DECISION SYSTEMS PERFORMANCE: AN EXPERIMENTAL INVESTIGATION OF COMPUTER-AIDED MANAGEMENT DECISION MAKING

by

ALBERT ANDREW MARCOTTE

S.B., Northeastern University
(1963)
S.M., Northeastern University
(1965)
M.B.A., Northeastern University
(1967)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF
PHILOSOPHY
at the
MASSACHUSETTS INSTITUTE OF
TECHNOLOGY
June, 1974

Signature of Author.....
Alfred P. Sloan School of Management, May 9, 1974

Certified by .....
Thesis Supervisor

Accepted by.....
Chairman, Departmental Committee on Graduate Students

DISCLAIMER

MISSING PAGE(S)

Pages 9 & 10 have been ommitted due to a pagination error.

DECISION SYSTEMS PERFORMANCE: AN EXPERIMENTAL INVESTIGATION OF COMPUTER-AIDED MANAGEMENT DECISION MAKING

by

ALBERT ANDREW MARCOTTE

Submitted to the Alfred P. Sloan School of Management on May 9, 1974, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

Decision Systems have two components -- a management decision maker and a decision support system (DSS). This dissertation evaluates the proposition that computer assistance, through a DSS, can improve human decision performance: that is, that DSS-aided decision making is more effective and efficient than similar non-aided decision making.

A laboratory experiment was conducted in which a management game was used to create a controlled decision environment. Six teams of Senior Executives were simultaneously exposed to two similar, non-structured decision making situations, one of which was directly aided by a decision support system. The research design permitted unobtrusive data collection for eight replications of the experiment. For both DSS-aided and non-aided decision making, effectiveness was measured by the quality, consistency, and rate of improvement in decision making. Efficiency was measured by resource use and resolution time to final choice.

Results significantly confirmed three hypotheses related to effectiveness (H1, H2, H3) and two related to efficiency (H4, H5). The study showed that:

> For non-structured tasks, DSS-aided decision making resulted in decisions having:
>
> H1: higher quality,
> H2: greater consistency,
> H3: higher rate of improvement,
> H4: lower resource use, and
> H5: shorter resolution time
>
> than non-aided decision making in similar, controlled circumstances.

Thesis Supervisor: Michael S. Scott Morton
Title: Associate Professor of Management

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

8 no pp. 9+10

CHAPTER 1

DECISION SYSTEMS IN PERSPECTIVE

The potential of computer-based system for improving management decision performance has long been recognized. Pioneers in the field were speculating on the benefits of interactive systems in the early 1960's. Licklider (61) represents these early views:

> "The hope is that in not too many years, humans and machines will be coupled closely together and that the resulting partnership will think as no human has ever thought..."

Gorry and Morton (49) suggest that early efforts were hindered by technological and conceptual barriers but, today, technology is no longer a problem.

Nonetheless, present evidence suggests that interactive computer systems have had only limited impact on management decision making in the field. Brady's (17) recent study of 100 top managers in major corporations concluded that computers have not had much of an effect on upper-level decision making. He found no evidence of direct use of computers by top management, but some influence was found at the middle management levels.

In contrast, Scott Morton's (95) research shows that management decision systems have a significant impact on the decision making processes of higher level executives. He found decision makers adopt and use a computer-based system on a regular basis. The contact and elapsed time to problem resolution decreases, more problems are found, more alternatives are generated and evaluated, and communications between managers are substantially improved. Gerrity (45) and Hedburg (53) also report similar observations. The three studies supply strong evidence that the limited impact in the field may not be indicative of the true potential of these systems.

1.1 Decision Systems: Conceptual Distinctions

Decision Systems are closely-coupled, man-computer partnerships which focus on management decision making. The basic idea behind Decision Systems is the concept of comparative advantage. Whitfield (116) proposes that the fundamental notion is that men and computers have complementary talents. Emery (4) claims these systems must draw upon the best capabilities of both man and computer to deal with management problems that are too ill-defined and complex to be handled well by either partner alone. Miller (71) insists that the principal objective is to improve management decision performance; that is, to improve the effectiveness and efficiency of management decision making.

Decision Systems involve a set of interacting components working together to make decisions and solve problems. The primary components of a Decision System are the

(1) Decision Maker

(2) Decision Support System

The terminology adopted throughout this thesis is to refer to the total system as the Decision System (DS), to the human component as the Decision Maker (DM), and to the machine component as the Decision Support System (DSS). A Decision System is illustrated in Figure 1.1.

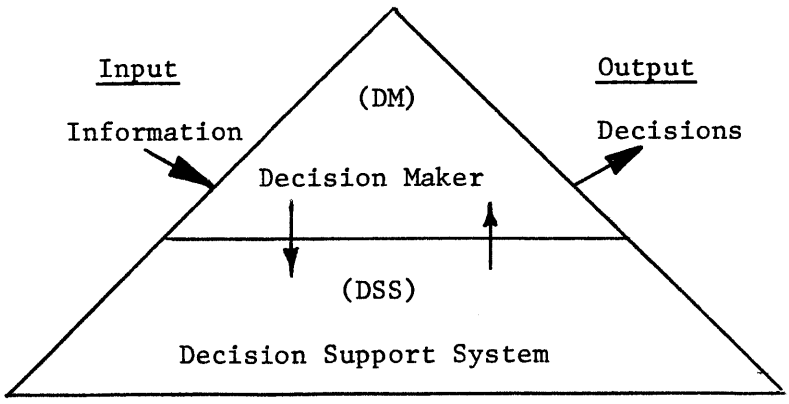


Figure 1.1 Decision System

The diagram illustrates important distinctions. First, Decision Systems have two components: a human component and a machine component. The machine supports the human in transforming information into decisions which result in achieving the goals of the decision maker. The extent to which goals are attained determines the effectiveness of the system. Effectiveness is a measure of external performance, the ability of the system's outputs - the decisions - to achieve desired ends. The expediency with which the system transforms information to decisions determines the efficiency of the system. Efficiency is a measure of internal performance, the ability of the system for transforming inputs into outputs.

Despite the fact that performance is the result of both components working together, the performance of the system is commonly attributed to the human component. Consequently, the goal of improving system's performance is synonymous with improving the effectiveness and efficiency of the decision maker in the system.

The decision maker can be either an individual, or more likely, a team working in concert with the machine. Thus, it might be more advantageous to regard the decision maker as the human component in the Decision System. This component is assumed to bring substantial skills to the Decision System, some of which may be difficult or impossible to provide in any other way. On the other hand, the human component may be subject to certain limitations which may be difficult to modify or overcome directly; that is, by changing its inherent capacity without aid from the Decision Support System.

The Decision Support System is a group of programs working as a system to aid management decision making. The software of these sophisticated interactive systems provides this capability through decision aids, access to models, information, and computational power. This component is designed to support directly parts of the

management decision making process and, thus, provide assistance in the solution to complex, non-structured problems. To do this, the system must have some of the characteristics discussed in the next section.

1.1.1 Characteristics

Decision Systems are characterized by certain features which distinguish them from other computer-based systems, particularly management information systems and data processing systems. Decision Systems interface with these systems through data and model bases. Ness (78) contends that data processing systems are the conventional transaction-oriented systems which support many operations in an organization. Blumenthal (13) asserts that management information systems supply information in standardized report form but usually lack the directness of support and other capabilities which characterize Decision Support Systems. Hedburg (53) stresses the need for adequate data collection systems which supply data for other systems. The relationships are pictured in Figure 1.2.

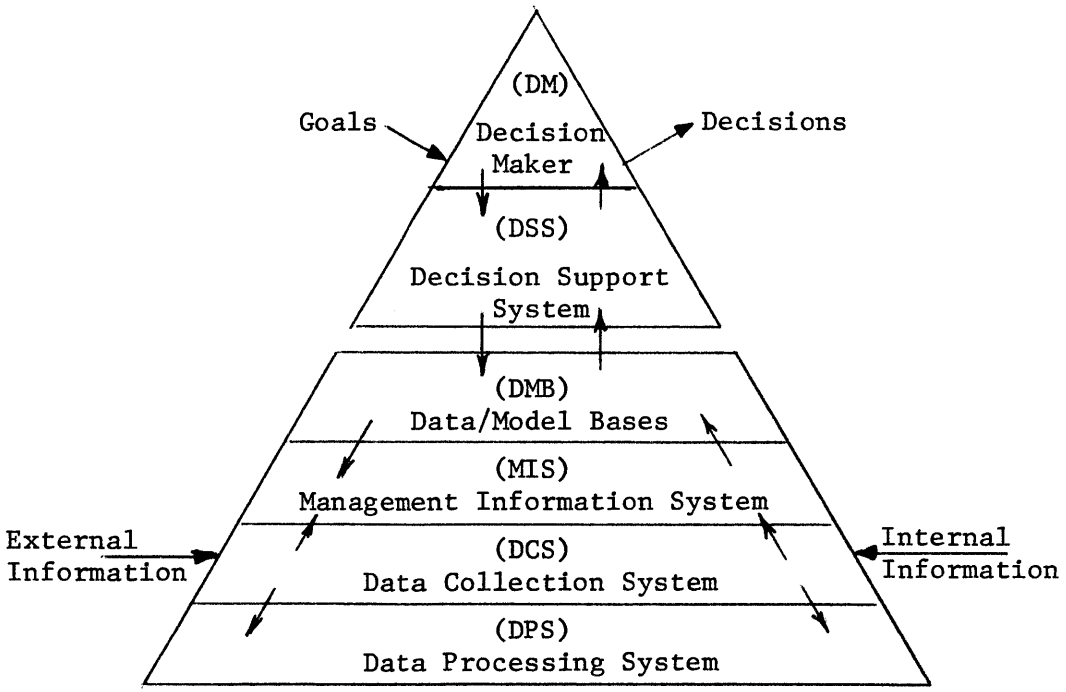


Figure 1.2 Computer-based Systems

The purpose here is to briefly summarize the more important characteristics which distinguish Decision Support Systems from other computer-based systems. Gerrity (45), Hedburg (53), Ness (78) and Scott Morton (93) claim that Decision Systems are distinguished by their (1) capabilities and (2) directness of support.

Decision Support Systems provide capabilities for interactive use of decision aids, information, models, and computational power. Scott Morton (95) contends that interactive models are necessities for Decision Systems. Gerrity (44) recognizes the need for memory (data bases), plans (models), and operators (decision aids). These capabilities support decision making processes by aiding in the retrieval, manipulation, and display of information for problem finding and in the identification, evaluation, and choice of alternatives for problem solving. Emery (39) asserts that these capabilities are necessary because the problems are non-structured and, thus, can not be solved effectively by either the man or the computer alone.

Decision Support Systems directly support management decision making. Direct support refers to the close coupling of man and machine. Terminals provide the decision maker with on-line access to the Decision Support System. The decision maker and system usually communicate in a conversational manner; no intermediate programming is required. Results are returned directly to the user's terminal in a sufficiently short time; therefore the natural flow of the human decision process is not materially hindered. These systems do not require a structural change in the manager's role. He controls the decision making activity; a high premium is placed on his judgment and skill. Decision making is facilitated because the manager interacts with a Decision Support System, not because the decision making is built into the system itself.

1.1.2 Current Status of the Research

This section clarifies the nature of this study by developing a framework for categorizing research. Presently, there is no adequate conceptual structure for classifying findings. The problem is recognized by Edstrom (36), Parsons (82), and Miller (71); each cite the need for an adequate taxonomy for structuring relevant research. The lack of an adequate framework has hidden the fact that the traditional research on decision making is, at best, only partially relevant for Decision Systems.

Research on decision making is distinguished by:

(1) focus of research

(2) type of decision making

(3) degree of task complexity

These criteria are used in Figure 1.3 to suggest that research may focus on assessing the impact on decision processes and performance for both aided and non-aided decision making in situations which range from simple to complex.

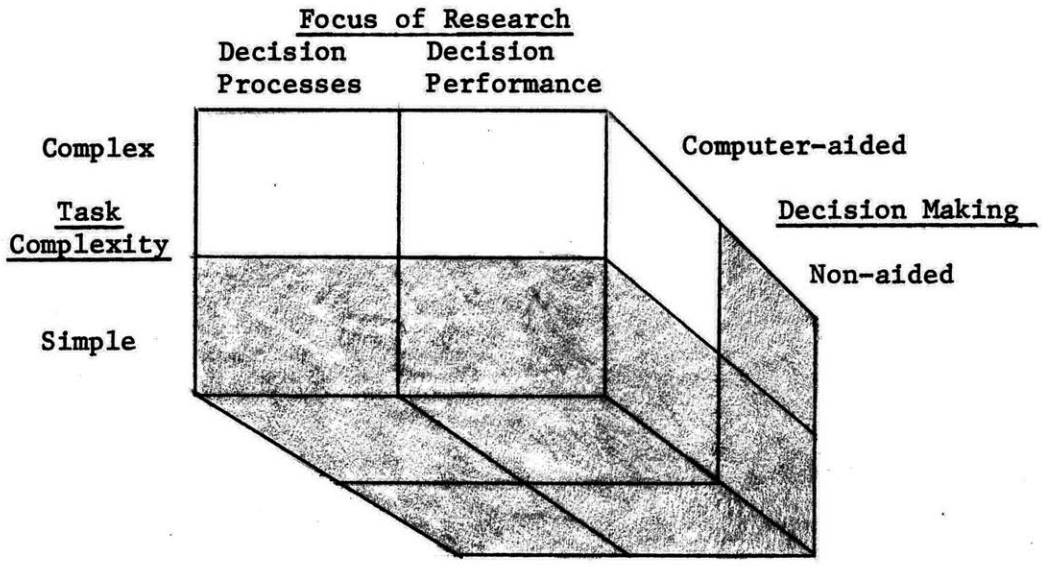


Figure 1.3 Classification of Research

Decision Systems research is concerned with computer-aided management decision making in complex problem situations. This is in sharp contrast with the traditional studies of decision making. Despite a notably large research effort most studies focus on non-aided decision making for simple task situations. For these reasons, the shaded parts of Figure 1.3 indicate that classical decision making research is only indirectly related to Decision Systems and, therefore, apparent relevance may be misleading.

Decision Systems research is depicted in the non-shaded parts of Figure 1.3. As illustrated, it centers on assessing the effect of computers on decision processes and performance for complex, non-structured task situations. The work of Gerrity (44), Hedburg (53) and Scott Morton (95) falls into the upper left section. These field studies of computer-aided management decision making focused on assessing the impact on decision processes for complex task situations. These few studies are the most notable research reported in the literature.

Unfortunately, there is no reported research which falls into the upper-right section. That is, there are no studies that focus specifically on decision performance for computer-aided management decision making involving complex, non-structured problems. The lack of research in this area stems from the inherent difficulty in measuring performance for complex situations. For studies that permit an objective evaluation of performance, most of the research has remained relatively inaccessible except to those directly involved in the research, especially for proprietary systems. These obstacles have hindered research in this area but have not lessened the need for studies on computer-aided decision performance.

This thesis is an experimental study of computer-aided executive decision performance for complex, non-structured tasks and, thus, falls naturally into the upper-right section of Figure 1.3.

1.2 Motivation for this Study

The motivation for this study was the need for knowledge concerning computer-aided decision performance. More information is required at this point. Even though there is voluminous literature on decision making and problem solving, little is known about computer-aided decision performance, especially for complex non-structured task situations.

There is no dearth of assertions concerning the impact which Decision Systems have on management decision performance. These claims, however, are not based on research findings. Carroll (22) notes that the potential of Decision Systems to improve performance:

> "has not been rigorously demonstrated in the laboratory nor in the field."

Despite this fact, Newman (81) contends that in the future more emphasis will be placed on improving higher level management decision performance through the use of interactive computer-based systems.

Computer-based systems having the characteristics discussed in previous sections are called Decision Support Systems. Actual systems displaying some of these features are described in Austutz (4), Edstrom (36), Gerrity (44), Hedburg (53), Ness and Sprague (78) and Scott Morton (91). Scott Morton (91) notes that "the evidence collected thus far establishes beyond any doubt that such systems can be built with current technology". Similar conclusions have been reached by Boulden and Buffa (14) who claim "experience shows that a manager will eagerly use a computer in decision making if it is fast, economical and easy to work with".

It is apparent that these systems can be built and may be used, but their impact on management decision performance is not clear. A basic question is: can Decision Support Systems improve management performance? This question was the principal motivation for this study.

1.2.1 Purpose of the Study

Despite the tremendous interest in computer-aided decision making, there is a paucity of research evidence concerning management decision performance. Observations of prototype Decision Systems, however, suggest Decision Support Systems may improve management decision performance. In particular, the work of Gerrity (45), Hedburg (53) and Scott Morton (95) allude to the potential for improvement. Their observations suggested the basic thesis of this work:

> Decision Support Systems can improve management decision performance; DSS-aided decision making is more effective and efficient than similar non-aided decision making.

The principal research objective is to test the validity of this assumption in an experimental study. The proposition is translated into three hypotheses related to effectiveness and two hypotheses related to efficiency. A management game is used to simulate a realistic decision environment which contains two comparative non-strutured decision situations. Decision making in one situation is aided by a Decision Support System (DSS) while decision making in the other situation is unaided. The gaming exercise provides data on actual results for DSS-aided and non-aided decision making. The quality of the decision making is measured for both conditions. This data is used for testing effectiveness hypotheses. Other data collected during the experiment provides information for testing efficiency hypotheses.

The long range goal of this research is to contribute to a better theoretical base for Decision Systems by testing this basic tenet. The classical method of scientific inquiry - experimentation, observation and measurement - is used in this investigation of computer-aided executive decision performance.

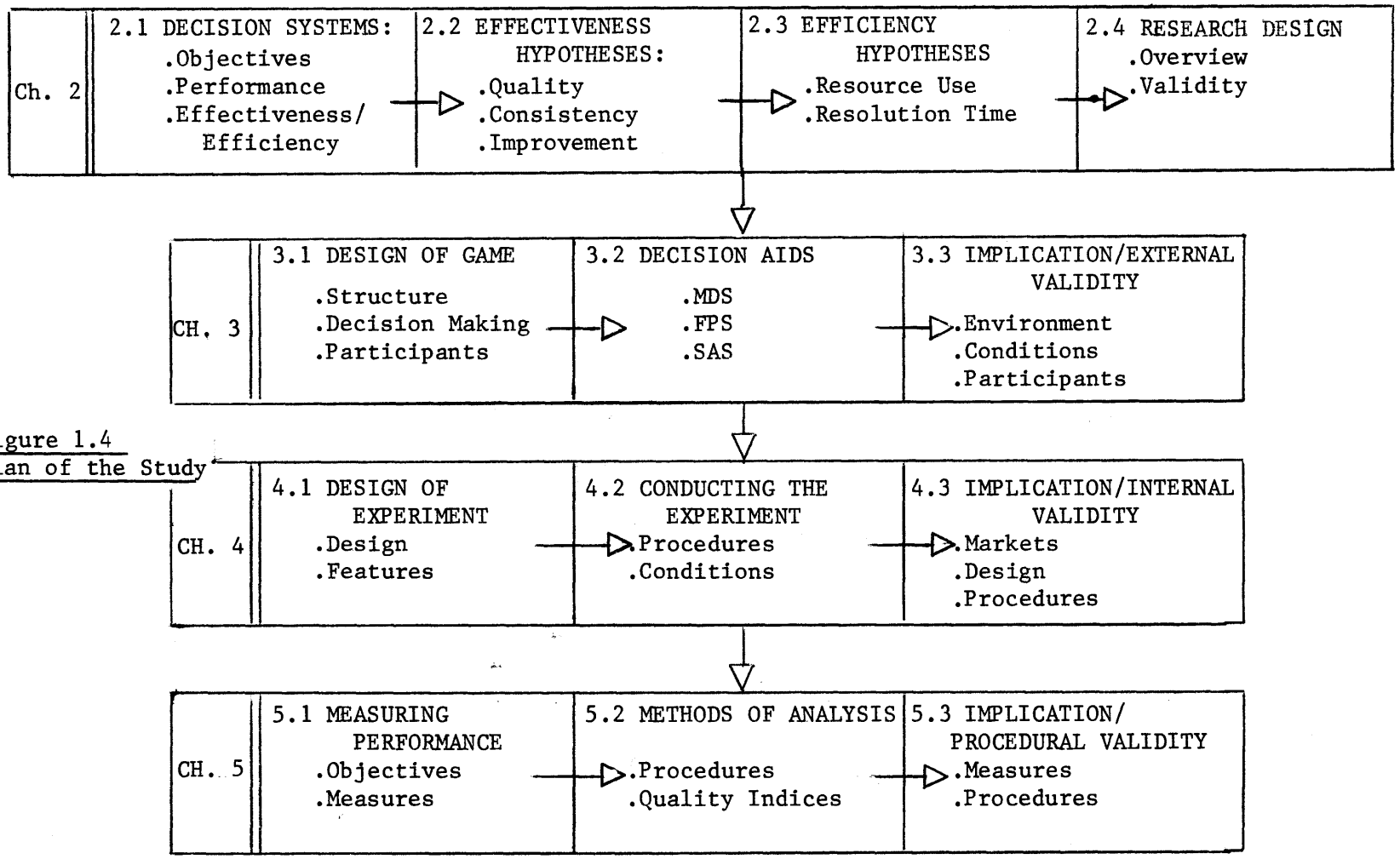


Figure 1.4
Plan of the Study

1.2.2 Plan of the Study

The contents of this study are divided into seven chapters. The content and organization of the main chapters are shown in Figure 1.4. The purpose of the figure is to illustrate the flow between sections and chapters and to briefly indicate the material covered by each chapter. Since each chapter provides a more detailed listing of its contents in the introduction, this section merely highlights their main parts.

Chapter 2 discusses the nature of Decision Systems performance and shows how it relates to the concepts of effectiveness and efficiency. These concepts are operationally defined and the thesis is translated into hypotheses for the study. The requirements for testing these hypotheses are used to develop a research design. An overview of the design is presented and the components of validity are discussed. This section serves as an introduction to the next three chapters since each details specific part of the total design and each discusses implications for the corresponding type of validity.

Chapter 3 describes the design of the management game that simulates the decision environment in the experiment and the design of the decision aids that provide the computer-based decision support in the game. Implications for external validity that relate to the game and the decision aids are discussed in the last section of the chapter.

Chapter 4 focuses on the design and conduct of the experiment. The structure of the design is explained as an introduction to the description of how the experiment was conducted. The experimental design's implications for validity are discussed and the quality of the design is judged in relation to specific criteria found in the literature.

Chapter 5 details the procedure that was used to measure decision quality for both DSS-aided and non-aided decision making.

The procedure relates to the nature of the game and the design of the experiment. Issues concerning reliability of the procedure are discussed and its validity is evaluated.

Chapter 6 presents the results of the study. Each hypothesis is formally tested and the results interpreted. The quality of the data for each hypothesis test is reviewed to determine the confidence that can be placed in results. Statistics on the use of decision aids are presented. The use of the Decision Support System is tied to the results of the hypotheses tests. The patterns of decision quality are compared to determine their similarities and differences.

CHAPTER 2

DECISION SYSTEMS PERFORMANCE

Decision Systems are man-computer partnerships whose main goal is to improve the effectiveness and efficiency of management decision making and, thus, improve management decision performance. Decision performance results from the interaction of the human and machine components in a Decision System. Therefore, decision performance must be considered from a system perspective.

This chapter discusses the nature of decision systems performance, presents the hypotheses for this study and gives an overview of the research design. The organization and contents of the chapter are shown in Figure 2.1..

