ATTITUDES TOWARD QUANTITATIVE MODELS AS A FACTOR
IN THE ACCEPTANCE OF RESEARCH RECOMMENDATIONS

DISSERTATION

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CHAPTER I

INTRODUCTION

During recent years the art of managerial decision-making has grown greatly in sophistication. New tools for analyzing problems have come from academic disciplines which in the past were not so closely associated to management theory. As a result, managers at all levels have felt a need to increase their familiarity with the methods and techniques of these disciplines. However, as was inevitable in such cases, management expertise in these techniques has lagged behind the desire and need to apply them. In practice, the new techniques are often introduced to the firm by someone other than the decision-maker. Complex quantitative models, for instance, are often first used by a consultant or an internal staff agency, and the decision-maker's initial contact is with the results of the analysis rather than with the performance of the analysis itself.

As a result of this phenomenon, the information upon which the manager's decision must be made often includes one-page abstracts of research findings, and the manager
must deal with these findings even though he may lack a clear understanding of the research methods. Under these conditions, it is hypothesized that the informational value placed on the research results by the decision-maker will be different from a situation in which he is fully conversant with the research methods and was himself involved in the analysis.

In general, such situations are not new to management. Managers have always had to deal with information, the production of which they were not involved in. However, the application of the newer management techniques brings a new dimension to such situations. Traditionally, these situations have taken two forms. First, it is the result of the simple act of delegation of authority. In such cases, a subordinate gathers and analyzes data, draws inferences, and passes the inferences on to the decision-maker. In these cases, the decision-maker did not take part in the analysis, but is usually familiar with the methods. He is, therefore, in a position to evaluate objectively the information, at least with regard to the methods by which it was developed. In the second form, the information is produced by technicians within the well-defined realm of their competence. In these cases, the decision-maker is not necessarily knowledgeable in the methods of analysis, but has traditionally relied upon experts for advice in their fields. An example of this might be the acceptance
of advice from an engineer on matters of reliability or of quality control.

In the application of the newer management techniques, however, a third type of situation arises. In these cases, the decision-maker must also depend upon the technician, but one whose role as an expert has not yet been clearly defined with relation to the decision to be made. Such situations occur, for instance, when the tools of operations research are brought to bear on problems previously solved by other methods. In such cases, the decision-maker can rely neither upon a familiarity with the techniques nor on a tradition of accepting such advice. He must place a value on such information by some other means.

It is with this third type of situation that this study is concerned. It encompasses situations in which relatively complex methods of analysis are used but in which the analyst and the decision-maker are different persons. It encompasses those instances in which the decision-maker is less than fully knowledgeable in the methods of analysis, and where the analyst is not generally regarded as an expert in the type of problem being faced, but where the decision-maker must, nevertheless, decide how much value to place on the results of the analysis in making some managerial decision.
More specifically, this study is concerned with the willingness of a manager to accept and use the results of complex analyses under conditions such as those just described. It is assumed at the outset that such willingness depends in part upon attitudes held by the manager and that these include attitudes toward both the analyst and toward the methods of analysis. As a limitation, however, this study will examine only the second of these two types. A considerable body of knowledge concerning influence and persuasion already exists which deals with attitudes toward analysts. The significance of attitudes toward methods, however, has been the subject of very little research. That area will, therefore, be the basis of this study.

A further limitation of this study will involve the types of analytical methods. In its broadest sense this problem involves any form of complex analysis brought to bear on managerial problems. The problem facing the manager is the same whether the analysis is performed by an industrial psychologist or by a systems analyst. In either case the manager may be faced with information coming from complex analytical methods with which he may be only vaguely familiar or totally unfamiliar. However, for purposes of manageability this study will be limited only to factors influencing one's willingness to accept the results of quantitative analytical models. It must be
left to further studies to discover whether conclusions of this research have a more general applicability.

The application of quantitative models to managerial decisions provides a timely example of the problem being studied. During recent years there has been a large increase in the development and use of such models. They are now being applied in problem areas in which such analyses were previously unknown and where more intuitive solutions previously were the rule. The result of this has been a gap in managerial capability. Managers presently holding high level decision-making positions have often had no training in the new techniques. They have also grown accustomed to solving the problems without the aid of these techniques. However, now they are faced with a dilemma. As the new techniques of management science are applied to their problems, they must set a value on the results of the models without being fully familiar with the mechanics of the models.

The methods of management science do little to resolve this dilemma. This is because the field tends to be more problem oriented than problem-solver oriented. An operations researcher, for example, may have full confidence in a solution he has reached through the use of linear programming. This confidence, however, stems from his knowledge of the model; his training convinces him that the model is appropriate to the problem and his experience
provides him with the assurance that the model was properly employed. The manager, however, may lack the basis for such confidence. If he is unfamiliar with the model, he cannot be certain of its applicability nor can he be sure of its proper application to his problem. Thus, the manager is faced with an additional source of uncertainty not faced by the analyst, since the manager must place a value on the results of the analysis without being certain as to either the model's applicability or to its proper employment by the analyst.

The nature of quantitative business models is in part responsible for this uncertainty. In all applications the model deals with abstractions from the real world. In fitting a model to a real problem, assumptions and qualifications must be made. Some of these can no doubt be brought to the attention of the decision-maker, but often assumptions are an inherent part of the mathematical treatment and only a full understanding of the model can bring complete comprehension. In many cases this creates a sense of uneasiness on the part of the decision-maker using the results of the model. He often senses that the results may be qualified by assumptions and abstractions which he does not fully comprehend and is, therefore, uncertain as to how much use the solution may be to him. It is a premise of this research paper that under these circumstances, the decision-maker will be
influenced by his attitudes toward the model in question or toward quantitative models in general and that these attitudes will influence his willingness to accept the results of the model.

In Chapter II, the existing literature will be examined which served to operationalize this study by pointing to specific questions to be analyzed. In Chapter III, research questions and hypotheses are developed to make possible the analysis of those questions. At this point, however, it may be useful to present a brief preview into the nature of those research questions. Altogether, four research questions will be posed. In simplified terms, they are as follows:

1. Do decision-makers possess attitudes toward specific quantitative models or toward such models in general which influence their willingness to accept research findings based on the use of such models?

2. Does the complexity with which the research findings are presented interact with such attitudes to determine the amount of influence on acceptance?

3. Does training in the particular model being used bear on the formation and effect of such attitudes?

4. Does general training in such models bear on the formation and effect of such attitudes?

It is the feeling of this author that these questions are relevant to many of management's more important problems and that many of the most current controversies in the field of management touch on these questions. Within
the field of operations research, for example, much has been written on the subject of implementation. One aspect of this problem is the issue of getting managers to accept the results of research studies. Quite obviously the attitudes of managers toward the research methods must be considered as part of the problem. If, as this study expects to find, attitudes toward methods affect the willingness to accept results, then it must follow that research will be most effective when performed and presented with consideration for these attitudes.

Another current controversy involves the extent of management education in quantitative methods. Much of current education trains managers in the application of such methods. However, in practice, the more complex of these methods are more likely to be applied by a technician, with the manager being involved primarily with the results. This is particularly true with new applications or advanced techniques which are beyond the more limited training of the manager. If this is the case, then the important factor of management training may not be the preparation to perform the analysis, but rather the attitudes developed toward the specific techniques and toward quantitative analysis in general.

Another current problem involves what might be called the generation gap in management. At the higher levels of decision-making is a generation of managers who
received much of their formal training before the current emphasis in the management sciences. Their subordinates, however, are increasingly better trained in these techniques. The result is often a problem of communications. The younger manager may wish to employ the new techniques with which he is familiar and confident but may have trouble selling the results to his superior who lacks both familiarity and confidence. The result may be frustration on the part of both managers. The problem may possibly stem from differences in attitudes resulting from differences in training and experience. Until these attitudes can be understood, there is little hope of resolving the problem to the satisfaction of both parties.

The above problem areas are indicative of a need for research in the area of this study. As the field of management grows in complexity it is natural to expect that decision-makers will increasingly be forced to deal with information resulting from complex quantitative analysis. It is also natural to expect that some of the analyses with which they must deal will be beyond their own analytical capacities. Under these circumstances it should be of value to gain insight into the factors that influence a manager's willingness to accept and use such information.
CHAPTER II

REVIEW OF THE LITERATURE

Briefly stated, this study is aimed at finding out how managers use the results of complex quantitative analyses when they are not participants in the analysis itself. More specifically, this study hopes to isolate some of the variables which affect the manager's willingness to use such information in decisions he makes.

The initial phase of this research effort, therefore, was a review of the literature in search of studies or other scholarly works that could shed some light on the issue. Special effort was made to find research studies that might help in predicting a manager's willingness to accept such information. The search involved literature in the fields of management, the behavioral sciences, education, and the management sciences.

The overall results of this survey were discouraging. Very little was found directly related to the subject at hand. While numerous references were found indicating a recognition of the problem, extremely little research appears to have been done on it. Some studies were found
that indirectly relate to the subject, but few of these have any value as predictors of managerial behavior.

Management Literature

In conceptualizing the problem some of the most valuable ideas came from Dr. Herbert Simon and his associates. Particularly interesting was their work in the area of authority and influence, and also in a process they refer to as "uncertainty absorption."

In uncertainty absorption, data are collected and processed with inferences made. The inferences rather than the data are then passed on to a decision-maker. When the inferences are transmitted, it is frequently the case that the uncertainty surrounding the original data or the processing are withheld. This has led Simon to observe that the uncertainty has been "absorbed."

Technically speaking, "absorption" is probably a poor choice of a word to describe what has happened. The uncertainty has not really been absorbed by another party; rather, it has been managed in such a way as to restrict its impact on the decision. In any case, however, the process referred to by Simon as uncertainty absorption is closely descriptive of the way in which research findings often influence decisions.

Through the process of uncertainty absorption, the recipient of a communication is severely limited in his ability to judge its correctness. Although there may be various tests of apparent validity, internal
consistency, and consistency with other communications, the recipient must by and large, repose his confidence in the editing process that has taken place, and if he accepts the communication at all, accept it pretty much as it stands. To the extent that he can interpret it, his interpretation must be based primarily on his confidence in the source and his knowledge of the biases to which the source is subject, rather than on a direct examination of the evidence (14:165).

It is clear from this passage that the problem faced by a manager receiving the results of a complex quantitative model is the same as the problem discussed by Simon. The decision-maker's ability to evaluate the communication is often limited to his confidence in the source and knowledge of the biases facing the source. However, Simon appears to delimit "source" to being a person or organizational entity. In terms of the present study, it may equally apply to a specific model or to quantitative models in general. It seems plausible to assume that a manager may also evaluate a communication through his knowledge of the methods by which the information was obtained and through an understanding of the assumptions (biases) inherent in those methods. It is highly probable that a manager possessing confidence in and an understanding of specific quantitative techniques will be more prone to evaluate favorably communications coming from a person who employed these techniques. Likewise, a manager who is skeptical of these techniques is likely to transfer that skepticism to a person employing them.
Unfortunately, however, Simon does not delve deeply into the recipient's role in the process. He discusses the locus of uncertainty absorption within the organization and notes that in part this is a function of the distribution of technical competence (14:166). However, he ignores the subject of the conditions under which a recipient will permit uncertainty to be "absorbed." In the present study a premise is made that not all such attempts are accepted by the recipient. Since Simon's work does not touch on this facet of the process, his work is of limited value to this study.

Other topics covered by Simon also helped in conceptualizing the problem faced by this study. In his writing on the topic of authority, he defined it as existing whenever a subordinate permits his behavior to be guided by a decision of someone else without independently examining the merits of the decision (19:11). From this description it is possible to see that the use of quantitative models may result in an effect similar to that resulting from a relationship of authority. If a decision-maker is unduly influenced by the output of quantitative models of which he is incapable of examining the merits, then he has, in effect, acquiesced to the "authority" of the model. This could be important in that it could be a source of a type of authority or influence known as expertese. In brief, if this study should show a marked tendency of some
managers to accept the results of models with which they are not familiar, then the effect would be that of bestowing an element of authority upon anyone who understands and employs such techniques.

Before leaving the work of Simon, one other area is of interest. In his study of the search process, he notes that a decision-maker will stop looking for new information when he discovers a satisficing solution (11:111). Broadly interpreted, this could mean that a decision-maker will be less receptive of new ideas if he has already reached a satisfactory solution. In terms of the present study, the willingness to accept the results of quantitative models with which the manager is unfamiliar may depend on the acceptability of a solution arrived at without using that information. If the decision-maker finds the decision difficult to make in the absence of the model output, this would suggest a high willingness to accept the results of the research in spite of the uncertainty involved.

**Behavioral Literature**

The area of literature most closely related to the research was probably that which concerned source credibility. However, as in the case of the rest of the literature, the relationship was not direct. The work done in this area in virtually every case was based on the
credibility of the person who was the initiator of a communication. It was never noted that the methods employed by that person could also be a source of credibility. In the present study, a basic premise is that methods of analysis may affect the credibility of a communication. In some cases, the methods may be the prime determinant of credibility while in other cases they may serve as an intensifier or detractor of personal credibility. The literature on source credibility, however, makes virtually no mention of this possibility.

The most important works in the area of source credibility were done by Hovland and his associates at Yale University. Their work dealt primarily with oral communications and persuasion. One of their findings was that an audience tended to feel that a communication from a credible source was fairer than one from a less credible source (12:27). This would imply that the acceptance of a quantitative model's results would depend upon the credibility of the analyst. For instance, a manager might be more willing to accept them from an operations researcher than from another manager. However, another study by Mills and Jellison found that persuasion is greater when the recipient feels the communicator is most like himself (46). This would imply the opposite conclusion. Neither case, however, touched on the problem directly concerning this study. Such studies are of interest
primarily from a methodological viewpoint in that they demonstrate that in order to observe the persuasibility of an analytical method, the credibility of the analyst must be eliminated as a factor.

Some of the literature on source credibility was of interest for its emphasis on format. Hovland for instance found that given any specific level of credibility, the format of presentation can affect the persuasiveness of the communication (12:99). Schweitzer found that format can improve the persuasiveness of a communication even if the source is not otherwise considered credible (54). Churchman, however, questions such findings. In his experiments he was unable to find any evidence which indicated that format affected the persuasiveness of a communication (25:35). Such contradictory conclusions indicate that the relationship of format to persuasiveness is not yet fully understood.

One final implication to be drawn from the literature on source credibility refers to what may be called expertness. Hovland noted it this way: "An individual's tendency to accept a conclusion by a given communicator will depend in part upon how well informed and intelligent he believes the communicator to be." (12:21). It is a premise of this study that the use of complex analytical techniques may at times provide an aura of expertness to a source of information. This may be particularly true if the recipient
is himself unfamiliar with the techniques. Viewed this way, the results of complex quantitative analyses may find increased acceptance through the process of increasing the credibility of the analyst. The possibility exists that credibility of methods may be transferred to their user.

Besides the above mentioned work on source credibility, the literature of the behavioral sciences contributed to this research project in several other areas. These include work in the areas of role expectations, personal traits, and dissonance. The work in role expectations contributed in a methodological way. Essentially, it provides an explanation of why quantitative model results may be accepted in certain cases where understanding is absent. If the recipient perceives the role of the analyst to include making decisions within the problem area, then he is unlikely to question his advice. In fact, he may be willing to accept it as a means of limiting his own personal risk. If the decision is considered by the organization to be in the realm of the analyst, then the recipient may feel safe from blame of failure if he accepts the advice. On the other hand, rejection of such advice could make him subject to blame if the advice is good. This possibility, of course, could be a source of bias in any experiment aimed at discovering attitudes toward the models. Therefore, any such experiment must be
constructed in such a way as to eliminate role expectations as a factor. This is consistent with the initial purpose of this study which is to observe the implementation of complex analytical research in cases where the analytical methods have not yet received general acceptance with regard to the problem to which they are being applied.

