The final outcomes of marketing decisions depend upon how competitors react. In many production and finance problems, competitive effects are negligible or considered exogeneous.
4. Measurement Problems in Marketing. The consumer oriented nature of marketing makes response relationships difficult, if not impossible, to observe. Recourse is often made to indirect techniques such as recall measures of advertising exposure. Production and inventory systems, on the other hand, generally require only data from physical systems within the firm. Buzzell has noted that, "It is clear... that the development of inventory models would be far more difficult if it were necessary to rely on estimates of stocks on hand as recalled by stock clerks."[1]

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[1] Robert D. Buzzell, Mathematical Models and Marketing Management (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1964), p. 74.

5. Instability of Marketing Relationships. The relationships between market responses and marketing decision variables tend to be temporally instable due to changes in tastes, attitudes, expectations, etc. This factor makes continuous market measurements and the revision of decisions crucially important in marketing.
6. Cultural Incompatibility of Marketing and Operations Research Personnel Initially, underlying cultural differences between marketing and operations research personnel formed a barrier to innovation. Marketing decision-makers usually gained their experience in the sales area of the company and were not able or willing to accept or utilize quantitative techniques. Operations researchers, on the other hand, did most of their work in the production area, which is characterized by measurable and quantifiable data. The operations research people, in general, were not interested in marketing problems because of the non-quantifiable nature of marketing and the cultural incompatability with marketing decision-makers.

The underlying explanation for these factors lies in the fact that marketing deals with behavioral rather than technological phenomena.

The preceding diagnosis of the factors contributing to marketing's past lag may encourage the reader to doubt the compatibility of marketing and management science. Other factors, however, suggest accelerated progress in the future. In the first place, the profit squeeze due to spiraling costs and increased competition is forcing firms to seek better methods for decision making. Since marketing costs are becoming a major proportion of total costs, firms will tend to focus more attention on marketing decision problems. Secondly, shortened product lives have made new products of crucial importance to the firm. The staggering failure rate of these new products is leading to the acceptance of more scientific approaches to product planning. Another factor which should help management science to advance in marketing

relates to the quantity and quality of marketing data available for decision purposes. Commercial and governmental data services are constantly expanding, while advances in psychometric procedures, especially multidimensional scaling, promise improved quality and relevance of available market data.

In addition to these factors which indicate greater pressures toward the acceptance of management science innovations, management science itself is maturing as a discipline. Advances in mathematical programming, such as integer programming, branch and bound methods for combinatorial problems, stochastic programming, and non-linear programming, enable the management scientist to treat much more complex and interrelated problems than was feasible in the past. As further evidence of the maturing capability of management science to deal with marketing problems, one could cite developments in statistical decision theory, simulation techniques, and heuristic programming. The advent of the third generation computer system, with its greatly enhanced storage capabilities, speed and software, holds great promise for implementing these new techniques in marketing. Remote consoles and graphical displays will allow considerable man-machine-data-model interaction in the future.

It is hoped that this book will contribute to the diffusion of management science methods in marketing by providing a framework for the assessment of past and potential contributions of management science to marketing problems.

..pose of This Book

This book will attempt to present an integrated discussion of the uses of management science in analyzing and solving marketing problems. This development will begin by structuring overall marketing problems from the point of view of the marketing manager. This structure will indicate the overall nature of the problems and will reflect th behavioral, quantitative, and institutional aspects of ...ing Existing management science applications to marketing will be positioned in this structure. In every problem area, the scope of each work ..ll be delineated and its relationship to other mathematical models will be outlined. The methodology of these applications will be analyzed and advantages and disadvantages of the various approaches will be discussed.

The outcome of this analysis will be a description of the state of the art of management science in marketing. In this development of the state of the art, a number of gaps in the application of modeling techniques to marketing problems and subproblems will become apparent. These gaps may reflect an undesirable definition or understanding of particular marketing problems, an unreasonable set of assumptions, or an unsatisfactory designation of factors to be considered exogenous in the analysis. The occurrence of these gaps should not be too surprising since the management science approach itself is very young, most of the literature in management science having been developed the last fifteen years. The identification of the shortcomings of previous approaches is intended to define a number of the opportunities

for the future. It is hoped that this book will supply a base for future analytic work on marketing problems. A number of the most productive avenues for advancing the management science approach in marketing will be indicated in each chapter.

It is the purpose of this book to (1) structure overall marketing problems, (2) position existing management science models in this structure, (3) indicate existing gaps in the application of management science in marketing, (4) assist the reader in developing his capacity to build and implement models for use in analyzing and solving marketing problems, and (5) indicate productive directions for future management science efforts in the area of marketing.

THE NATURE OF MANAGEMENT SCIENCE

Definition of Management Science

It is difficult to define and bound an area of study which is experiencing a constant development of new techniques that extend its scope and composition. Management science is such an area. Despite this difficulty, two prominent features are reflected in the name given to this area of study. "Management," in the context of the methodology, carries with it a strong implication of problem solving. Thus, management science is directed at understanding and solving management problems. The second component of the name is "science." This carries with it a strong implication of scientific methodology. This methodology can be described as:

1. Formulation of a problem
2. Development of a hypothesis for understanding or solving the problem (usually in the form of a model)

3. Measurement of relevant phenomena
4. Derivation of a solution or basis of understanding of the problem
5. Testing of the results
6. Revisions to reflect the testing of the hypothesis
7. Emergence of valid results

This is essentially the methodology used in the empirical physical sciences. These two aspects are central propositions of management science and lead to a definition of management science as the understanding and solution of management problems by the application of scientific methodology.

It should be noted that this definition does not restrict itself to a specific enumeration of techniques. Although management science efforts up to this time have tended to be quantitative, this is not a necessary condition for work in the area of management science. There is no natural dichotomy between quantitative and behavioral, or non-quantitative, efforts. The techniques applicable to management problems, such as operations research, econometrics, mathematics, statistics, and the behavioral sciences, are all relevant to the area of management science.