2.1 Decision Systems: Main Objectives

- 2.1.1 Performance
- 2.1.2 Effectiveness and Efficiency

2.2 Decision Effectiveness Hypotheses

- 2.2.1 Decision Quality
- 2.2.2 Decision Consistency
- 2.2.3 Decision Improvement

2.3 Decision Efficiency Hypotheses

- 2.3.1 Resource Use
- 2.3.2 Resolution Time

2.4 Research Design to Test Hypotheses

- 2.4.1 Overview of the Design
- 2.4.2 Validity in Design

2.5 Chapter Summary

Figure 2.1 Contents of Chapter 2.

The first section discusses the nature of performance, effectiveness and efficiency. The second and third sections translate these concepts into hypotheses and reviews relevant research. The fourth section provides an overview of the research design and reviews the nature of validity; this serves as an introduction to chapters 2, 3 and 4.

2.1 Decision Systems: Main Objective

The principal objective of coupling a manager and a computer in a Decision System is to improve management decision performance. Gerrity (45) insists:

> "the value of a man/machine Decision System should be measured by its ability to improve decision making performance."

Newman (81) contends that decision performance relates to the effectiveness and efficiency of management decision making. Improving management decision performance, therefore, is synonymous with improving the effectiveness and efficiency of management decision making. These improvements result from the aid supplied by the Decision Support System.

This perspective provides the basic thesis of this work:

> Decision Support Systems can improve human decision performance; DSS-aided decision making is more effective and efficient than similar non-aided decision making.

This contention is important; it is a basic tenet in the field. Despite its significance, it is remarkable that it has never been fully tested. It is important, therefore, to regard this principle as an assumption since no systematic test of its validity has been made under controlled, laboratory conditions. The objective of this dissertation is to evaluate the validity of this contention. All of the hypotheses developed here relate to some aspect of this statement.

To evaluate the validity of this compound thesis, each part is treated separately. It is entirely possible that DSS-aided decision making might be more effective but less efficient or the opposite might be true. In either case, the statement would be false.

Therefore, the statement is translated to:

DSS-aided decision making is more effective than similar non-aided decision making.

and

DSS-aided decision making is more efficient than similar non-aided decision making.

Hypotheses related to effectiveness are distinguished from those related to efficiency. This is also necessary because effectiveness and efficiency measure different aspects of systems performance.

To measure performance requires adopting a systems perspective. Gerrity (45) laments:

> "even now, Man-Machine Decision Systems are not yet widely viewed or studied as systems. Rather the computer and human components of the system still are often treated separately ...to the detriment of the total system."

Recognizing this, the systems perspective is adopted here. It is particularly important when considering the performance of the system shown in Figure 2.2.

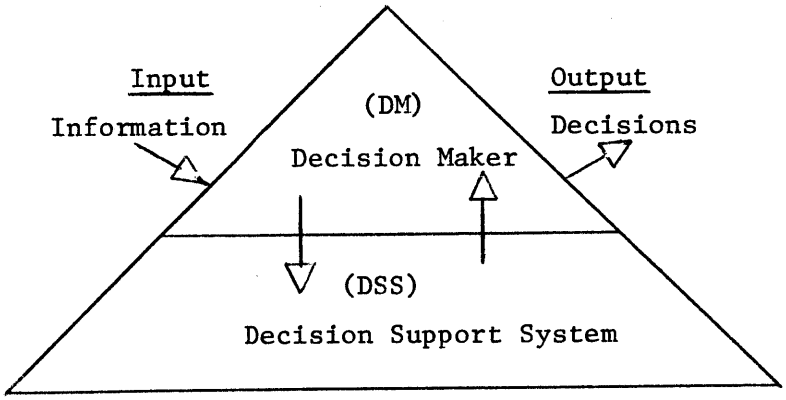


Figure 2.2 Decision System

This figure is the common reference for the following discussion on performance and its relation to measuring effectiveness and efficiency for a Decision System.

2.1.1 Performance

Decision Systems performance is a combination of human and machine performance. Even though the dual source is unquestionable, Parsons (82) claims systems performance can not be separated into component performance because of the confounding interaction of each component. In other words, neither the man nor the machine accounts solely for the performance of the system.

Despite the fact that performance is the result of man and machine working in concert, the performance of the system is commonly attributed to the decision maker rather than the Decision Support System. There are two reasons; first, the decision maker has the responsibility for the decision and second, the Decision Support System is controlled by the decision maker. Consequently, the decision maker ultimately determines the outputs - the decisions - of the system.

What is needed is a method for measuring systems performance. Criteria for evaluating performance in Decision Systems experimentation must account for the joint performance of the decision maker and support system, not performance of one or the other alone. Hall (51) proposes that systems performance has two components: effectiveness and efficiency, and that the output of the system is the basis of measurement for effectiveness while resource use is the basis of measurement for efficiency. Effectiveness is a measure of the external performance of a system. Efficiency is a measure of internal performance. In short, by recognizing the differences between effectiveness and efficiency and using proper measures, the performance of the system, as a whole, can be evaluated and not just one or the other of its components.

2.1.2 Effectiveness and Efficiency

The concepts of effectiveness and efficiency are quite distinct. The efficiency of a system provides few clues about its effectiveness. Similarly, the effectiveness of a system may bear no relationship to costs of operation. Together, however, these concepts provide a means for measuring total systems performance.

The concepts of effectiveness and efficiency can not be measured directly, however. They must be operationally defined. This requires translating each concept into specific constructs which can be reliably measured, and stating the conditions under which measurement will occur. The purpose of this section is to develop the concepts of effectiveness and efficiency and show how they will be measured for this study.

Effectiveness

A system is effective when desired objectives are obtained. Similar definitions are found throughout the literature by Ackoff (2), Boulding (15) and Hall (51). Decision Systems effectiveness, therefore, relates to the potential for reaching the objectives of the decision maker. Anthony (5) suggests:

> "Effectiveness relates to accomplishment... when a specific desired end is attained we shall say that an action is effective."

The concept of effectiveness has not been operationalized for Decision Systems. Nevertheless, it is clear that effectiveness is a measure of how well the outputs of a Decision System attain the goals of the decision maker. Measured directly in terms of the system's outputs, effectiveness shown in Figure 1.2 is determined by the:

(1) quality of the decisions

(2) consistency of the decisions

(3) improvement in the decisions

The primary goal of Decision Systems is to increase profits by improving decision effectiveness through better quality, consistency and rate of improvement in decision making.

Efficiency

A system is efficient when it transforms input to outputs in a reasonably expeditious manner. Anthony (5) states that efficiency means the ability to produce greater outputs with the same inputs or the same outputs with fewer inputs. Boulding (15) claims the most common measure of efficiency is the ratio of outputs to inputs but this ratio cannot be used as a measure of efficiency when the input and output which pass through the systems boundary remains constant. For this case, Hall (51) proposes that the measure of efficiency must be based on resource use and associated measure related to the transformation process.

These observations suggest two dimensions related to efficiency of the system:

(1) resource use

(2) resolution time

Another major goal of Decision Systems is to improve system efficiency by reducing the resource use and the elapsed time to decision resolution.

Summary

The nature of decision performance is summarized in Figure 2.3. Decision performance is composed of twin components - effectiveness and efficiency - which, in turn, have a number of dimensions. Effectiveness relates to the quality, consistency and rate of improvement in decision making. Efficiency relates to resource use and the resolution time. These relationships are shown in the figure on the following page.

Decision Making	Decision Performance				
	Effectiveness			Efficiency	
	Decision Quality (H1)	Decision Consistency (H2)	Decision Improvement (H3)	Resource Use (H4)	Resolution Timme (H5)
Computer Aided					
Non-Aided					

Figure 2.3 Decision Performance

The basic thesis can now be translated to specific hypotheses for effectiveness and efficiency. All hypotheses will be subject to the same experimental conditions which have two salient characteristics. First, hypotheses will be tested in situations where decision making involves complex, non-structured managerial tasks. Second, the experimental design will permit comparison of DSS-aided and non-aided decision making under similar, controlled circumstances. Therefore, each hypothesis statements will compare these two conditions.

2.2 Decision Effectiveness Hypotheses

Hypotheses related to decision effectiveness are introduced briefly here. Details and relevant research are presented in separate sections. The effectiveness hypothesis is:

> For non-structured managerial tasks, DSS-aided decision making is more effective than non-aided decision making in similar controlled, circumstances.

The preceding discussion has shown that effectiveness is a multidimensional concept. Because of this, the statement will not be tested directly. Instead, hypotheses related to each dimension of effectiveness will be tested. This statement translates to three supporting hypotheses which are:

> For non-structured managerial tasks, DSS-aided decision making will result in decisions whose:
>
> (H1) - quality is higher
>
> (H2) - quality is more consistent
>
> (H3) - quality has a higher rate of improvement
>
> than non-aided decision making in similar, controlled circumstances.

Each of these hypotheses relates to the level or pattern of decision quality. To better illustrate what is expected, details of each hypotheses are discussed in reference to the same theoretical graph shown in Figure 2.4. The graph illustrates theoretical levels and patterns of decision quality over time which might be expected for DSS-aided and non-aided decision making.

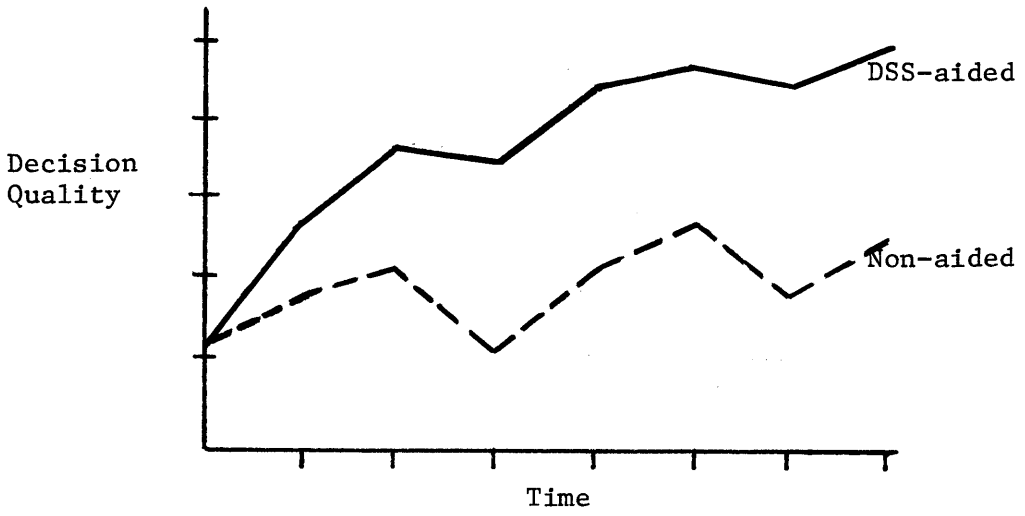


Figure 2.4 Theoretical Decision Quality

Both DSS-aided and non-aided quality levels are shown to emphasize the comparative nature of this study. The graph is predicated on the belief that decision makers can adopt and use a Decision System for non-structured problem solving. In the few instances in which these systems have been built, decision makers have made meaningful use of fairly sophisticated systems; Ferguson and Jones (42), Gerrity (45), Hedburg (53), Morton (92). These studies have also shown that decision makers quickly learned to exploit the capabilities of the particular Decision System.

This graph is not exact but is merely used to illustrate expected levels, variations and trends for DSS-aided and non-aided decision quality over time. Since decisions are made at discrete points in time, the quality of decision making is a series of points rather than a continuous function. For purposes of exposition, however, a broken line is used to clarify expectations.

The graph represents decision quality expected from groups working on similar problems. Howard and Morgenroth (54) found similar decision environments produce essentially the same decision processes and patterns of decision performance. Moskowitz (74) found that groups experience variations in decision quality as task complexity changes. Therefore, variations in quality are expected for DSS-aided and non-aided decision making.

2.2.1 Decision Quality

H1: For non-structured managerial tasks, DSS-aided decision making will result in decisions whose quality is higher than non-aided decision making in similar, controlled circumstances.

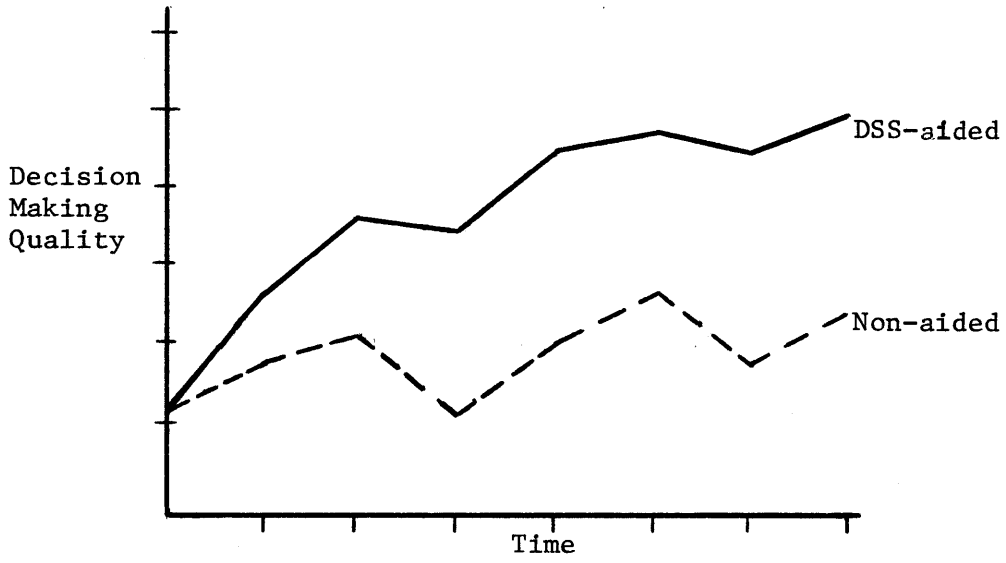


Figure 2.5 Decision Quality Hypothesis

Figure 2.5 graphically illustrates the decision quality hypothesis. DSS-aided decision making quality is expected to be better than non-aided decision quality for similar circumstances. Comparative quality levels are expected to vary over time but DSS-aided decision quality is expected to remain higher than similar non-aided decision quality. The difference in quality levels is expected to vary with the degree of aid provided by the Decision Support System. Similar fluctuation in quality are expected to occur at the same points in time but decreases in DSS-aided quality are expected to be smaller than decreases in non-aided decision quality. In summary, DSS-aided decision making will result in decisions whose quality is higher than the quality of non-aided decision making for similar situations.

Relevant Literature

For comparative situations, DSS-aided decision making quality is expected to be better because Decision Systems may decrease inherent human limitations and, therefore, aid the decision processes of managers. Beged-Dov (11) proposes that Decision Systems must supply relevant information, models and aids for manipulating, recording and transforming data. Simon (103) claims that this allows the decision maker to allocate his limited decision making resources and capabilities on fewer tasks within the total decision process and in so doing may improve his decision quality. Newman (81) claims that if we concentrate on providing computer and display aids that overcome limitations, then decision making abilities can be expanded tremendously. These contentions are discussed below.

Decision Systems facilitate decision making. These systems can aid all phases of the decision process and may increase the decision maker's ability to find problems, evaluate consequences, and make choices. Gerrity (44) reports that DSS-aided decision makers found problems that may have gone unrecognized. Morton (95) notes that more alternatives were generated and tested in less time with the aid of his Decision Support Systems. It seems clear that decision processes have been significantly influenced by Decision Systems. The implication is that decision quality may also have been changed but this has never been substantiated.

Decision making is shaped by the capabilities and limitations of the decision maker. Howard and Morgenroth (54) modeled the decision processes of 130 non-aided decision makers and concluded that, "decision processes of higher level executives displayed a surprising degree of simplicity, a simplicity imposed by the limitations of man's intellectual capacities."

The capabilities of the human decision maker are quite limited. Schakle (98) found that humans are limited in computational power and precision. Newman (80) reported limited ability to

handle complexity. Miller (68) asserts that short term memory tends to be limited and unreliable. Hunt and Markos (57) reported limited information handling ability. Bruner (18) shows that the decision maker is severely constrained by his inference capabilities. Dickson (33) found that the ability to process many facts at the same time is poor, especially for unfamiliar tasks. The exact boundaries of these limitations are not clear. Newman (81) asserts that, "there are, undoubtedly upper limits to man's intellectual ability, but we are a long way from determining just where those limits are."

These limitations contribute to illogical and suboptimal decision making in complex situations where few aids are provided. Ebert (35) reported computer aids overcome some of these characteristics, especially for complex problems. There is additional evidence that performance can be improved. In one of the most extensive studies on computer-aided problem solving, Newman and Rogers (80) reported slight differences in performance between control and experimental groups for simple tasks requiring concept formation and inductive reasoning. In military command situations, Gebhard (43) found computer-based solutions to simple problems were used as a basis for decision making and led to improved decision quality.

The strongest indication is found in the work of Gerrity (44) and Morton (95). Although both field studies focused on the impact on decision processes rather than performance, each alludes to increased decision quality. Morton (95) documented significant impacts on the decision process but observed:

> "In point of fact, there is no certain way of showing in general that decisions are "better"...(but)... these particular managers claimed that MDS improved decision making as well as shortened the decision making cycle..."

Gerrity (44) and Hedburg(53) have reported similar observations. Taken together, the findings and observations suggest DSS-aided decision quality can be higher than non-aided decision quality for situations of similar complexity.

2.2.2 Decision Consistency

H2: For non-structured managerial tasks, DSS-aided decision making will result in decisions whose quality is more consistent than non-aided decision making in similar, controlled circumstances.

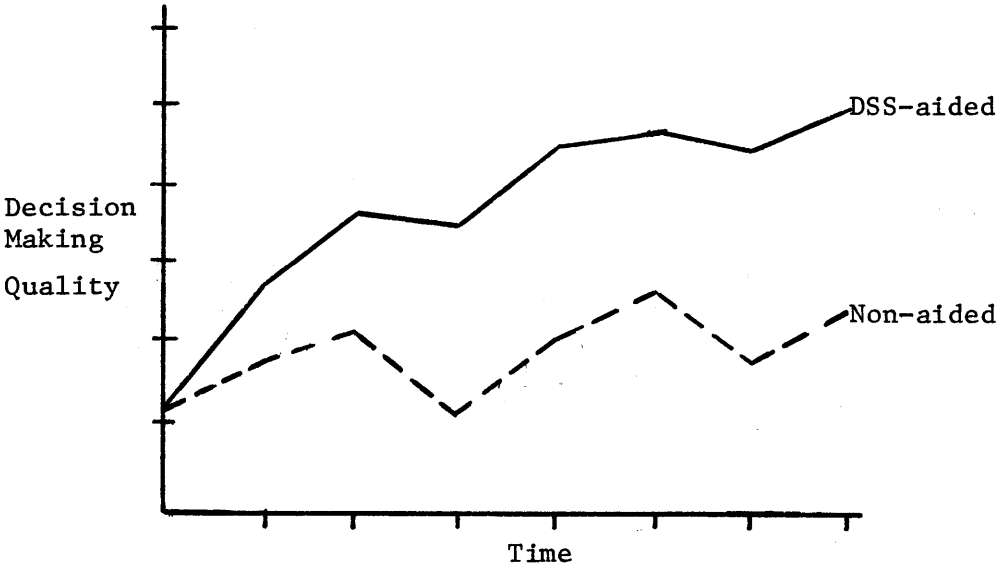


Figure 2.6 Decision Consistency Hypothesis

The consistency of DSS-aided decision making is expected to be better than the consistency for non-aided decision making. Consistency is a measure of the variance in decision behavior. As shown in Figure 2.6 variation within the dotted range lines is expected to be smaller for DSS-aided decision making than for non-aided decision making. Quality levels are expected to vary as the complexity of the decision environment changes but DSS-aided quality is expected to show smaller comparative decreases for similar circumstances. The smaller decreases are in sharp contrast to the major decreases expected for non-aided decision making. In summary, DSS-aided decision making will result in decisions whose quality is more consistent than the quality of non-aided decision making for comparative circumstances.

Related Literature

For similar situations, DSS-aided decision making is expected to be more consistent because Decision Systems can provide formal models tailored to the need of the decision maker. Models provide a consistent structure of relationships and thus, produce logically consistent results. Morton (97) contends that the direct availability of models is the feature that distinguishes Decision Systems from the more traditional Management Information System.

Research suggests that decision performance may be improved by providing models and, thus, making decision rules more consistent over time. Bowman's (16) research shows that managers make good decisions on the average but also may exhibit high variance in their decision behavior. He asserts that models based on parameters determined from the manager's actual past decisions and centering on critical variables are the key to more consistent decision making. Similar arguments for model based decision making are proposed by Little (63), Gorry and Morton (49)and Charnes and Cooper (24).

Kunreuther (60) claims that managers consider only a limited number of factors in their decision making. The implication is that decision making is likely to be geared to a decision rule based on a few variables which the manager has found to be important from past experience. Therefore, it seems that the non-aided manager may be erratic in his decision making behavior since he considers only the variables that he is able to handle using his limited models. Thus, variability may stem from a lack of good models.

Non-aided decision makers exhibit considerable inconsistency in their information processing behavior. Schroder (96) asserts that the capacity for processing information tends to increase,

passes through a maximum and falls off with increasing complexity but that the tolerance for complexity increases with experience. Newman (81) reported decision makers are better able to handle complexity if they have some way of structuring it. Nevertheless, these findings suggest that decision consistency can be increased simply by structuring complexity with a model.

It is likely that model-based decision making introduces greater consistency in real-world decision process. Westendorf (114) showed that managers in an experiment group supported by models improved both long and short range decision consistency over the control group in a complex game. Additional research verified that the relative superiority of model-based decision making improves as task complexity increases. Morris (73) reported confirming results which showed that models tend to increase consistency of decision making in actual situations. These results indicate that models reduce the chance of overlooking critical variables and may provide the ability to handle greater complexity.

There are claims in the man-machine systems literature that decision consistency increases when decision making is aided by computer support. The evidence cited above suggests that DSS-aided decision making can be made more consistent than similar non-aided decision making by providing systems which supply information models and computational power to the decision maker.

2.2.3 Decision Improvement

H3: For non-structured managerial tasks, DSS-aided decision making will result in decisions whose quality has a higher rate of improvement over time than non-aided decision making in similar, controlled circumstances.

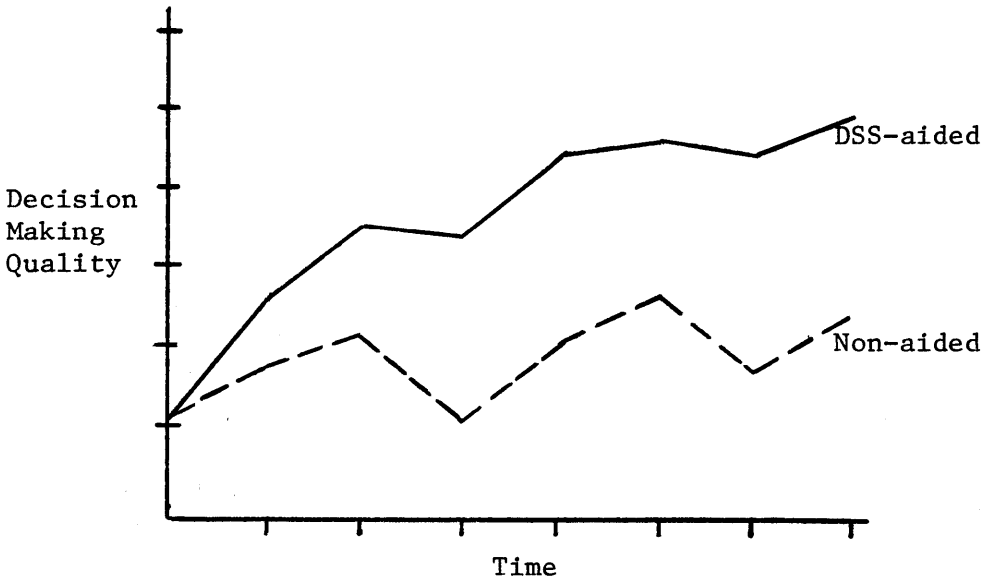


Figure 2.7 Decision Improvement Hypothesis

The rate of improvement for DSS-aided decision making is expected to be greater than the corresponding rate for non-aided decision making. Rate of improvement is a measure of the net rate of change in decision quality over time. As shown in Figure 2.7 the slope of the line for DSS-aided decision quality is expected to be greater than the slope for non-aided decision quality. The quality of decision making in both states is expected to increase but DSS-aided decision quality is expected to approach potential faster. Therefore DSS-aided decision quality is expected to have a higher rate of improvement than non-aided decision quality.