Personality traits as a factor in decision-making is an area that has received much attention of behavioral scientists in recent years. Numerous studies have correlated various personal factors with such decision variables as decision time and number of alternatives considered. While some correlations have been found, nothing has yet been discovered that might be of predictive value for this study.

Brim, for example, found personality and social variables that strongly correlated with certain decision variables. However, the influence proved to be situational and dependent on the decision to be made (1). Since he made no classification of types of decisions, his findings do not aid in predicting the effect of personality on the type of decision being considered by this study. In another study, Brim found that people who are frustrated in accomplishing a task have a relatively high desire for certainty (24). A possible implication of this is that a person, faced with an otherwise difficult
choice, may be anxious to accept anything that might permit him to resolve his conflict. Frustration may, therefore, be a factor in the willingness to accept the results of a complex quantitative model.

In Hovland's studies, he found that persuasibility may be inversely related to self-esteem (12:191) and aggressiveness (12:192). A person who is sensitive with regard to his lack of ability to interpret model results may, therefore, be more willing to accept such results at face value. Likewise, a person who is not highly aggressive may also be unlikely to question such results.

Another research effort that involves personal factors somewhat related to this study is the work done by Rotter. He has shown experimentally that people differ in their predisposition to trust conclusions reached by others (34:214). Although his research was limited to interpersonal trust under conditions of emotional involvement (e.g., one study was based on acceptance of the Warren Commission findings), it is possible that such a predisposition could be meaningful in the situation now being examined. If this were the case, it is possible that a predisposition to trust could affect the willingness to accept the results of complex models.

The above examples of interrelationships between personal factors and decision variables do little to predict whether attitudes toward complex quantitative models
determine acceptance of model outputs. However, if this study should find such a relationship, then personal factors such as those noted may add to the explanation.

One final area of behavioral research worthy of note is the work on dissonance by Festinger. While dissonance is primarily a post-decision phenomenon, nevertheless, anticipated dissonance has been shown to be a factor in the pre-decision thought process (8:144). Theoretically, therefore, if a person expects to be ill-at-ease with decisions based on information he does not fully comprehend, then he may be expected to avoid relying on such information. This is consistent with Festinger's theory that a person will avoid experiences likely to increase dissonance. However, Festinger carries his theory one step farther by noting that in the presence of potentially dissonant information, if it cannot be avoided, a decision-maker would tend to seek out other information capable of reducing the dissonance (9:126). In the present study, this would imply that a decision-maker, faced with potentially dissonant information from a quantitative model would desire additional information about that model. If such information were not forthcoming, a state of conflict would exist and this might be reflected in a reluctance to make the decision. While Festinger does not actually carry his discussion this far, certain implications for this study can be drawn from his work. If a decision-
maker's attitude toward the model (or toward quantitative models in general) is unfavorable, he will avoid using the results of the model as a basis for his decision if he feels he can base the decision on other information. If he feels he cannot totally disregard the model, he will use its output, but the anticipation of post-decision dissonance will lead to an initial feeling of insecurity with the decision. This feeling, however, may diminish as he attempts to achieve consonance, possibly through rationalization, which conceivably could result in an improved attitude toward the model. This last possibility, while of interest, is not directly pertinent to this study which is concerned with the decision rather than post-decision attempts to reduce dissonance. It may have an indirect bearing if past uses of models coupled with later attempts to reduce dissonance have resulted in an improved attitude toward such models. However, even this is of limited significance since this study is primarily concerned with the effect of attitudes, not with their formation.

Management Sciences Literature

The area of literature most closely concerned with the problem facing this study was the management sciences. Although frequent references were made to the problem, little research was found directly related to it.
Some comments by B. F. Wynne are representative of much of this literature. "The problem in communicating research results to the executive mind thus consists of stripping the research argument of its mathematical complexities and irrelevancies while retaining the rigorous logic for the executive understanding." (58:17). He goes on to say that "In any OR report every effort must be made to play down the thought that specialized knowledge has been required to accomplish the stated results." (58:17). He concludes by emphasizing that any reference to methodology or mathematical notation must be left to an appendix (58:21). Taken together, these comments represent a feeling on the part of many operations researchers that managers tend to resist information if the complexities of the methods are beyond their comprehension. Operations researchers, therefore, appear to feel that the means of presentation may be a major factor in subsequent acceptance of research findings. They seem to predict that an inverse relationship exists between complexity of presentation and acceptance of the results. Wynne carries his conclusions a step further by saying that to suggest to a practical manager that a problem be solved with "game theory" or "monte carlo," will give an impression of "frivolity," thereby defeating the recommendation (58:18). This implies that by merely mentioning the name
of some complex technique to an untrained manager, the researcher hurts his chances of influencing the decision.

While the above quotations from Wynne are no doubt somewhat extreme in their criticism of executives, they do tend to reflect a general attitude of researchers who constantly face the problem being studied in this paper. This attitude was voiced by Churchman: "It is a well-known fact that managers feel threatened by modern techniques of analysis. In order to preserve their status, they resist the recommendations that analysis provides." (25:35). If this is in fact true, then it would suggest that in general, managerial attitudes toward complex models are unfavorable.

Not all of Management Sciences literature is critical of managers. In many cases it is admitted that much of management's resistance comes from a past history of having bought the results of poor research. Having been dazzled by complex equations in the past, experience has taught managers to be more careful about it in the future (20:18). However, recognition of this fact does not diminish the problem; how does a manager place a value on research when he lacks the background to comprehend all aspects of it? Were a fully objective determination of such value possible, this study would be unnecessary.

Some literature in operations research has tried to establish a more definitive relationship between the
researcher and the executive with an aim to getting the most in benefits from research. Hankin sees a major part of the job of a researcher as being the selling of his findings. He concludes that the optimum sales approach depends on six factors including the pre-knowledge of the methods by the recipient, his level of intelligence, and the format of presentation (35:297).

Churchman and Schainblatt listed four classes of relationships between researcher and manager (26:70). In the first class, the two are completely separate functions. In that class the problem of acceptance of model results is the greatest. In the second class, the researcher has the job of persuading the manager. Here it is the task of the researcher to know enough about the manager to be able to convince him that the research is valuable. The acceptance problem still exists in that case, particularly if the manager is sensitive to the hard sell. In the third class, it is the job of the manager to understand what the researcher has done. Those who support this theory feel that a satisfactory relationship is possible only when the manager has become a scientist. In such circumstances the problem faced by this study might not exist. In the final class, mutual understanding must be achieved; both parties must understand the other. Churchman and Schainblatt, of course, aim for the development of the fourth class under which the
greatest benefits of research can be achieved. No doubt this fourth class exists in some instances; however, it is probably rare in practice. More frequently the first two classes are probably dominant and it is with such instances that the present study is concerned. It is difficult to envision in the foreseeable future a world in which a large proportion of executives would also be qualified operations researchers.

One interesting aspect of the Churchman-Schainblatt article is the emphasis placed on managerial education in research methods. They never really claim that the manager must be a fully qualified researcher, but they imply that there is some minimum level of training in research methodology that will enable the manager to communicate successfully with the researcher. They imply that beyond some point, the marginal utility of further managerial training would be slim. Gurnez and Brownlee reinforce this idea. They noted that while there may be no limit to the amount of mathematics that could be useful to a business executive, the opportunity cost of acquiring such knowledge would make the optimum level relatively low (32:52). Implicit in these conclusions is the idea that an executive requires a certain amount of quantitative knowledge in order to communicate with researchers, but that beyond some point the value of additional knowledge is limited. Relating this to the present study, it could
be concluded that decision-makers with some minimum level of training in quantitative methods would react differently than would untrained decision-makers when faced with the results of quantitative research. Assuming that the research was relevant and accurate, then the trained executives should tend to be more receptive.

**Educational Research**

The above references concerning training in quantitative methods demonstrate a relationship between the field of education and the subject at hand. Unfortunately, however, no educational research was found directly related to this problem. Virtually every study that was found related to the subject of education in quantitative methods viewed the student as a "doer" rather than as a "user." Consequently, the success of specific teaching methods was always measured by the ability to work a problem rather than by attitude change toward the quantitative methods. Only two studies had any particular relevance. These were the Carnegie Foundation study by Pierson entitled *The Education of American Businessmen*, and the Ford Foundation study by Gordon and Howell entitled *Higher Education for Business*. Both studies are now classics and have done much to encourage modernization of education for business.
Both studies concluded that a deficiency existed in the teaching of quantitative subjects in higher education. Pierson indicated that a need existed for the teaching of more basic mathematics (16:186). Gordon and Howell, however, felt that more "interpretative" mathematics was needed (10:197). This latter approach tends to support the contention that the businessman is less of an analyst and more of a user of the results of analysis. The important point in that study was that the executive needed the proper amount of quantitative training to enable him to communicate with scientists and engineers. Unfortunately, the study left it to the reader to decide how much basic mathematics was needed before the interpretation of results could be taught.

Summary

Although literature concerning this research topic was scanty, the survey of it aided in conceptualizing the problem and also provided guidance in developing operational research questions.

From the management science literature came the view that executives fear research methods they don't understand. If this is true, then it might be predicted that awareness of the use of such methods would lead to resistance toward accepting the results of the research. Some management science literature also predicts that this
resistance will grow as the presentation of the results becomes more complex, although such eminent management scientists as Churchman question that prediction. The literature on source credibility, however, reinforces the importance of format although it does not predict the reaction to any specific type of format.

From the literature in education and in management science comes the prediction that training in quantitative methods will decrease resistance and improve receptivity.

These then are the predictors derived from the relevant literature that might indicate how managers employ the results of complex models when they themselves did not perform the analysis. They lead to hypothesizing that model awareness leads to resistance, that the resistance may grow as the presentation becomes more complex, but that training in quantitative methods tends to overcome that resistance. The remaining chapters of this study will, therefore, develop and test these hypotheses.

Besides pointing to the above predictors of behavior, the literature survey also was helpful in a methodological way. By indicating factors that interact with those being studied, the survey has called attention to variables that must be controlled so as to permit the observation of the independent variables being studied. From the work on source credibility and role expectations it has become apparent that factors of interpersonal relations must be
controlled before attitudes toward quantitative models can be observed. If an experiment permitted a subject to accept information on the basis of his attitude toward the communicator, then his attitude toward the model might be obscured.

Simon's search process and Festinger's work on dissonance make it clear that the amount of information available to subjects in an experiment must also be controlled. The response set evoked by attitudes toward information may include a desire for clarifying information. If complete clarification is permitted, then the attitudes being observed may become hidden. Also from Simon's search process can be seen the type of information that might be needed. It must be possible for the subject to reach a decision without reliance on the model. This would permit him to complete his search without accepting the model if he is so inclined. Only if he has a choice of accepting or rejecting the model results, can factors of acceptance be observed.
CHAPTER III

STATEMENT OF THE PROBLEM AND HYPOTHESES

Research Questions

The main objective of this study is to find out how attitudes toward quantitative models affect a decision-maker's willingness to accept the results of such models. More specifically, the study is concerned with situations in which someone other than the decision-maker employed the model, and the decision-maker is provided only with the results of the analysis.

Although the cornerstone of the study consists of the attitudes held by decision-makers, the phenomenon to be observed is the behavior resulting from these attitudes. Consequently, the task facing the study will not be to measure attitudes but rather to observe behavior under conditions where attitudes have been evoked. If behavioral differences can then be observed, conclusions may be drawn concerning the existence of such attitudes, their form, and their effect.

The particular behavior to be observed will be the willingness of a decision-maker to accept the results of
complex quantitative models. Since one's "willingness" to accept such information is difficult to observe directly, it must be observed through some more clearly measurable form of action. With this in mind, the basis of this study will be the observation of choice behavior and decision confidence. In the first instance, willingness to accept information will be indicated by the propensity to choose an alternative pointed to by a model. In the second instance, the amount of confidence held in that choice will indicate the strength of the acceptance or rejection. For example, in a situation in which two alternatives were possible but only one of which was indicated by the model results, then the choice of that alternative coupled with a strong feeling of confidence in the correctness of that choice would indicate a relatively strong willingness to accept the model results. The selection of the indicated alternative but with a lesser amount of confidence, would indicate a lower level of acceptance; and strong confidence in the other alternative would be indicative of a very low willingness to use the results of the model.

The use of choice behavior and decision confidence in such situations is not without precedence and the rationality can be easily explained. Kyburg and Smokler assert that the only theoretically sound way to measure a person's degree of belief is by examining his overt behavior (13:9). Thus choice behavior is actually a test
of pragmatic validity; in order to measure someone's willingness to accept information, observe the conditions under which he actually does accept it. If it is hypothesized that he will accept under certain conditions, then observe him under these conditions as a test of the validity of the construct.

Decision confidence has also proven to apply as a measure in such cases. Murray found that degree of belief varied directly with the strength of the evidence (49:324). Therefore, the more acceptable the model is to the decision-maker, the stronger will he consider its output as evidence and the greater will be his degree of belief in his judgment. Hoge and Lanzetta reached a similar conclusion when they found that difficulty in making a decision results in a lower feeling of certainty in the decision (38:1086). The implication here is that the more willing a subject is to accept a model's output, the more confidence he will have in the decision indicated by that model.

Therefore, using choice behavior and decision confidence as a means of measuring a decision-maker's willingness to accept the results of a model, the following research question can be stated:

Research Question #1 If a decision-maker is provided with information obtained from a complex quantitative model under such conditions that he lacks full knowledge of either the model or of the way in which it was applied, then is his attitude toward the model reflected in his choice behavior and the confidence he has in his choice?
While an answer to this question might provide some very general insight into decision-making, nevertheless its value is limited by certain aggregations. Two types of such limiting aggregations appear particularly pertinent. First, the use of the word "provided" implies that responses will be independent of the way in which the information is presented. But as was noted in Chapter II, there is reason to believe that format of presentation has a bearing on receptivity, and that complexity of presentation may be particularly important. The implication is that as the presentation becomes more technical, receptivity will decrease. This leads to a need for a second research question:

**Research Question #2** Do choice behavior and confidence in choice vary according to the complexity with which the information is presented?

Another type of aggregation that limits the value of the first research question stems from the fact that it treats all levels of lack of knowledge equally. In reality, this factor should fall on a continuum in which some decision-makers are completely ignorant of the way in which the information was produced while others are highly knowledgeable. While many factors may account for this, one appears to be most basic; education in the applicable quantitative technique. A person who is unfamiliar with the technique of necessity cannot determine whether it was properly employed. Someone trained in the method may
or may not be able to make such a determination, but in any case his attitudes toward the model may have been partly developed as a result of his training in its use. This raises the question brought up in the preceding chapter as to the effect of training in quantitative methods. At that time it was noted that much of the literature in the management sciences assumes that executives who have received such training will be more receptive to solutions obtained through quantitative models, even when the model itself was employed by someone else and the executive is provided only with the results. In order to test this premise, a third research question, therefore, is necessary.

Research Question #3 Do choice behavior and confidence in choice vary according to familiarity with the model?