The definition of management science proposed here is very broad and is intended to include all analytical model building efforts directed at solving and understanding business problems. This will lead to a common, compatible field of knowledge that will encourage rigorous, productive analyses of the problems of management science.

Management Science Models

Before discussing the types of models used in management science, it would be useful to define what is meant by a model. A model is simply "a representation of some or all of the properties of a larger system."

he representation could be physical or abstract. For example, a wooden model airplane is a physical representation of a larger system -- the actual real world airplane. An alternate model would be a set of blueprints which represents the larger system. A third model might be a set of mathematical equations that represent the larger system.

In management science, four commonly used types of models can be identified:

1. Implicit models
2. Verbal models
3. Logical flow models
4. Mathematical models

The system may be the phenomena underlying the relevant behavior, or the system may be the decision procedure itself. In this way a model can be used as a representation of the environment or the environment as viewed through a particular decision procedure.

Implicit models are models that are not made explicit by some communicable form of representation. All decisions that are not made on the basis of an explicit model are made on the basis of an implicit model. This exhaustive classification is based on the premise that all decisions are made by the use of a model. This is not an unacceptable proposition since a "model" was defined in a very general sense as a representation of a larger system. With this definition it is clear that all decisions are made on the basis of a model, since some representation of the problem must be perceived before it can be solved or a decision reached. If the model is not recorded in communicable form, it is an implicit model that remains in the decision maker's cognitive structure until it is communicated and made explicit.

There are several methods of making an implicit model explicit. The first method is to communicate the model in the form of written or spoken words. This representation is a verbal model. The communication of the model is the first step in making it explicit. An example of a verbal pricing model may be, "follow the price of the largest firm in the industry unless it would produce losses or the price change does not appear to be permanent." This verbalization of an implicit model exposes the behavioral postulates assumed on the basis of the decision model.

The next type of model is the logical flow model.[2] This is an extension of the verbal model by the use of a diagram. The diagram makes explicit the sequence of decisions to be made and the way in which they are related. In Figure 1-1, the simple verbal decision model is described by a logical flow diagram. This formulation of a model is useful since it serves to clarify the relationships between the model's components.

The next step in model exposition is to quantify the model's components and the relationships between the components. This leads to a mathematical model. In the mathematical models, not only the sequence but also the magnitude of the interrelationships is indicated. In

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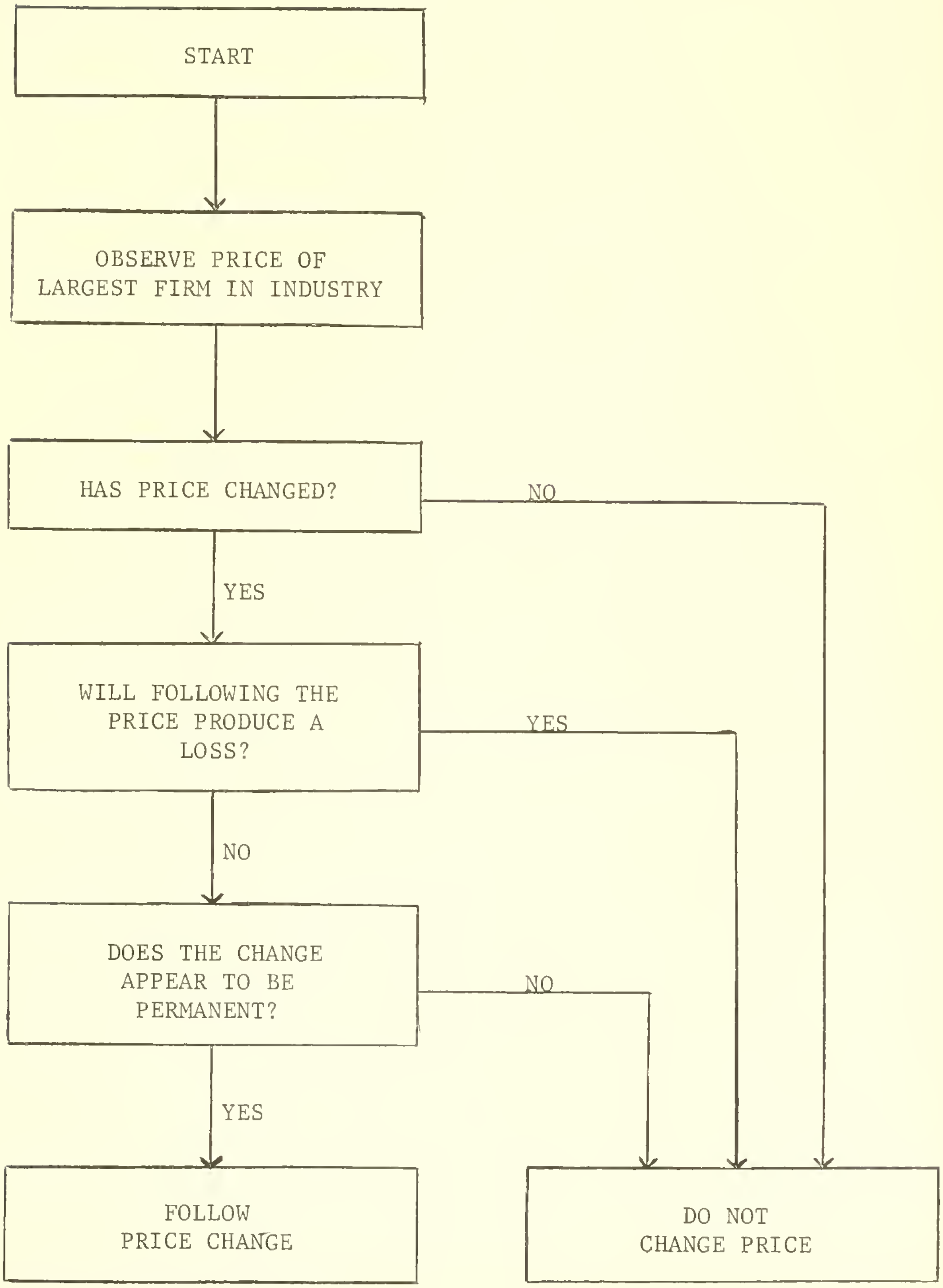
[2] See W. F. Massy and J. Saavas, "Logical Flow Models for Marketing Analysis," Journal of Marketing, Vol. XXVIII (January, 1964), pp. 32-37.