Related Research

For comparative situations, DSS-aided decision quality is expected to have a higher rate of improvement because Decision Systems can materially affect the decision maker's abilities. Since part of the total decision problem is shared by the machine, the decision maker can concentrate his resources on fewer tasks for which he has a comparative advantage. The net result should be that decision quality improves at a faster rate.

The non-aided decision maker, on the other hand, is faced with formidable problems in non-structured situations. Since task complexity is determined by the nature of the environment, he has little chance of reducing it. Moreover, inherent human limitations of the non-aided decision maker can not be changed directly (e.g. direct increase in short-term memory). These two facts suggest that the rate of improvement for non-aided decision maker slowly increases as the decision maker learns to cope more by structuring parts of the total problem.

These observations are supported by research related to human information processing capabilities. Powers (86) reported subjects came close to good solutions for very simple tasks but only in the latter stages of learning. A tentative finding was that poorer decision making in the initial and intermediate stages might be accounted for in part by the subject's lack of skill in considering simultaneously all relevant aspects of the task and their ability to process information.

Research concerning non-aided human information processing ability has implications for decision improvement. Gibson and Nicol (47) claim decision makers tend to want too much rather than too little information. McKendry (66) found managers can judge the potential value of new information but are unable to effectively utilize relevant information, especially if it is multi-dimensional. Hunt (55) and Schroder (96) reported findings which suggest that there are many situations where better information may not be used simply because humans have difficulty aggregating available evidence. Consequently, non-aided decision makers find it difficult to improve or revise strategies even when warranted by new information. Vaughn (113) showed that limited information processing capacity results in decision makers generating and testing too few courses of action.

These findings contrast with results reported for computer-aided decision making. Hedburg (53) found decision makers could handle more information. Morton (95) reported that decision makers generate and test more alternatives in the solution of complex problems. Newman and Rogers (80) claim that fewer errors are made in arriving at a solution to concept formation problems. Newman (81) contends that decision makers increase their ability to handle complexity if the system structures information properly. This limited evidence suggests that the rate of improvement for DSS-aided decision making may be greater than for similar non-aided decision making.

2.3 Decision Efficiency Hypotheses

Hypotheses related to the efficiency of decision making are introduced here. Further detail is provided on each hypothesis and research related to both is discussed in the following section. The efficiency hypothesis is:

> For non-structured managerial tasks, DSS-aided decision making is more efficient than non-aided decision making in similar, controlled circumstances.

The measures of efficiency are based on resource use and resolution time. Therefore, this major hypothesis translates into two supporting hypotheses which are:

> For non-structured tasks, DSS-aided decision making will result in:
>
> (H4) - lower resource use
>
> (H5) - shorter resolution time
>
> than non-aided decision making in similar, controlled circumstances.

Even though Decision Systems include human and machine resources, only the human resource can be considered in evaluating these hypotheses because of the need for comparative measures of DSS-aided and non-aided resource use. Consequently, the measures used here are the number of man-hours devoted to DSS-aided and non-aided decision making.

These hypotheses relate to different aspects of decision time - contact time and elapsed time. Man-hours of effort is a measure of the contact time that decision makers use in arriving at decisions. Resolution time is a measure of the elapsed time from the beginning of the decision process to the final choice of an alternative. Together, they provide good measures of decision making efficiency.

2.3.1 Resource Use

H4: For non-structured managerial tasks, DSS-aided decision making will result in lower resource use than non-aided decision making in similar, controlled circumstances.

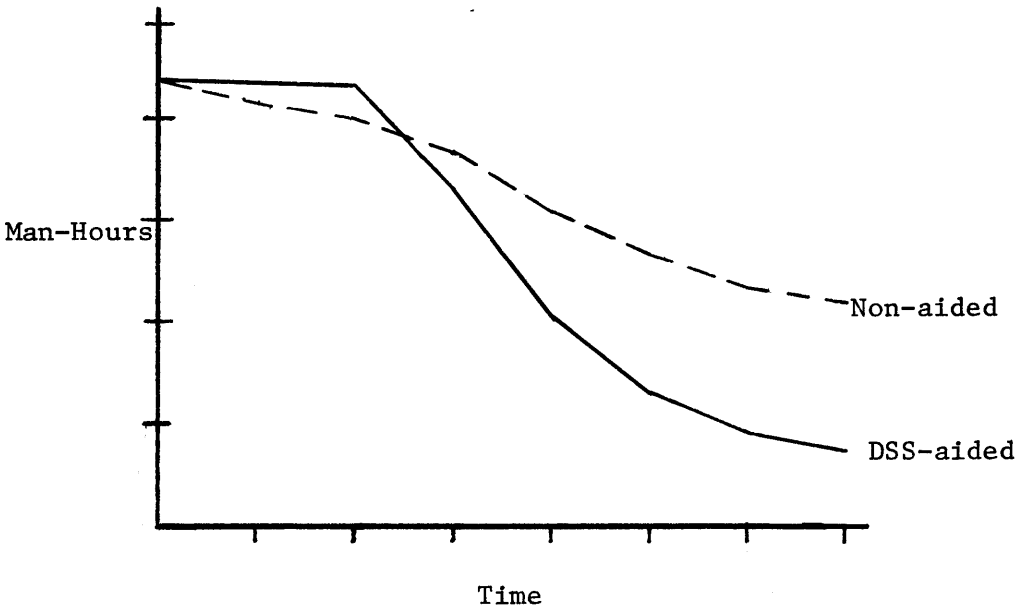


Figure 2.8 Resource Use Hypothesis

Resource use is measured by man-hours of effort required for comparative decision activity. Fewer man-hours for DSS-aided decision making are expected to be used. Initially, man-hours are expected to be high in both cases because the firms must make complex decisions in a new environment. Moreover, for aided decision making, they must learn to use the decision support system. As shown in Figure 2.8, after a few quarters, the man-hours for aided decision making are expected to decrease at a faster rate and stay below those required for non-aided decision making.

2.3.2 Resolution Time

H5: For non-structured managerial tasks, DSS-aided decision making will result in shorter resolution time than non-aided decision making in similar, controlled circumstances.

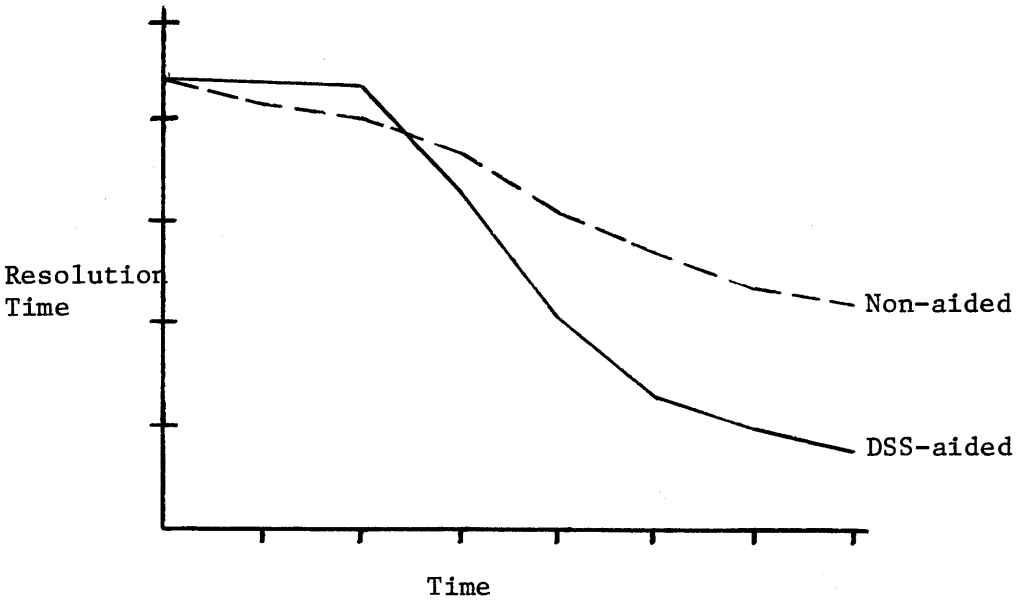


Figure 2.9 Resolution Time

The resolution time - the time until final choice - is expected to be shorter in most cases for DSS-aided decision making. Resolution time can be measured objectively by recording the elapsed time from the beginning of decision making to choice of an alternative. As shown in Figure 2.9, resolution time of DSS-aided decision making is expected to lower and may decrease over time while resolution time for non-aided decision making is expected to be higher for similar circumstances.

Related Research

Fewer man-hours of effort are expected to be used for DSS-aided decision making because Decision Systems facilitate problem solving by providing immediate access to data, models and decision aids. Consequently, decision processes can proceed with minimal interruption at a pace dictated by the decision maker. The flow of non-aided decision making, on the other hand, is usually subjected to artificial interruptions because of the need for time-consuming analyses by either the decision maker or his staff. Decision Systems can reduce artificial barriers to decision making and, therefore, reduce the man-hours of effort need to make required decisions.

There is some evidence to support these contentions. Joyner and Tunstall (58) reported an increase in efficiency for computer-aided problem solving for fairly simple task situations. They claim that the increase in efficiency stems from reducing the barriers to problem solving and segmentation of the decision process into a series of distinct, logically sequenced steps. Moreover, this was followed by a reduction in the complexity of the information processing required at any given time.

The most striking evidence is found in the work of Scott Morton (95). He reported that the contact time for three managers involved in a complex, non-structured marketing problem was reduced from the original six days to one-half day after the Decision System was introduced. The manager's contact time is different than elapsed time to decision. Elapsed time for non-aided decision making originally spread over twenty-two days. Sixteen days were used by the manager's staff to carry out detailed analyses which were reviewed by the managers as part of their decision process. Evidently, the quality of analyses was improved and the flow of the decision process was facilitated, thus reducing elapsed time to one day. Morton (95) attributes some of the reduction to a substantial improvement in communication among managers.

2.4 Research Design to Test Hypotheses

To test the hypotheses discussed in previous sections of this chapter requires a suitable research design. Kerlinger (59) claims that the suitability of a particular design must be judged in terms of its appropriativeness for testing hypotheses and its inherent validity. Since alternative designs have differing degrees of inherent validity, the preferred design is one having the highest validity because validity determines the value of the work and the degree of confidence associated with results.

Validity is a multifaceted concept whose nature is best understood by distinguishing among its basic components. Campbell and Stanley (20) identify three major components of validity: validity of results (external validity), validity of methods (internal validity) and validity of analytical procedures (procedural validity). Obviously, each component relates to specific parts of a research design.

The design used in this study is quite complex. Three chapters (3, 4 and 5) are devoted to detailing specific parts of the total design and to evaluating their implications for the corresponding type of validity. This section serves as the introduction to these three chapters. The purpose here is:

(1) First, to introduce the complete design and show how details in the following chapters fit together to produce data to test the hypotheses.

(2) Second, to review the nature of external, internal and procedural validity and establish the correspondence between specific parts of the design and each component of validity.

This organization parallels the organization of chapters 3, 4 and 5. The first two sections of each chapter describe details of the design while the third section discusses implication for validity. The details of the design are provided first because they are necessary for evaluating critical issues related to each component of validity.

2.4.1 Overview of the Research Design

Research design is more than the design of an experiment. It includes all of the steps which eventually lead to hypotheses testing. The objective of any design is to produce appropriate data for the hypotheses tests. Different types of data are needed for the effectiveness and efficiency hypotheses. Consequently, these needs determine the required parts of the design. These needs are discussed below to show how they influenced the design.

The data needed to test each of the effectiveness hypotheses are measures of actual decision quality for DSS-aided and non-aided decision making. A number of requirements must be met in order to obtain the data. A decision environment must provide two similar decision making situations. To create the experimental and control conditions, decision making in one environment must be aided by a Decision Support System while its counterpart in the other environment remains unaided. The actual results of decision making can be obtained directly by conducting the experiment.

Extensive analysis is required to measure the quality of decision making. The quality of actual decision making can be measured by finding ratios of actual profits to potential profits which would have resulted had decision making been optimal or near optimal. These ratios are the data needed for testing hypotheses related to effectiveness.

To test each of the efficiency hypotheses requires data on resources use and resolution time for DSS-aided and non-aided decision making. The data on man-hours used and the time to final choice can be collected during

the course of the experiment and used directly to test the hypotheses.

Translating these needs into an appropriate design involved:

(1) Design of the Simulation and Decision Aids

(2) Design and Conduct of the Experiment

(3) Design of Measures and Methods of Analysis

The distinction between components of validity strongly influenced each of these areas. Early in the study, goals for increasing the validity of the design were developed. These goals are:

1. Comparison of Aided and Non-aided decision making
2. Adequate control of experimental variables
3. Simultaneous exposre to experimental condition
4. Parallel observations of conditions
5. Unobtrusive data collection
6. Replication of the experiment
7. Reliable methods of analysis
8. Realistic and complex decision environment
9. Conditions having high generalizability
10. Range of non-structured decision making

These goals were achieved in the design pictured in Figure 2.10. Features of the design are described below. The purpose is to provide an overview of the design rather than specific details which are described in later chapters.

A management game is used to simulate a complex business environment in which firms compete in a Foreign Market and Domestic Market. These markets are highly similar; they are structurally identical and are effected by exactly the same variables. The similarity, however, is not apparent to firms because of complex interactions. Six firms compete in both markets by making non-structured marketing decisions (price, promotion and R&D) which determines sales and, in turn, marketing profits.

An integral part of the game is a set of interactive decision aids, one of which is a Decision Support System. This marketing Decision System is designed to directly support managers of each

Design Phase	Design of Simulation and Decision Aids		RESEARCH DESIGN Design and Conduct of Experiment		Design of Measures and Methods of Analyses	
	EXTERNAL VALIDITY		INTERNAL VALIDITY		PROCEDURAL VALIDITY	
Time Required	4 months		Exp. begins — 2 weeks —	Exp. ends	3 days	14 months
Subphase Activity	Game Environment	Participants Groups	Treatment Condition	Observation Data Collection	Analyses Comparative Standards	Measures Tests
Research Design: Goals . High External Validity . High Internal Validity . High Procedural Validity	Foreign Market Game and Decision Aids Domestic Market	25 Senior Executive Decision Makers Firm 1 Firm 2 Firm 3 Firm 4 Firm 5 Firm 6	Marketing Decision System (MDS) FPS SAS SAS FPS 8 replications	Actual Results In Foreign Market For 8 qtrs. Actual Results In Domestic Market For 8 qtrs. -Actual Results Document Collection -Console Trace -Questionnaire -Interview -Observation	Potential Results for Foreign Market Comparative Standards for Foreign Market Potential Results for Domestic Market Comparative Standards for Domestic Market	Quality Indices for aided Decision Making Quality Indices for Non-Aided Decision Making Hypotheses test for Related Samples
Features that achieve design goals	Identical Decision environment created by simulation form realistic and complex decision environment offering a range of non-structured decision making	Matched-pair firms that act as their own control and permit comparison of aided and non-aided decision making.	Simultaneous exposure to experimental stimuli full control over experimental variables, conditions and treatments.	Parellel Observation of experimental and control conditions - unobtrusive observation and data collection.	Analytical procedures assure reliable methods of analysis	Non-parametric tests for 6 related samples for 8 replications of the experiment.

Figure 2.10

firm. The Decision Support Systems can be supplied or withheld from either market to create experimental conditions.

The experimental design creates the experimental and control conditions by making the Decision Support System available for use in the Foreign Market while precluding use in the Domestic Market. All other conditions are the same for all firms in both markets. Consequently, the experimental condition involves DSS-aided decision making in the Foreign Market while the control condition involves non-aided decision making in the Domestic Market.

The design uses firms as their own control; that is, each firm is simultaneously exposed to the experimental and control conditions. Firms may be used as their own controls because results in the Foreign Market are independent of results in the Domestic Market. Therefore, differences in actual results are attributable to the experimental variable - the Decision Support System.

Conducting the experiment is synonomous with allowing firms to play the game for enough quarters to supply adequate data. The actual results for each firm are collected for both the experimental and control conditions for eight quarters. A variety of unobtrusive data collection methods are used to obtain additional information. Among these methods are console traces, questionnaires interviews, observation and document collection. Most of this data is collected after the end of the gaming exercise.

After the game has ended, decision quality for each firm's DSS-aided and non-aided decision making is measured for every quarter. A ratio of actual marketing profitability to potential marketing profitability which would have resulted had the firms' marketing decision been optimal or near optimal is used to measure relative quality. These measurements are the data for hypotheses tests related to decision effectiveness. In contrast, the data related to efficiency require no elaborate analyses prior to hypotheses testing.

2.4.2 Validity in the Research Design

To conduct research which does not violate the canons of scientific procedure while producing results which are generalizable to a wider context requires that the design have high validity. Validity is much more a matter of degree than an absolute. Because every aspect of validity is so closely interwoven, at times, these criteria may be at odds with each other. Research designs which increase one may jeopardize the others. Clearly, the goal is a design that is high in external, internal and procedural validity. Every part of the research design has implications for validity. The correspondence between parts of the design and each type of validity should be evident from a discussion of each component.

External Validity

External validity centers on generalizability. It depends upon the similarity of the experimental and real world situations. Greater external validity is achieved as representativeness of the laboratory environment increases. The validity of results, however, is dependent on the validity of methods and procedures. In other words, results are valid only to the extent that methods and procedures are valid. Campbell and Stanley (20) note that external validity asks the question of generalizability: to what populations, settings, treatment variables, and measurement variables can effects be generalized? Raser (87) identifies the representativeness of the experimental (1) environment, (2) conditions, and (3) population as the critical issues for consideration.

Certain factors related to these variables may jeopardize external validity and thereby decrease the ability to transfer results to a wider context. Of particular importance is the realism and complexity of the simulated environment and the similarity of the conditions and subjects in the Game to their real world counterparts. These factors relate to the design of the simulator, interactive decision aids and the participants in the MIT Management Game.

Internal Validity

Internal validity is a measure of the quality of experimentation. It depends upon the quality of the design and procedures used in the experiment. Greater external validity is achieved by design which innately control variables that might confound the effects of the experimental stimuli. Parsons (82) suggests that for man/machine experimentation the factors influencing internal validity relate either to how the experiment was designed or to the procedures used in conducting the study. These factors are usually situation-specific and must be evaluated in the context of the particular experiment.

The problems encountered in man/machine studies may be more severe than those in conventional experimentation because of the scope and complexity of the experimentation. Therefore, the researcher must explore the implications of all experimental factors which have the potential for jeopardizing either internal or external validity. Among the more important factors in this study are procedures used for the formation of experimental and control conditions, the participant assignment methods, the data collection procedures and methods of observation. These factors are associated with the design and conduct of the experiment.

Procedural Validity

Procedural validity is related to the quality of the measures, analytical procedures, and statistical tests used in the research design. It depends upon the quality of the methods for transforming raw data into appropriate hypotheses test. Mackenzie and Barron (64) note that there are many transformations which are required to obtain data for hypotheses testing and finally apply statistical procedures to obtain results and each has the potential for influencing procedural validity.

Potential problems are the appropriativeness of measures, the reconciliation of differences for DSS-aided and non-aided

decision making, the assumptions behind analytical procedures, and the use of statistical tests. These factors relate to the design of measures and methods of analysis.

Summary

Validity is intimately related to each part of the total research design. External validity depends upon the similarity of this experimental and real world situation. Internal validity depends upon the quality of the experimental design and methods for conducting the experiment. Procedural validity depends upon the reliability of measures and methods of analysis.

The previous discussion has shown that factors influencing each type of validity logically correspond to parts of the research design. The correspondence is:

Type of Validity	Research Design	Chapter
External	Design of the Simulation and Decision Aids	3
Internal	Design and Conduct of the Experiment	4
Procedural	Design of Measures and Methods of Analysis	5

The following three chapters first present details of the research design and then discuss implications for the corresponding type of validity.

Each chapter uses data from the questionnaire and interviews to show participant response to the critical issues related to validity. Each section presents data in histogram form. Since each question which elicited the responses is printed with the histogram no further detail regarding this data is given until data collection methods are discussed in Chapter 4.

2.5 Chapter Summary

This chapter documents underlying concepts, develops hypotheses and introduces the research design used in this study. The thesis that Decision Support System can improve human decision performance; that is, DSS - aided decision making is more effective and efficiency than similar non-aided decision making is translated into three testable hypotheses related to effectiveness and too related to efficiency.

Effectiveness hypotheses are:

> For non-structured managerial tasks, DSS - aided decision making will result in decisions whose:
>
> (H1) quality is higher
> (H2) quality is more consistent
> (H3) quality has a higher rate of improvement

Efficiency hypotheses are:

> For non-structured tasks, DSS - aided decision making will result in:
>
> (H4) lower resource use
> (H5) shorter resolution time

than non-aided decision making in similar, controlled circumstances.

Research related to each of these hypotheses is reviewed. The review reveals that these hypotheses have never been tested (even singularly) in a controlled laboratory experiment.

The chapter also introduces the research design that was used to simultaneously test each of the hypotheses. The goals of good research: high external, internal and procedural validity; are discussed and related to specific characteristics of the research design as an introduction to Chapters 3, 4, and 5 which explores details of the complex design used in this study.

CHAPTER 3

DESIGN OF GAME AND DECISION AIDS

The MIT Management Game exercise is a unique laboratory for the study of Decision Systems performance. Certain features of the Game create the opportunity to study computer-aided and non-aided decision making in a realistic decision environment. Interactive decision aids are provided to support decision making: Marketing Decision System (MDS), Financial Planning System FPS), and Statistical Analyses System (SAS).

This chapter describes the Game and the decision aids and discusses their implications for external validity. The organization and content of the chapter is shown in Figure 3.1.

3.1 Design of the Game

- 3.1.1 Structure of the Game
- 3.1.2 Nature of Decision Making
- 3.1.3 Participants in the Game

3.2 Interactive Decision Aids

- 3.2.1 Marketing Decision System
- 3.2.2 Financial Planning System
- 3.2.3 Statistical Analysis System

3.3 Implications for External Validity

- 3.3.1 Issues Related to Game Environment
- 3.3.2 Issues Related to Game Conditions
- 3.3.3 Issues Related to Game Participants

3.4 Chapter Summary

Figure 3.1 Contents of Chapter 3

The first section describes the details of the Game and the complexity of the marketing decision making facing the participants. The second section describes each of the decision aids. MDS is described in detail and an example of how firms used this system is given. Although the first two sections are brief, they provide the necessary detail for evaluating specific issues related to the external validity of this study.

3.1 Design of the Game

From the firm's point of view, the Game is an exercise in executive decision making. Participants act as upper-level management teams competing in a Foreign Market and Domestic Market. Management teams control their firms by making marketing, production and financial decisions which determine the financial and operating results that are reported at the end of each period.