As stated above, research question number 3 covers only part of the contention of the management scientists. It only deals with the acceptance of results from a specific model by subjects familiar with that model. The contention of many management scientists is that quantitative training in general affects receptivity, even where the specific model in question was not covered in the training. This is the interpretation one can make from the Pierson study which emphasized the need for business training in basic mathematical subjects (16:186). It is implied in such works that there may be a transference of
effect; that training in quantitative methods may result in a change in attitude toward quantitative analysis in general, even where the specific technique that was used was not previously studied. Therefore, a fourth research question must be posed:

Research Question #4 Do choice behavior and confidence in choice vary according to general levels of training in quantitative models, even where no familiarity exists with the specific model being used?

Hypotheses

In order to design an experiment for answering the four research questions posed above, it is first desirable that they be restated in the form of testable hypotheses. For this purpose, the following four null hypotheses have been developed:

Hypothesis #1 When information resulting from the use of a quantitative model is provided to a decision-maker, awareness that the information came from such a model will not affect his choice behavior or the confidence he has in his decision.

Hypothesis #2 When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, the complexity with which the information is presented will not be reflected in either choice behavior or decision confidence.

Hypothesis #3 When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, familiarity with the model will not be reflected in either choice behavior or decision confidence.

Hypothesis #4 When information resulting from the use of a quantitative model is provided to a
decision-maker under conditions where he is aware that the model was used, but is unfamiliar with the specific model, general training in quantitative business models will not be reflected in either choice behavior or decision confidence.

The first of the above null hypotheses is non-directional in that awareness is not initially assumed to either increase or decrease the acceptability of the information. This study must first determine whether any effect exists and then try to establish its direction or magnitude. The other three hypotheses each may have contrasting directional alternate hypotheses. This is because model familiarity and general quantitative training are predicted to increase information acceptability while technical complexity is predicted to decrease it.

The following chapter will discuss the design of an experiment aimed at testing these hypotheses.
CHAPTER IV

RESEARCH METHODS

Introduction

From the research questions posed in Chapter III, four independent, one intervening, and two dependent variables become apparent. From the literature survey, three additional variables can be seen which must be controlled in order to observe the interaction of the independent and dependent variables.

The independent variables upon which this study is based are: 1) awareness of model, 2) complexity of presentation, 3) model familiarity, and 4) general familiarity with quantitative business models. The first research question deals with the effect of attitudes toward the models. In order to observe these attitudes in action, it is necessary to divide the subjects into two groups. One group, which will serve as a control, will not be made aware of the use of the model. The second group will be made aware that a particular model was used. This will permit a comparison to be made in which the difference in results will be due to attitudes evoked by the
awareness of the model's use. In the second research question, complexity of presentation is the variable at issue. This will be varied by making one group aware of the model's use through a simple statement to the effect that it was used, while another group is made aware in more technical terms. In the third research question, the independent variable is familiarity with the specific model being used. In this case, the sample must be composed of two types of subjects; one type which has been trained in the use of the model in question and the other type which has received no such training. In research question number four, general familiarity with quantitative business models is the independent variable. Here the two groups are divided according to their general background in quantitative business methods.

In each of the above cases, the effect of variations in the independent variable will be measured by observing two dependent variables; choice behavior and decision confidence. Choice behavior would, of course, be the most direct and meaningful result of variations in the independent variables. If variations result in different decisions, then there can be no doubt as to their significance. However, since choice may not always be sensitive enough to be affected by slight changes in the independent variables, another measure is needed which would reflect the effects of changes in independent variables even where
a different choice does not result. Decision confidence is such a measure and is therefore used as a second dependent variable in this study.

The intervening variable which is of significance to this study is that of attitudes toward the quantitative model. If the independent variables do in fact affect the dependent variables, this will be accomplished by either evoking or intensifying such attitudes.

In order to observe the relationship between dependent and independent variables, other variables must be controlled. The first of these is source credibility. If attitudes toward the model are to be observed, attitudes toward the analyst must be eliminated as a factor. A second variable that must be controlled is the importance of the information with regard to the decision being made. If the willingness to accept this information is to be observed, it must be possible to reject the information as well and still reach a decision. The information must not be so critical that in its absence a decision is impossible. And finally, the ability to search for clarification must be restricted. Since the willingness to accept information is meaningful only if a certain amount of uncertainty surrounds it, it is necessary to prevent the subjects from achieving full clarification and thereby eliminate the uncertainty.
The above description of research variables can be summarized in the following design:

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLES</th>
<th>INTERVENING VARIABLE</th>
<th>DEPENDENT VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness of model</td>
<td>Attitudes toward the model</td>
<td>Choice Behavior</td>
</tr>
<tr>
<td>Complexity of presentation</td>
<td></td>
<td>Decision Confidence</td>
</tr>
<tr>
<td>Model familiarity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General background in business models</td>
<td></td>
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</tbody>
</table>

**Experimental Task**

Given the research model described above, it was decided that the best way to observe the interrelationships between variables was to observe a group of managers in a decision-making activity. The activity decided upon was a laboratory experiment built around business case problems. In developing the cases, the above discussion establishes nine specifications.

1. **Awareness of model**: The case problem must create a situation in which the output of a quantitative model is provided to a decision-maker in such a way that he is aware of the model's use but is unable to evaluate objectively its output. This inability to evaluate the information can stem either from a lack of familiarity with the model or from a lack of sufficient detail to enable the subject to evaluate objectively the way in which the model was used. At the same time, a control group is needed which is given the same information but in such a way as to conceal the fact that the model was used.
2. Complexity of presentation: In making the subjects aware of the use of the model, two approaches must be employed. One approach must be kept as simple as possible, giving only the results of the model and the fact that the model was used. The second approach must convey the same information but in the more technical language of the model.

3. Model familiarity: Two groups of subjects must be studied. One group must have had prior training or experience in the use of a specific quantitative model being considered, while the second group must be unfamiliar with the model.

4. General familiarity with quantitative business models: The sample must fit into two groups: those with a fairly advanced background in quantitative business models and those with a limited background. At least one case problem must be developed around a model with which neither group is familiar.

5. Source credibility: The qualifications of the person employing the model must be omitted from the problem statement. The subjects must not be able to replace a lack of faith in a model with confidence in an individual or analyst.

6. Importance of the information: The rest of the information provided in the problem must be sufficient to permit a decision to be made even if the model output is
rejected. The model output must not be absolutely crucial to a decision.

7. Search for clarification: When faced with the model results, the subjects must be either unfamiliar with the model or uncertain as to its application. In order to maintain this uncertainty, the subjects must be provided with insufficient information to employ the model themselves, and access to this information must be denied.

8. Choice behavior: Two alternatives must be provided such that one will be most likely if the model information is relied upon to determine the decision while the other will be most likely if the attitude toward the model prevents its output from playing a major role in the decision.

9. Confidence in choice: The subjects must be made to indicate the amount of confidence they have in the decisions they make. This, along with their choice, will serve as an indicator of their willingness to accept the information provided them.

The above nine specifications serve as the characteristics that must be inherent in any experiment aimed at answering the questions posed in this study. These were, therefore, incorporated into an experiment which serves as the basis of this research project.

First of all, the above specifications determine the criteria for the subjects to be tested. It is necessary
to have a homogeneous group of subjects, some of whom have a fairly extensive background in quantitative business methods while the rest have been trained to a significantly lesser degree. An opportunistic sample well suited to this requirement was found in the student body of the Graduate School of Systems and Logistics of the Air Force Institute of Technology. The students in that school are enrolled in a 12-month program leading to a Master of Science degree in Logistics Management. By testing two classes, one beginning the program and the other about to complete it, the desired sample could be obtained. The group would be relatively homogeneous since both classes are selected one year apart, but by the same criteria. The classes are composed of military officers and Department of Defense civilians with experience in various functional areas of military logistics. The class that is completing its program has just finished the following course work:

- 5 weeks of intensive mathematics and Fortran review.
- 7 quarter hours of Systems Analysis.
- 8 quarter hours of Statistics.
- 3 quarter hours of mathematical programming.
- 3 quarter hours of Quantitative Methods in Cost Analysis.

The class that is beginning its year of study has been chosen from the same population by the same criteria but has not yet been exposed to the above academic work.
The two classes, therefore, meet the requirements of the experiment. They comprise a homogeneous sample of managerial personnel. One group has an extensive background in quantitative business methods. The other group lacks such a background (after eliminating those in the incoming class who have received such training in their earlier education).

The second requirement in structuring the experiment was to select the appropriate models. For one part of the experiment it was necessary to have a model with which one group was familiar but with which the other group was not. This would permit measuring the effect of model familiarity. A second model was needed with which neither group was familiar. This would permit the observation of the effect of a general quantitative background. At the outset, it was also decided that a third model was needed. This was because three forms of presentation were being used (a control form, a simple form, and a technical form). It was decided that each subject should be faced with each form. Arbitrarily it was decided that the third model should also be one with which one group was familiar. Therefore, three models would be needed; two with which one group, but not the other, was familiar; and one with which neither group was familiar. In selecting the models, the school curriculum was used. It was found that one entire ten-week course in Systems Analysis was based on
inventory models and dynamic programming. Therefore, the EOQ inventory model was selected. It was further found that three weeks in another course were devoted to queuing models. Therefore, this was chosen as the second model. For the model with which neither group was familiar, a discussion with members of the faculty of the School of Systems and Logistics led to the selection of the Markov Chain process. This is not covered in the curriculum.

The selection of these three models provided a virtual certainty of appropriateness to the group of students about to graduate. It was certain that they were familiar with the inventory and queuing models and there was a very small probability that any were familiar with the Markov process. This left the simple task of eliminating those few subjects who were familiar with the Markov process. With the incoming class, less certainty existed. It was expected that some would be familiar with one or more of the models from past experience. However, discussions with the faculty of the School of Systems and Logistics led to the belief that few incoming students had such a background. Therefore, it was decided to use these three models and eliminate from the analysis any subjects who were later found to be too well prepared in their use.

Once the three models were determined, cases could then be developed around each. In developing these, several criteria were used. First, an attempt was made
to be realistic. The problems that were chosen were felt to be fairly typical of the types of problems that face managers. Also, the criticality of the problems was held to a minimum. Problems were avoided that might have had a major impact on the firm. It was felt that if the problems were too weighty, the reality of the situation would be lost. In major decisions, managers would be more skeptical of accepting research findings without searching for clarification. In less important decisions, such conditions would be more likely and realistic.

For each model, a case problem was developed. In each case, the problem was first stated and then information was provided for a decision. The conclusions coming from the model were just one element of that pool of information. The subjects were given two alternative solutions. The model results pointed to one alternative while most of the rest of the information pointed to the other. The value of the information was established through pre-tests. During the pre-tests some subjects received all the information except the model results. This information was revised in a succession of pre-tests so as to develop a pool of information that would virtually always lead to the selection of the alternative not indicated by the model (this alternative will hereafter be called the uninformed alternative). Also in the pre-test, some subjects were given the same information but were also
given the model results. In a succession of pre-tests, the model output was varied so that a majority receiving that information would tend to favor the alternative indicated by the model (hereafter referred to as the informed alternative). The pre-tests were necessary to establish a predictable value for the model results. In the final experiment, it was necessary that if a subject rejected the model, it could be predicted that he would tend to choose the uninformed alternative, but that if he relied on the model, he could be predicted to favor the informed alternative. Appendix A gives the case problems that were finally refined through this pre-test process. For each case, three forms were developed. In the first form, the model results are given without reference to the model. In the second form, the results are given and the subject is told simply that the model was used. In the third form, the model output is also given, but in more technical terms.

Through the pre-test process it was established that the more acceptable were the model results, the more likely would be the selection of the informed alternative. This permits the observation of the independent variables in action. If a variable changed so as to decrease acceptability, this could then be observed as a shift in favor of the uninformed alternative. Anything that increased
acceptability would be observed as a shift in favor of
the informed alternative.

In the actual experiment, each subject was given a
different form of each case. For example, one subject
might receive the control form (unaware of the model's use)
of the EOQ problem, the simple presentation of the queuing
problem, and the technical presentation of the Markov
problem. The matrix in figure 1 shows the assignment of
problem forms (in Roman numerals) to each group of subjects.

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>2</td>
<td>III</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>3</td>
<td>II</td>
<td>III</td>
<td>I</td>
</tr>
</tbody>
</table>

Fig. 1--Assignment of Problem Forms to Subject Groups

The reason for this pattern of assignments was so
that each subject would be faced with each form of presen-
tation. Then, in rating his decision confidence, a com-
parative rating would result.

Three tasks faced each subject. First he had to read
each problem and select the alternative he felt was best.
Next he was asked to indicate on a scale how confident he
was that each decision was correct. Finally, he was asked
to indicate how familiar he was with each model. This
last step was to be used to eliminate those subjects who
did not properly fit into the sample. Appendix A shows
each of these instruments.
In order to analyze the data obtained from the first two of these instruments it was necessary to obtain a score for each subject indicating his willingness to accept the model results. This score is a composite of his choice of alternatives and his rating of decision confidence. The confidence rating was on a nine-point scale from zero to eight. Eight indicates complete confidence while zero indicates a total lack of confidence in the correctness of the decision. In the choice behavior, each subject made one of two choices: the one indicated by the model or the other alternative. Merging the two values gives a composite score. For instance the selection of the informed alternative, coupled with a high level of confidence, will indicate strong willingness to accept the model results. The choice of the uninformed alternative, coupled with high confidence, indicates a lack of willingness to accept the results of the model. The possible combinations of values number 17. The uninformed alternative with an eight rating of confidence receives a value of one. The uninformed alternative with zero confidence is a nine. The informed alternative with a zero rating also receives a nine and the informed alternative coupled with confidence of eight receives a 17. Figure 2 is the conversion scale.

Before proceeding further it should be noted that individual scores tell little. An individual with a score of 12 may not necessarily be more willing to accept the
Composite score  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Confidence Rating  3 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8
Choice

Fig. 2--Conversion Scale for Obtaining Composite Scores

information than someone with a 10. Within each experimental group, a distribution of scores is expected. Since the groups in each experimental treatment are similar, a similar distribution would be expected in each group receiving the same treatment. However, if a different treatment results in a different distribution of scores in one group, then that difference may be interpreted as a propensity to increase or decrease the acceptance of the information. Actually, two possible results may indicate such a propensity. For example, if one treatment tends to decrease acceptability, this may be reflected in the following changes in the distribution of scores. First, a larger percentage may choose the uninformed alternative. Second, those not changing their choices will reflect changes in confidence. Those still choosing the informed alternative would have less confidence in their decision while those choosing the uninformed alternative would tend to be more confident. The reason that individual scores are of limited value is that subjects can be expected to differ in the confidence they have in their decisions. Thus, a score of 12 by one individual in one treatment may not be different from a score of 10 by a subject in another
treatment. However, since the distributions of scores for large samples with the same treatment should be the same, an average score of 12 by a group with one treatment might be significantly different from an average score of 10 by a group with another treatment. This would be true even though some in the first group scored less than 10 and some in the second group scored more than 12.

Experimental Design

The experiment described in the previous section involves a comparison of the distribution of scores between various experimental groups subjected to various experimental treatments. In order to test the four hypotheses, two separate experimental designs are involved. For hypotheses one, two, and three there are three experimental treatments and two experimental groups. This design will be used to analyze either the scores obtained from the EOQ problem or from the queuing problem. The experimental groups are composed of those familiar with the model and those unfamiliar with it. The treatments refer to the form of presentation. In one treatment, a control presentation is used in which the subjects are unaware of the use of the model. In the second treatment a "simple" presentation is used in which the subjects receive the same information but are also told what model was used. In the third treatment, a "complex form of presentation is used in
### Fig. 3—Experimental Design for First Three Hypotheses

which the model results are presented in technical terms. Figure 3 describes this design.