FIGURE 1-1

Logical Flow Diagram



the pricing example, a mathematical model to describe the environment might be:

$$\text{PROFIT} = U \cdot q$$

where

$$q = 0 \text{ if Price} > \text{Price of largest firm}$$
$$= 5000 \text{ if Price} \leq \text{Price of largest firm}$$

$$U = \text{Profit}$$

With this model the existing decision structure and new procedures could be tested. Mathematical models can be described in a number of ways. Two useful dimensions of classification relate to methods in which the model treats time and risk. The first classification is divided into segments: static and dynamic. That is, those models that do not consider time effects and those that do. The second classification is divided into stochastic and deterministic models. Stochastic models consider risk or probabilistic phenomena while deterministic models assume certainty of outcomes and events.

The four model types described above may be used compatibly. For example, a mathematical model may be one part of a logical flow model which is derived from a verbal description of an implicit model. The type of model to be used depends on the degree of explicitness desired in the problem or decision situation. The desired degree of explicitness depends upon the advantages that accrue to the researcher or decision maker who approaches his problems using the more formalized mathematical models. First, mathematical specification has the advantage of making assumptions overt. This renders the assumptions more open to debate, testing, and revision. Secondly, mathematical

models often provide a useful framework for measuring market phenomena. Finally, the language of mathematics is the richest framework in which to manipulate a model. Such manipulation may involve the optimization of policy functions or the explanation of "what if" types of questions. These and other uses of mathematical models are discussed in greater detail in a later section of this chapter.

Techniques for Analyzing Models.

With the understanding that a model is an implicit or explicit representation of a larger system, it is useful to examine the techniques that can be used to analyze models.

The most general technique that can be applied is to ask questions about the effects of changing the model or the inputs to the model. These "what if" questions represent experiments on the model. The technique of experimentation applied to a model is simulation. The model itself is not a simulation. Simulation is the technique of asking "what if" questions of the model. This definition implies that simulation is the process of testing alternate input or structural relationships within a model. The limit of such testing would be enumeration. In general, simulation is considered to be the testing of a small number of alternatives, but it is difficult to establish an exact number of trials for "small." To analyze a larger number of alternatives, but restrict the testing to be less than enumeration, heuristic programming can be utilized. Heuristic programming techniques are based on an orderly search procedure. This procedure is guided by a heuristic or a useful rule-of-thumb that helps restrict the search to less than enumeration.

It cannot guarantee that the best alternative will be selected, but hopefully it considers the relevant alternatives.

The three techniques of simulation, heuristic programming, and enumeration can be applied to models to generate useful information. They all involve the testing of alternatives. Enumeration examines all possibilities while simulation is thought of as testing fewer than the total number of possibilities. Heuristic programming is a search procedure which is guided by a search rule that reduces the number of tests from the number in the exhaustive set to something less.

The successive trial techniques indicated in the last paragraph are not necessarily directed at producing solutions for model problems. They explore the implications of alternatives but they do not find the best alternative by an algorithmic procedure. Several techniques may be applied to models in an attempt to generate optimal results.

The most basic optimizing technique is calculus. If certain assumptions are met, calculus can be used to identify the optimal alternative for the model.

Several algorithmic techniques are available for the analysis of models. Mathematical programming is the most prominent. Mathematical programming algorithms may be divided into linear, non-linear, integer, dynamic, and stochastic programming. These optimizing and algorithmic techniques will be reviewed in Chapter 2 of this book.

In addition to experimental and optimization methods, other techniques can be applied to models. Mathematical models that are characterized by probabilistic relationships can be analyzed by methods developed in probability and statistics. Statistical techniques can

also be valuable in measuring and testing mathematical models. Statistical decision theory and game theory are useful methods for analyzing models that depict decision situations under conditions of risk and uncertainty.

The appropriate technique to be applied in analyzing a model will depend on the structure of the model and purpose the model is expected to serve. One of the purposes of this book is to explore the appropriateness of these techniques to models that are intended to aid in marketing decisions. It is hoped that the reader will develop facility with each technique and thereby make it a tool he can use in analyzing marketing problems. The collection of these techniques should form a tool kit that can be used to solve marketing problems and to understand market phenomena. The specification of this tool kit and the instruction in how it has been and can be used in marketing is the task of this book.