Each firm is required to make sixteen decisions every quarter. The decisions fall naturally into three interdependent functional areas. The required decisions associated with each area are:

Function Area	Required Decision
Marketing	1. Domestic Price
	2. Foreign Price
	3. Domestic Promotion Expenditure
	4. Foreign Promotion Expenditure
	5. R&D Expenditure
Production	6. Units to be Produced
	7. Shipments to Foreign Market
	8. Machine Capacity
	9. Labor Force
Finance	10. Cash Remitted
	11. Domestic Securities Balance
	12. Foreign Securities Balance
	13. Domestic Loan Balance
	14. Foreign Loan Balance
	15. Number of Shares Outstanding
	16. Dividend

The results returned to each firm include both public and private information. All firms receive confidential reports concerning their financial and operating status which includes over 250 information items organized into ten reports:

Balance Sheets

Profit and Loss Statements

Reconciliation of Retained Earnings Statements

Sources and Uses of Funds Statement

Inventory Reconciliation Statement

These ten reports are included in Appendices C and D.

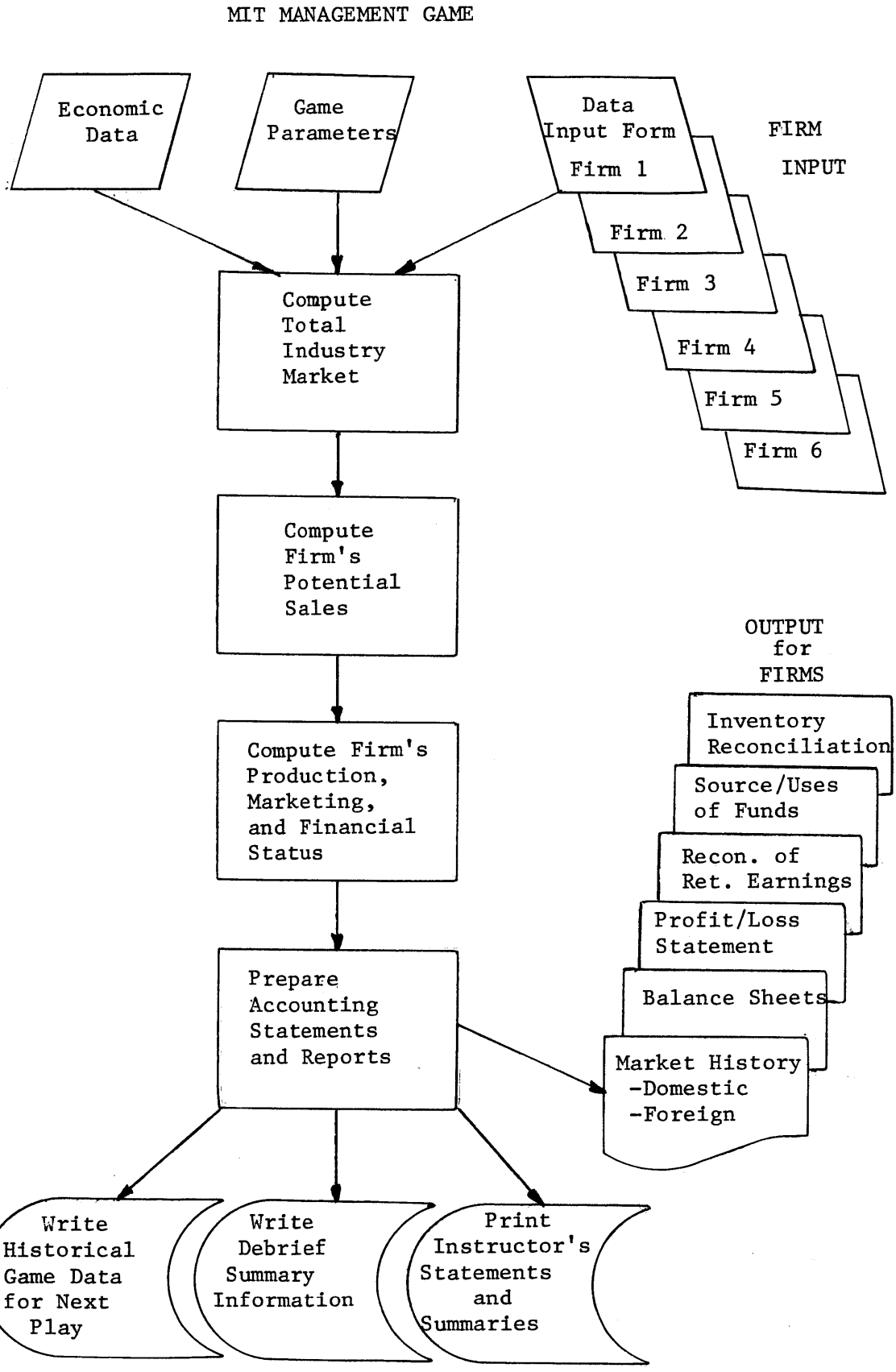


Figure 3.2 Management Game Operations

Since all companies are considered publicly held, each firm also receives an identical "market summary" report which contains information on each market's data and competitive data that is normally available in the market place. A copy of this report is included in Appendix B.

To better illustrate the sequence of events, Figure 3.1 highlights the coneptual operation of the game. In essence, it is a "behind the scenes" look at what happens when firms submit their decisions on the Data Input Form. A copy of this form is shown in Appendix A. This form also captures data for experimental purposes. After the decisions for all firms are entered, the game is run by the administrator and results are returned. The input required from each firm and output returned as well as the conceptual activities in the game are pictured in the diagram.

3.1.1 Structure of the Game

The purpose of this section is to describe the Game because the generalizability of results depends upon the realism and complexity of the experimental environment. The realism and complexity of the Game is related to the nature of the (1) markets, (2) customs, (3) industry and (4) firms.

The Game simulates a multi-firm industry serving two independent markets - the Foreign Market and the Domestic Market. Each market is independent in that sales in one do not influence sales in the other. Six firms have by tradition been considered an industry. Since activities of the industry represents the strategies of all firms, the dynamic interaction of many variables influence the growth or decline of each market.

Markets

Markets react to general economic conditions and the industry's price, promotion, and research and development policies. Changes in each market's size are determined by general economic conditions

and the actions of each firm in the industry. Changes in GNP and a seasonal factor which represents a quarterly sale pattern influence growth. The interaction of each firm's price, promotion, R&D, and inventory policies have a predominating effect on each market, however. The simultaneous interaction of these twenty-six variables produce complex market behavior. This dynamic behavior is influenced by past history, time-dependencies and the interaction of all competitors.

The markets are robust enough to reward a variety of consistent, feasible strategies. For example, if firms resort to price cutting as a primary tactic, markets become very price sensitive and the low price, higher volume, market expands relative to the higher priced market. At the other extreme, firms may expand the market by increased promotion and R&D expenditures and thus create a market which supports both higher and lower priced products. Firms can develop competitive positions which emphasize any one or a combination of their decision variables and thus attract different kinds of customers to the firm.

Customers

Each market has two classes of customers who are differentially sensitized to different combinations of marketing factors. Repeat customers are sensitive to pricing, past sales levels and inventory availability. Shopper customers are sensitive to the relative differences between competitors' price, promotion, R&D and inventory policies. Therefore, a firm's share of the market is determined by both present and past marketing and production strategies relative to those of its competitors.

The interaction of each competitor's market strategy and economic and seasonal conditions cause the relative size of the repeat and shopper pools to fluctuate each quarter. Customers entering or leaving the market are shopper customers. Once a

customer has purchased from a firm, he becomes a repeat customer. The majority of repeat customers tend to remain with a firm under certain conditions. Repeats, however, can become shoppers but may return to the firm if its products are more attractive than its competitors. In addition, a firm's ability to attract and service customers may experience quarterly changes. Consequently, marketing problems continually recur for each firm in the industry.

Industry

The industry is composed of six firms. Each firm's operating and financial status is identical when the teams assume management responsibility in Quarter 12. The operating history for Quarters 2 to 11 is unique to the firm and was produced by the game administrator and his associates, each of whom ran independent firms for 11 quarters. To create identical starting conditions for Quarter 12, the prior four quarters were collaboratively rerun until ending results of Quarter 11 were consistent across all firms.

The nature of the competition is determined by the interactions of firms in their quest for customers in both markets. The interaction results in complex non-linear reactions in the market place and, which, needless to say, are extremely difficult to predict. In addition, each firm's actions are not known with certainty by its competitors. Needed information with respect to the market and competition may not be reported or may be inaccurate, if reported. Thus the character of the competition, and its present status, are only partially known by each firm. What actions firms will take in the future can be estimated only on the basis of noisy information, if past history is any guide.

Firms

The management of each firm is a four or five man team. The management of each firm controls similar marketing organizations located in both the Foreign Market and Domestic Market. Each marketing organization sells a product which can be differentiated

from competitive products by the firm's pricing, promotion and R&D strategies in each market. Because the same product is sold to both repeat and shopper customers, who are sensitive to different product images, decisions in each market require thoughtful balance along a number of dimensions.

The production facility for each firm is located in the Domestic Market. The capacity of the facility is a function of the effective labor and machine capacities, both of which may be increased. Changes, however, require lead times and incur significant costs associated with hiring, firing, overtime and additions to capacity. Limits on maximum changes permitted in any quarter require firms to anticipate their needs substantially in advance of requirement. Costs associated with the plant, product, selling and administration are both fixed and variable. Some of the real costs in each of the areas are unknown to the firms.

The production process is characterized by time delays for training workers, installing capacity, manufacturing the product and shipping. Goods destined for each market must be designated in advance of production since each incur different delays and costs in the production process. Goods for the Foreign Market are more expensive because of higher labor, materials, overhead and shipping costs. Finished goods are warehoused in both markets.

Firms have a number of financial transactions available for handling their need for and use of funds. Firms can finance operations through debt in either market but can sell stock only in the Domestic Market. In addition, funds can be transferred between markets and surplus cash can be invested in securities in either market. The stock of each firm is sold only in the Domestic Stock Market.

3.1.2 Nature of Decision Making

The purpose of this section is to describe the nature and inherent difficulty of the decision making of the marketing function. This study focused on marketing decisions because they involve complex, non-structured decision making. Moreover, marketing decisions have counterparts in each market; therefore, they fulfill a necessary condition for the experimental design and, thus, have implications for validity.

These five marketing decisions in the Game are shown in Figure 3.3.

Domestic Market	Foreign Market
Domestic Price.....	.....Foreign Price
Domestic Promotion.....	.....Foreign Promotion
Research and Development	

Figure 3.3 Marketing Decisions in Game

Firms recognized the importance of these decisions and concentrated most of their time and effort on marketing throughout the game. The quality of these decisions is essential to the profitability of the firm. Profitability is directly related to sales which, in turn, is a function of price, promotion, research and development and inventory availability. Although inventory is not an explicit market decision, it is influenced by sales and, thus, must be considered as an integral part of marketing.

What, then, is the nature of the marketing decision making facing each firm? Stripped to its essentials, the task centered on finding a series of sequentially interdependent decisions for price, promotion, and R&D with respect to inventories that would

maximize the profitability of the firm over an appropriate decision horizon. All of that must be done under conditions of highly uncertain demand and without all of the necessary information or models.

The complexity of this task is directly related to the nature of the markets and stems mainly from its dynamic, non-linear and interactive characteristics. First, the markets are dynamic; that is, the effects of past decision strategies of all firms influence the present decision quarter. Second, the relationships among factors which create markets and determine sales are non-linear. Parametric curves are not simple linear functions but complex relationships. Third, firms in the market are completely interactive; the actions of all competitors influence each other.

The sequential interdependency of the decisions is directly related to the dynamics of the system. The set of feasible decisions for any quarter rest on the present decision state which is a reflection of all past decisions. The results of past decisions affect, guide and determine the feasibility of later decisions. Moreover, the evaluation of present decision alternatives should include consideration of the expected consequences in future quarters over an appropriate decision horizon. If this is not done, decisions which are optimal with respect to the present quarter may be sub-optimal over the longer decision horizon.

The evaluation of consequences is related to the degree of understanding or knowledge each firm has about the system. The effect of non-linearity either mask interactions or produce behavior which appears counter-intuitive. Firms have only partial understanding of the impact of the controllable and non-controllable variables on the structure and parameters of their decision environment. The influence of all the variables, the structure of the environment and the relationship represented by the parametric curves are difficult to deduce with certainty in either market.

The information available for later decisions was contingent upon the nature and consequences of previous decisions. Firms rarely know the present status of competition because some reported information was inaccurate. Therefore, their estimates of what competitors have done were somewhat vague. These compound effects make understanding the system even more difficult.

Predicting the outcome of an alternative set of decisions, and doing this for a number of periods is difficult, at best. Because of the interaction in the market, firms not only had to estimate their impact on the market but that of competitors as well. Estimates of each competitors' marketing decisions and the pattern of economic and seasonal variables for the upcoming quarter and predictions of their influence was necessary. This was especially important when market demand exceeded inventory available for sale in the quarter or, in the longer run, capacity in the industry. Particularly in these cases, poor estimation can lead to stockouts and substantial losses. Thus, interaction and the inability to predict its effects created difficulty in estimating demand and making marketing, production, and finance decisions.

The complexity of the task is increased by the number of factors which impacted the market each quarter. From the firm's point of view, the size of the total markets and their sales are influenced by the interaction of twenty-six variables, only three of which are directly controllable by each of the six firms. Price, promotion and R&D decisions are made by the firm each quarter and are, therefore, controllable decision variables. In addition, inventory is only partially controllable since sales last quarter and, thus, inventory available for sales this quarter are determined not only by the firm's decision but by the actions of competitors and the economic and seasonal indices. In short, the size, dynamics and interactions taxed the firm's ability to deal with marketing problems.

3.1.3 Participants

The purpose here is to supply pertinent statistics on the participants in the Game. The participants acted as research subjects and, therefore, represent a sample of the real world population to which results may be generalized.

The simulation was designed as an exercise in executive decision making for use in graduate and advanced management programs at MIT. One of these programs is the Senior Executive Program. This program is an intensive, total-learning experience for established top-level managers, which includes classes, seminars, and guest speakers.

All twenty-five Senior Executives in the 1972 Spring Session of the Senior Executives Program participated in the Game and, therefore, in the experiment.

Pertinent statistics for these Senior Executives are shown in Figure 3.4.

Educational Background

Doctors:	5
Masters:	4
Bachelors:	16

Professional Affiliations

Organizations represented:	25
Positions represented:	23

Ages within Group

Range 33-56
Average 43.7

Figure 3.4 Profile of Senior Executives

These statistics briefly summarize more extensive data given in Appendix E which suggests the breadth of Senior Executive's professional experience, educational backgrounds and management positions held at the time of the experiment. The profile which emerges is a mature group of professional managers characterized by extensive backgrounds, training and experience in a variety of positions in production and service organizations.

3.2 Interactive Decision Aids

This section describes each of the interactive decision aids. Three systems are available to all firms; a Marketing Decision System (MDS), a Financial Planning System(FPS), and a Statistical Analysis System (SAS). MDS directly supports the making of non-structured price, advertising, and R&D decisions for the Foreign Market. FPS helps firms make financial decisions concerning cash remittances. securities and loans for either market. SAS has capabilities for plotting, regression analysis and model building and maintains historical data bases for both markets. These systems are an integral part of the MIT Management Game.

The three systems have common characteristics. Each is interactive. All firms use the system directly from their hard-copy terminals. Each system monitors user input and prompts the user when help is needed. All systems have inbuilt tracing features which capture user interaction. Although different forms of interactive dialogues are used, all systems respond in terms familiar to the manager and thus provide capabilities which are useful for solving problems and making decisions in the Game.

To describe every detail would only obscure the essential nature of each system. The purpose here is to describe the capabilities and use of each system. MDS, the Decision Support System, is emphasized because it directly aids marketing decisions and its availability in the Foreign Market created the experimental condition while its absence in the Domestic Market created the control condition for the research design. Since everything else is the same for both conditions, differences between DSS-aided and non-aided decision making should be attributable to the Marketing Decision System.

3.2.1 Marketing Decision System

The Marketing Decision System (MDS) supports decision making in the Foreign Market. The system helps firms make marketing decisions by providing estimates of how different combinations of price, advertising, R&D, and inventory influence the size of the market and sales for each firm. The system also aids firms in estimating how different economic and competitive conditions effect the market. In short, the system assists firms in evaluating the consequences of alternative marketing strategies, either their own or their competitors' strategies.

The capabilities listed above, however, fails to capture how the system is used to aid marketing decisions. Further elaboration is needed; descriptions of the (1) options, (2) conceptual operation, (3) inputs and outputs, and (4) system's commands are provided below. An example of actual use illustrates the capabilities of this system and shows how firms use the system.

Options

The Marketing Decision System has two options. the Modeler (M) option and the Future (F) option. The Modeler option provides sales and market estimates for the next quarter only. The Future option provides the same estimates for each sequential quarter for any number of periods in the future. Both options fully recognizes the dynamic nature of the markets by accounting for effects of past decisions and present market status. The future option may be pictured as a number of sequentially inter-dependent modeler runs.

Operation

Conceptually, the system's operation is quite simple. The system accepts twenty-six values for input, runs a model of the market, and produces estimates of the size of the market and sales for each firm. The heart of the system is a model which is a structurally perfect representation of the Foreign Market.

That is, each variable and relationship is identical to its counterpart in the real market. The structure of the market discussed in section 3.1.1 gives the details of this model. The quality of the estimates produced by the system, however, is highly dependent upon the input values supplied by the user.

Input

The user must supply the input shown in Figure 3.5 for every quarter simulated by the system.

Name of Variables	Number of Required Values	Values supplied by user are estimates of:
GNP	1	Gross National Product
SEAS	1	Seasonal influence
PRICE	6	Each firm's price
ADV	6	Each firm's advertising expenditures
R&D	6	Each firm's R&D expenditures
INV	6	Each firm's inventory levels
SHIP	6	(optional) each firm's additions to inventory

Figure 3.5 Required Inputs for MDS

The number of required values for each variable is shown above. Only GNP and SEAS require one value each while PRICE, ADV., R&D, and INV. require six values for each variable, one for each of the firms in the market. Each of the twenty-six values must be known to the system before the model is run and output is generated.

Output

The system's output consists of estimates on the size of the total market, firm sales and market share. Two types of output are provided: a summary report and a complete report.

The summary report is shown in Figure 3.6

```
QTR 15 FROM 15  MARKET 2
TOTAL  = 1291088.  OUR SALES   = 175109.  SHARE = 13.55
```

Figure 3.6 MDS Summary Report

This report is automatically printed on the user's console after the user requests a run using the CALC command. The quarter being simulated and the beginning quarter (in case the Forward option is being used) are both identified in the first line. The second line gives the estimates for the size of the total market, the firm's sales, and the firm's market share.

The complete report is shown in Figure 3.7

```
QTR 15 BEGAN AT 15
MARKET 2.   GNP 206.00.  TOTAL UNITS 1326269.
```

FIRM	UNITS	PRICE	LOST SALES	% THIS
1	207873.	8.75	1800.	15.7
2	257621.	8.10	20000.	19.5
3	258856.	8.50	1500.	19.4
4	173970.	9.00	8700.	13.1
5	226308.	8.75	0.	17.1
6	201641	9.25	90000.	15.2

Figure 3.7 MDS Complete Report

This report provides supplementary information for the firm. In addition to the information supplied in the summary report, it gives estimates of each competitor's sales, lost sales and market share. The values for GNP and Price are copies of the input values supplied by the user. The form of this report is familiar to the decision maker because it is similar to the Market Summary Report shown in Appendix B.

Commands

The system is command driven; that is, operations are controlled directly by the user. No question and answer dialogue is involved unless the user fails to supply necessary values or makes a request that the system does not understand. These command names and functions are shown in Figure 3.8.

MARKETING DECISION SYSTEM

COMMANDS

COMMAND NAME	ACTUAL COMMAND	FUNCTION
BEGIN	BEGIN n	Simulation begins at period n
INPUT COMMANDS		
GNP	GNP	Type to input GNP value
SEAS	SEAS	Type to input SEAS value
PRICE	PRICE	Type to input PRICE values
ADVERTISING	ADV	Type to input ADV values
RESEARCH & DEVELOPMENT	R&D	Type to R&D values
INVENTORY	INV	Type to input INV values
SHIPMENTS	SHIP	Type to input SHIP values
OUTPUT COMMANDS		
CALCULATE	CALC	Type to begin simulation
SUMMARY REPORT	SUM	Prints summary report
REPORT	REPORT	Prints full report
LIST	L	Lists all input values
ADDITIONAL COMMANDS		
HELP	HELP	Prints console aid messages
START	S n	Moves pointer with line
PRINT	P n	Prints values for variable n
CHANGE	C n v	Changes parameter n to v
END	END	Ends input line
QUIT	Q	Ends use of MDS

Figure 3.8 : Marketing Decision Systems Commands.

Input Command specify the type of values which follow the command. For example,to supply prices for each firm the user types

Price x.xx x.xx x.xx x.xx x.xx x.xx end

Output Commands are used to get results on the console while other Commands facilitate input. Use of each Command should be obvious from the example to follow.

An Example of Use

An example of actual use is shown here. It is a selected reproduction of parts of firm 1's trace. The actual trace contained 28 runs. This sample illustrates MDS use; comments are provided to explain what the user was doing. All upper case lines are system responses while lower case lines represent the decision maker.

```
LOGIN
firm 1                                          *User logs in, selects
                                                 MDS and the MODELER
PASSWORD                                         option.
Little

MDS, FPS, SAS OR LOGOUT?
mds

MODELER OR FUTURE OPTION?
m

REQUEST?
1

QUARTER 15 BEGINNINGQUARTER 15                   *User lists the input
GNP 206.00 SEAS HIGH                             set (saved from
FIRM PRICE     ADV          R&D          INV     previous runs earlier
  1  8.75    30000.       300000.     10000000.  in day by the system)
  2  8.10    30000.       300000.     10000000.
  3  8.50    25000.       250000.     10000000.
  4  9.00    30000.       200000.     10000000.
  5  8.75    50000.       300000.     10000000.
  6  9.25    25000.       225000.     10000000.

REQUEST?

calc
QTR 15 FROM 15 MARKET 2
TOTAL =  1326269.   OUR SALES  = 207873.  SHARE = 15.67

REQUEST?                                        *User request run and
                                                 summary report and
report                                           then a complete report
QTR 15 BEGAN AT 15
MARKET 2,  GNP 206.00  TOTAL UNITS  1326269.
```

```
QTR 15 BEGAN AT 15 TOTAL UNITS 1326269.
FIRM        UNITS     PRICE     LOST SALES       % THIS
  1          207873   8.75         0.             15.7
  2          258856   8.10         0.             19.5
  3          257621   8.50         0.             19.4
  4          173970   9.00         0.             13.1
  5          226308   8.75         0.             17.1
  6          201641   9.25         0.             15.2

REQUEST?

PRICE 9.50  end                          *User tests range of prices
                                          in the following sequence
REQUEST?
calc
QTR 15 FROM 15  MARKET 2
TOTAL =  1292088.   OUR SALES = 175109.  SHARE = 13.55

REQUEST?
begin 15
REQUEST?
price 9.25 end
REQUEST?
calc
QTR 15 From 15  Market 2
TOTAL = 1269604.   OUR SALES = 182324.   SHARE = 14.36

begin 15

REQUEST?

price 9.00 end

REQUEST?

calc
QTR 15 FROM 15  MARKET 2
TOTAL  =  1274800.  OUR SALES = 190398.  SHARE = 14.94
```

●
●
●

*The abbreviated sequence above illustrate how MDS was used to aid in the pricing decision. The trace showed 9 prices were tested in this sequence. The user then turns his attention to the advertising decision.