In testing the fourth hypothesis the same sample will be rearranged into two different groups so as to be able to analyze the problem about the Markov chain. In this design, the same treatments are used but the experimental groups are somewhat different. One group will have a fairly extensive background in quantitative business models while the other group has significantly less of a background. Figure 4 describes this design.

### Fig. 4—Experimental Design for Hypothesis Four
Statistically speaking, the subjects in this experiment could be assigned to the various cells in either of two ways. Assignment could be either completely random, or an attempt could be made to match the subjects in each cell. The nature of this sample makes neither approach completely feasible or even desirable. First of all, the researcher has no control over which subjects are familiar with a specific model or with business models in general. Assignment to these groups depends upon one's entry date into the school. Therefore, a thorough matching of subjects in all cells would be almost impossible. On the other hand something close to randomization could be achieved if desired. Although the subjects in the sample groups could not be assigned randomly by the researcher, nevertheless an assumption of randomness is not unrealistic. Both classes were chosen by the Air Force from the same population using the same criteria. Therefore there is no reason to believe major differences exist between classes. Consequently, by randomly assigning members of the graduating class to cells 0_{11}, 0_{21}, and 0_{31}, and members of the incoming class to cells 0_{12}, 0_{22}, and 0_{32}, something fairly close to full randomization could be achieved. However, it is felt that randomization may not be the best method of assignment. The subjects in the sample differ among themselves in at least two noticeable ways. First, they differ with regard to military rank, with a range running
from Lieutenant to Lt. Colonel. Such a difference indicates that the subjects vary in both age and managerial experience, either of which could affect the results of the study. Also, they differ in mathematical aptitude, a factor which could also influence their willingness to accept the results of a mathematical model. A random assignment of subjects to the various treatments would tend to balance out these differences as the sample grows large. However, in this research project, a more direct approach was possible which would guarantee that these factors would not serve as a potential source of bias. Instead of randomly assigning the subjects to the various treatments, they were assigned so as to equalize military rank and quantitative aptitude among cells.

An attempt was made to have approximately the same numbers of Lieutenants, Captains, field grade officers, and civilians in each cell. Since military rank is a function of time in the service, this resulted in balancing the cells in both age and experience and, therefore, eliminating these as a source of bias in any comparison of one sub-sample to another. The subjects were also balanced according to mathematical aptitude. This was done by using their quantitative scores on the Graduate Record Examination. Where a subject had not taken that examination, his score on the Advanced Test for Graduate Study in Business was used. This resulted in approximate equality of
quantitative aptitude between cells, and, therefore, eliminated that as a potential source of bias. Other than these two factors, the subjects were randomly assigned to cells. For example, from the class about to graduate, the captains with the three highest GRE scores were assigned to cells $0_{11}$, $0_{21}$, and $0_{31}$. The next three were also randomly assigned to these cells, and so on.

The above procedure, while having the advantage of eliminating certain potential sources of bias, resulted in a problem of selecting the proper statistical test. Generally, applicable tests are categorized as suitable to related samples or to independent samples. The sampling approach described above fits neither category perfectly. First of all, the subjects are not well enough matched to fit the tests for related samples. The two classes of students were not the same size, so different numbers of subjects would fall in the cells associated with model familiarity and model unfamiliarity. Also, the matching described above was of necessity performed before the tests were administered. As noted before, some subjects had to be eliminated due to previous training but this was not possible until after the tests were taken. Therefore, the pre-test matching was no longer completely accurate when the results were ready to be analyzed. As a consequence, matched pairs were not available for analysis and tests for related samples became unfeasible.
With regard to tests for independent samples, the data do not fit perfectly here either, since complete randomization of assignment is not attempted. However, the purpose of random assignment of subjects to treatments is to average out potential bias that might exist among subjects. Since the assignment procedures achieved this goal without randomization, the effect was the same even though the method was not. Therefore, in selecting the appropriate statistical test, a test for independent samples was chosen.

In summary, the following procedure was used to assign subjects to treatments. The Air Force process of selecting subjects for schooling determined whether a subject would be familiar or unfamiliar with a specific model or with quantitative business models in general. Quantitative aptitude and military rank were then used along with randomization to determine which subject received what experimental treatment. After the testing, previous training in the models was used to eliminate subjects unsuited to the experiment. As a result of all this, slight differences in size exist among cells but there is no reason to believe that the subjects differ in any other way except for model familiarity and quantitative background, and these differences are needed as key elements of the experiment.

Before describing the statistical analysis, it is desirable to first rearrange the experimental cells into
the form of tree diagrams. Figures 5 and 6 accomplish this. The branches of these trees correspond exactly to the cells of figures 3 and 4. However, the tree form makes it clearer to describe the statistical comparisons performed. In all future references to sample groups, the numbers or letters used in these figures will be employed.

**Analysis**

The purpose of statistical testing in this study is to determine whether the various experimental treatments result in variations in the observed willingness to accept the results of quantitative business models. The function of the test will be to compare the distribution of scores observed in the various groups shown in figures 5 and 6. In each case the null hypothesis will be one of no difference. If this can be statistically rejected, it will be possible to infer that the treatments do in fact affect the willingness to accept such information.

The nature of the data dictate certain criteria for selecting the proper test. First of all, the test must be capable of dealing with ordinal data. Although a scale of values is used for the scores, nevertheless, it would be highly questionable to infer that the data measured constant intervals. The scores are subjectively assigned by the participants and it would be impossible to assume that each subject placed an identical value on each score.
Fig. 5--Experimental Groupings for Problems One and Two
Fig. 6--Experimental Groupings for Problem Three
Also, the pre-testing showed a tendency toward inflating the confidence ratings. This is observed as a small interval between scores located at each end of the scale and a large interval between the central values.

A second criteria is for a test that does not assume a normal distribution of scores. As noted above, the data from this experiment seem to approximate more closely a bi-modal distribution and even this is uncertain. Therefore, a test is needed which is free of assumptions regarding the underlying shape of the distribution.

In order to meet the above criteria it was necessary to select a non-parametric or distribution-free statistical method. Such a method is the Mann-Whitney U Test (18:116). This test is useful in determining whether two independent groups could have been drawn from the same or similar populations. It employs ordinal data and does not assume that the observations were drawn from a normally distributed population. Also, this test does not require that the samples to be compared be of the same size.

The mechanics of the Mann-Whitney Test involve a pooling of the two samples in order of increasing size and then the computation of the number of observations in one group that rank lower than each observation in the other group. This is the statistic U. The sampling distribution of U under an H₀ of no difference between samples is known. Therefore it is possible to determine
for any $U$ the probability that such a value could have occurred if the samples did in fact come from the same population. The statistic $U$ is sensitive to differences in location (central tendency). Therefore, if an experimental treatment in this study should affect the distribution of scores as reflected in the distribution's central tendency, this statistic will reflect such a change. For large samples where one group is larger than 20, the sampling distribution of $U$ rapidly approaches the normal distribution. Therefore a $U$ value can be converted to a $Z$ value and the probability can be determined associated with observing a value as extreme as the computed $Z$. Since all comparisons to be made in this study will involve at least one group that is greater than 20, this approach will be used.

In computing the necessary $Z$ values, worksheets were prepared and are shown in Appendix B. Essentially these provide for the following steps (18:125).

1. The scores from two groups are merged and ranks are assigned to each score. The ranks are then summed for each group and these values become $R_1$ and $R_2$.

2. A correction factor is calculated to correct for ties. This is the value $\Sigma T$.

3. The statistic $U$ is computed as follows:

$$U = n_1n_2 + \frac{n_1(n_1+1)}{2} - R_1$$
4. The Z value is computed as follows:

\[ Z = \frac{U - \frac{n_1 n_2}{2}}{\sqrt{\left(\frac{n_1 n_2}{N(N-1)}\right) \left(\frac{N^3 - N}{12} - \sum T\right)}} \]

5. A table of probabilities associated with values of Z is referenced to determine the probability that the observed distributions could have come from the same population.

Using the above approach it is now possible to compare the observed scores in the groupings shown in figures 5 and 6 in order to test the hypotheses made in this study.

H₀ #1. When information resulting from the use of a quantitative model is provided to a decision-maker, awareness that the information came from such a model will not affect his choice behavior or the confidence he has in his decision.

In testing this hypothesis it is necessary to compare those groups that are aware of the model's use to the control groups which are not aware of it. For an aggregate measure it is therefore necessary to combine the four aware groups 1, 2, 3, and 4, and compare them to the two control groups A and B.

Test #1  1 + 2 + 3 + 4 VS A + B

This test will permit inferences to be made about awareness in general. However, it conceals the fact that awareness can be achieved in different ways. In this study two means of bringing about awareness are used. One is a simple statement to the effect that the model was used while the other involves awareness through more technical
terms. In order to determine whether the method of bringing about awareness has any bearing on acceptance, two additional comparisons must be made. Those receiving the simple presentation must be compared to the control groups, and those receiving the technical presentation must be compared separately to the same control groups.

Test #2  \(1 + 3\) VS \(A + B\)
Test #3  \(2 + 4\) VS \(A + B\)

Another problem in test number 1 is that it aggregates both familiarity groups. If each group were affected differently, this aggregation would tend to obscure the effects. Therefore, in order to establish whether the conclusions from test number 1 apply equally to both subgroups, each familiarity class must also be tested separately. First, the subjects who are familiar with the model and aware of its use must be compared to the subjects who are familiar with it but unaware of its use. Next the same must be done for the unfamiliar groups. The next two tests will accomplish this.

Test #4  \(1 + 2\) VS \(A\)
Test #5  \(3 + 4\) VS \(B\)

The above five applications of the Mann-Whitney U Test will permit the testing of the first hypothesis. Test #1 will give a general indication of whether awareness of a model's use evokes a response set by which attitudes toward the model or toward such models in general affect the
acceptance of the information. The next two tests will indicate whether this general conclusion varies with the level of complexity with which the information is presented. The remaining tests will determine whether the general conclusion applies equally to both familiarity classes or if the general conclusion represents merely the aggregation of different effects.

H₀#2. When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, the complexity with which the information is presented will not be reflected in either choice behavior or decision confidence.

In this hypothesis, the question is whether a presentation made in technical terms will adversely affect the likelihood that the information will be accepted. The comparison must, therefore, be between groups receiving a technical presentation and groups receiving simple presentations.

Test #6  1 + 3 VS 2 + 4

This test will give an aggregate indication of effect but it would also be of value to observe the effect among those familiar with the model and among those unfamiliar with it. This could indicate whether a particular type of presentation is particularly effective or distracting when used on a particular type of audience. First, a comparison will be made between complexity and simplicity of presentation for the groups who are familiar with the model, and
then for the unfamiliar groups. The tests for this are as follows:

Test #7  1 VS 2
Test #8  3 VS 4

H₀ #3. When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, familiarity with the model will not be reflected in either choice behavior or decision confidence.

The comparisons needed to examine this hypothesis were already performed in the testing of hypothesis 1. They involve a comparison of the aware groups to the unaware groups for each familiarity class. They are:

Test #4  1 + 2 VS A
Test #5  3 + 4 VS B

These tests will indicate how awareness affects each familiarity group. In addition, if the testing of hypothesis 2 should show that complexity is a major factor, then each of the four experimental groups will have to be compared separately to the appropriate control group. This would indicate whether the effect of familiarity (or the lack of familiarity) varied with the method of presentation. The appropriate tests for this would be:

Test #9  1 VS A
Test #10  2 VS A
Test #11  3 VS B
Test #12  4 VS B
On the other hand, if the testing of hypothesis number 2 should show that complexity is not a factor, then the above four tests may be omitted.

$H_0 \#4$. When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, but is unfamiliar with the specific model, general training in quantitative business models will not be reflected in either choice behavior or decision confidence.

This hypothesis must be tested in conjunction with hypothesis 3. It is important only with regard to a comparison that shows how skilled subjects differ in their reaction to familiar and to unfamiliar models. If training and familiarity prove to be important in hypothesis 3, then does the effect of the training carry over to other models as well? In order to examine this issue, it is necessary to determine whether the better trained group is affected by the awareness that a model has been used with which they are not familiar. The test of this hypothesis is:

Test $\#13 \quad 5 + 6 \ VS \ C$

If the results should prove different from those found earlier in test 4, then inferences may be drawn regarding transference of effect of training in quantitative business models.

Test $\#13$ will be meaningful only if it was earlier found that complexity is not a major factor in acceptance. If complexity is a factor, then each level of complexity must be examined. The group receiving the simple
presentation must be compared to its unaware counterpart as must the group receiving the complex presentation.

Test #14  5 VS C
Test #15  6 VS C

If complexity is found to be significant, then the inferences to be made in this hypothesis will depend on whether the effect of test 14 is similar to test 9, and whether test 15 shows the same effect as test 10.

Altogether, 15 comparisons are shown above to be pertinent to the four hypotheses. Actually, many more will be performed. In most cases, each test may be performed on each of the three problems, although in some tests the data from only one or two problems will be appropriate. Where more than one problem is analyzed by a test, the results will serve as a replication of the test and will give an indication of the consistency of the results.

In all of these comparisons, the Mann-Whitney U Test will be used as the basis of the analysis. The results of these analyses are the subject of Chapter VI.
CHAPTER V

CONDUCT OF THE EXPERIMENT

Composition of Sample

In the final experiment, the subjects are graduate students at the School of Systems and Logistics of the Air Force Institute of Technology. During the time period available to this researcher, three classes of students were available for testing. Together, the three classes provided a possible 214 subjects. While this group was sufficiently large for the conduct of the experiment, it was not large enough to draw upon for a pre-test sample. It was originally estimated that about 100 subjects would be needed for a pre-test, and to have taken these from the 214 available graduate students would have left too few remaining for the conduct of the experiment. Therefore, a different group was needed from which to draw subjects for the pre-testing.

The School of Systems and Logistics also provided the subjects for the pre-tests, but the population from which they were drawn was different from that used in the final experiment. The Continuing Education Department of that
school conducts short courses in 34 subjects. It was from
the students in these courses that the pre-test sample was
drawn. Students in eight classes were approached and asked
to volunteer for the pre-test. The subjects were all
either military officers between the ranks of 2nd Lieuten-
ant and Colonel or civilians with the Department of Defense
with grades between GS-7 and GS-14. The education level
ranged from High School graduate to holders of a Doctor
of Philosophy Degree. While this spread in rank and
education was different from that found in the sample
used in the final experiment, it was satisfactory for
the purpose of the pre-test. A total of 97 subjects
participated in the pre-testing.

As already noted, the subjects in the final experiment
were graduate students at the School of Systems and Logis-
tics. The subjects were all either military officers or
civilians in the Department of Defense and each was the
holder of a bachelor's degree. The officers ranged in rank
from 1st Lieutenant to Lt. Colonel and the civilians were
all GS-12, GS-13, or GS-14 civil service employees. Of
the total of 214 students, 176 were tested and 150 were
used in the analysis. The 26 not used were eliminated for
several reasons. For three, no Graduate Record Examination
score was available so they could not be satisfactorily
assigned to the experimental groups. Two were foreign
officers with limited ability in English. The remainder
were subjects who had to be eliminated because of previous training in the models.