Uses of Management Science Models

The definition of management science developed earlier in this chapter indicates that management science is directed at understanding and solving problems. The uses of models will be discussed within this framework. Two broad classes of uses can be identified. The first relates to the understanding of problems as reflected in problem identification, definition, and exploration. The second class of uses is related to finding solutions to problems. Both these classes of uses represent attempts to extend the manager's ability to comprehend his environment and make better decisions. In general, models are designed

to expand the "bounds of rationality" that limit the manager's ability to find optimal or good solutions to his problems.[3]

The class of uses related to problem identification, definition, and exploration can be subdivided into uses associated with descriptive and predictive models. See Figure 1-2 for the classification of model uses. Descriptive models are concerned with providing detailed and accurate representations of "larger systems." For example, in marketing, the system may be consumer behavior. A model of the system may be used to transform a large body of detailed data relating this system into a more understandable and meaningful form. For example, a model of consumer behavior may be utilized to transform test market data obtained from a consumer panel into a more relevant form. The panel data may be transformed by the model into brand switching rates or estimates of the brand loyalty characteristics of consumers. The model may indicate areas where data are needed and lead to search for this information by experimentation or statistical studies. In the example of the consumer model, the transformed data may indicate a lack of information on psychological characteristics of the panel members and lead to a special study to obtain this information. Consideration of the descriptive adequacy of the model may lead to the testing of alternate structural hypotheses and the generation of additional insights into the system. If an originally postulated consumer model does not accurately

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[3]For a discussion of limits of rationality, see Herbert A. Simon, Administrative Behavior (2d ed.; New York: Macmillan Co., 1961), pp. 80-96.

FIGURE 1-2

Uses of Management Science Models

I. Understanding Problems - Descriptive and Predictive Models

A. Descriptive Models

1. Transform data into more meaningful forms

2. Indicate areas for search and experimentation

3. Generate structural hypotheses for testing

4. Provide a framework for measurement

5. Aid in systematic thinking about problem

6. Provide bases of dispute that will lead to common understanding of problem

B. Predictive Models

1. Make forecasts of future events

2. Validate descriptive models

3. Determine sensitivity of predictions to model parameters

II. Solving Problems - Normative Models

A. Provide framework for structuring subjective feelings and determining their decision implications

B. Provide a tool for the analysis of decisions

C. Assess system implications of decision

D. Yield solutions to problems

E. Determine sensitivity of decision to the model's characteristics

F. Provide a basis for updating of decisions

describe behavior, this might suggest that alternate model formulations should be developed and tested. The testing of different model structures should help the decision maker gain a better understanding of his problem situation. The model also provides a framework that is useful in specifying the variables to be measured in gathering new data and testing hypotheses.

The explicit nature of a descriptive model will provide a basis for reconciling differing opinions about the nature of the larger system. This reconciliation of ideas should lead to systematic thinking about the problem areas. All these uses are related to improved problem solving because they lead to better problem definition and specification and understanding.

The second class of models useful in understanding problems are models which not only describe but also forecast the system's future behavior. These predictive models may be used to generate forecasts that are useful in planning and controlling the firm's efforts. A descriptive model may be used as a predictive model simply by forecasting the model's parameters and inputs and then using the model to generate a system forecast. For example, if a descriptive consumer model is given forecasted data as inputs, the output of the model will be a transformation of the forecasted data and will provide a prediction of future consumer behavior. If this forecast does not correspond to the actual results, either the descriptive model or the method of forecasting inputs may have to be revised in order to

provide a better description and prediction of system behavior. If the forecast and actual results correspond, confidence in the descriptive validity of the model will be enhanced.

Predictive models may also be used to determine the sensitivity of the model's output to the magnitudes of the variables and their structural relationships. A number of predictions could be generated by changes in the model's parameters and inputs. The magnitude of the change in the predictions could be compared to the magnitude of the parameter and input changes to measure the sensitivity of the model. If the consumer model cited as an example earlier were rerun for various psychological inputs for the consumers, the sensitivity of the output could be assessed. If the sales predictions changed greatly as the result of changes in the consumer psychological inputs, additional study would be indicated. If a model is found to be sensitive, it would then be worthwhile to determine if this was due to the nature of the model or the system being modeled. It would be important to know if the consumer model is artificially sensitive or if the psychological state of consumers is critical to sales results.

Predictive models may also be used to answer "what if" types of questions. These conditional predictions are extremely useful in exploring the implications of alternative specifications of the marketing mix or the market impact of alternative forms of competitor retaliation. For example, the manager might have a simulation model of his market environment. He might then use the model to predict market response conditional upon some specific marketing mix and some particular

mode of competitive response. These conditional predictions would assist him in evaluating the sales and profit implications of alternative marketing strategies.

The uses outlined in the last two paragraphs indicate that the application of descriptive and predictive models yields information and poses questions that are valuable in the identification, exploration, and understanding of management problems and the system in which they exist.

The second class of uses of models is related to normative models. Normative models attempt to specify how problems should be solved if some value criterion is to be optimized from the decision maker's point of view. This is in contrast to descriptive and predictive models which indicate how a system does or is expected to operate. It might be noted, however, that descriptive-predictive aspects are generally imbedded in any normative model.

The value of normative models lies in the fact that they yield solutions or recommend decisions to solve problems. In a normative sense a model and an appropriate solution technique can be powerful tools for solving problems. The model can serve as a mechanism to structure the complex empirical and subjective considerations relating to the problem. Such a model may place the problem in a total context and explicitly identify its system implications. For example, a model of the new product decision could be used to integrate the empirical and subjective information which managers possess in the areas of

demand, cost, risk, and investment. In this way, the implications of changes in one of these areas can be identified in other areas and in the decision outcome.

When this model is solved by an appropriate normative method, it will yield a solution to the problem within the limitations of the model's assumptions. To find a solution to the new product model may require a specification of the characteristics of the marketing plan, such as price, advertising, and selling levels, as well as the details of the production commitment. If these and other specifications are made, a new product solution can be specified, given the model's decision rules. A normative model may also be tested for sensitivity. If the solution is very sensitive to changes in particular inputs or parameters, this would indicate the need for more accurate data concerning that variable or parameter. Yet another useful aspect of normative models is that once they are formulated they can be used to update decisions rapidly whenever the levels of parameters are altered due to fluctuations in the environment. In the case of new products, a model might be used to evaluate the implications of early market data and assess the desirability of changing the new product's marketing plan.