●
●

```
REQUEST?

Begin 15                                    *User sets price to the
                                             original 8.75 and tests
REQUEST?                                     values for advertising.
                                             Price was then incremented
price 8.75                                   and various advertising
                                             levels retested.
REQUEST?
adv 60000

REQUEST?
calc
QTR 15 FROM 15  MARKET 2
TOTAL =  1348265.  OUR SALES = 222801.    SHARE = 16.53

REQUEST?
begin 15

REQUEST?
adv 30000 end

REQUEST?
calc
QTR 15 FROM 15  MARKET 2
TOTAL = 1329892.  OUR SALES = 209993.  SHARE = 15.79
```

●
●
●

*This illustrates how price/inventory combinations were tested. The user tested 6 combinations in the sequence from which the sample was taken. The user now turns his attention to R&D.

●
●

```
REQUEST?
begin 15
                                            *User resets price to
REQUEST?                                     original level and
price 8.75                                   begins to test price/
                                             R&D combinations. Price
begin 15                                     is then incremented and
REQUEST?                                     other levels of R&D tested.
r&d 275000. end

REQUEST?
calc
QTR 15 FROM 15  MARKET 2
TOTAL  = 1277660.   OUR SALES =  198236.  SHARE = 15.52
```

```
begin 15
REQUEST?
r&d 325000 end

REQUEST?
calc
QTR 15 FROM 15  MARKET 2
TOTAL = 1286043.  OUR SALES = 202848.  SHARE = 15.77

REQUEST
```

*At this point, the user had completed his sensitivity studies. Having decided tentatively what his decision might be, he now begins to confirm his final determination.

```
 REQUEST?
GNP206.00  SEAS  high

REQUEST?
price 9.15  8.10  8.50  9.00  8.75  9.25 end

REQUEST?
r&d 300000  250000  225000  250000  300000  225000 end

REQUEST?
adv  45000  60000  30000  30000 50000  25000 end

REQUEST?
inv  195000  250000  250000  175000  200000  175000 end

REQUEST?
1
QUARTER 15  BEGINNING QUARTER 15
GNP 206-00  SEAS HIGH
FIRM   PRICE        ADV.         R&D        INV
  1     9.15       45000.      300000.    195000.
  2     8.10       60000.      250000.    250000.
  3     8.50       30000.      225000.    250000.
  4     9.00       30000.      250000.    175000.
  5     8.75       50000.      300000.    200000.
  6     9.25       25000.      225000.    175000.
```

```
REQUEST?
begin 15
REQUEST?
calc
QTR 15 FROM 15 MARKET 2
TOTAL =  1245000.   OUR SALES   = 195000.  SHARE =1566

QTR 15 BEGAN AT 15

MARKET 2,  GNP 206.00  TOTAL UNITS 1245000.

FIRM      UNITS     PRICE   LOST SALES    % THIS
  1      195000.    9.15       1806.       15.7
  2      250000.    8.10      17922.       20.1
  3      250000.    8.50      11445.       20.1
  4      175000.    9.00       5116.       14.1
  5      200000.    8.75      28236.       16.1
  6      175000.    9.25      29364.       14.1

begin 15
REQUEST?
price 9.25 end
REQUEST?
Inv 195000  250000  250000  175000  200000  175000 end
REQUEST? calc
calc report
QTR 15 FROM 15  MARKET 2
TOTAL  =  1245000.  OUR SALES = 195000.  SHARE = 15.66
QTR 15 BEGAN AT 15
MARKET 2, GNP 206.00  TOTAL UNITS 1245000.

FIRM   UNITS      PRICE      LOST SALES     % THIS
  1   195000.     9.25              0.      15.7
  2   250000.     8.10          17779.      20.1
  3   250000.     8.50          11345.      20.1
  4   175000.     9.00           5033.      14.1
  5   200000.     8.75          28124.      16.1
  6   175000.     9.25          29289.      14.1
```

●

*At this point, the user began to use the Future option to evaluate the future effect of his present decision. Since the trace is similar, these runs are not shown.

●

●

3.2.2 Financial Planning System

The Financial Planning System (FPS) produces pro-forma financial and operating statements given estimated sales in the Foreign and Domestic Markets and the decisions of the firms. The system is based on a perfect model of the firm. The simulation accurately predicts a firm's status for an upcoming quarter for any set of decisions and expected sales levels. The system supports financial decision making in both markets by determining profit, cash and operating positions for the firm. It helps firms determine the proper cash, securities and loan balances for the next quarter of operation. To make these decisions several analyses can be run simultaneously to compare resulting differences.

The Financial Planning Systems has two options; the Planner (P) option and the Forward (F) option. The Planner option allows firms to simulate one period in the future. The Forward option allows firms to simulate operations for any number of sequential periods in the future. The interactive dialogue for both options is similar.

Several Planner and Forward runs can be initiated at one time by the firms simply by supplying the required input which consists of eighteen values:

(1) an estimate of domestic sales
(2) an estimate of foreign sales
(3-18) sixteen decisions of the firm

This input may be entered in either of two modes. In the request mode, the system prompts the user for each line of input. In the accept mode, the user enters all required data without interruption from the system. In either mode, however, the system monitors input and automatically requests missing information. Additional commands are available for printing input data on the console and for changing values prior to running the simulation.

Once input is complete, the system determines financial and operating status for the firm in a form identical to the reports normally received as a result of actual operations. These ten reports include foreign and domestic:

(1) Balance Sheets
(2) Income Statements
(3) Sources and Uses of Funds
(4) Reconciliations of Retained Earnings
(5) Reconciliations of Inventory

A copy of the actual reports is shown in Appendix C and D.

Output is requested by the user by specifying line items or special reports to be printed on the consoles. Since the complete reports listed above for either market require four pages of output, special commands allow firms to select specific line items from any report and have them printed on their console. To print special reports requires entering only the report number shown below. Five special reports were produced by the system. These consisted of selected combinations of line items of particular interest to firms. These reports are:

Report Number	Contents
1	A statement of net income after tax, net change in cash position, goods available for sale for both markets.
2	A manufacturing analysis of the overhead, overtime, labor, hiring and firing and reshipment expenses.
3	An abbreviated profit and loss statement for the Domestic Market.
4	An abbreviated profit and loss statement for the Foreign Market.
5	A statement of cash, securities, and loan positions for both markets.

To summarize, this system aids all firms in making financial decisions. It helps firms to determine the financial and operating consequences of different sets of decisions and sales forecasts and, thus, has the potential for improving the utilization of financial resources.

3.2.3 Statistical Analysis System

The Statistical Analysis System (SAS) assists decision makers in performing regression analyses and building models. The system's capabilities are all intimately related to the data bases maintained by the system. The data base contains information on both markets. These bases are automatically updated by the system as the Game is run. In addition, firms can specify their own data elements and transformations to the system.

The system capabilities include plotting, regression analysis and model building. Plotting routines allow the user to print scattergrams and time series plots on the console. The multiple linear regression package supplies complete statistics for the regression equation. Statistics included means and deviations for all variables, pairwise correlations, analysis of variance and significance tests. The model building capabilities allow users to define their own expressions and transformations based on any data elements. User supplied transformations become part of the system maintained data bases and are available for modification or regression analysis.

The system prompts users through a series of questions while monitoring all responses and data input. This interactive dialogue allows the user to specify exactly what he wants done. The system automatically performs the necessary calculations and prints the requested output on the console. In short, the system's output is useful for making marketing decisions. It helps firms develop models for predicting the size of the market and their market share. These models have the potential for aiding decision making, especially in the Domestic Market since no other formal support is provided for this market.

3.3 Implications for External Validity

This section discusses the implications for external validity which relate to the nature of the simulator, the decision aids and the participants in the Game.

External validity centers on the degree of confidence that laboratory results match what would occur in the world at large. The ability to generalize from one to the other is a question that can never be answered with certainty. Further proof is required in the laboratory and, more importantly, in the field. Campbell and Stanley (20) underscore the necessity of repeating experimentation in order to establish confidence.

Hopefully, the knowledge gained in the laboratory is a good indication of what will be found in the real world. The quality of experimental results rest on the foundation of high internal and procedural validity. If high internal and procedural validity are present in the research design, external validity is mainly dependent upon the degree of representativeness of the laboratory counterparts of the environment, conditions and population to which results may generalize. These correspond to preceding parts of this chapter in the following manner.

(1) Environment - Nature of Game Environment
(2) Conditions - Nature of Decision Task and Aids
(3) Population - Participants in Game

This framework will be used to structure the evaluation of external validity for this research.

3.3.1 Issues Related to Environment

The environment used in this study was not the real world; "reality" was simulated by the MIT Management Game. Even though the environment was simulated, the potential of games for experiments having high external validity has long been recognized. Shubik (99) notes that computer-based management games have greater potential to represent the complexity found in the real world than

do the more traditional experimental situations. Chapanis (23) asserts that games contrast sharply with the sterile, controlled environments which characterize most decision making research.

The central issue in the use of simulation as a research vehicle is whether the degree of realism and complexity in the simulated environment is representative of the real world. Raser (87) asserts that the concepts of realism and complexity are more appropriate for judging the validity of a game for research purposes than the traditional criteria of isomorphism of the model and reality. Shure, Rodgers and Meeker (101) rightly caution against the temptation to judge validity solely on the basis of isomorphism to the reference system.

Realism and complexity can be evaluated from different perspectives, for example, from actual similarity to a referent or perceived similarity to a situation. Actual similarity is usually measured by isomorphism of the simulation to the real world. Of greater relevance to the present study, however, is the perceived similarity of environment. Hedburg (53) maintains that the perceived semblance between the simulation and its counterpart are more crucial than the actual similarity because the research subjects responses will automatically be more natural.

The environment should be sufficiently realistic so that decision processes normally used in the real world would be only minimally distorted. Moreover, the environment should be complex enough to provide problems that challenge the capability of the decision maker. Goffman (46) suggests that involvement is not a function of objective reality but rather the psychological reality of the situation. The crux of the situation is whether or not the simulated environment creates the psychological equivalent of reality for the decision makers.

The realism of the environments in the MIT Game was suggested by description of the Foreign and Domestic Markets. These markets are dynamic, non-linear and interactive. Each was influenced by many (26) variables, most of which were non-controllable from the firm's point of view. The inherent complexity of the problems facing each firm were determined by the nature of the markets. For example, to "understand" the nature of the markets or to estimate the status of competition was difficult. Each firm influenced both markets, but the character of each was shaped by the interaction of all competitors and the economic variables. These characteristics are found, as Forrester (42) contends, in real world situations faced by practicing managers.

The degree of realism and complexity perceived by the participants can be evaluated by their response to the questionnaire and comments during the interview. Figure 3.9 show perceived realism.

(Questionnaire, item)
How realistic was the marketing environment in the game?

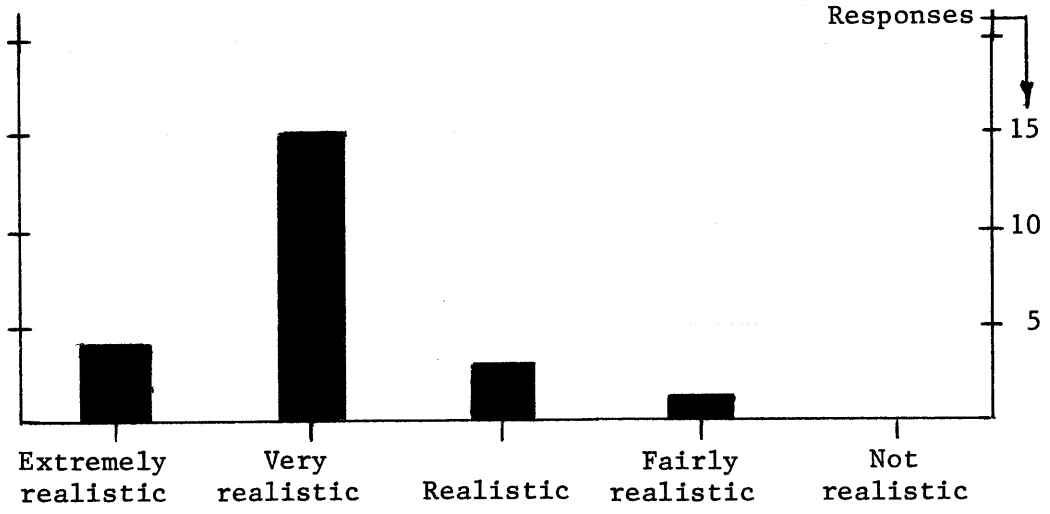


Figure 3.9 Perceived Realism of Environment

If no decision aids were provided, how complex were the marketing problems in the game?

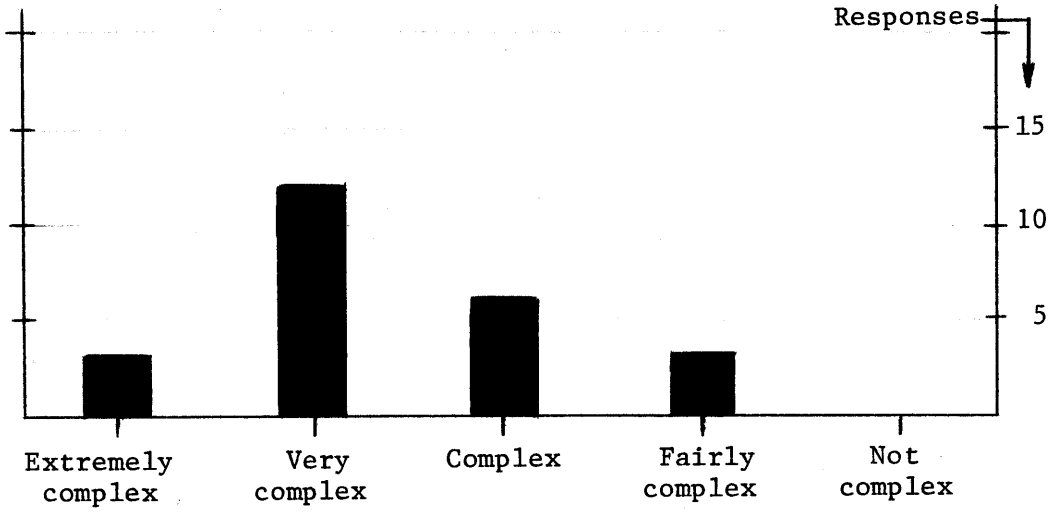


Figure 3.10 Perceived complexity of marketing problems.

The interview permitted more open-ended responses and served as a check on the questionnaire items. A range of responses is reported.

(Interview, items)

Do you (team members) feel that the Foreign and Domestic Markets were realistic?

"Yes, it was damn realistic - it certainly kept me intrigued"
"Maybe its a game but I thought it was quite realistic"
"I'm sure we didn't understand how the markets work and that is realistic in my business"
"Well, maybe, but it's certainly not the real world - Fairly realistic I'll say"

How complex were the problems you faced in each market?

"Too complex"
"Ha, those markets were bears"
"I felt comfortable - maybe lost is a better word"
"Those damn markets were tough - complex enough in my book"
"They're no where near as complex as the real world'

Viewed as a whole, the responses to the questionnaire and the interview indicate that the environment and the associated decision problems were perceived as both fairly realistic and complex. The ongoing decision environment was, in large measure, the psychological equivalent of reality for the participants. Participant responses should be representative in this environment.

3.3.2 Issues Related to Conditions

Related to the realism and complexity of the environment is the representativeness of conditions created in the study. The generalizability of conditions depend upon the similarity of circumstances between the laboratory and its real world counterparts. The critical question is: to what specific situations can results be transferred? Among the relevant considerations here are the (1) representativeness of the task and decision making behavior and (2) the quality of information and (3) decision aids. In other words, is each of these similar to what might be found in real world situations.

Decision Task and Processes

Briefly, the decision task involved making a set of sequentially interdependent decisions to meet certain profit objectives under conditions of limited information and decision support in a dynamically uncertain environment. Forrester (42), Moskowitz (74), and Conrath (27) have noted that these characteristics are found in many actual decision making situations. Powers has remarked:

> "The task of a decision maker in "real-world" systems is that of making a number of decisions sequentially in time, where the outcomes and payoffs of earlier decisions affect, guide, and serve as inputs to the making of later decisions. The objective is usually the maximization of total profit over the interdependent sequence of decisions."

Trull (112) claims that the difficulty of handling these tasks stems from the lack of a measure or index of effectiveness, coupled with a surfeit of alternatives and an absence of reliable probabilities associated with decision variables. At the very least, decision tasks in the game are inherently difficult and may resemble those encountered by the professional manager. Certainly, task complexity far exceeds what is found in traditional laboratory studies.

Coping with the decision task shapes the decision processes. The decision making studied here involved consideration of a large number of alternatives involving many controllable and non-controllable variables whose identification and evaluation was difficult, at best, given the uncertainty in the environment, and the multiple, conflicting goals and lack of adequate formal methods or measures of effectiveness. These features are similar to (108) Soelburg's characterization of non-structured decision making.

This type of decision making has been labelled non-programmed by Simon (104). Scott Morton (93) notes the nature of non-structured problems as:

> "the problems were ill-structured, hard to find, and once found, hard to define in operationally useful terms."

In much the same terms, Mason and Mitroff (65) characterized these problems as "wicked" and expressed the conviction shared by many Management Scientists (1) (33) that: "real management problems appear overwhelmingly wicked or ill-behaved." Ebert (35) suggests that decision making similar to the marketing decisions in this game may be characteristic of a much broader group of decision problems classified as dynamic decision problems under conditions of uncertainty.

Quality of Information

The quantity and quality of information on which decision making was based are important considerations in determining the representativeness of conditions. Several responses during the interview testified to the fact that the quantity of information (over 250 information items each quarter) tended to overload managers in some cases. However, the problem was not of particular importance; the information was available, but its use was left to the discretion of the decision maker.

Of more importance was the quality of the marketing information provided in the "Market Summary" report shown in Appendix B which

firms received every quarter. This report was designed to simulate the quality of marketing information that might be found in the real world. Therefore, information pertaining to projections of GNP, sizes of total markets, actual and lost sales, promotion, research and development expenditures were reported with varying degrees of "noise" in much the same way that industry statistics would be. The quantity and quality of reported information were identical for each market.

Certain information which the participants believed would have been helpful was not available. For example, only total sales were reported. Firms had no way of knowing their relative number of repeat and shopper customers. Information was lacking on seasonal influences and exact breakdowns of inventories were unknown. Since the companies were considered publicly held, the "Market Summary" contained accurate information of financial status for all companies but only minimal information was available concerning operations.

The quantity and quality of information were considered similar to what participants normally received on the job as evidenced by responses in the interview:

"I felt comfortable with it - the information. It would have been a lot easier without the noise but that's pretty realistic"

"Same kind of information I get at work although those last sales reports were really off"

"we should have known how many different types of customers (repeats and shoppers) we got each quarter"

"I would have liked more information - accurate information- hell - sometimes we were only guessing - we never really knew what competition was doing"

"Too damn much - I bet we only looked at 5% of all that stuff - those "market summary" reports, that's where the market information is - the firm reports...well, I really wasn't that concerned with them"

Interactive Decision Aids

The support provided by the interactive decision aids relates to the representativeness of the situation. Surveys (17), (14), (44) indicate that interactive support of this kind is not prevalent in the real world at present, but may become more available in the future. In this sense, the decision aids created an atypical situation. The point to note is that interactive programs may represent what might be commonplace in the future. The remainder of the discussion should be considered from this perspective.

The Financial Planning System (FPS) produced pro forma financial and operating statements based on anticipated Foreign and Domestic sales and the decisions of the firm. Since the necessary calculations were known to the participants, anyone could have produced the same results, although much more time and effort would have been required. Even though the aid provided by FPS was not unusual, the participants valued it highly. Some participants indicated that similar aids were available in their companies or that the service was provided by the accounting function.

The Statistical Analysis System (SAS) allowed the decision maker to access, print and graph data, perform regression analyses and build models. It is doubtful whether regression analyses could have been carried out by most of the participants without the aid of a system. Many participants indicated, however, that their companies had similar capabilities available. Senior Executives, on the whole, did not use these services themselves but instead relied on the staff if this type of analyses was needed.

The Marketing Decision System (MDS) was a true Decision Support System. It allowed the decision maker to interact directly with a simulation model of the Foreign Market. Certainly, the interactive interface, access to data and computational support is representative of the better Decision Support System while the quality of

the model may be superior to models in the real world. In this sense, MDS was atypical. The quality of output, however, depended upon use. The system could produce deceiving results if input estimates supplied by the decision maker were not of high quality. Responses to the questionnaire indicate the decision makers' perceptions of the quality and usefulness of MDS and are shown in Figure 3.11 and 3.12.

(Questionnaire, items)

Estimate the quality of MDS as a model of the Foreign Market.

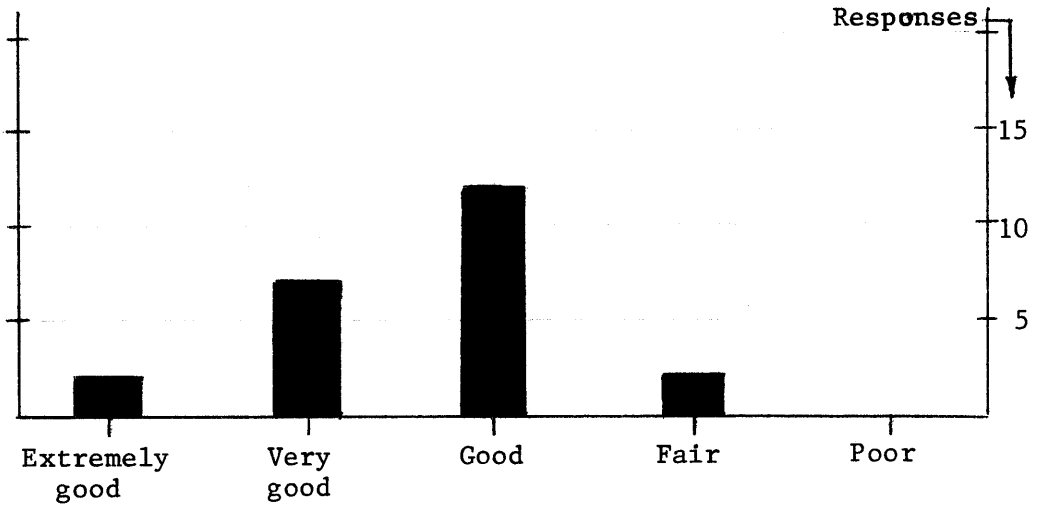


Figure 3.11 Perceived quality of MDS

Estimate the usefulness of MDS for the Foreign Market.

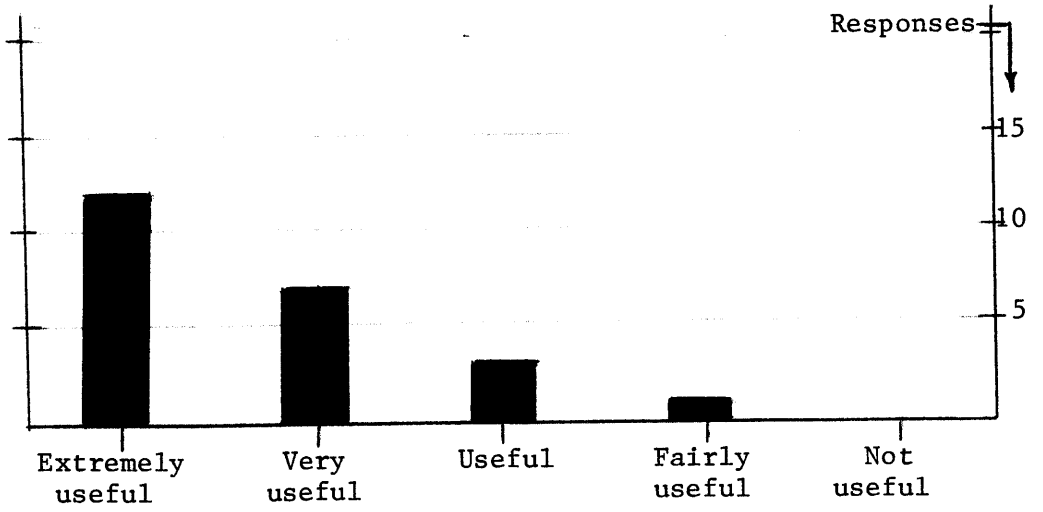


Figure 3.12 Perceived usefulness of MDS

It is interesting to note that the usefulness of the system was rated higher than the quality of the model. In the interview, firms clarified their response to these questionnaire items. A sample of the answers is given below.