The subjects came from three graduating classes. The class of 1970 was tested in the last week of the classroom portion of its program. The only phase of the program remaining was the thesis. These students had received all of their quantitative training and could properly be classed as familiar with the EOQ and queuing models and relatively well trained in quantitative business techniques. The class of 1971A was tested in the first week of its second quarter at the school. These students had completed a mathematics refresher course and a course in statistics but were not yet trained in the models covered in this experiment. The class of 1971B was tested on the first day of orientation upon arriving at the school and had not yet received any training. These last two groups, after eliminating those with prior training in the models, could properly be classed as unfamiliar with the models being covered and as relatively untrained in quantitative business methods.

The 150 subjects were divided into six groups. The groups varied in size for two reasons. First, the combined strength of the classes of 1971A and 1971B was larger than that of the class of 1970. This meant that three of the groups would be larger than the other three groups. Also, the assignment to groups was made before the subjects with
prior knowledge were eliminated. This was necessary since prior knowledge was not known to this researcher until the test was taken. These factors also account for some of the variance in rank and quantitative aptitude that existed in the groups, since they were matched before the eliminations were made.

The subjects were divided into four rank groups (Lieutenants, Captains, field grade officers, and civilians) and then they were matched by quantitative aptitude. Table 1 shows the final distribution of subjects according to the groups for the analysis of the first problem.

**TABLE 1**

Characteristics of Experimental Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Lieutenants</th>
<th>Captains</th>
<th>Field Grades</th>
<th>Civilians</th>
<th>GPA</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23%</td>
<td>50%</td>
<td>23%</td>
<td>5%</td>
<td>600.5</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>48</td>
<td>29</td>
<td>5</td>
<td>599.5</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>70</td>
<td>7</td>
<td>7</td>
<td>606.5</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>64</td>
<td>16</td>
<td>3</td>
<td>600.8</td>
<td>31</td>
</tr>
<tr>
<td>A</td>
<td>24</td>
<td>48</td>
<td>24</td>
<td>5</td>
<td>599.5</td>
<td>21</td>
</tr>
<tr>
<td>B</td>
<td>16</td>
<td>64</td>
<td>16</td>
<td>4</td>
<td>605.7</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>

The difference in sample size between groups 1, 2, and A on the one hand and 3, 4, and B on the other is due to the fact that the class of 1970 was not as large as the two classes of 1971 combined. The difference in rank structure is due to the larger proportion of captains in the two newer classes, partly a result of a recent lowering of the promotion time to that grade. For the analysis of
problem 2, eight of the subjects in groups 3, 4, and B were eliminated so the total sample fell to 142. The distribution, however, did not differ significantly from that in table one. For problem 3, 15 subjects were eliminated due to familiarity with the Markov model. Again, it did not significantly change the distribution shown above.

From table 1 it is seen that the various groups were similar with regard to rank and quantitative aptitude. While exact matching of subjects was an impossibility, it can be assumed that these two factors have been controlled and will not significantly affect the independent variables in this study.

**Pre-Tests**

There were two primary purposes behind the pre-testing. First, it was necessary to be sure that the instruments were clear and unambiguous. The second purpose was to establish the value of the information (model output).

Three separate pre-tests were conducted. Unlike the final experiment, however, the pre-tests were not conducted in a controlled environment. With the permission of each class instructor, this researcher appeared before various continuing education classes at the School of Systems and Logistics and asked for volunteers. The experiment was described to the classes only as an experiment
in decision-making. The subjects were not told that the variables being studied involved the use of quantitative models. This was concealed in order to avoid a possible bias in results. After explaining what was needed, the volunteers were given the test booklet which they completed at their leisure and returned several days later.

The pre-tests consisted of three problems in one of two problem forms, a scale for indicating decision confidence, and a cover letter. Only one of the two problem forms was the same as one that would be used in the final experiment. That was the control form of the problem in which the model output was provided but without mentioning the specific model which was used. The other pre-test form omitted all reference to either the model or its output. Together these provided a measure of the value of the information obtained from the model. One group of subjects received all of the information related to a problem except the results of the model. This gave an indication of what decisions would be made in the absence of the use of the model. The other group received the identical information but was also given the results of the model (but without being told that the model was used). This gave an indication of how the decisions would change if the model information was given. The difference between the two decisions, therefore, would be a measure of the value of the model information. For example, if 90 percent
of the subjects who were not given the model information chose alternative A and if 80 percent of the subjects who were given the model output chose alternative B, it can be assumed that the model output is of such a value as to determine the decision of approximately 70 percent of the participants. Later, in the final experiment, it can be inferred that any independent variable which detracts from the acceptability of that information will show up as an increased propensity to choose alternative A or as a decrease in confidence in the case of subjects who still choose B.

With regard to increasing clarity and decreasing ambiguity, the pre-testing resulted in numerous changes in the instruments. It was found that earlier problem forms were sometimes weak in defining what the alternatives were. Also, some of the information was found to be ambiguous in that it had different implications to different subjects. The pre-test results, coupled with informal interviews with some of the participants, brought to light these problems and they were corrected. One other problem observed in the pre-testing involves the confidence scales. It was found that the original wording resulted in overly inflated ratings and in the disproportionate selection of even numbered ratings and the exclusion of odd numbered ones. The rating scale was, therefore, revised with a resultant decrease in the inflation factor and a greater
dispersion of ratings. The inflation factor, however, was never fully eliminated. In the first pre-test it was found that subjects almost never had less than moderate confidence in their decisions. Even when a particular problem resulted in half the sample choosing each alternative, the subjects were still very confident in their choices. A change in the wording of the scales helped somewhat, but the inflation was never fully eliminated. While the inflation problem is beyond the scope of this study, some possible explanations can be hypothesized. Morris saw it as a case of maintaining an appropriate self-image when he wrote: "There is often a need to maintain a self-image of confidence and certainty in decision making as well as to project such an image both to his superiors as an indication of executive ability and to his subordinates to inspire respect and confidence in leadership." (15:190). This implies that practicing managers develop confidence as a habit and that they may be psychologically unable to hold very low levels of confidence in any decision they make. Another possible explanation may come from dissonance theory. This theory predicts that a subject will tend to avoid information contrary to a decision he has made. If this is true, once a decision has been made the subject may tend to discount contrary information when estimating his confidence. The result would be that a subject who maintains that he is
moderately confident, may have in fact faced more conflict than his confidence rating indicates. Consequently, a very slight change in the information may have led him to choose the other alternative even though, after the fact, it would appear that a more significant change might have been necessary. In any case, the inflation remaining is not an insurmountable problem since a distribution-free statistical test is being used and rankings rather than absolute values of the ratings are important. Nevertheless, even here some problem remains and the clustering of scores around the upper values of the confidence scale will tend to obscure significance that might have been found if the entire scale had been employed.

The second purpose of the pre-testing was to establish the informational value of the model output. As already noted, the value of such information can be observed as the difference in decisions made by subjects possessing the information and those not having the information. For the purpose of analysis it was useful to be able to establish certain predetermined values. First of all, it was necessary to have close to unanimity in the selection of one alternative (the uninformed alternative) when the model output was absent. This would permit the prediction that when the model output was disregarded or mistrusted, there would be a resultant increase in attractiveness of the uninformed alternative. By the third pre-test, the
problems were such that at least 75 percent of the subjects receiving that problem form (without the model output) chose the uninformed alternative.

In the case of the problem form that provided the model information, it was attempted to weight that information so that about two-thirds of the subjects would choose the informed alternative. In this case unanimity was not desired since it might make the instrument insensitive to the variables to be tested. If the information is too potent, then it might be impossible for subjects to reject it, even if some apprehension is present. Therefore, a goal of two-thirds was arbitrarily established. Since this problem form was used in the actual experiment, the success of the pre-testing can be seen in the results obtained in the experiment itself. In the first problem, 63 percent of the subjects chose the alternative pointed to by the model (the informed alternative). In the second and third problems, the figures were 57 percent and 56 percent respectively. While all of these figures fall somewhat short of the two-thirds goal, they are considered satisfactory and further revisions and pre-testing were considered unnecessary.

As a result of the pre-testing, certain conclusions were permitted with regard to the value of the information. If the model output was not provided to the decision-maker, no more than 25 percent would be expected to choose the
informed alternative. When that information is provided, a minimum of 56 percent would select it. It can, therefore, be concluded that the information coming from the models, if used in making the decision, will play a significant role in determining which alternative will be chosen. Anything that serves to detract from the acceptance of that information should, therefore, be observable by a decrease in the selection of the informed alternative and an increase in the selection of the uninformed alternative.

**Testing of the Sample**

A total of 176 subjects participated in the experiment. 150 of these were usable in the analysis of problem 1, 142 were usable in the analysis of problem 2, and 135 were usable in problem 3. The test was administered at four different times in the auditorium of the School of Systems and Logistics at Wright-Patterson Air Force Base, Dayton, Ohio. Each experiment was allotted forty minutes, but most subjects finished in less than 30 minutes. In no case did it appear that time was a constraint on any subject.

Instructions were both written and oral. The written instructions were identical for all subjects. In order to prevent bias from the oral portion, a speech was prepared and memorized so that all subjects could be assumed to have had identical instructions. The first task for each
subject was to read each problem and make his decisions. Only after all three decisions were made were they permitted to rate their confidence. Upon completion of that, the subjects returned those portions of the experiment to the researcher and picked up the instrument asking them to indicate their model knowledge. This instrument was purposely withheld until the rest of the task was completed so as to conceal for as long as possible the variables being studied. It was felt that it was best that the subjects be unaware of the exact purpose of the study until they were finished, so as to eliminate a possible source of bias from developing. In the introductions they were told only that it was an experiment in decision-making. The subjects in the earlier groups were also asked not to discuss the experiment with anyone scheduled to participate later.

As noted before, three classes were tested: the classes of 1970, 1971A and 1971B. For the classes of 1970 and 1971B the test was given during regular class hours and attendance was in effect mandatory. Ideally, these two classes would have been all that were needed. However, in the case of 71B (the class that was just beginning their course of study), it was unknown how many would have to be eliminated due to prior training. Therefore, volunteers from the class of 71A were used to compensate for any possible losses. Classes 71A and 71B could be used
interchangeably in the experimental groups that were unfamiliar with the models. 71B had not yet begun the course work, and although 71A had completed the first quarter, they were not yet exposed to the type of models in question.

Reliability

In any experiment of this nature, a major problem involves the reliability of the research instrument. In this experiment the scores that were compared were obtained by asking each participant to indicate how confident he was in his decision. Such scores would naturally be expected to vary somewhat over time. It is unlikely that all subjects would feel the exact same amount of confidence in the same decision at different times. The problem, therefore, is to see how great this variance is and to establish its possible effect on the research findings.

The reliability measure needed to evaluate the research instrument is a coefficient of stability. This would give an indication of how the observations vary over time. The traditional means of obtaining this coefficient is the test-retest approach and the computation of a Pearson product-moment correlation coefficient from the two sets of scores (7:282).

In this research project it was not feasible to use the test-retest approach on the same sample used in the
experiment itself. By the time the retest was given, it would have been likely that the sample would be biased. In the experiment, the last step was to ask the subjects about their knowledge of the models involved. This was likely to indicate to them the purpose of the test. In the actual experiment this did not matter since they had already turned in the other portions of the test. However, in the retest, this knowledge might have resulted in a bias.

Therefore, in order to avoid bias, a different group of subjects was used for the test of reliability. The first time they were tested the subjects were not given the instrument asking for model knowledge. Furthermore, they were asked to refrain from discussing the experiment with other participants.

The subjects used were similar in nature to those used in the experiment. They were military officers working toward graduate degrees in business. However, instead of being at the School of Systems and Logistics, these subjects were in residence at the Ohio State University. When asked to participate, they were informed that they would have to take two tests with an interval of several weeks between them. They were not told it would be the same test both times. However, when they were re-tested, they were informed that the tests were the same, so as to prevent them from imagining differences that were not there.
Fifteen subjects took the first test but only twelve took the retest. The retest was taken two to five weeks after the original test. While this may have been insufficient time to completely eliminate memory as a factor, a longer period may have been affected by maturation. Some subjects were taking courses in related subjects and it was feared that if too long an interval were used, they may have developed attitudes that could influence their answers.

Since each participant answered all three problems, a total of 36 observations was available. The computed reliability coefficient was .743. The computations are shown in Appendix C.

The results of this reliability test are both interesting as well as distressing. They are distressing because they indicate that the instrument is not highly reliable. Although there is a definite correlation between the test and retest, a considerable amount of unexplained variance exists. In the testing of the hypotheses, this error variance can be expected to partly obscure any significance that may exist.

The interesting element involves the nature of this variance. At the outset, it was expected that confidence would tend to vary with time. However, it was not expected that decisions would vary also. Altogether, of the 36 observations, 13 indicated some change over time. Eight of
these merely indicated some change in confidence, but five involved reversals of the decision itself. The nature of these reversals is particularly interesting. In the original test, all five subjects indicated that they were at least moderately confident in their decision. Upon reversing their choice in the retest, each was again at least moderately confident that his new decision was correct. While it might not be surprising to find subjects who indicate low confidence changing their decisions, it is surprising to find subjects change their minds who had initially appeared fairly certain of their decision. This phenomenon, however, is in line with the earlier discussion of inflation of ratings. At that time it was shown that the participants rarely displayed less than moderate confidence in their decisions. These two findings together may indicate that decision-makers are not always consciously aware of the amount of conflict they experience in making a decision. Consciously they may feel the decision is "cut and dry," whereas in fact the decision may have been very close, and very slight differences in evidence may have been all that were needed to change their minds.

For the present study, the low reliability could have two interpretations. First, it may reflect a lack of precision of the instrument to get a true measure of a person's willingness to accept certain information. On the
other hand, it may indicate the lack of reliability (consistency) of the decision-maker. It is possible that there is no true measure except with respect to a moment in time. The frequency with which the decisions were reversed adds credence to this second possibility. In either case, the measures used in this study include a certain amount of unexplained variance which will be reflected in the hypothesis testing as a decreased ability to prove statistical significance.
CHAPTER VI

RESULTS AND DISCUSSION

Altogether, thirty statistical comparisons were needed in order to test the four hypotheses. Each comparison was based on the Mann-Whitney U Test. The results are described below and are also presented in tables 2 through 5, grouped according to the hypothesis to which they pertain.

H₀ #1: When information resulting from the use of a quantitative model is provided to a decision-maker, awareness that the information came from such a model will not affect his choice behavior or the confidence he has in his decision.