Normative, descriptive, and predictive management science models may be useful in developing an understanding of problems and in finding solutions to management problems. This book will explore the usefulness of management science models in the functional problem area of marketing.

MANAGEMENT SCIENCE AND THE DECISION-INFORMATION SYSTEM

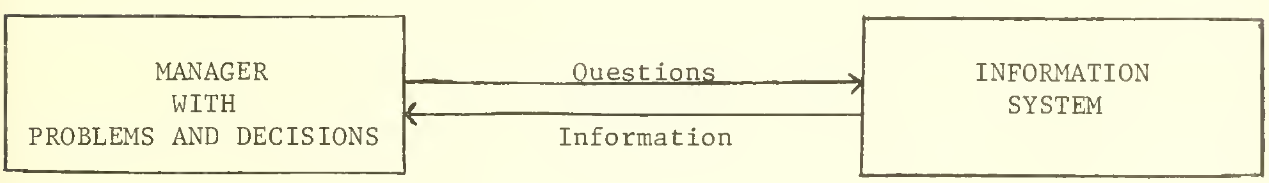
Management Science and the Man-Information Interaction

The utility and role of management science models may be interpreted within a paradigm of the decision making system of the firm. This total system will be depicted as a man-information interaction. The "man" is the manager who has a problem or a decision to make. The "information" is contained in an information system that responds to his demands and needs. This information system attempts to translate environmental information into a more relevant form. The manager questions the system and the system replies with information. (See Figure 1-3.)

The basic concept of an information system is useful in realizing the position of models in the decision structure. The information system is made up of a number of internal components. Within the system are

FIGURE 1-3

Decision-Information System



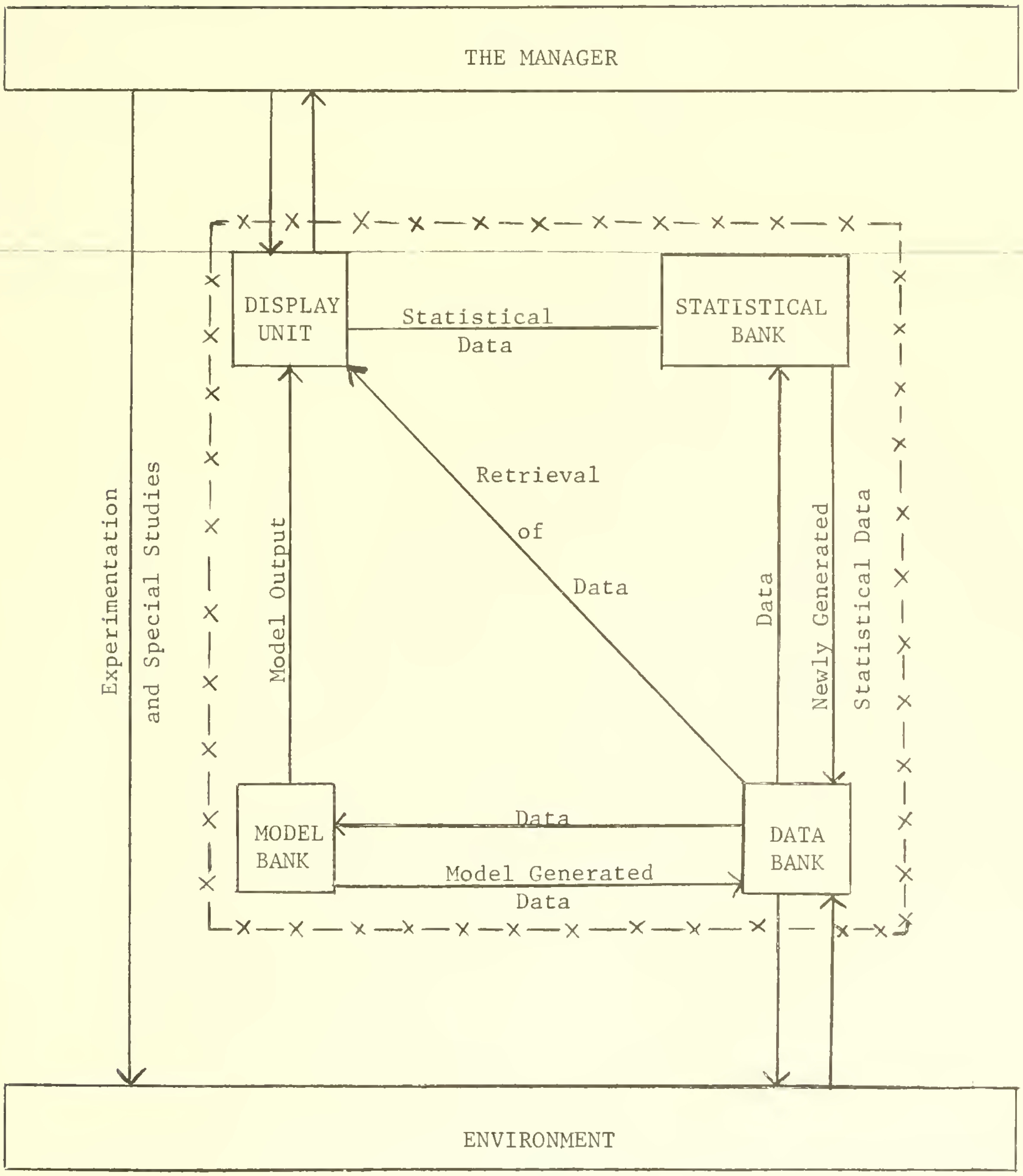
a data bank, a statistical methods bank, a model bank, and a display unit. These internal components interact with two external elements -- the manager and the environment. The environment includes all the conditions, activities, and influences affecting the firm. These components are depicted in Figure 1-4.