> "It certainly was useful for us - the model could be improved, it requires too many variables for a run"
> "The system?, it was useful - highly useful- the model- not so good, it didn't predict exactly, never did"
> "MDS was really useful - so I guess its a good model"
> "I thought it was a good system but you had to use it right"
> "Why the hell didn'twe have an MDS for the Domestic Market"
> "There is no question that the system was very useful - it saved us in the Foreign Market - I would like to have the same thing back home...the quality of the model was O.K., I think, but its hard to be sure"

No participant had a similar system available on the job, nor did many know of any similar systems. The majority, however, were interested in the possibility for developing such systems.

The results of this study may be generalizable to those conditions in which the manager is confronted with decision tasks and processes of similar or lower complexity than those discussed here. The quality and quantity of information may be a facsimile of existing conditions in the real world, while the nature of the decision support may be more representative of the future.

3.3.3 Issues Related to Participants

Two critical issues influence external validity with respect to Participants : first, the degree of representativeness of the participants to the larger universe and, second, their motivation in the game.

The participants in the present game-experiment were all Senior Executives at the Sloan School of Management at MIT. The extent to which these managers are representative of a larger population of higher-level executives relates to the generalizability of this research. Certainly, there are few reasons to believe that they are non-representative in this respect. To the contrary, this group of Senior Executives is more representative of managers in the real world than are some of the groups used in previous studies of decision making. Dill's (34) classic remark is appropriate:

> "what college sophomores do, alas, may not be much more relevant than the behavior of monkeys for predicting how executives, nurses and research scientists will perform."

The profile of the group- its diversity - suggests other implications. In many studies reported in the literature, experimental subjects have had similar educational backgrounds, job positions or experience. For example, Gerrity (45) focused on portfolio managers. Hedburg studied twenty year old graduate students and thirty year old bank executives. Ebert (35) and others (58) (75) (116) used undergraduate students as experimental subjects. The Senior Executives participating in this study, however, represent diversity along a number of dimensions as suggested in Appendix E . The implication is that results may not be limited to groups with specific characteristics but, in fact, may be applicable to a wider context.

The ideal group of subjects are those selected from the population to which the researcher would like to generalize. The target population of interest is the group of higher-level executive

who make key decisions in the real world. This study was extremely fortunate to have had the cooperation of Senior Executives as research subjects; to some extent, they may be representative of the universe of professional managers who may use Decision Support Systems in the future. Limitations should be noted, however. This group of managers may be atypical in the sense that they received seven weeks of extensive training prior to the experiment and that this select group was able to attend the course at MIT.

The issue of participant's motivation has important implications for representativeness of the behavior exhibited by the decision makers. Raser (87) suggests that motivation is related to realism in that natural rather than staged responses are necessarily desirable and that the degree of challenge should intrigue the participants. Certainly, game involvement is not necessarily as intense as real life involvement, nevertheless, it is equally foolish to ignore the evidence that games are usually more involving than frequently assumed and that a great many "real life" situations are not particularly engaging. Anyone who has conducted complex games can testify to the intense involvement of most players.

The involvement of this group of Senior Executives in the game was interesting. The game culminated their nine week program. Extremely conscientious, this class was characterized by one administrator as "one of the best Senior Executives group ever". The experiment provided the opportunity to test new-found skills. From all outward appearances, the group was naturally competitive and the game offered an environment for matching wits with classmates. Scheduled events were not missed by either Senior Executives or the Game Administrator; the game ran smoothly and this tended to keep interest high. In the interview, participants reported that they viewed the game as a learning process and relished the exposure to computer-based decision support.

Statistics of attendance may be indicative of the motivation of participants and, therefore, involvement in the experiment. Since the Game lasted over a period of three weeks, several related measures are shown below to indicate the degree of involvement of the experiment.

Attendance at console sessions is shown in Figure 3.13.

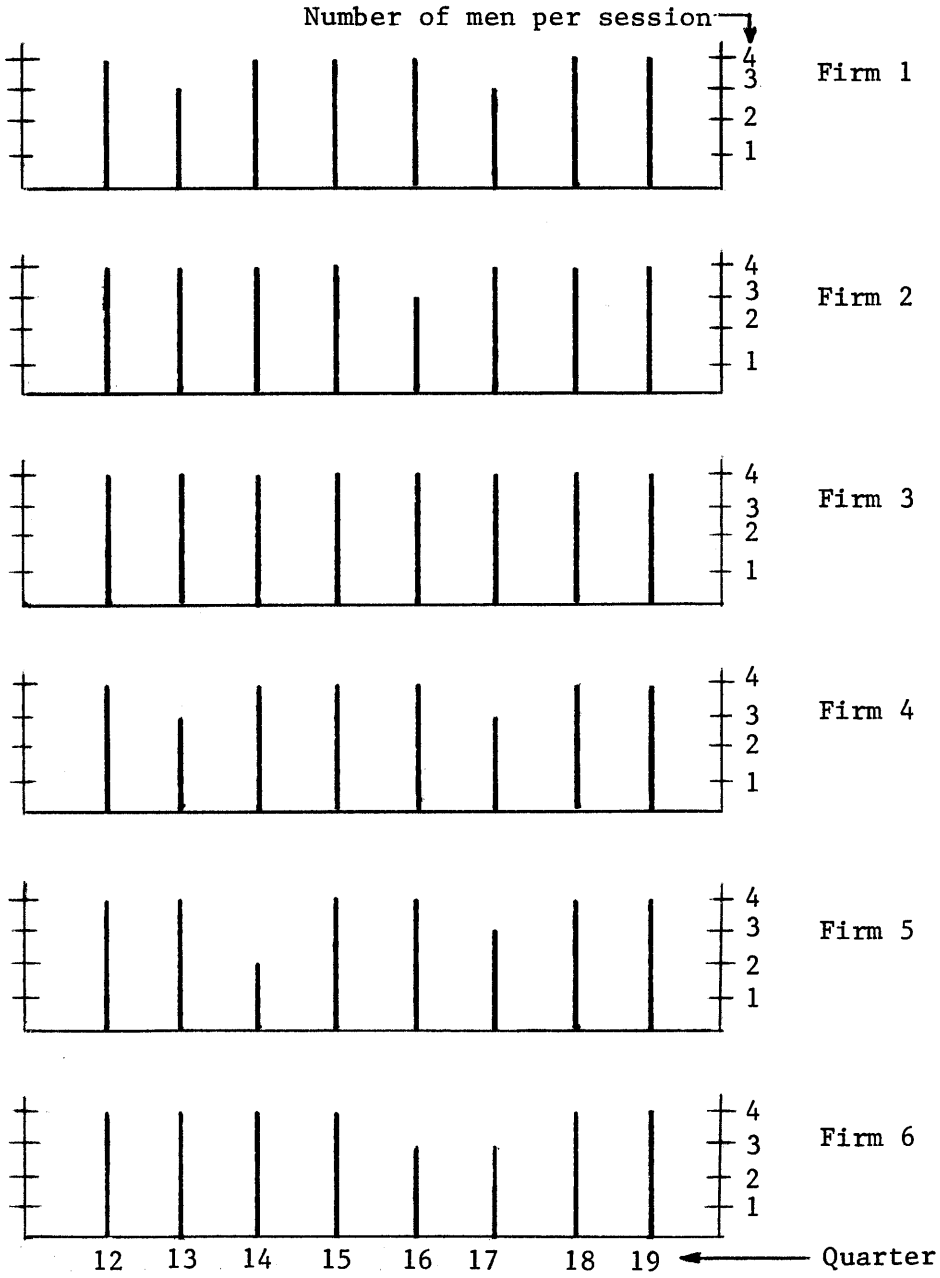
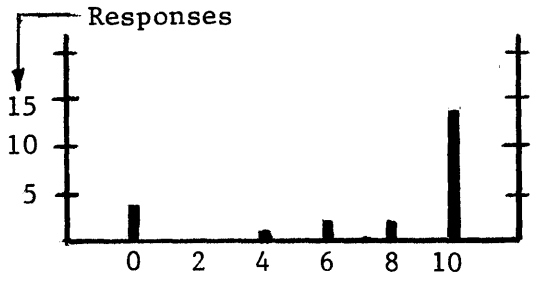


Figure 3.13 Statistics of Attendance

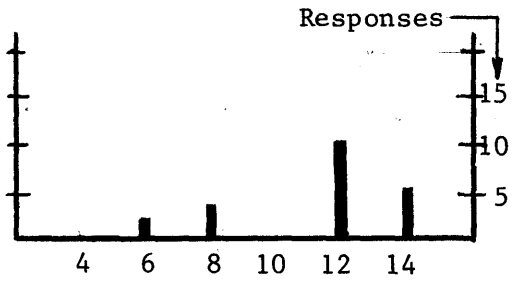
Furthermore, Senior Executives indicated high involvement by the number of hours spent on the game in addition to console sessions. Figures 3.14 to 3.17 gives the time distributions.

Questionnaire, items)
Please estimate as accurately as possible the number of hours in addition to scheduled console sessions which you spent in game related activity.



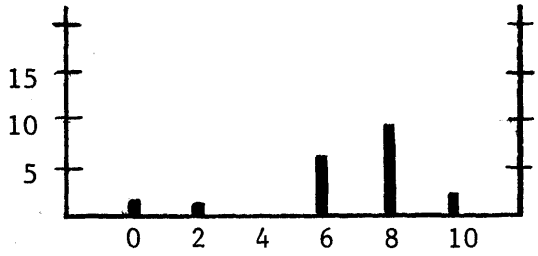
Pregame weekend hours

Figure 3.14



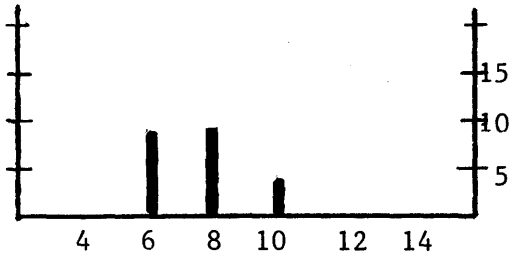
First game-week hours

Figure 3.15



Intragame weekend hours

Figure 3.16



Second game-week hours

Figure 3.17

Figures 3.14 to 3.17: Additional hours devoted to Game excluding 24 hours of console sessions

This data suggest that Senior Executive voluntarily spent considerable time on game-related activity, both in the scheduled console sessions and during their free time. This implies that they were naturally motivated to participate in the experiment.

3.4 Chapter Summary

This chapter documents the design of the Game and the interactive decision aids and explores implications for external validity. The structure of the Game creates a realistic decision environment which is similar to real-world situations. The nature of the non-structured decision making simulates the complexity of actual managerial decision making. The complexity of the decision making environment in the Game far exceeds what is found in traditional laboratory studies.

The use of Senior Executives as research subjects is in sharp contrast to the usual subjects for experimental research. All of these factors contribute to the high generalizability of this research.

The nature and use of the interactive decision aids, MDS, FPS, and SAS is shown by console trace. The trace illustrates how firms used the system in making the non-structured marketing decisions.

Issues related to external validity are resolved using questionnaire data. The data suggest that the environment and associated decision making was perceived as highly realistic, task complexity was formidable, and that the quality of information was a facsimile of actual conditions. Consequently, the results of this study are generalizable to similar conditions in the real world.

CHAPTER 4

DESIGN AND CONDUCT OF THE EXPERIMENT

The design and conduct of an experiment determines the internal validity of a study. Better experimental design controls factors which jeopardize validity. What can threaten validity is the possibility that other variables are responsible for observed results. The design used here and the way in which the experiment was conducted control factors that have potential for influencing results. Consequently, the study has high internal validity.

This chapter provides detailed description of the design and conduct of the experiment and evaluates its inherent validity. The organization and contents of the chapter are shown in Figure 4.1.

Figure 4.1 Contents of Chapter

The design of an experiment should be distinguished from the conduct of that experiment. Design translates goals into an experimental plan. Conducting the experiment involves implementing this plan. Recognizing this, the first section lists the goals that guided the design and describes every aspect of the experimental design. The second section describes the way the experiment was conducted and data collection procedures. The third section discusses major issues related to the design and conduct of the experiment in order to evaluate the validity of the design.

4.1 Design of the Experiment

This section describes the design of the experiment - its structure and related design considerations. The experimental design presented here may be more complex than the more traditional designs in the literature (e. g. Chapanis(23), Kerlinger (59), Campbell and Stanley (20)). The design is easier to understand if some of the original goals are kept in mind. These goals are reviewed here; they served as guides for the design of this experiment.

(1) Comparative study of aided and non-aided decision making
(2) Adequate experimental control of all variables
(3) Simultaneous exposure to experimental conditions
(4) Parallel observations
(5) Unobtrusive data collection
(6) Replication of the experiment
(7) Reliable measurement procedures
(8) Realistic and complex experimental environment
(9) High generalizability
(10) Range of non-structured decision making

All of these goals increase validity and are related to the design and conduct of the experiment.

4.1.1 Structure of the Experimental Design

Experimental designs are the specified arrangement of conditions that produce data and are characterized by:

(1) Nature of the experimental environment
(2) Nature of the experimental conditions or treatments
(3) Assignment of subjects to experimental and control groups
(4) Character of the observations

Taken together, these features determine the structure of any design.

The structure of the experimental design used in this study is shown in Figure 4.2. Certain conventions make the diagram easier to understand. The vertical dimension indicates temporal order while

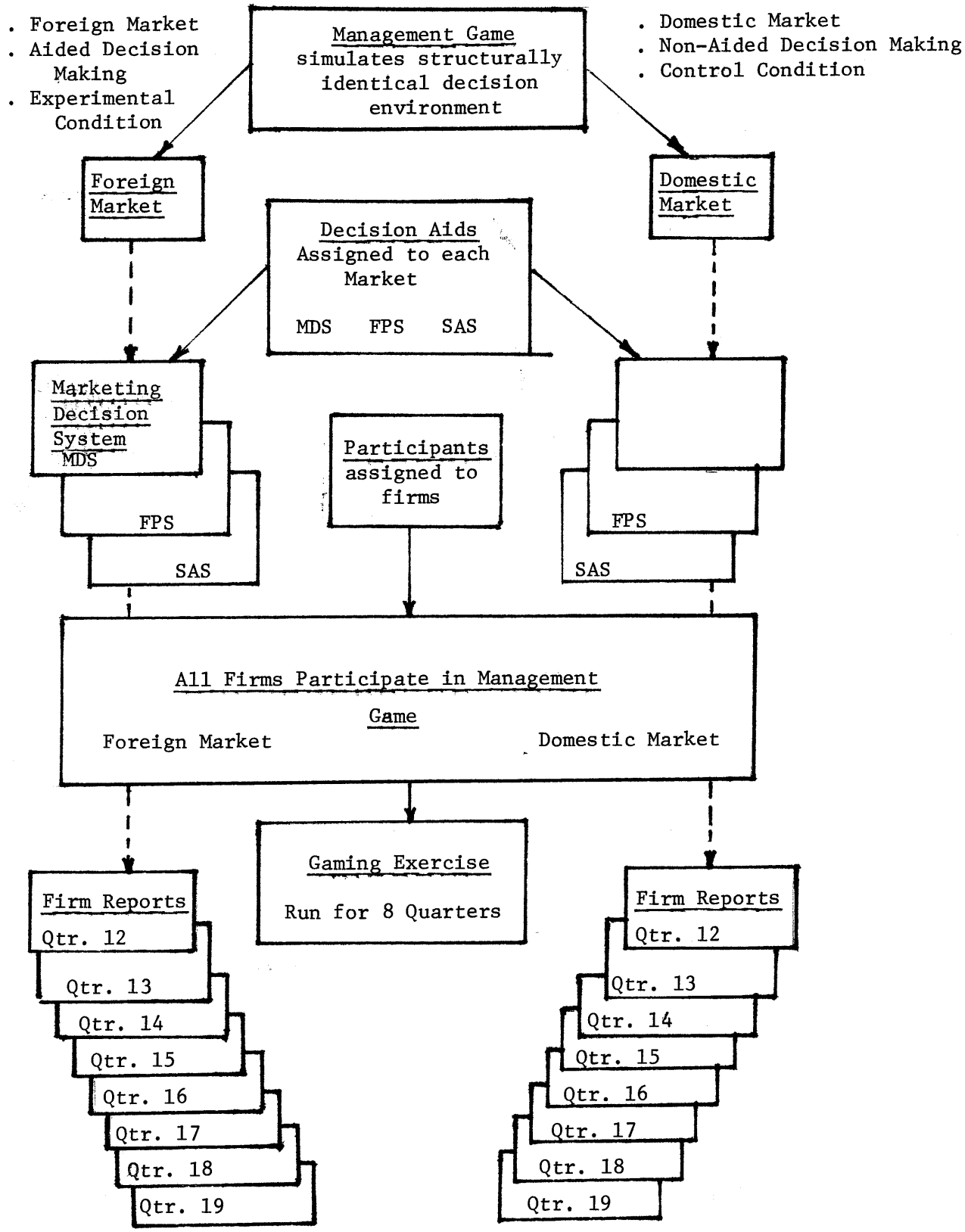


Figure 4.2 Design of the Experiment

the horizontal dimension indicates simultaneous occurrence of events. The features of the design and issues related to validity are discussed in later sections. The immediate task is to explain: (1) how the game was used to create the decision environment, (2) how the experimental conditions were created, (3) how the participants were assigned to groups and (4) how the data was collected. To do this each part of the diagram is reproduced in greater detail and explained below.

Decision Environments

The MIT Management Game was used to create structurally identical decision environments for the Foreign Market and the Domestic Market as illustrated in Figure 4.3.

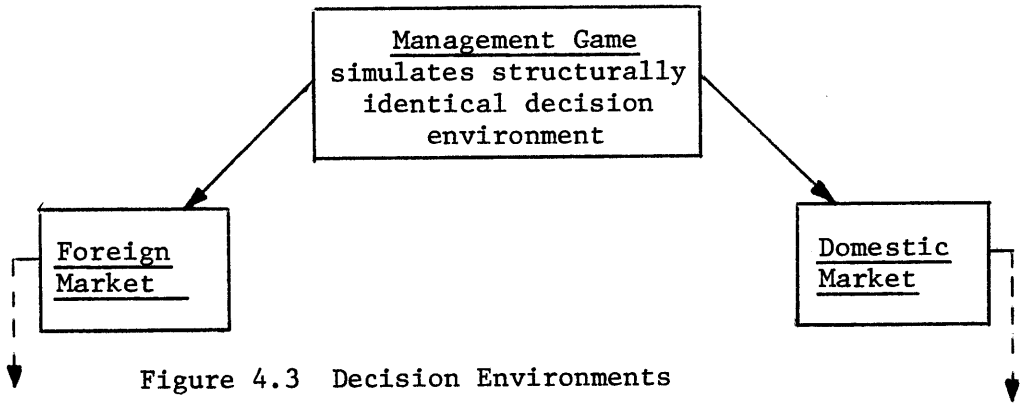


Figure 4.3 Decision Environments

For purposes of the experiment, the Foreign and Domestic Markets were generated by the same model; only constants and multipliers for GNP and the breakpoints for normal values were dissimilar. The variables, structure and parametric curves were identical. In fact, the same computer code generated both markets.

Consequently, this design created conditions in which teams competed in two markets which were structurally identical except for size and growth rates. Thus, the nature of the decision environment and the task complexity is, for all intents and purposes, quite similar, if not identical. The reason that environments must be similar is that it allows parallel observation

and use of firms as their own control. For these two conditions to hold simultaneously, the decision environments must be as similar as possible. All of these conditions, which were created by the researcher, were unknown to the Senior Executives who participated in the experiment.

Conditions

The conditions created by this design are illustrated in Figure 4.4.

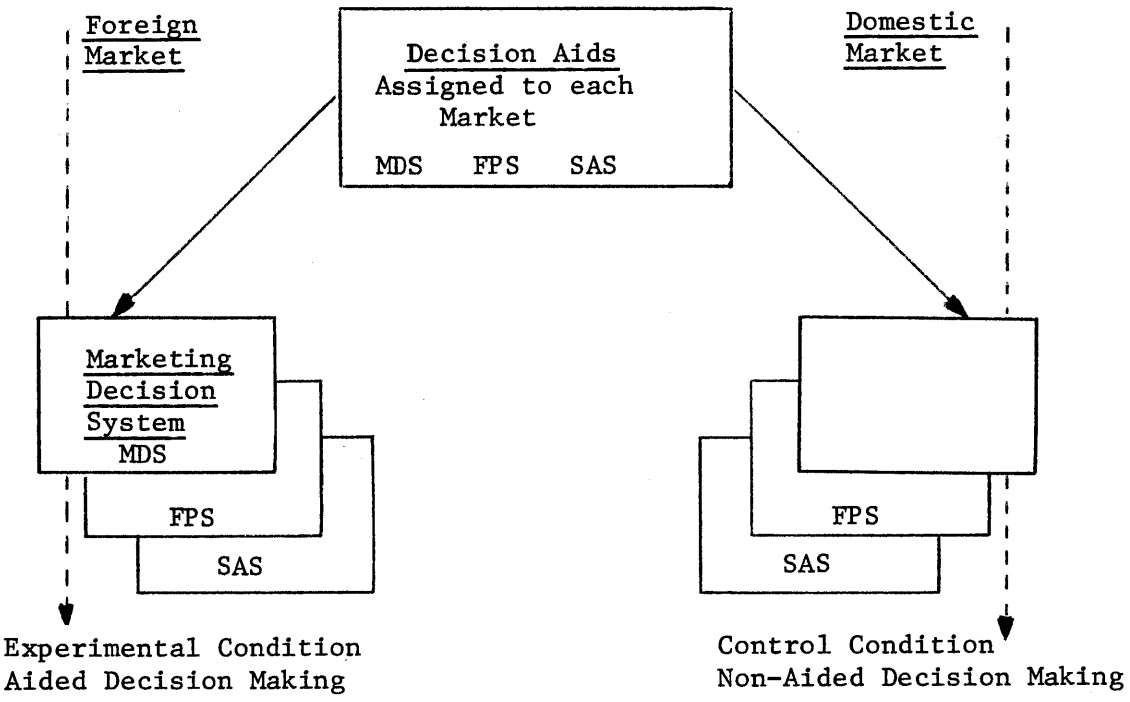


Figure 4.4 Experimental and Control Conditions

The experimental conditions were created by providing a Marketing Decision System (MDS) to aid marketing decision making in the Foreign Market while simultaneously prohibiting its use in the Domestic Market. Therefore, the non-structured marketing decisions were directly aided by MDS in the Foreign Market while their counterparts in the Domestic Market were not.

In addition, a Financial Planning System (FPS) and a Statistical Analysis System (SAS) were available for use. FPS primarily assisted financial planning but had little or no impact on marketing decisions. SAS, on the other hand, had the potential for aiding marketing decisions in either market through the development of models, but was rarely used.

Technically, decision making in the Domestic Market can not be considered non-aided because firms used SAS to develop simple models in both markets. For purpose of this study, however, the Domestic Market is considered non-aided because no direct decision support was provided by the condition created in the experiment. The distinction is made because MDS has some of the characteristics of a true Decision Support System while SAS does not.

Figure 4.4 shows that the following terms obviously refer to the same condition and can be used interchangeably depending upon the emphasis desired.