In testing this hypothesis, the initial comparison must be made between the four groups that are aware of the model's use and the two control groups that were not told that the model was used. This will indicate whether attitudes, evoked by awareness, result in any perceptible difference in decisions. Using the numbers assigned to the various groups in figures 5 and 6 of Chapter IV, this involves a comparison of groups 1+2+3+4 VS A+B for problems 1 and 2; and a comparison between groups 5+6+7+8 VS C+D for problem 3.
### TABLE 2

**STATISTICAL TESTS FOR HYPOTHESIS #1**

#### A. GROUP DESIGNATIONS

<table>
<thead>
<tr>
<th>Aware</th>
<th>Unaware</th>
<th>Aware</th>
<th>Unaware</th>
<th>Aware</th>
<th>Unaware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar w/Model</td>
<td>Familiar w/Model</td>
<td>Unfamiliar w/Model</td>
<td>Unfamiliar w/Model</td>
<td>Strong Background Com-Simple Complex Pres.</td>
<td>Weak Background Com-Simple Complex Pres.</td>
</tr>
</tbody>
</table>

| 1 | 2 | 3 | 4 | A | B | 5 | 6 | 7 | 8 | C | D |

#### B. Statistical Tests

<table>
<thead>
<tr>
<th>Test #</th>
<th>Case Problem #</th>
<th>More Accepting Group(s)</th>
<th>Less Accepting Group(s)</th>
<th>Level of Rejection For Ho</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1+2+3+4</td>
<td>A+B</td>
<td>.2802</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>A+B</td>
<td>1+2+3+4</td>
<td>.0376</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>5+6+7+8</td>
<td>C+D</td>
<td>.4592</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1+3</td>
<td>A+B</td>
<td>.3682</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>A+B</td>
<td>1+3</td>
<td>.0910</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5+7</td>
<td>C+D</td>
<td>.6818</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2+4</td>
<td>A+B</td>
<td>.3270</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>A+B</td>
<td>2+4</td>
<td>.0548</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>6+8</td>
<td>C+D</td>
<td>.4066</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1+2</td>
<td>A</td>
<td>.0628</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>A</td>
<td>1+2</td>
<td>.0872</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>C</td>
<td>5+6</td>
<td>.6600</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>B</td>
<td>3+4</td>
<td>.8886</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>B</td>
<td>3+4</td>
<td>.1970</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>7+8</td>
<td>D</td>
<td>.1416</td>
</tr>
</tbody>
</table>
In problem 1, the groups that were aware of the model tended to be more accepting, but the probability that two such samples could have come from the same population was $p = .2802$. Therefore, it is impossible to reject the null hypothesis of no difference. In problem 3, the aware group also tended to be more accepting but in this case the probability was $p = .4592$. Again the null hypothesis could not be rejected. In problem 2, however, the groups that were aware of the model showed a decreased willingness to accept the information and in this case the two-tailed probability was $p = .0376$. In that problem, it appears likely that awareness was a significant factor.

Therefore, the three tests give conflicting results. In two instances there is little reason to believe that awareness played an important part, but in the third, the null hypothesis could be rejected at a level of .05. One possible source of the discrepancy could be a possible counter-balancing of effects resulting from the aggregation of the four aware groups into one group for this test. Since the aggregations involved a merging of both familiarity groups and both levels of complexity, either could be the basis of the discrepancy. If aggregation is in fact the cause, what must be found is a counter-balancing that has occurred in problems 1 and 3 but not in problem 2.

In order to observe the effect of aggregation by level of complexity, it is necessary to observe the effect of
each level independently. This means a comparison of the control (unaware) groups to the experimental groups receiving the simple presentation first, and then to the groups receiving the complex presentation. If opposite effects are found in problems 1 and 3 but not in 2, then that could be the source of the discrepancy. In order to make such a comparison, the following tests must be conducted: For problems 1 and 2---1+3 VS A+B and 2+4 VS A+B; for problem 3---5+7 VS C+D and 6+8 VS C+D.

In problem 1, awareness through the complex format resulted in an increased acceptance with the ability to reject the null hypothesis of \( p = .3682 \). Awareness through the simple format also increased acceptance with a \( p = .3270 \). Since both groups were affected in the same way and to similar extents, there was no counter-balancing.

In problem 2, the groups receiving the complex formats showed decreased acceptance with \( p = .0910 \) and the groups receiving the simple form also showed decreased acceptance with \( p = .0548 \). Again the direction and magnitude of effect was the same, so no counter-balancing was observed.

In problem three, both groups showed slightly increased acceptance with \( p = .6818 \) and .4066 respectively. Again no counter-balancing was observed.

From the above tests, it is apparent that the discrepancy in the tests of \( H_0 \#1 \) were not caused by a counter-
balancing of effects due to aggregation by level of complexity.

In order to see if the discrepancy is due to a counter-balancing resulting from aggregation by familiarity class, a procedure similar to that used above is needed. In this instance, however, each familiarity class must be compared to the corresponding control (unaware) group. If the two familiarity classes act similarly, no counter-balancing would be involved. If they react differently in problems 1 and 3 but not in 2, the discrepancy in the testing of $H_0$ #1 is explained. For problems 1 and 2, the pertinent comparisons are 1+2 VS A and 3+4 VS B. For problem 3 they are 5+6 VS C and 7+8 VS D.

In problem 1, the two groups familiar with the EOQ model showed an increased willingness to accept the information. The ability to reject the null hypothesis had a p = .0628. For the unfamiliar groups, there was virtually no difference from the control group. The two unfamiliar groups were slightly less accepting but the ability to reject the null hypothesis was only p = .3836. Therefore, in problem 1, there was some counter-balancing observed and the aggregation of familiarity classes resulted in a group that was relatively similar to the control groups.

In problem 2, both familiarity classes tended to be less accepting than the groups which were unaware of the model. For the familiar groups, the null hypothesis could
be rejected at $p = 0.0872$ and for the unfamiliar groups at $p = 0.1970$. In this problem, the two classes therefore reacted in the same direction and the effect was fairly similar in magnitude. No significant counter-balancing, therefore, resulted from combining the groups.

In problem 3, the highly trained groups were slightly less accepting with a $p = 0.6600$. The untrained group tended to be more accepting with $p = 0.1416$. The result of the combination, therefore, was to counteract the two effects.

From the above comparison, it can be concluded that the contradictory results obtained in the initial testing of the first hypothesis resulted from the aggregation of subgroups by familiarity class. In problems 1 and 3, the two familiarity classes reacted in different ways and, therefore, the effect of combining the classes was to obscure these reactions. In problem 2, the two classes reacted in the same way and, therefore, the effect of combining them (with the resulting increase in sample size) was to reinforce the effect.

From the above statistical tests certain conclusions can be drawn with regard to the first hypothesis. To begin with, it is not possible to reject the null hypothesis which states that awareness of a model's use does not affect the decision-maker's willingness to accept the output of the model. However, the acceptance of the null
hypothesis is far more complex than a simple rejection of awareness (and the attitudes evoked by it) as a significant factor in the use of this type of information. In this case, it means only that for the population as a whole, there is no predictable effect with regard to such awareness. If awareness is a factor, then it is clouded in a complex system of effects which may vary by subgroup in the population. As far as the tests discussed so far have shown, it is still possible that one or both familiarity groups are affected by awareness, but the effect is not necessarily the same for each group. Only if it can be shown that awareness significantly affects both familiarity groups, and under what conditions the two groups will be similarly affected, could it be predicted when and in what direction awareness will affect the population as a whole. In part, this issue is studied in the other hypotheses of this study.

H₀ #2: When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, the complexity with which the information is presented will not be reflected in either choice behavior or decision confidence.

The statistical comparison needed to test this hypothesis involves comparing the groups which received the complex problem form to the groups receiving the simple form. If the comparison indicates a high probability that the groups are from different populations, then the null
### TABLE 3

**STATISTICAL TESTS FOR HYPOTHESIS #2**

#### A. Group Designations

<table>
<thead>
<tr>
<th>Familiar With Model</th>
<th>Aware That the Model Was Used</th>
<th>Strong Background</th>
<th>Weak Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Pres.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

#### B. Statistical Tests

<table>
<thead>
<tr>
<th>Test #</th>
<th>Problem #</th>
<th>More Accepting Group(s)</th>
<th>Less Accepting Group(s)</th>
<th>Level of Rejection For Ho</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>2+4</td>
<td>1+3</td>
<td>.9522</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1+3</td>
<td>2+4</td>
<td>.7872</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>6+8</td>
<td>5+7</td>
<td>.7414</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>.9920</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>.6020</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>.3524</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>.9840</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>.8572</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>8</td>
<td>7</td>
<td>.8104</td>
</tr>
</tbody>
</table>
hypothesis may be rejected. Using the group designations employed in figures 5 and 6, the problem involves a comparison of groups 1+3 VS 2+4 for the first two problems, and 5+7 VS 6+8 for problem 3. In problem 1, the two groups showed almost no difference. In fact the null hypothesis could only be rejected at a level of $p = .9522$. Likewise in problem 2 almost no difference was detected with $p = .7872$. For problem 3, rejection was possible only at $p = .7414$. From the above tests it can be concluded that the level of complexity made virtually no difference to the population as a whole.

However, as in the testing of the first hypothesis, it is also necessary to find out whether complexity has a different effect on the various familiarity groups. To test this possibility it is necessary to compare the effect of complexity for each familiarity group separately. For problems 1 and 2, the comparisons to be made are 1 VS 2 and 3 VS 4. For problem 3, the applicable comparisons are 5 VS 6 and 7 VS 8. In problem 1, complexity made virtually no difference to either familiarity group. The null hypothesis could be rejected for the familiar group only at a level of $p = .9920$, and for the unfamiliar group at $p = .9840$. In problem 2 the results were similar with an ability to reject of $p = .6020$ and $.8572$ respectively. For problem 3 the values were $p = .3524$ and $.8104$. 
In all comparisons, virtually no differences occurred due to the level of complexity with which the information was presented. The null hypothesis cannot, therefore, be rejected. In fact it can be safely said that the complexity of presentation had no effect on the subjects of this experiment. In interpreting this conclusion, one qualification is necessary. Complexity is a relative term and the level of the complex presentation employed in this experiment represents only one possible degree of complexity. In this case, two criteria were used in establishing that level. First, the terms which made the presentation complex were designed to appear complex only to those subjects who were unfamiliar with the model. Subjects who were trained in the use of the model should have had little trouble in understanding the terms. Second, the complexity was presented in such a way that the results of the model's application were still clear. Therefore, even if the complex terms tended to confuse the subject, he still was aware of what alternative the model pointed to.

The qualification therefore, is as follows: At the level of complexity used in this study, complexity appears to have had no effect on the willingness to use the information. As long as the complexity does not interfere with the communication of results, it appears to play no part in the decision. From this, a rather significant implication can be seen. Decision-makers appear to
disregard mathematical terms they don't understand, and concentrate on the material which is clear to them. This appears to refute the contention of many management scientists that complex mathematical terms tend to hinder the acceptance of research findings. It confirms instead the contention of Churchman who found that the mode of communication made no difference in such cases (25:35). It appears that complexity hinders acceptance only where it interferes with the communication of research results. If the researcher clearly indicates what decision the model points to, then complexity or mathematical terminology should be neutral in effect.

H₀ #3: When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, familiarity with the model will not be reflected in either choice behavior or decision confidence.

In the testing of hypothesis 1, it was implied that if the two familiarity groups are affected by awareness, the effect will not necessarily be in the same direction or of the same magnitude. Therefore, in testing hypothesis number 3, each familiarity group must be tested separately. Since hypothesis number 2 indicated that complexity had no effect, it is now possible to combine the two complexity levels for each familiarity group, thereby increasing the sample size. This permits the elimination of tests 9 through 12 described in Chapter IV.
### TABLE 4

**STATISTICAL TESTS FOR HYPOTHESIS #3**

#### A. Group Designations

<table>
<thead>
<tr>
<th>Aware Familiar w/Model</th>
<th>Unaware Familiar w/Model</th>
<th>Aware Unaware Weak Background</th>
<th>Unaware Weak Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+2</td>
<td>3+4</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>

#### B. Statistical Tests

<table>
<thead>
<tr>
<th>Test #</th>
<th>Problem #</th>
<th>More Accepting Group(s)</th>
<th>Less Accepting Group(s)</th>
<th>Level of Rejection For Ho</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>1+2</td>
<td>A</td>
<td>.0628</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>A</td>
<td>1+2</td>
<td>.0872</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>B</td>
<td>3+4</td>
<td>.8886</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>B</td>
<td>3+4</td>
<td>.1970</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>7+8</td>
<td>D</td>
<td>.1416</td>
</tr>
</tbody>
</table>

The applicable comparisons for this test are as follows: For problems 1 and 2, the comparisons are 1+2 VS A, and 3+4 VS B. This involves a comparison, for each familiarity group, between subjects who are aware that the model was used and subjects who are not aware of that fact. In problem 3 only the untrained groups may be tested. For them the Markov process is the same as the other two models since they are untrained in any of them. Therefore, a comparison of the experimental and control groups has the same meaning as in the other two problems. For the trained group this is not the case since they are untrained in the Markov model but skilled in the other
two. Therefore, for problem 3 the only meaningful comparison for testing this hypothesis is 7+8 VS D.

Essentially, the purpose of these tests is to compare the groups that are aware of the model's use to the groups that are unaware of it. If they differ significantly, it may be inferred that awareness has an effect on the particular familiarity class being tested.

For the groups which were familiar with the model in problem 1, awareness resulted in an increased willingness to accept the information. In that problem the null hypothesis could be rejected at a $p = .0628$. In problem 2, awareness decreased the acceptance with $p = .0872$. Both of these tests reflect two-tailed probabilities since the results pointed in different directions and a directional alternate hypothesis is, therefore, not realistic. In neither problem can the null hypothesis be rejected at the traditional level of .05. However, since both problems showed probabilities fairly close to this level, it is felt that sufficient reason exists to at least question the truth of the null hypothesis. The main problem, however, is to explain why the effects were opposite in the two problems. The tests themselves offered no way in which to explain this phenomenon. Instead, sample subjects were interviewed with the aim of explaining this contradiction. The subjects contacted were those who indicated a willingness to accept the model output in
problem 1 but rejected it in problem 2. Although only eight participants were interviewed, a likely explanation was found.

In problem 1, all subjects who were satisfied with the model selected the alternative to which it pointed. The behavior was as predicted. In problem 2, however, the opposite occurred with most subjects. Satisfaction with that model did not result in the selection of the alternative to which it pointed. In that case, some of the subjects viewed the problem as primarily one of scheduling or human relations. When the queuing solution showed a monthly savings of only $232, those who saw it as a scheduling problem felt convinced that a greater saving was possible through better scheduling. Those who saw it as a human relations problem felt that $232 was insufficient savings to warrant the adverse human relations effects. Knowing that the queuing model treated neither scheduling nor human relations, these subjects saw it as support of their own conclusions. The subjects who received the control form of that problem did not know how the information was obtained and, therefore, did not know whether scheduling and human relations were considered. They felt less willing, therefore, to reject the results of the analysis than did those who knew what model had been used. Briefly, therefore, acceptance of the model in problem 2 tended to lead to the uninformed alternative
rather than to the informed alternative as originally predicted.

While this explanation appears adequate to explain the contradictory results obtained in testing this hypothesis against subjects who are familiar with the model, it is probably insufficient to justify a conclusion that trained subjects tend to be more willing to accept a model's output when they are aware of the model's use. Instead, it will be merely concluded that awareness probably affects acceptance by such subjects, but the direction of the effect will be left as inconclusive.

For the groups which were unfamiliar with the model being used, the appropriate comparisons are 3+4 VS B for the first two problems and 7+8 VS D for problem 3. In the first problem virtually no difference appeared. The ability to reject the null hypothesis was $p = .8886$. In problem 2, awareness tended to decrease acceptance of the information but the probability that the two populations were similar was $p = .1970$. In problem 3, acceptance increased somewhat with awareness with $p = .1416$.