The environment is monitored by the information system and the resulting data are stored in a data bank. These data can be examined by the manager through the display unit after being retrieved from the data bank. A simple system depicting this retrieval function is a series of filing cabinets containing records of environmental activity. The manager can retrieve this information by instructing his secretary to find a particular file and deliver it to him. The physical file is then the display unit and the secretary serves the retrieval function with the filing cabinet functioning as the data bank. A more complex system might be a computer based system that displays data on a TV screen in the manager's office, the retrieval being performed by a computer program searching magnetic disk records that make up the data bank.

The manager may not be interested in the raw data per se. In decision purposes he will generally require the data to be processed in some manner. In the simplest case, he may want totals or averages. More complex manipulations, such as multiple regression, cluster analysis, or contingency tables, might also be desired. These are carried out within the system by the use of a statistical methods bank. This bank would have the capability of statistically manipulating the data and displaying it in the desired form on command from the manager. The data

FIGURE 1-4

Information System



Information System Boundaries - —X— X—

transformed in this manner may also be sent back to the data bank to be stored for retrieval or use at a later time.

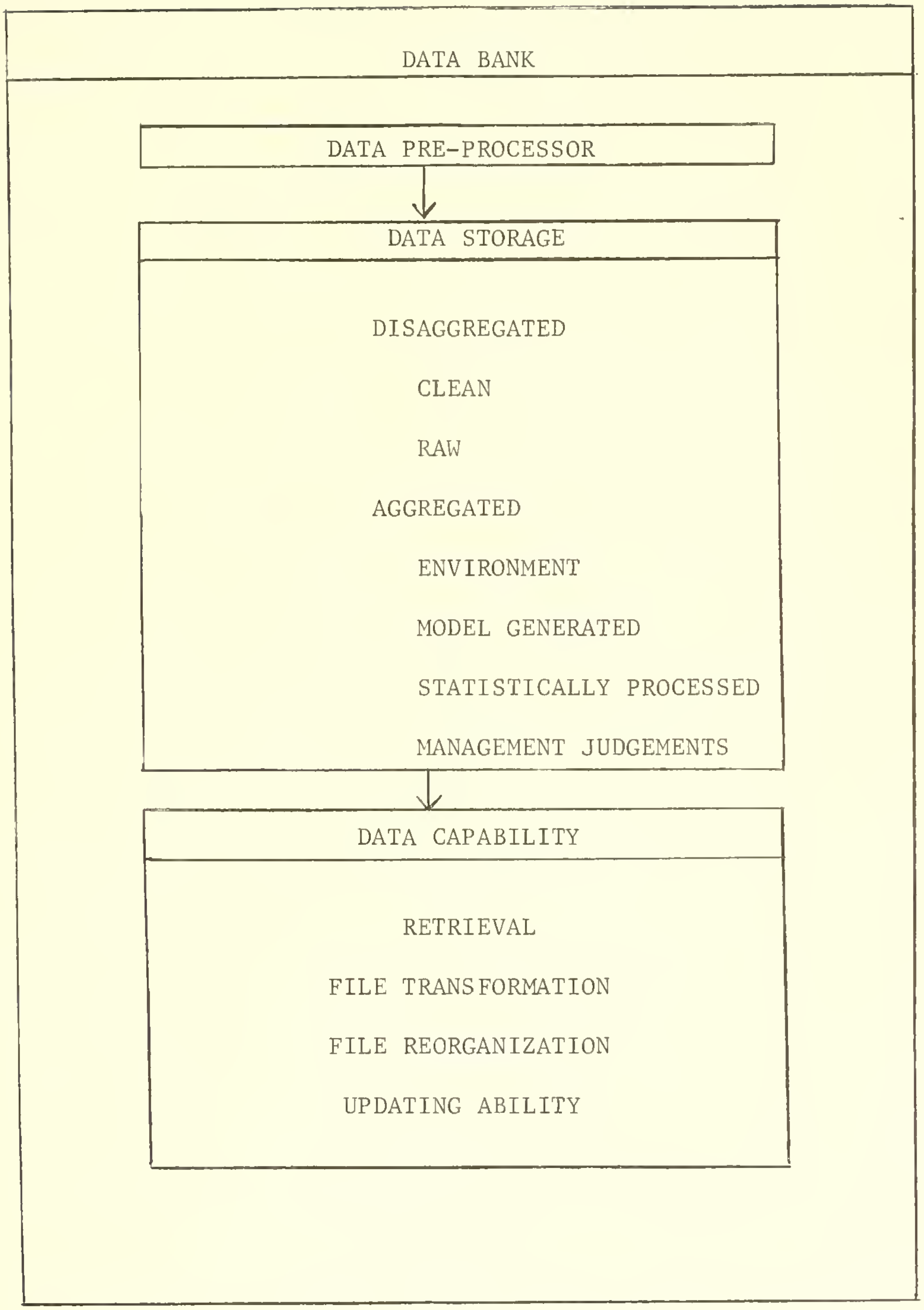
The manager may address the system with a request for information that is interpreted in terms of this particular decision. A model bank would contain management science models that are designed to solve particular problems. He can call upon one of these models to transform input data from the data bank in the hope of achieving help in understanding and solving his problem. This input data may be the original or it may be the output of a descriptive or predictive model. The model output would be displayed and could then be stored in the data bank for future retrieval and display. If the manager is not satisfied with the retrieved, statistically manipulated, or model generated data, he can initiate tests that will generate new data. His requests for experimentation in the external environment will generate results that will be monitored by the system and stored in the data bank. This new data may then be displayed for the manager's use in making decisions, formulating new models, and understanding his environment. With this brief outline of the information system, each component will now be analyzed in more detail.