Foreign Market	Domestic Market
Aided Decision Making	Non-Aided Decision Making
Experimental Condition	Control Condition

Figure 4.4 Comparative Experimental Conditions

Groups

Participants were assigned to six firms before the Game started. Figure 4.5 shows the participant assignment and indicates that each firm competed simultaneously in the Foreign and Domestic Markets. Since the same firms competed simultaneously in both markets, they acted as their own control. This is in sharp contrast to the usual situation in which subjects are assigned to an experimental and control groups which consist of entirely different people.

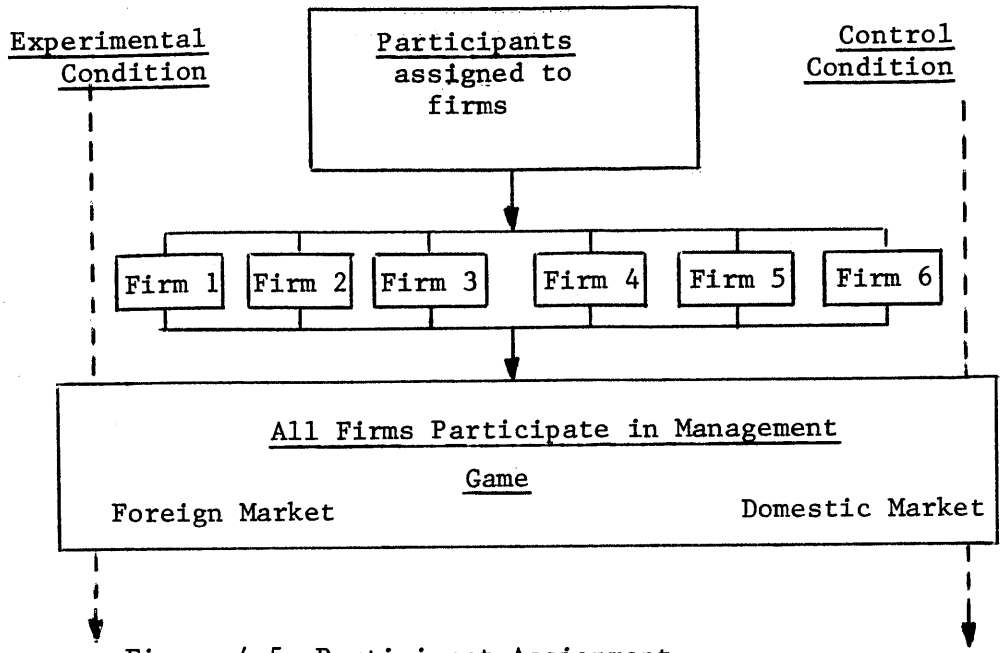


Figure 4.5 Participant Assignment

The twenty-five Senior Executives were assigned to the six firms by the Senior Executive Program Administrator. Since the game was played late in the program, he was conversant with the backgrounds, talents and interests of the participants. Every effort was made to use generally accepted procedures of gaming to balance each firm with respect to these dimensions. The figure shows that the experimental "subjects" in this research were six firms. Each firm consisted of a four-man team since one man was unable to attend, thereby reducing the one five-man team to four men.

Specific organizational assignments were not made by either the program or game administrators or by the experimenter. Some differentiations in terms of responsibility for functional areas occurred on the basis of expertise and interest, however. Since each man participated in the same program of study at MIT and, moreover, was capable of handling any functional area, teams as a whole, concentrated their main efforts on the critical decisions in the marketing area.

Observation

This experiment involved comparison of aided and non-aided decision making. Figure 4.6 indicates that the game was run for eight quarters and permitted simultaneous observation of actual decision making for both conditions over these periods.

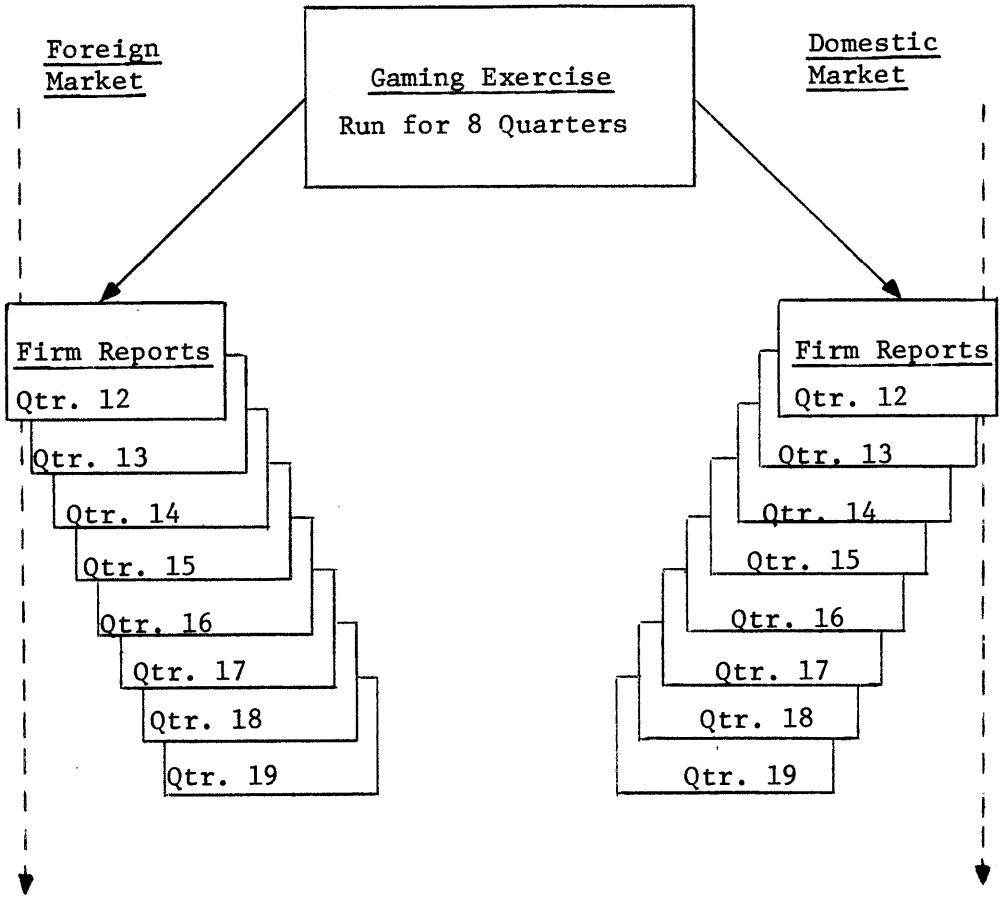


Figure 4.6 Actual Results Produced by Game

The experiment provided quarterly data on actual results - all firm and administrator's reports. An important point is that observation and data collection was unobtrusive because the researcher acted as an assistant to the Administrator and, therefore, had access to all results from the Game. Additional data was produced by procedures described in the next section.

4.1.2 Associated Design Considerations

Several associated design considerations which characterize this experiment include factors related to (1) the firms and (2) the research situation. From the researcher's standpoint, some of these factors were controllable, while others were not. The total number of participants, team assignment, and the game schedule were dictated by the situation - the ongoing Senior Executive Program - rather than by the experimental design. In other words, the experimenter had to work within the confines of an established gaming exercise.

Factors Related to Firms

The firms were teams of Senior Executive decision makers. Because the assignments were made by the Program Administrator, the researcher had no control over the total number of participants or their assignment to teams. Fortunately, four men were assigned to each firm. Prior management gaming exercises had shown that this was an adequate number of decision makers for each firm. Even though participation in the experiment was voluntary, every Senior Executive was highly cooperative.

The level of computer expertise was approximately equal across the six firms. A survey by the researcher revealed that only one decision maker in one firm had substantial skills in computation but even he did not have extensive exposure to interactive decision aids. In contrast, other Senior Executives had little expertise in computation or in using Decision Support Systems.

Every Senior Executive was exposed to similar conditions during the experiment. For purposes of the experiment, car pools were reassigned (for travel between Endicott House and the MIT campus, one hour trip each way) so that firms would have that opportunity to discuss the days events. This proved effective; firms reported the game was the focus of interest over the two-week exercise.

Factors Related to the Situation

The researcher had more control over the experimental situation as most factors were related to the simulation. The starting conditions for each firm were equal; that is, each assumed management of an identical firm in Quarter 12. The quality and quantity of information reported each quarter was equal for all firms during the entire experiment.

The game schedule, however, was developed in conjunction with the Senior Executive Program Administrator. Similar to the schedule for previous gaming exercises in the Program, the game consisted of eight quarters of play with decisions due at daily intervals, except on weekends. The actual schedule is shown in Appendix F .

The schedule determined the length of the console sessions at MIT and the time between decisions. A three-hour console session was scheduled for each decision period. Each firm had its own console during these sessions. In addition, a console was available at Endicott House during the experiment. The time between decision periods was never less than twenty-four hours but the major decision making activity occurred during the scheduled console/work sessions. Firms felt that console availability and the length of time between decisions were sufficient for high quality decision making.

Assistance was available at all times during the simulation exercise as part of the course. The assistance was provided by the Game Administrator, Professor David N. Ness, and two assistants, Albert Marcotte and Freddy Meurs. Assistance needed by the firms usually involved clarification of facts concerning the simulation or instruction in the use of the decision support programs. Firms requested aid; none was volunteered. On the whole, requested assistance was nearly equal between markets and across firms. More assistance was required in early periods and decreased exponentially during the game.

4.2 Conducting the Experiment

Conducting the experiment was synonomous with running the Game. In other words, the gaming exercise was the experiment. The experiment, however, was transparent to the decision makers because the game was a scheduled event in the Senior Executive Program, and no data was overtly collected nor did the researcher consciously influence the participants.

Schedule

Since the experiment and the game were identical, the game schedule given in Appendix F and depicted in Figure 4.7illustrates the important events in conducting the experiment.

Pregame				First Week Console Session							Second Week Console Sessions					Postgaame			
T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T
M		G_c		G_g		12	13	14			15	16	17	18	19	Q	I	I	D

legend:

M - Game manuals distributed
G - Introduction to Game (G_g), to consoles (G_c)
- Scheduled console sessions for quarter number
Q - Questionnaire distributed
I - Interview sessions
D - Debriefing sessions

Figure 4.7 Summary of Game Schedule

Certain aspects of this schedule are considered here; the distribution of game manuals, the introduction to the game, console sessions and debriefing sessions.

The 191-page Game Manuals contained all of the documentation on the simulation, the decision support packages and the firm and market history for the previous eleven quarters. The Table of Contents and a synopsis of each section's contents are given in Appendix G . It was distributed five days prior to the first

scheduled console session, because this much time was required for the decision makers to familiarize themselves with the complex material. During the Game, no particular emphasis was placed on any of the decision aids. No further introduction was provided for any aid other than the material supplied in the game manual. Participants were neither encouraged nor discouraged from using any of the systems. Use was left entirely to their discretion. A session on console use covering all aids was held prior to the beginning of the exercise. Since SAS was more complicated, the majority of time was devoted to it. The experimenter did not bias the experiment towards the use of MDS.

The introduction to the Game by the Administrator consisted of a three-hour lecture followed by a question and answer session. Emphasis was placed on the simulation rather than on the decision support packages. During this session, participants were given an overview of the Game and performance evaluation procedures, The firms knew what goals would be used to evaluate firm performance and how achievement was measured. No particular instructions were given to participants that might have biased the experiment.

Eight console sessions, one per period, were scheduled for three hours each over a two week period. Thus, decision makers were involved in the experiment for at least twenty-four contact hours, in the afternoon as noted on the schedule. These sessions can best be described as "work sessions" in which consoles and access to the decision support programs were available to each team.

The console sessions became the focus of the game. The mode of operation involved returning results of the previous period no later than the beginning of the session. Decisions and associated information were collected from the firms at the end of each scheduled session. Using this input, the game was "run" that evening and the cycle repeated. The debriefing session was conducted after questionnaire and interview data was collected. Therefore, data could not have been biased by the debriefing.

4.2.1 Nature of Experimental Procedures

The experimental procedures centered on conducting the experiment and collecting data which was used as the basis for hypotheses tests and evaluation of the validity of the experiment. The data collection procedures are characterized by the methods, timing and type of data collected. The methods for data collection included:

(1) document collection
(2) computer tracing
(3) questionnaires
(4) interviews
(5) direct observation

Table 4.1summarizes the data collection procedures. Data related to the experiment was collected from varied sources by different methods and at different times. The times are relative to the game; before the game (B), during the game (D), and after end of play (E). The methods are document and trace collection (C), direct observation (O), questionnaire (Q) and interview (I).

Table 4.1

Summary of Data Collection

Type of Data	Time	Method
(1) Firm Goals	D	C
(2) Decisions/Plans	D	C
(3) Firm Reports	D	C
(4) Administrator Reports	D	C
(5) Trace of Console Sessions	D	C
(6) Decision Processes Data	D	O
(7) Working Documents	E	C
(8) Questionnaire	E	Q
(9) Post Game Interviews	E	I

Table 4.1 highlights the unobtrusive nature of data collection procedures used in this study. As shown, all documents collected during the game were by-products of the exercise. The trace of each console session was collected automatically by routines internal to the game. Decision process observations were dictated in private by the experimenter at the end of each day's session. Collection of working documents, questionnaires and interviews took place after the end of the game.

Document Collection

Document collection was used to gather needed data that was produced in running the game. Since the researcher acted as a gaming assistant, he had natural access to all documents and handled both the collection of Input Forms and the distribution of results for the game. To xerox copies of input documents and have the computer print extra copies of results was a simple matter. Document collection is summarized in Table 4.2

Table 4.2

Document Collection

Name of Document	Collection Time/Source
Data Input Form	Quarterly/Firm
Market Summary	Quarterly
Firm Reports	Quarterly/Firm
Individual Goals	Quarter 11
Firm Goals	Quarter 12
Administrator's Report	Quarterly/Firm
Console Carbon-Trace	Console Session/Firm
Working Documents	End of Game/Participant

Computer Trace

The computer trace captured each firm's use of the interactive decision aids. Trace routines that were part of the programs automatically stored every interaction between the user and MDS, FPS, and SAS on tapes. Use was automatically time coded. This trace included data for forty-eight console sessions.

Trace data was similar to that from the console carbon trace. Captured on tape, the trace data, therefore, did not require any further processing prior to analyses. A sample of this data is shown in section 3.2.1. Console carbon paper trace, on the other hand, served as a check on the computer trace. In addition, the carbon paper trace contained written comments and analysis which were not captured by the computer trace.

Questionnaire

The extensive questionnaire data was collected after the end of the experiment. The questionnaire shown in Appendix H was used to obtain data for the purposes shown in the eight areas listed in Table 4.3

Table 4.3

Questionnaire Contents

Section	Purpose	Questions
I	Personal contributions and reactions to game	10
II	Perceived versus actual understanding of game, information used for decision making	26
III	Individual and corporate goals, policy and objectives	9
IV	Organizational influences	13
V	Perceived usefulness and quality of decision support packages	16
VI	Influence of model and information quality on results	37
VII	Determination of transfer of knowledge perceived similarities and/of differences between markets	17
VIII	Perceived realism and complexity of markets awareness of experimentation	23

The questionnaire contained scaled response items, closed and open-ended questions. Most of the questions were pretested on prior groups of Senior Executives to determine reliability and improve format and clarity. Several questions were redundant; critical issues and measurements were addressed by multiple questions. The questionnaire required two to five hours to complete; the average time was three and a quarter hours. Every Senior Executive returned a completed questionnaire before the debriefing session. This was most gratifying because the game marked the close of formal classes and the participants had busy social schedules and graduation exercises to attend. Most returned the questionnaire prior to the interview. The experimenter checked each questionnaire as it arrived and, therefore, was able to clarify any information during the interview.

Interview

The interviews were conducted with each firm during the week end following the completion of game play but prior to the debriefing session. The researcher and a helper conducted these interviews at Endicott House, the Senior Executive residence at MIT. The helper ran the recording equipment and made sure no questions were overlooked. All interviews were tape recorded for future reference. Tapes are of sufficient quality to permit accurate transcription even when a number of people responded simultaneously.

The interviews were structured around a series of pretested questions which were identical for each team. The interviewer encouraged clarification of responses to interview question and answers to particular questions in the questionnaire. To answer all questions required one hour and forty-five minutes to three hours; the average was two hours and forty minutes. These fourteen hours of tape recorded interviews provide data that were difficult to capture in any other way.

Direct Observation

Additional data was obtained by direct observation. Forms designed for rapid data entry were used to collect quantitative data; therefore, firms were not disturbed by the data collection procedures. The data included recording man-hours and resolution time for foreign and domestic marketing decisions. Qualitative observations were dictated on tape by the experimenter at the close of each day. This data served mainly as a check on some aspects of questionnaire and interview data and to supplement information concerning the dynamic nature of decision making.

4.2.2 Associated Experimental Conditions

The physical environment was more than adequate for purposes of the experiment. All console sessions were scheduled in a large room at the Alfred P. Sloan School of Management at MIT. The floor plan and arrangement of facilities is shown in Figure 4.8

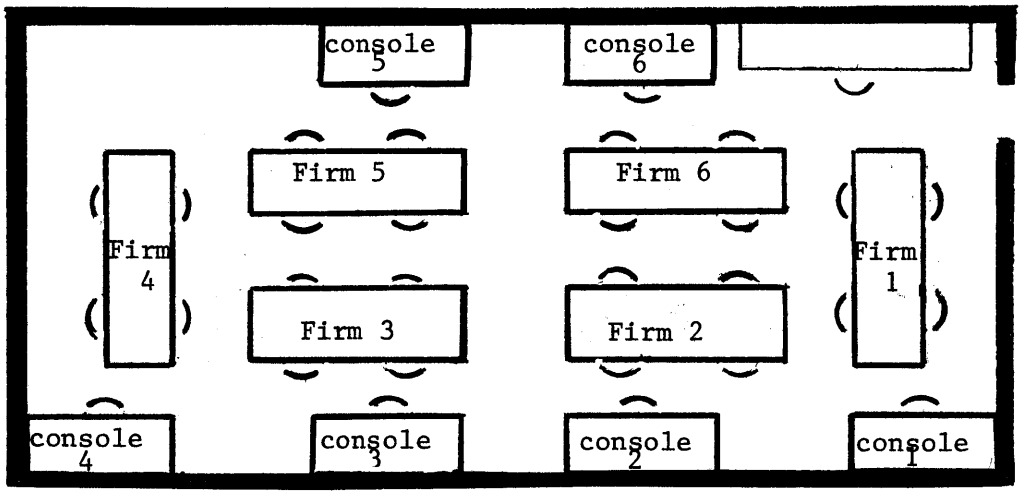


Figure 4.8 Physical Arrangement of Facilities

The room was large enough to assign a work area to each firm. Each area contained its own large conference-type table. The work areas defined privacy zones; firms worked within their assigned areas and did not violate the confidentiality of the work of other teams. Firms used the same tables and consoles each session.

The room also contained three wall-mounted blackboards which were used for instructional purpose by members of the firms and the Game Administrator and his assistants.

The consoles used in the experiment were IBM 2741's or their equivalent. Only hard copy was produced; no CRT consoles were used. To capture console use, three-part carboned paper was used by each firm; the original was used by the team while the carbons were collected by the experimenter. Thus the carbon "trace" acted as a backup to the computer trace. In addition to capturing all of the console input and output, the carbons contained notes and calculations made by teams at the console.

Posted on the wall next to each console were flow diagrams detailing the operation of each of the decision support programs and log-in procedures. These handy references served as guides to program use, especially in Quarters 12 and 13. The flow diagrams remained posted for the duration of the experiment. Firms indicated that the diagrams were valuable aids.

The location of the experiment allowed participants to use other resources of the Sloan School (Xerox machine, calculators, etc.) and was convenient to dining facilities. Thus, many firms made extensive use of the room and facilities at times other than scheduled console session.

4.3 Implication for Internal and External Validity

This section evaluates factors related to the design and conduct of the experiment which have implications for the validity of this work. The most critical factors relate to:

(1) the similarity of the Foreign and Domestic decision environments

(2) the structure of the experimental design

(3) the procedures for conducting the experiment

Each of these areas is discussed and the validity of the research design is evaluated using criteria from the literature.

Validity determines the degree of confidence that can be associated with results. Both internal and external validity are intimately related to the design and conduct of any experiment, especially in situations where the independent variable is manipulated to determine its effects. This is the case here. Consequently, those factors within the framework of the experiment that can threaten either type of validity are considered in greater detail.

Factors which jeopardize validity have the potential to confound results. What can threaten validity is the possibility that some other variable is responsible in some degree for the observed results. It can do this by reducing, enlarging or being entirely responsible for the observed effects.

4.3.1 Issues Related to Similarity of the Markets

Most of the methods for achieving high internal validity have been called experimental control. The goal, of course, is to design experiments which regulate all factors which could confound results. The design used in this study has a number of features to accomplish this aim. Because the design is intimately related to the nature of the foreign and domestic decision environments, the similarity of these markets will be discussed prior to discussing factors related to the design.

Similarity of the Decision Environments

There are two critical issues related to the similarity of the decision environments; actual similarity and perceived similarity of the Foreign and Domestic Markets. Actual similarity relates to the degree to which both markets are structural facsimilies. Perceived similarity, on the other hand, relates to the firm's awareness of the underlying structure of each market.

These issues are important because the research design required firms to be simultaneously exposed to two similar decision making environments, one of which was aided by a Decision Support System while the other was not. Therefore, the Foreign and Domestic Markets should have high structural similarity. The design also required that firms should not recognize basic structural similarity and, thus, transfer knowledge gained in one market to the other market. The nature and complexity of the model which generated the markets allowed both goals to be achieved to a very high degree.

Actual Similarity

To evaluate the actual similarity of the Foreign and Domestic Markets requires an appropriate test. Brodbeck (18) suggests that in cases where two models are being compared the degree of similarity can be judged by a "Turing-type" test. In other words, if there were separate models for each market and each firm's decisions were comparable, how similar would the behavior of both markets be given the same starting conditions? This test cannot be applied directly here because the same model generates both markets and, in addition,the same observable behavior could result from different causes.

The basic idea behind this test can be used, however. Morris (73) asserts that behavior is a function of structure. Everything else being equal, structurally identical models should produce similar

behavior. Since the markets are simulated, the structure is defined by (1) the variables, (2) the relationships among variables and (3) the influences of each variable on the total market. Therefore, the degree of similarity can best be determined by comparing how the model is used to generate the Foreign and Domestic Market.

The criteria for comparing structural identity suggests that the markets are highly similar. Since each market is generated by the same model, both react to exactly the same twenty variables - GNP, a seasonal index, six prices, six promotion expenditures and six R&D expenditures. The pattern and values for the seasonal index as well as the effects of prices, promotion and R&D are identical for both markets. The relationships among factors are also the same for each market. The multipliers for GNP and the breakpoints for curves are slightly different, however. Even though breakpoints are different, the same percentage change in comparative decision variables has identical effect in either market and, thus, is of no consequence. The multipliers for GNP cause the Foreign Market to grow slightly faster than the larger Domestic Market, all else being equal. This effect, however, is completely overshadowed by the action of firms; that is, each competitor's price, promotion and R&D strategy has the more pervasive influence on each market since the number and nature of their relative influence determines, in large measure, the status of the market each quarter.

To summarize, actual similarity is high; the Foreign and Domestic Markets can be considered structural facsimiles because the same relationships determine each market's behavior. The combined actions of the six firms and the seasonal index dominate the effects of slight differences in GNP. Consequently, it would seem that the inherent behavior of each market creates similar decision environments for the firms.