From the above tests of untrained subjects it is not possible to reject the null hypothesis. It cannot be concluded that untrained subjects react in any way to awareness that a particular model was used. And even if such an inference could be made, the direction of the effect is wholly unexplained. In one problem it appeared
to result in increased acceptance, in another in decreased acceptance and in the third in no effect at all. The conclusion of affirming the null hypothesis is consistent with the findings of hypothesis 2. If the subject is unfamiliar with the model, he apparently ignores the fact that it was used and makes his decision primarily on its output. He apparently is neither "scared off" by his lack of knowledge, nor is he "overpowered" by the presige of the mathematics.

In summary, hypothesis 3 leads to the conclusion that the two familiarity groups may very well be affected differently by the awareness that a model was employed. For subjects who are familiar with the model there is some indication (although not statistically certain) that awareness of the model's use evokes attitudes toward the model which affect the way in which the information is used. For subjects who are not familiar with the model, such an effect is either non-existent or relatively weak. In any case, the direction of the effect for either group is uncertain and is evidently determined by factors not examined in this research effort.

H₀ #4: When information resulting from the use of a quantitative model is provided to a decision-maker under conditions where he is aware that the model was used, but is unfamiliar with the specific model, general training in quantitative business models will not be reflected in either choice behavior or decision confidence.
TABLE 5
STATISTICAL TESTS FOR HYPOTHESIS #4

A. Group Designations

<table>
<thead>
<tr>
<th>Aware</th>
<th>Unaware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Background Complex Presentation</td>
<td>Strong Background Simple Presentation</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

B. Statistical Tests

<table>
<thead>
<tr>
<th>Test #</th>
<th>Problem #</th>
<th>More Accepting Group(s)</th>
<th>Less Accepting Group(s)</th>
<th>Level of Rejection For H0</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>3</td>
<td>C</td>
<td>5+6</td>
<td>.6600</td>
</tr>
</tbody>
</table>

In testing the previous hypothesis it was concluded that there is some reason to believe that a person who is trained in the use of a particular model has developed attitudes toward that model which affect his willingness to accept the results of that model when it is used by another party. In the present hypothesis, the question is whether such attitudes carry over to unfamiliar models as well. In order to test this hypothesis, it is necessary to have a sample of subjects with a relatively high level of training in quantitative business methods and confront them with a model with which they are unfamiliar. This is what was done in problem 3. The appropriate test is, therefore, a comparison between groups 5+6 VS C. In essence this will employ a sample of subjects who are aware that a model was used which was not covered in their
training and compare them against a similar sample that
is not aware of the particular model being used.

The result of this comparison was that very little
difference was found between the experimental groups and
the control group. Awareness was found to result in a
very slight decrease in acceptance, but the null hypothesis
could be rejected only at a level of $p = .6600$.

The conclusion to be drawn from this test is that if
model familiarity does in fact affect acceptance, then
the effect is not transferred to models in which the
decision-maker has not been trained. Training in quanti-
tative business methods does not appear to result in
significant attitudes toward such methods in general.
If training in business models has any effect on accept-
ance, it appears to be limited to the specific models
covered in the training.
CHAPTER VII

CONCLUSIONS

Summary of Findings

At the beginning of this report an observation was made to the effect that managers are primarily the users of the results of quantitative analysis rather than the users of the mathematical models themselves. The distinction here is important. The value of a model to an analyst depends primarily upon his knowledge of the model and his training and ability in employing it. For someone who comes in contact only with the results of such analyses, the value of a model depends far more upon attitudes. In such cases, the value of a model depends upon the value the user places on its results. And in the absence of the knowledge needed for a fully objective evaluation, attitudes may be influential in determining such values. Two types of attitudes appear particularly pertinent in such cases: attitudes toward the analyst who used the model and attitudes toward the model itself. This study has examined the effects of this latter type of attitude and its conclusions can be summarized as follows:

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1. Generalizations with regard to the effect of attitudes on the population as a whole are not possible. The effect of such attitudes differs by subpopulation.

2. The complexity with which research results are presented neither strengthens nor diminishes the willingness to accept those results.

3. Subjects who are untrained in the use of a model do not appear to be influenced by the knowledge that such a model was used. Attitudes toward an unfamiliar model do not appear to influence the acceptance of the model's conclusions.

4. Subjects who have been trained in a model tend to develop attitudes toward that model which influence their willingness to accept the results of that model when employed by another party.

5. The effect noted in number 4 above does not carry over to unfamiliar models. Attitudes developed through training in quantitative models appear to be limited to the specific models that were studied.

The task of the first research question was to determine whether the attitudes in question were important and, if possible, to establish the nature of these attitudes within the population being tested. The findings of that inquiry indicated that the effects of such attitudes are highly complex. For the population as a whole it is impossible to predict either the direction of the effect or, indeed, whether there will be any generally observable effect at all in any given instance. This inability to draw definite conclusions was found to stem from two factors. First, the direction of effect was found to be uncertain and could be either favorable or unfavorable to the acceptance of the results, depending upon the nature
of the problem. Second, it was found that the existence and magnitude of such attitudes varies with the familiarity of the subject with the model in question. Together, these two findings make it impossible to draw meaningful conclusions for the population as a whole that would apply to all cases. All that can be inferred at this point is that such attitudes appear significant to at least some classes of decision-makers. However, even for those classes it is impossible at this time to say whether the attitudes are either generally favorable or unfavorable.

Although the above findings appear highly inconclusive, they still permit this researcher to question some often heard generalities. It is frequently claimed that managers are either overawed by, or suspicious of, mathematical solutions to business problems. The findings of this study indicate that such generalities are inappropriate. The group of managers studied showed no general disposition in either direction. In fact, the findings indicate that even where a manager is influenced by attitudes toward such methods, the influence may not always be in the same direction. Situational variables appear to interact with such attitudes in determining the direction of effect. Unfortunately, the conditions under which the attitudes will lead to either increased or decreased acceptance were not a subject of inquiry of this study.
In the second research question, the task was to determine whether attitudes were affected by the technical complexity with which the information was presented. The results in this case are fairly conclusive. Complexity appears to neither strengthen nor diminish the willingness to accept the results of the model. In fact, the results of this study indicate that technical language has no effect at all. In the case of highly trained subjects, this is not unexpected. However, for the subjects who were unfamiliar with the technical language, this conclusion is surprising. Apparently, these decision-makers were not at all bothered by the use of technical terms and formulas which they did not understand. What they didn't understand they apparently ignored. Not only didn't it affect their decisions, but it didn't even shake their confidence.

Two implications of this finding may be important. First, it seems to support the frequently stated principle of technical writing that says that formulas and other mathematical explanations should be placed in appendices. The implied rationale for this principle is usually that such material results in resistance. In this case, however, the support for the principle is solely for the sake of efficiency. Since such material appears to have no influence on the decision to accept or reject the
conclusions, then it is wasteful to force the recipient of the report to wade through it.

The second implication involves the idea of communications. In communicating research findings, it is usually necessary to convey more than just a simple statement of the results. Frequently, it is necessary to present the results along with certain limitations and assumptions that are equally relevant. If technical language is employed, it is possible that only some of the pertinent information will be communicated. The information that is understood will be communicated; that which is too technical will be ignored. It is, therefore, important that all relevant information be presented at the same level of complexity—preferably in the simplest language possible.

The third research question involved the issue of whether attitudes are affected in a meaningful way by training in the model. Unfortunately, the results of that inquiry are not as conclusive as had been hoped. In the case of subjects trained in the use of the model, there is a strong likelihood that training has resulted in the formation of attitudes that affect the willingness to accept the conclusions of such models. However, the "strong likelihood" falls somewhat short of being statistically significant at the .05 level. With the untrained subjects, the problem is just the opposite. In that case it appears fairly conclusive that attitudes toward the
model have at most a negligible effect on acceptance. However, there is too much variability between the results of the three case problems to permit acceptance of that conclusion without at least some misgivings. These findings are, therefore, conditional and must be considered as unproven until further research either confirms or contradicts them.

In the case of the untrained subjects, the findings appear consistent with the findings from the second research question. Information which is not understood is simply ignored. Since the subjects were unfamiliar with the models, they apparently ignored the fact that they had been used. They were neither frightened off nor impressed. They react to the information the same as they would have if they had not known it came from such a model.

With subjects trained in the model, there is a reaction to its use but the direction of the reaction cannot be proven from this research. And until the variables affecting the direction can be known, this finding is of little practical use.

In the final research question the aim was to determine whether there was any transfer of effect resulting from training in quantitative models. Earlier it was concluded that training does apparently result in the formation of pertinent attitudes. In the analysis of this problem, however, it appears that these attitudes do not carry
over to models not covered in the training. Apparently, training in a few models does not result in the formation of relevant attitudes toward quantitative business methods in general. The implication here is possibly significant. For training to be effective, it probably should be as broad as possible. Detailed coverage in a few techniques is probably not as far-reaching in effect as broader coverage in many techniques. This study, of course, cannot indicate the optimum amount of training desirable in each technique; it merely indicates that breadth of coverage is important.

Together, these four research questions permit some generalizations to be made with regard to the existence and effect of attitudes toward quantitative models applied to business problems. First, the subjects are neither overawed by, nor overly suspicious of, methods and terminology beyond their understanding. There is a tendency to ignore that which is not understood. Training in a technique, however, does appear to result in the formation of attitudes which influence the use of the information when that technique is applied. However, the attitudes formed through such training appear limited to the specific technique and do not carry over to quantitative solutions in general.
Limitations

This study could properly be classed as exploratory research. It covered an area in which very little other research has been done. For that reason the coverage tended to be broad rather than specific and, therefore, the conclusions are tentative in nature. But in reaching these tentative conclusions it must be observed that the experimental sample is not in some ways representative of managers in general. Some characteristics of this sample set it apart from other groups.

First, the subjects were in an academic environment. Except for those who had just arrived at the school, they had grown accustomed to dealing with case problems of this nature. It is entirely possible that such subjects are not prone to question the sources of information. In most academic exercises such information is meant to be taken as factual. Although the instructions tried to create a sense of realism, it cannot be proven that this was achieved in all cases. It is still possible that practicing managers could be more sensitive to the sources of information than were the subjects used in this experiment.

Another possibly significant characteristic of this population involves the fact that they were all associated with the military. Their managerial experience, therefore, is primarily within very large organizations. It is
possible that such a background could have influenced their thinking on what was the best solution to the case problems.

One final population characteristic involves the recency of training of the subjects who were familiar with the models. In this study, all of the subjects in that category had received their training within the six months preceding the experiment. It is very possible that the effects of training show decay over time and that the conclusions would have been different if the test were taken two or three years after the training.

Another area in which this study was limited involved the level of complexity used in the technical presentation. The findings of this study indicated that complexity was not a significant factor. But, in reality, this conclusion is proven only for the particular level studied. Complexity in this study meant one paragraph of technical terms. This is hardly the same as the presentation of a 100-page technical report. It is, therefore, still possible that complexity could be a factor if it is carried far enough.

Reliability is also a limitation in this study. As was shown previously, the measurements used in this experiment showed a certain amount of instability over time. It was also shown that decision confidence was not a fully accurate indication of the willingness to accept information. For these reasons, this study was limited in its
ability to draw definite conclusions. A more reliable instrument might have permitted more conclusive inferences.

One final limitation is actually a word of caution in interpreting the findings of this study. This researcher has meant to imply no value judgment with regard to whether acceptance of model results was good or bad. The situation around which this experiment was based involved information which could not be objectively evaluated by the recipient. Therefore, if a subject showed a high willingness to accept such information, it means he is likely to accept good as well as bad research findings. If he displays resistance, he will tend to resist both good and bad research. Therefore, if any reader of this report feels a value judgment is called for, he must make it himself.

Recommendations for Further Research

During the course of this research project, many additional areas of inquiry were indicated. Some of these were anticipated before this project was started; others arose as the results were being analyzed.

First of all, an effort should be made to find out why the direction of effect varied from problem to problem. At the outset, the three problems were expected to be replicative of each other in most respects. The results, however, indicate that different factors were involved in each. It is possible, of course, that the differences
were merely chance variations. However, such appears unlikely to this researcher. Instead it appears that attitudes toward methods interacted with other variables in the problems to determine the direction of effect. The next step in this area of research should, therefore, be to try to isolate these variables. Once this was done, it should be possible to revise this experiment to provide a far greater ability to observe the true effect of the attitudes being studied.

Further studies should also be extended to different populations. It should be interesting to see whether military managers differ from industrial managers with regard to the variables being studied. Also, subjects who were trained in the models in the less recent past should be studied to see whether there is any decay of attitudes formed through training.

Also, with regard to training, it should be interesting to see whether the method of teaching is important. The subjects in this study had a fairly detailed education in the models. They were trained more as analysts than as users of the information. It should be interesting to see whether the same attitudes would result from a less detailed, interpretive coverage of the models.

Another area for further study involves the level of complexity. Would the findings hold up if a much longer, more technical presentation were used?
And finally, additional work should be done with regard to the relationship of confidence to choice behavior. This study has indicated the possibility that a subject could be fairly confident in a decision and yet still be very close to changing his mind. It is not difficult to see the possible implications of this to marketing research, for instance. A consumer who expresses strong brand loyalty could actually be very close to switching brands.

It is felt that research of the nature described above would do much to describe how managerial decisions are made. It would also provide some insight into the nature of the relationship between the researcher and the manager. In the past, management literature on decision-making has been too concerned with how decisions should be made and too little concerned with how they are made.
APPENDIX A

RESEARCH INSTRUMENTS

Besides the instruction sheet, the research instrument consisted of three parts: the case problems, a rating scale, and an instrument for indicating familiarity with the models. A copy of each instrument is included in this appendix. With regard to the case problems, three forms of each problem were used. The forms were all identical with the exception of the paragraph in which the information obtained from the model was presented. Therefore, instead of reproducing each form of every problem, only one form will be included in its entirety and only the paragraph from the other two which differs from that form will be presented in this appendix. The form that is completely reproduced is the control form. For each problem, that form is immediately followed by the paragraph from the simple and complex forms which differ from it.

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AN EXERCISE IN DECISION MAKING

This exercise consists of three case problems. For each problem you will be asked to make a choice between two alternatives. You will then be asked to indicate on a rating scale how confident you are that your choice was correct.

These cases differ in one important respect from other problems you have faced in schoolhouse work. Typically, in a classroom problem, an assumption is made that all relevant information has been given. Your decision, therefore, involves only an analysis of the information specifically given to you. Your confidence in your decision is consequently dependent only upon your feelings as to how well you were able to interpret and analyze that information. In actual managerial decisions, however, this assumption of completeness may not apply. Although decisions of necessity must be based on available information, nevertheless, there may often exist a feeling that pertinent information is missing. Also, past experience or training may create a skepticism about some of the information that is available. These comments are not meant to imply that the problems in this exercise are "tricky" or misleading. No attempt has been made to mislead. Instead, these comments are only intended to set the stage so that, in making your decisions, you will assume the role of an actual decision-maker rather than of a student.

At the end of each case there are two alternatives. You are simply asked to indicate which you prefer by circling the appropriate letter. After solving all three problems, you will then be asked to indicate how confident you are of your decision. Wait until you have solved all three problems before attempting this. Do not rate your confidence after each question separately.

Since this exercise will also be administered to other classes, please do not discuss it with anyone other than those who are taking it with you. Prior knowledge would necessitate the elimination of a person from the experiment.

A time limit of 30 minutes is imposed for making your three choices. This should be more than ample time. When your choices have been made you may then go on immediately to the confidence scale, and upon completion bring this booklet to the front of the room. At that time you will be given a very short questionnaire which you
are to complete (it should take only two or three minutes), sign your name and return it to the front of the room. At that time you are free to leave.