The Data Bank

The data bank represents the system's first contact with the environment. The data bank serves as a store house for the information that the firm views as relevant for its decisions. A typical data bank structure is outlined in Figure 1-5. This data bank has a data

FIGURE 1-5

Data Bank



pre-processor associated with it. The pre-processor can be used to code and clean data. Clean data are data that are correctly recorded and organized. Since errors may occur in data during collection and preparation for processing, the data will need to be cleaned before it is in suitable form for display to management or for use in models.[4] The pre-processor may not be used to clean all data. Highly referenced and used data will probably be cleaned as it is admitted to the bank, while other data may be directly stored and cleaned only when it is used. The cleaning activities of the data pre-processor lead to two classes of data -- clean and raw.

The type of information entering the bank may be in aggregated or disaggregated form. Disaggregated data are data that are expressed in elemental bits of information. For example, a salesman's call report generates disaggregated data if the minute details of the calls such as person visited, time of visit, place of visit, time of waiting, are recorded. Aggregate data are data that represent combinations of disaggregated data. In the case of call reports, the number of calls carried out by the total sales force would be an example of aggregate data. The appearance of aggregate data in the data bank may reflect monitoring of this sort of aggregated data or aggregated data generated by the statistical bank, model bank, or managerial input to the system that reflects the subjective feelings and judgments of the firm's executives.

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[4]For a further discussion of data handling needs, see D. B. Montgomery, "Computer Uses in Marketing Research: A Proposal," Journal of Marketing Research (May, 1967), pp. 195-198.

The last element of the data bank is a data processing capability. The first aspect is an output capability and is the ability to retrieve particular data on command. The next three are related to data manipulation. They are file transformation, file reorganization, and file updating. The first two reflect the need to regroup and classify data so they can be displayed in a relevant manner or so they can be used by the statistical or model bank. The last reflects the need to maintain current information in the files.

In Figure 1-5, an outline of the desired capabilities of the data bank was given. It might be useful at this point to outline some of the relevant data which might be stored in such a bank. Figure 1-6 presents such an outline with a few examples. The primary dichotomy in such data relates to whether the data are obtained from records internal to the firm or whether they must be gathered by measurement external to the firm. In the case of internal data, a further dichotomy relates to whether the data are based upon internal accounting records or whether they are generated by other reports and studies. A few examples are given in the figure. Information from any study which might be useful in the future in terms of developing market response functions would be stored in such a bank. Operationally, of course, information with a higher likelihood of use will be kept in relatively more accessible storage than data having a smaller likelihood of use. External data may also be further dichotomized into secondary and primary data. Secondary data are external data which have been gathered for purposes other than that of the firm. Examples would be government data which

FIGURE 1-6

Data Categories in a Hypothetical Marketing Data Bank

I. Internal Corporate Records

  A. Financial and Cost Data

  B. Internal Report Data

    1. Salesmen's Call Reports

    2. Special Studies on New Product Ideas

    3. Performance Information on New Product Ideas Which Have Been Implemented

    4. Life Cycle Information on Products in the Line

II. External Data

  A. Secondary Sources

    1. Government Data

    2. Commercial Data (e.g., M.R.C.A. Panel Data, Nielsen Store Audits, Brand Rating Index's Data)

  B. Primary Data

    1. Test Markets

    2. Market Experiments

    3. Studies of Corporate and Brand Images

might be used to estimate market potentials or commercial data such as MRCA panel data which might be used to estimate price sensitivity in various market segments. Primary external data relates to data which the firm deliberately generates in its environment. Data generated by test markets and market experiments are prime examples here. These examples are not a complete listing of all kinds of marketing data. The data bank should contain all the data relevant to the decision demands upon the system.

The Statistical Bank

Information may follow three paths to the manager in this general information system. The first is direct display while the other two are indirect paths through the statistical or model banks. The statistical bank should contain programs which will enable the manager to test for relationships as well as estimate and test various models and market response functions. Figure 1-7 outlines some of the general capabilities which such a statistical bank should contain.

The first of these are the analysis of variance and other classical parametric procedures which are helpful in analyzing the results of market experiments and exploring marketing data for useful relationships. The increasing use of experimental procedures in marketing makes the inclusion of these procedures a necessity.

Multivariate methods are especially useful in measuring and testing the multiple factor relationships which exist in marketing. Historical data from the data bank will generally serve as input to these procedures.

FIGURE 1-7

Statistical Bank

I. Analysis of Variance and Other Parametric Procedures

II. Multivariate Procedures

   A. Regression Analysis

   B. Discriminant Analysis

   C. Factor Analysis

   D. Cluster Analysis

III. Non-Parametric Statistics

   A. Cross-Classification

   B. Goodness of Fit Measures

   C. Rank Order Measures

IV. Time Series Analysis

V. Decision Theory Program

VI. Numeric Estimation Techniques

One of the most widely used of these techniques is regression analysis, which finds many uses in estimating and testing market response functions. It is especially important that the statistical bank should have complete econometric capability in terms of all the available tests of the assumptions which underlie the model. This will tend to lessen the propensity to misuse this technique of data analysis. Perhaps the statistical bank itself should warn the user of potential pitfalls and recommend appropriate tests and courses of action. Such system warnings should help prevent naïve use of this method. Similar remarks apply to cluster analysis, factor analysis, discriminant analysis, and any other multivariate techniques which might be included in the statistical bank.

A non-parametric statistics subsystem plays several useful roles. In the first place, it applies to data which do not satisfy measurement assumptions of the parametric techniques. Cross-classification procedures are especially useful for exploring relationships between sets of classificatory variables and a response measure. Tests to determine the "goodness of fit" are important in the statistical bank in order to determine the descriptive adequacy of models and standard distributions in the face of data. Rank order measures of association are relevant to similar tests when the data are only measured on an ordinal scale.