Your cooperation in this research effort is greatly appreciated. Hopefully, it will help add to the store of knowledge of how certain factors affect decision-making.
INDUSTRIAL DISTRIBUTORS INC. CASE

Background. Industrial Distributors Inc. is a distributor of industrial machines, parts and supplies. It operates a central warehouse in Chicago and three regional warehouses in the North-Eastern United States. One of the more than 2,000 items they handle is a high-speed thermal regulator. The item was recently redesigned by the manufacturer and the old stock is being replaced by the new regulators. At the same time the inventory policy regarding this item is being reviewed.

Decision. As the inventory manager you are faced with two alternative policies:
- A. Stock item at the Chicago warehouse only.
- B. Stock item at each regional warehouse.

Information Bearing on the Decision. The following information is provided as an aid to decision making.
1. Many customers for this regulator are also users of other products of the firm.
2. For most customers, routine delivery within a week of the order is satisfactory. For a substantial number of sales however, one-day service must be provided for this item.
3. Air freight can give one-day service from Chicago, but the transportation cost is five times as great as that of routine shipments by truck.
4. The item is manufactured in Chicago and the cost is $2,000 each, FOB factory.
5. Calibration is required at the regional warehouse after shipment from Chicago, but before delivery to the customer.
6. Demand for the regulator averages 120 per region per year. Demand is fairly steady with no pronounced seasonal pattern.
7. A cost study has indicated that total distribution costs for regional stockage would be $11,400 per year. To provide the identical probability of on-time delivery with centralized storage would cost $9,000. This figure includes air freight shipment for customers desiring one-day service. A policy to stock the item only in Chicago would therefore result in a cost savings of $2,400.

Choice. Circle one of the following alternatives:
- A. Stock item at the Chicago warehouse only.
- B. Stock item at each regional warehouse.
In problem 1, the only difference in presentations was in paragraph number 7. Below is the form of that paragraph in the simple and complex presentations.

Simple Presentation Format

7. An analyst from the Statistical Analysis Section performed a cost study on this item based on the use of an EOQ Inventory Model. The results of his study indicated that total distribution costs for regional stockage would be $11,400 per year. To provide the identical probability of on-time delivery with centralized storage would cost $9,000. This figure includes air freight shipment for customers desiring one-day service. A policy to stock the item only in Chicago would, therefore, result in a cost savings of $2,400.

Complex Presentation Format

7. An analyst from the Statistical Analysis Section performed a cost study on this item based on the use of an EOQ Inventory Model. The analysis involved the computation of fixed order quantity EOQ's for each stockage policy and then the computation of the comparative costs of each alternative. Safety levels were established to provide 95 percent confidence of no stock-out during an order cycle. Order costs, lead times and the distribution of demand during lead times were calculated from one year of historical data. Using a standard EOQ formula, the optimum order quantity for central stockage was found to be 10 units and for regional stockage 6 units per region. Safety stocks were 4 and 2 respectively. The results of this study indicated that total distribution costs for regional stockage would be $11,400 per year. To provide the identical probability of on-time delivery with centralized storage would cost $9,000. This figure includes air freight shipment for customers desiring one-day service. A policy to stock the item only in Chicago would therefore result in a cost savings of $2,400.
WORLDWIDE INSURANCE COMPANY CASE

Background. The Cash Value and Loan Department of the Worldwide Insurance Company employs 48 female clerical workers in processing requests for policy loans and requests to cash in policies. In one type of action handled by the department, the procedure calls for the clerk to go to a records storage area to obtain information needed to complete the transaction. While the clerk waits, the information is looked up for her by a researcher. Only one researcher works on this type of transaction and lately there have been complaints that too much time is spent waiting in line for this information. A proposal has been made to provide the researcher with a remote computer terminal connected to a central data bank, thus enabling her to obtain more rapidly some of the information she needs.

Decision. As the head of the department, you are faced with two alternatives:

A. Support the proposal for the remote terminal.
B. Reject the proposal for the remote terminal.

Information Bearing on the Decision. The following information is provided as an aid to decision making.

1. The researcher must compile the information from two sources. The computer terminal will only replace one source. The other must still be looked up manually since it involves data not maintained in the central data bank.
2. Rental on the computer terminal will be $440 per month. It will cut the processing time for the researcher by twenty-five percent.
3. The wage of a clerk is $2.50 per hour.
4. The researcher is presently able to handle all requests, although at times there may be several clerks backed up in line. The line, however, is erratic and much of the time the researcher is idle.
5. The erratic nature of the line has led one supervisor to suggest that the girls tend to intentionally make their requests when other girls are already in line so as to be able to take a break from work and talk to the other girls in line.
6. One study found that the average waiting time for this information was 15 minutes. This includes both processing time and time spent waiting in line.
7. A feasibility study was made of the remote terminal and two benefits were found. First, by cutting processing time by 25 percent, the time a clerk waited while her request was being processed was also cut by 25 percent. Second, clerks waiting behind her in line would have their total waiting time cut since the entire line
would move faster. The study indicated that a total of 92 minutes or 1.53 manhours per clock hour could be cut from the time the clerks spent in this activity. This would mean a monthly cost savings of $672. This represents a savings of $232 more than the cost of the remote terminal.

Choice. Circle one of the following alternatives:
A. Support the proposal for the remote terminal.
B. Reject the proposal for the remote terminal.
In problem 2, the only difference in presentations was in paragraph number 7. Below is the form of that paragraph in the simple and complex presentations.

**Simple Presentation Format**

7. The Statistical Analysis Section, when approached with the problem, indicated that they felt it was amenable to solution by means of a Single Channel Queuing Model. By applying this model to the problem, two benefits of the terminal were found. First, by cutting processing time by 25 percent, the time a clerk waited while her request was being processed was also cut 25 percent. Second, clerks waiting behind her in line would have their total waiting time cut since the entire line would move faster. The study indicated that a total of 92 minutes or 1.53 manhours per clock hour could be cut from the time the clerks spent in this activity. This would mean a monthly cost savings of $672. This represents a savings of $232 more than the cost of the remote terminal.

**Complex Presentation Format**

7. The Statistical Analysis Section, when approached with the problem, indicated that they felt it was amenable to solution by means of a single channel queuing model with a "first come first served" queue discipline. Assuming that arrivals were random, an assumption of a Poisson input in the steady state could be made. This would permit the standard queuing formula $T = \frac{\lambda}{\mu}$ to be used to determine the expected time in the system under each alternative (where $\mu$ = service rate and $\lambda$ = arrival rate). By applying this queuing model, two benefits of the terminal were found. First, by cutting processing time by 25 percent, the time a clerk waited while her request was being processed was also cut 25 percent. Second, clerks waiting behind her in line would have their total waiting time cut since the entire line would move faster. The study indicated that a total of 92 minutes or 1.53 manhours per clock hour could be cut from the time the clerks spent in this activity. This would mean a monthly cost savings of $672. This represents a savings of $232 more than the cost of the remote terminal.
APEX MEDICAL SUPPLY CO. CASE

Background. Apex Medical Supply Company is a distributor of hospital equipment and supplies in a three state area. It has recently taken on a new line of laboratory equipment manufactured by a firm in Italy. The market for this equipment includes hospitals and independent medical laboratories. As a result of the additional volume of sales brought on by the new line, the sales manager has asked that an additional salesman be added to his sales force to concentrate on this new line.

Decision. As Vice President of Marketing you have two alternatives:

A. Approve the hiring of an additional salesman.
B. Turn down the request for the additional salesman.

Information Bearing on the Decision. The following information is provided as an aid to decision making:

1. The present sales force has well-established connections with hospitals but have previously made few contacts with independent medical laboratories. The new man would be used primarily to establish and maintain such contacts.

2. The cost of a new salesman would be about $20,000 per year. This would include salary and expenses. Apex salesmen do not work for commissions.

3. The total market for the type of equipment the new line will compete with has a potential profit of $150,000 per year. At the present time, Apex has about 20 percent of this market.

4. The new line is not significantly different from what the competition is offering, so brand loyalty is not too strong. Past experience indicates that 70 percent of present customers will place their next order with Apex, while 10 percent of those now doing business with the competition can be expected to make their next purchase from Apex.

5. The Sales Manager feels that the additional salesman will increase the likelihood of repeat customers by about seven percent and will increase the likelihood of customers coming over from competitors by 50 percent. He estimates that the new salesman will permit Apex to get between 35 and 40 percent of this market.

6. A more detailed study shows that the new salesman will enable the firm to capture 37 1/2 percent of the market. However, with the present sales force, sales would eventually stabilize at 25 percent. Therefore the new man
would increase sales by 12½ percent of the market. This would mean an increase in profit of $18,750 per year less the cost of the new salesman.

Choice. Circle one of the following alternatives:
A. Approve the hiring of an additional salesman.
B. Turn down the request for the additional salesman.
In problem 3, the only difference in presentations was in paragraph 6. Below is the form of that paragraph in the simple and complex presentations.

Simple Presentation Format

6. When the problem was shown to an analyst from the Management Analysis Section, he indicated that the data appeared to fit the requirements for a Markov Chain analysis. After applying this technique, the following brand-share predictions were made: The new salesman will enable the firm to capture 37\(\frac{1}{2}\) percent of the market. However, with the present sales force, sales would eventually stabilize at 25 percent. Therefore, the new man would increase sales by 12\(\frac{1}{2}\) percent of the market. This would mean an increase in profit of $18,750 per year less the cost of the new salesman.

Complex Presentation Format

6. When the problem was shown to an analyst from the Management Analysis Section, he indicated that the data appeared to fit the requirements for a Markov Chain Analysis. By placing the brand-switching probabilities into two transition probability matrices \(P_1\) and \(P_2\) he was able to use a Markov analysis to find row vectors \(w_1\) and \(w_2\) such that \(w = wP\). These gave the steady state probabilities for purchasing the Apex products with and without the additional salesman. Assuming constant probabilities of brand-switching over time and no competitive counter-actions, the following brand-share predictions were made: The new salesman will enable the firm to capture 37\(\frac{1}{2}\) percent of the market. However, with the present sales force, sales would eventually stabilize at 25 percent. Therefore, the new man would increase sales by 12\(\frac{1}{2}\) percent of the market. This would mean an increase in profit of $18,750 per year less the cost of the new salesman.
MEASUREMENT OF DECISION CONFIDENCE

The problems you have just worked on were intended to portray the environment within which many managerial decisions are made. The cases varied in the kind and amount of information provided and also in the amount of desired information that may have been missing. Now that you have made your decisions it is necessary to know how your confidence varies among the three decisions. For that reason you will now be asked to indicate for each decision how confident you are that you are right.

In determining your degree of confidence you are to consider the following:

1. The strength of the evidence leading to your decision.
2. The strength of the evidence that might have pointed to the other alternative.
3. The extent to which you might have desired additional information, and your feelings as to the likelihood that such information might have led to a different choice.

Your level of confidence will be measured on the attached scale running from 0 to 8. On the far right are three columns, one for each case problem. Circle the number in each column most descriptive of the amount of confidence you hold for your decision in that problem. Descriptions are provided for the even numbered ratings, but the odd numbers in between may also be used if you are unsure as to which of two descriptions is most applicable.
## CONFIDENCE SCALE

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<td>8. Absolutely sure—there is no doubt that I have made the right choice.</td>
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<td>6. Quite sure—I would be very surprised if my choice were wrong.</td>
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<td>4. Moderately sure—I think I made the best choice but there is some doubt in my mind.</td>
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<td>2. Slightly sure—My choice appears to be the better of the two, but the other alternative had almost as much merit.</td>
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<td>0. Not sure at all—I would feel just as confident if I had based my choice on the flip of a coin.</td>
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MODEL FAMILIARITY

In each of the three problems, some of the information that was provided was obtained through the use of certain quantitative models. The models employed were the EOQ Inventory Model, the Queuing Model, and the Markov Chain. Analysis of the results of this experiment requires a knowledge of your level of familiarity with each model. Therefore, please circle the number(s) in each column at the right reflecting your background in each model. If appropriate, circle more than one number in a column.

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<thead>
<tr>
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<th>EOQ Inventory</th>
<th>Queuing Model</th>
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1. I have not had any training or experience in this type of model.

2. This model was briefly covered in a management or business course which I completed, but no time was spent on the details of its computation.

3. This model was covered in a management or business course in sufficient detail that I now feel that I could employ it if the occasion arose.

4. I have completed a course in quantitative methods which included this model and which provided practice in its application.

5. I have had experience or training in the use of this model but of a nature not covered by any of the above statements. (Explain)
APPENDIX B

WORKSHEETS FOR STATISTICAL TESTS

The statistical testing of hypotheses in this study employed the Mann-Whitney U test as described by Siegel (18:116). Worksheets were prepared as an aid to computation and are included in this appendix. It should be noted that two Z values are computed. This is for the purpose of a double-check. The two values should have the same absolute value and will differ only with regard to the sign. The group corresponding to the Z value with the negative sign will be the group with the relatively larger scores.
COMPUTATIONS

\[ T = \frac{t^3 - t}{12} \quad \text{Nr. Ties} \quad \begin{array}{c} t \\ T \end{array} \]

\[ \Sigma T = \]

\[ U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \quad U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \]

\[ Z = \frac{U_1 - \frac{n_1 n_2}{2}}{\sqrt{\frac{n_1 n_2}{N(N-1)}} \left( \frac{N^2-N}{12} - \Sigma T \right)} \quad Z = \frac{U_2 - \frac{n_1 n_2}{2}}{\sqrt{\frac{n_1 n_2}{N(N-1)}} \left( \frac{N^3-N}{12} - \Sigma T \right)} \]

Probability of \( Z = \) ___
APPENDIX C

COMPUTATION OF COEFFICIENT OF RELIABILITY

The coefficient of reliability was based on the test-retest scores of 12 subjects. Since three problems were worked by each subject, 36 paired observations were available as follows:

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In computing the coefficient of reliability, a modified procedure was used for computing a product-moment correlation coefficient. This procedure is described by Ferguson (7:232) and is as follows:

\[
P_{xx} = \frac{2\left[\Sigma X_1 X_2 - \left(\frac{\Sigma X_1}{N}\right)\left(\frac{\Sigma X_2}{N}\right)\right]}{\left[\Sigma X_1^2 - \left(\frac{\Sigma X_1}{N}\right)^2\right] + \left[\Sigma X_2^2 - \left(\frac{\Sigma X_2}{N}\right)^2\right]}\]

Using the test-retest data above: \( p_{xx} = .743 \).
APPENDIX D

SUMMARY OF INDIVIDUAL SCORES AND GROUPINGS

The sample was divided into six groups. Each group received a different experimental treatment for each problem and, therefore, corresponds to a different cell in the experimental design for each problem. Using the group designations employed in figures 5 and 6, the following table shows where each of the six groups fell in the analysis of each problem.

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For example, for Group I, in the first problem the subjects were trained in the model but unaware that it was used. In the second problem, they were trained in the model and were made aware of its use by the simple presentation format. In problem 3, this group was generally well trained and given the complex form of the presentation.

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Each group has from 17 to 31 subjects. Each subject has three scores: one in each problem. The following tables show the scores of each subject by group and by problem. Where no entry is made for a subject, it means his score was eliminated from analysis in that problem due to prior training in the model. For each subject, the first entry is the score in problem 1, the second entry is the score in problem 2, and the third entry is the score in problem 3.

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BIBLIOGRAPHY

Books


Periodicals