Finally, time series analysis, statistical decision theory programs, and numeric estimation techniques are needed. The first is useful in analyzing the dynamics of market response or simulation output. For example, spectral analysis will be a major component of the time series subsystem. The second, statistical decision theory, is useful

in unprogrammed decision situations. However, one of the barriers to its use is the computational burden involved in problems large enough to be meaningful. A program which will perform the numerical analysis, preferably in real time from a remote console, should increase the use of this procedure by marketing managers. The last element of the statistical bank is numeric estimation techniques. It is included to provide the manager with the ability to estimate probability models whose estimating equations contain complex functions of the model's parameters. In general, a well designed statistical bank should be able to estimate model parameters, specify response relationships, and test model structure.

The Model Bank

The final internal component of the decision-information system which requires discussion is the model bank. The three major classes of models in such a model bank are outlined in Figure 1-8, along with a few examples of representative models. The first of these, descriptive models, are useful in understanding market phenomena. For example, this section may contain a simulation model depicting the company-market interaction. The second class of models in the bank are predictive models. This section may contain price or competitive models designed to predict the responses that will be elicited by the firm's decisions. The last section of the model bank will contain normative models that can be used to produce solutions for problems such as advertising budget determination or the selection of the best competitive strategy. Each section of the bank may contain a number of models. The purpose of the

FIGURE 1-9

Hypothetical Model Bank

MODEL BANK

DESCRIPTIVE MODELS
    SIMULATION OF MARKET
    CONSUMER BEHAVIOR MODEL
PREDICTIVE MODELS
    STOCHASTIC MODEL OF CONSUMER BEHAVIOR
    MODEL OF RESPONSE TO COMPETITOR'S PRICE CHANGES
NORMATIVE MODELS
    ADVERTISING BUDGET MODEL
    COMPETITIVE STRATEGY MODEL
    PRICE DETERMINATION MODEL
    NEW PRODUCT MODEL
    MATH PROGRAMMING ALLOCATION MODEL
    OPTIMUM MARKETING MIX MODEL

bank is to present a collection of models so that the best one can be selected when the system is attempting to help solve a manager's problem. The "best" model is the one that answers the manager's needs at the lowest cost. With this requirement upon the system, it is logical to place a number of models in the bank. Even if several models were directed at the same problem, it would be wise to include them if the complexity and cost of execution of each model were different so that some particular management needs could be most efficiently satisfied by each of them.

The Man

This discussion of the components of the information system has now led to the point of interaction between the system and the manager. The design and specification of the system are oriented towards the manager and his needs. To design the system components such as the model bank, a clear understanding of the demands on the system is needed. The manager's demands will depend upon the relevant problems he faces and the decision structure he uses in approaching the system. The most elementary decision demands on the system will be with respect to data retrieval and an assessment of what the present marketing situation is. This may widen to a need to understand the underlying phenomena of consumer and market behavior. At the next level, the manager may desire the ability to forecast marketing events. The highest level demands on the system are problem centered demands relating to advertising, pricing, distribution, personal selling, product planning, and competitive strategy decisions. A manager may approach the system with a

formal decision structure. For example, his procedure may begin with problem recognition and definition and proceed through the process of generating, assessing, and selecting from alternatives to end at testing, implementation, and control of the decision. At any point in this structure, the manager may request information and guidance from the system.

The system should be designed so that a manager may approach the system and interact with it to solve the relevant problems. This man-system interaction will be the underlying emphasis in the development of this book.

This book will not concern itself with the entire information system. The focus of this effort is largely restricted to the model bank. The design and implementation considerations underlying the data bank and statistical bank will not be considered. In the following chapter, management science techniques will be examined with respect to fashioning a marketing model bank that can be used in solving marketing problems. The structuring and definition of marketing problems will be used as a focus for constructing models that are oriented towards a particular information system user -- the marketing manager.

PLAN OF DEVELOPMENT OF THIS BOOK

The purpose of this book is basically to describe and to provide a basis for the extension of the state of the art of the application of management science to marketing problems. This is not a text for the study of quantitative techniques, but rather a problem centered exposition of how the techniques, as expressed in marketing models, can be

used to help make marketing decisions. Although it is assumed that the reader has some familiarity with management science techniques, the second chapter of this book will briefly review and summarize some of the techniques of management science.

With this basic tool kit of techniques, the modeling of marketing decisions can begin. The first area of study will be the nature of market response. In the third chapter of this book, models of market response will be presented and evaluated in the context of understanding, describing, and exploring marketing problems. This study of marketing phenomena will be utilized in Chapters 4 to 7. These chapters are directed at the particular marketing problem areas of advertising, price, distribution, personal selling, and product planning. In each of these areas the relevant problems will be structured, analyzed, and studied from a management science point of view. The interaction between each of the marketing variables will be considered in an evolutionary manner. Although it would be desirable to consider all interactions under one problem heading such as marketing mix problems, pedagogic considerations led the authors to describe marketing mix effects in this evolutionary manner. Advertising will be considered as a single variable in Chapter 4, but price and advertising multivariate problems will be discussed in Chapter 5. Distribution and personal selling variables are considered as independent variables until Chapter 8. Chapter 8 is titled "Product Planning Decisions" and serves as a culmination of the evolutionary exposition of the marketing mix problem. In Chapter 8, the simultaneous specification of all the marketing variables is attacked. A similar

evolutionary approach is taken to competitive strategy. Although each chapter includes consideration of competitive effects, the problem of selection of a competitive strategy is not rigorously faced in its complete form until Chapter 8. Chapter 8 integrates the marketing mix and competitive strategy within the context of new product and product line decisions. The last chapter of this book discusses the problems of implementation of the management science approach in the real world organization.

Throughout the text, selected readings have been added to help demonstrate specific applications of management science in marketing. These detailed descriptions of specific model formulations should increase the reader's capability to build models that will extend the state of the art of management science and should enhance the reader's ability to analyze, evaluate, and apply the future literature in marketing models.