High structural similarity of the markets means that essentially the same decision environments exists for each firm for both the experimental and control condition. The conditions are created solely by the use of MDS in the Foreign Market while precluding its use in the Domestic Market. Consequently, any confounding between the nature of the decision environments and the experimental and control conditions is reduced to minimum because of the high structural similarity of the markets. Differences in decision making behavior are, therefore, attributable to the experimental variable - the MDS - and not to differences between markets.

Structural similarity does not imply that each firm encountered identical decision situations each quarter. Circumstances are unique but they are created by the firms themselves and not by the structure of the markets. The situation facing each firm is primarily a function of its past decisions and the past and future decisions of its five competitors. Since no firm has exactly the same decision history nor the same competition, individual firms are faced with unique circumstances each quarter. These circumstances do not influence the experimental and control conditions, however, because the analytical procedures recognize all differences.

Perceived Similarity

Forrester's (42) work alludes to the difficulty in detecting the structure of dynamic, non-linear models from their observable behavior. This difficulty was clearly evidenced in the game because dynamic interactions tended to obscure and confound one another. As a result, firms believed that the markets were distinctive, not knowing that any differences were, in fact, determined mainly by their own interactions. Moreover, participants never suspected at any point in the game that both markets were essentially identical.

These conclusions are clear from the questionnaire and interview data. Both contained a number of items related to perceived similarity of the markets and the possibility of knowledge transfers between markets.

(Questionnaire, item)
In your mind, how similar are the Foreign and Domestic Markets?

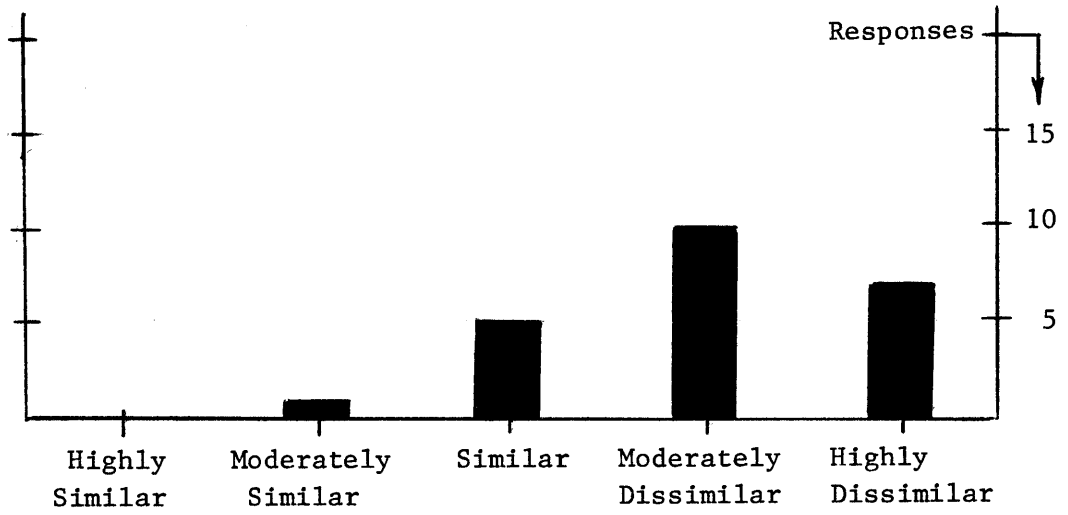


Figure 4.9 Perceived similarity of markets

(Questionnaire, item)
If you think they are similar, why do you believe this to be the case?

"They were slightly similar. Some of the same kinds of variables like GNP and Price effected both, but other variables like Advertising and R&D didn't have the same influence at all"

"Not too similar - they certainly weren't the same market. The manual says they were influenced by the same variable - but I don't believe it"

"The only thing you could say about the similarity is that some things seemed to behave the same way some of the time"

"I don't think they were similar at all - in fact, they were completely different"

To determine knowledge transfer between markets, the series of questions shown below were included in the questionnaire.

(Questionnaire, item)

Which market do you feel you understand better, the Foreign Market or the Domestic Market?

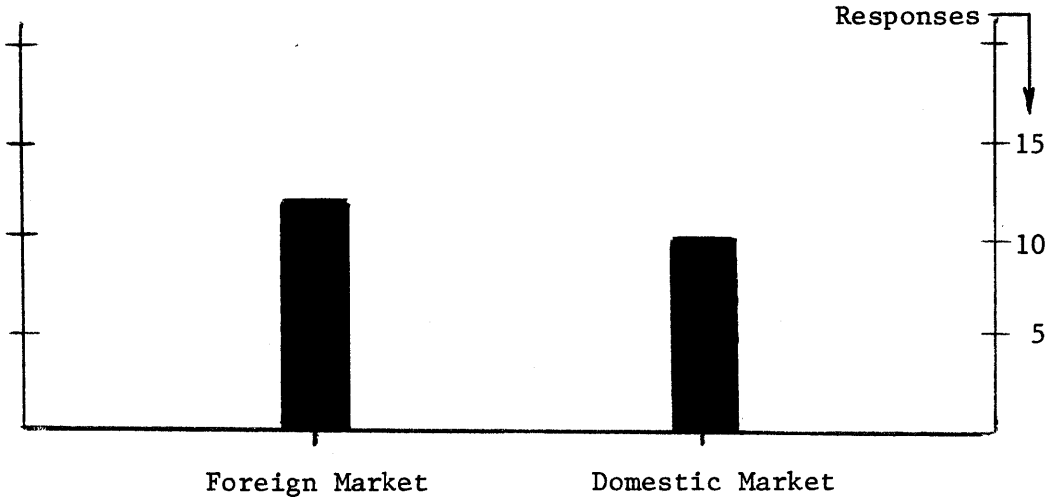


Figure4.10 Comparison of Understanding

(Questionnaire, item)

How useful was the knowledge gained in the Foreign Market for understanding the Domestic Market?

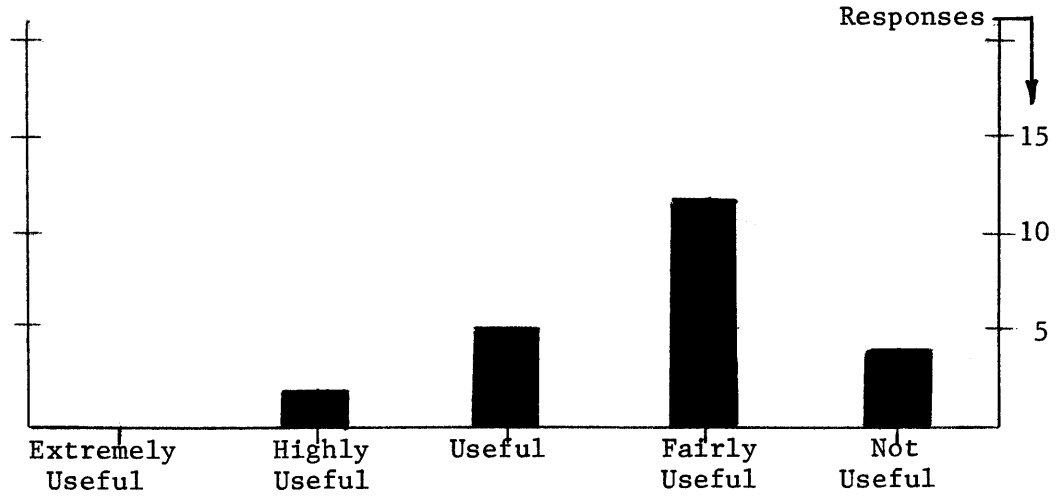


Figure 4.11 Usefulness of knowledge, Foreign to Domestic

(Questionnaire, item)
How useful was the knowledge gained in the Domestic Market for understanding the Foreign Market?

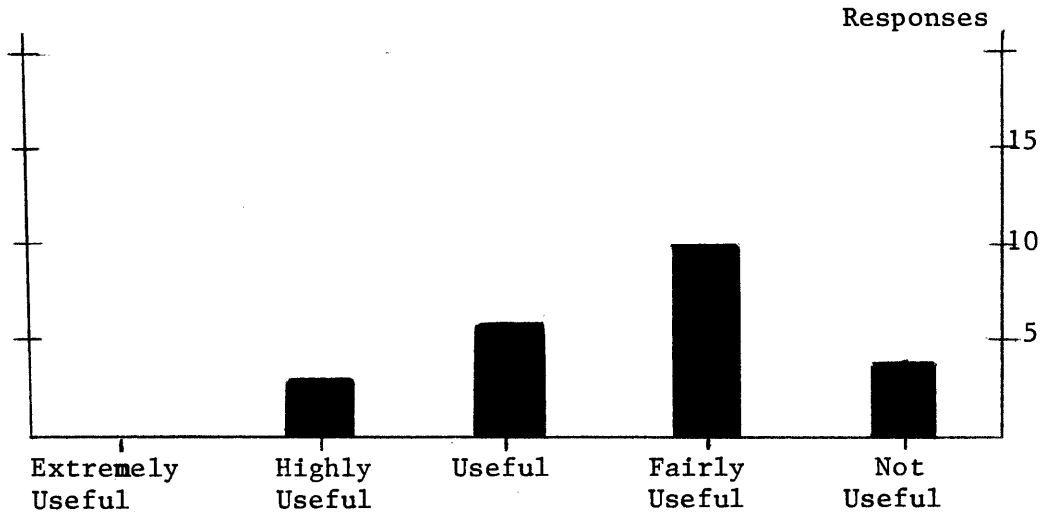


Figure4.12 Usefulness of knowledge, Domestic to Foreign

(Questionnaire, item)
How would you rate the transfer of knowledge between the markets?

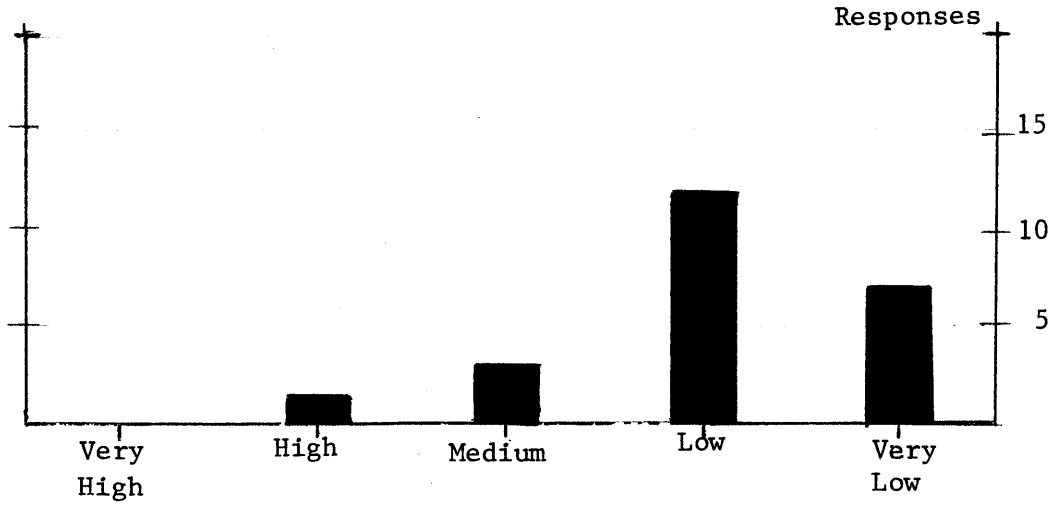


Figure4.13 Knowledge transfer between markets

This data clearly shows that the similarity of the markets was not perceived nor was knowledge gained in one market particularly useful for competing in the other market.

4.3.2 Issues Related to Design of Experiment

Alternative designs are well documented in the literature (20) (82) (97). They are classified into three categories by Campbell and Stanley (20) based upon the researcher's ability to control factors influencing validity. Pre-experimental and quasi-experimental designs are characterized by lack of complete control. True-experimental designs, on the other hand, are usually characterized by random assignment of subjects to experimental and control groups, full control over experimental stimuli and parallel exposure and observation of both groups to determine the effects of the experimental stimuli. True-experimental design has higher inherent validity than do the other two types and for this reason are preferred if conditions permit their use.

The design used in this study is a true-experimental design. Certain features noted at the bottom of Figure4.14 further increase the basic design's inherent validity. Rather than assign "subjects" by the usual randomizing techniques (which would have permitted using only three firms for each market) the design used related samples instead. Siegel (102) notes the advantages:

> "In comparisons of two groups, sometimes significant differences are observed which are not the results of the treatment... One way to overcome the difficulty imposed by extraneous differences between groups is to use two related or matched samples."

Matching can be achieved by using each subject as his own control or by pairing subjects and then assigning the two members of each pair to the two experimental conditions. When a subject "serves as his own control", he is usually exposed to both treatments at different times. When the pairing method is used, each pair must be as much alike as possible with respect to extraneous variables which might influence experimental results.

Even though matched-pairs and own-control designs are superior in themselves, there is potential for improvement. Their main advantages and disadvantages are shown in Figure 4.15.

	Matched-Pairs Design	Own-Control Design
Advantage	Simultaneous exposure to experimental and control condition	Perfect Matching
Disadvantage	Poor matching	Sequential exposure to experimental and control condition

Figure 4.15 Comparison of Participant Assignment Methods

The experimental design used here combines the advantages of matched-pair and own-control designs while overcoming the disadvantages of both. That is, perfect-matching was achieved because each firm acted as its own control and, in addition, each firm was simultaneously exposed to the experimental and control condition. No more precise matching is possible than that achieved by identity. Thus, differences related to the subjects are minimized, while simultaneous exposure to conditions precludes the possibility that extraneous variables might influence experimental results. Besides simultaneous exposure to the experimental and control condition, the design permitted parallel observation of the decision making behavior of each group in both states for eight replications of the experiment. Parallel observation increases confidence since no time-dependent effects are recorded by the data collection methods.

Several other features deserve consideration. All of the necessary arrangements were established prior to the beginning of the experiment. No testing or data collection of which the firms were aware took place before or during the experiment. All data

collected during the game was furnished as a by-product of running the game. Questionnaire and interview data was collected at the end of the exercise. Moreover, the Senior Executives who participated in the experiment were totally unaware of the nature of the research; the experiment was transparent. From their point of view, they were involved in a scheduled management gaming exercise. From the researcher's point of view, the game was a laboratory in decision making behavior. All participants in the experiment had been exposed to identical programs at MIT, thus, all training was equivalent for seven weeks preceding the experiment. In addition, all were present for the game introduction and no one dropped out of the experiment once it was started. None had prior experience with Decision Support Systems. The researcher acted as a gaming assistant during the game. Having had prior gaming experience and being fully aware of the nature of the experiment, he dilligently avoided any interaction which had the potential for influencing results.

At this point the internal validity of the experimental design can be technically assessed. This requires identifying factors which threaten validity by confounding the effects of the experimental stimuli and thus serve as rival hypotheses for explaining the results. Campbell and Stanley (20) summarize the literature by identifying the impact of:

(1) Selection - biasing from subject assignments
(2) History - effects of intervening events
(3) Maturation - time dependent effects
(4) Testing - effects of multiple testing
(5) Instrumentation - effects of measurements
(6) Mortality - differential loss of subjects
(7) Interaction - interaction of factors

The experimental design used in this research has high internal validity when measured in terms of these factors. The effects of selection are not relevant because each firm served as its own control. There were no selection biases; matching by identity is exact. The effects of history should be recognized. Console

problems influenced one team for a quarter but, on the whole, events were applied equally to both experimental and control conditions. Maturation or the effects of time dependent psychological processes (97) would effect both conditions equally because of simultaneous exposure. The effects of testing and instrumentation were nil; none was done during the experiment. Mortality or the loss of team members did not occur. Interaction between factors would seem negligible. Because the game was a scheduled part of the Senior Executive Program and the experimenter's role was non-reactive, the well known "experimenter" and "Hawthorne" effects are not plausible hypotheses either.

To summarize, the design controls all of these factors and, therefore, has high internal validity. Consequently, observed results should be associated with the experimental variable rather than with extraneous factors which might have had the potential for influencing results.

4.3.3 Issues Related to Conduct of the Experiment

The use of teams in conducting the experiment rather than individuals was dictated by the situation rather than the design. Team management, however, does reflect the trend toward organizational control by professional managers rather than the lone entrepreneur working in isolation. Farris (41) notes this trend:

> "Executive decision making in organizations... is seldom done by individual members of the organization acting alone. People work together in project teams or task forces, coordinate their efforts with broader purposes of the organization, and exchange stimulation and support with their colleagues."

Team composition is not of compelling relevance because the experiment used each firm as its own control. Results of the experiment are based on comparison of decision making effectiveness between markets rather than between teams. Therefore, imbalance between teams, if it existed,is not a significant factor in internal validity.

The use of teams has implications for external validity, however. The results may extend to management situations involving teams or groups of decision makers but may not apply to situations in which decision makers work in isolation. Although this is a limitation of the study, it may not greatly restrict generalizability.

Campbell and Stanley (20) identified subject-related factors that interact with the experimental stimuli (X) and, thus, threaten external validity. They are:

(1) interaction of selection and (X)
(2) reactive arrangements and (X)
(3) other interaction with (X)

Each of these factors centers on the relationship between the teams and the Decision Support System or other experimental arrangements and attempt to uncover effects that are unique to specific populations, conditions or environments and thus reduce generalizability. For this study, there are no apparent interactions that are directly related to teams and the MDS because all firms had little experience with Decision Systems prior to the experiment.

4.4 Chapter Summary

This chapter completely documents the design and conduct of the experiment and discusses implications for internal and external validity. Design goals are reviewed and translated to specific structural features of the experiment. Associated design considerations related to the firms and the experimental situation detail how the researcher worked within an established gaming exercise. All procedures and conditions for conducting the experiment are described.

Extensive data collection methods reveal the wealth of supplemental information collected during and after the actual experiment.

Questionnaire data is used to explore all of the technical issues related to internal and external validity. Each technical factor gleaned from a thorough review of the literature which had the potential for jeopardizing validity is analyzed and considered for this research. The conclusion is clear; this experimental design neatly controls all of these factors and, therefore, has extremely high internal and external validity.

Compared to traditional designs found in the literature, this experimental design is unique. The design resulted from an overt consideration of the goals of good research. This chapter clearly shows that the experimental design used in this study either meets or exceeds all of these goals, and, therefore, high internal and external validity is assured.

CHAPTER 5

DESIGN OF MEASURES AND METHOD OF ANALYSIS

The measures used to determine decision quality of DSS-aided and non-aided decision making are an important part of the research design. The quality of measurement depends upon the method of analysis. The value of the analysis must be determined in light of the needs of the study. The goal was to determine the relative, not absolute, quality levels for decision quality for every firm for each quarter. The quality of the method determines the procedural validity for the study.

This chapter describes the procedures, presents the table of quality indices which it produced and discusses issues related to procedural validity. The organization and contents of the chapter are shown in Figure 5.1.

5.1 Measures of Performance

- 5.1.1 Objectives
- 5.1.2 Measures

5.2 Method of Analysis

- 5.2.1 Procedure for Measuring Decision Quality
- 5.2.2 Quality Indices

5.3 Implications for Procedural Validity

- 5.3.1 Issues Related to Measures
- 5.3.2 Issues Related to Procedures

5.4 Chapter Summary

Figure 5.1 Contents of Chapter 5

The first section describes the objectives of measurement and translates them into appropriate measures. The second section describes the procedure for measuring decision quality while the third section discusses the implications of the measures and the procedure for validity.

5.1 Measuring Performance

The measures and methods used to analyze decision performance are critical parts of the research design. They deserve special consideration because they determine the quality of the results. The measurement of aided and non-aided decision performance requires measuring effectiveness and efficiency. Effectiveness is related to quality, consistency and rate of improvement in decision making while efficiency is related to resource use and resolution time.

The measurement of effectiveness requires finding a standard of comparison. This standard is the "potential" level of decision quality. The analytical procedures described here were used to find the decision quality levels for each firm in both the Foreign and Domestic Market over eight quarters. The measurement of efficiency requires data on man-hours and the resolution time for foreign and domestic marketing decisions. This data was collected in a straightforward way from the experiment. Since the measurement of decision effectiveness is more complicated than the measurement of efficiency, this chapter will focus on the methods of analysis and issues involved in measuring effectiveness.

5.1.1 Objectives

The primary objective in measuring decision effectiveness was to develop reliable measures which would recognize the unique situations facing each firm in both markets and thus provide a basis of comparison between firms in each quarter. Since conditions encountered by each firm are unique, measures must account for subtleties in each situation. These measures of effectiveness are based on the decision quality of each firm. To measure decision quality requires developing an index which reflects the relative value of actual decisions to the firm.

To evaluate the quality of any activity requires the comparison of actual performance with some standard which would provide an indication of the worth of the actual activity relative to this standard. Thus, it is a measure of performance for the

activity. Furthermore, to compare the quality of two or more activities requires the comparison of both against a comparable standard so that the relative quality of each has significance and can be evaluated.

In the game, a number of different comparisons of actual to standard could have been made in attempting to evaluate decision quality. The most meaningful, however, is the ratio of profits earned as a result of actual decisions to those which would have been earned had the firm's decisions been optimal or near optimal. The ratio of actual profits to potential profits is a meaningful index of decision making quality.

This measure of comparison was adopted primarily because it overcame any differences between the Domestic and Foreign Market, even though the markets are structurally identical. These differences result from two sources:

(1) the levels and rates of growth of GNP

(2) the market conditions created by the interactions of each firm's decisions.

The former is not under the control of the firms, but is determined by the Game Administrator. The latter is created by the interactions of the firms. Thus, each firm faces a unique set of conditions each decision quarter. These conditions are a function of the past decisions of both the firm and its competitors and the future decisions of competition.

The uniqueness creates problems in assessing the effectiveness of decision making and in comparing the quality between firms. For example, the profit potential and actual profit for each firm may vary from quarter to quarter and may vary among firms within the same quarter, thus making actual profit a poor measure of decision quality.

The only way to overcome these problems is to determine the profit potential for each firm in each quarter and use this as a base for comparing actual profits. In this way differences between markets may be reconciled.

The measurement objectives can be realized by basing results on ratios of:

$$\frac{\text{Actual Profits}}{\text{Potential Profits}}$$

5.1.2 Measures

The dimensions of decision effectiveness and my methods of measurement are summarized in Figure 5.2

Figure 5.2 Measures of Decision Effectiveness

Dimensions	Measures
Decision quality level	The ratio of actual profits/potential profits. This index compares the profits resulting from the actual decisions to the potential profits which would have resulted had decisions more closely attained goals.
Consistency of Decision Quality	The variance of the indices of the decision quality level. The variance measures the fluctuation in decision quality.
Improvement in Decision Quality	The net rate of change of the indices of decision quality. The net rate of change is an indication of the rate improvement.

5.2 Method of Analysis

To determine the quality indices requires finding the ratio of actual profits to potential profits. Therefore, an expression for profitability is needed. Marketing profitability for a quarter or, more precisely, the contribution to the firm's profits from the marketing function is given by the expression.

$$P_q = (p_q - m) * s_q - c_1 * a_q - c_2 * r_q - c_3 * i_q$$

where
P_q is marketing profitability for quarter
s_q is sales for quarter
p_q is price for quarter
m_q is Marketing's cost of product
a_q is advertising expenditure for quarter
r_q is R&D expenditure for quarter
i_q is inventory carried into period
c_1 is an advertising allocation multiplier
c_2 is an R&D allocation multiplier
c_3 is the inventory carrying cost

This expression accounts for all decision variables under the control of marketing in the game. It is also a valid representation for profitability in both the Foreign and Domestic Markets given appropriate values for the Ci parameters.

Finding actual profitability for any quarter requires substituting the actual values for the decision variables (p, a, r, i) and the resulting sales into the expression and is no problem.

Determining potential profitability for any quarter, on the other hand, requires finding values of the decision variables that maximize P_q. The simplicity of the task is deceptive.

There are four decision variables: price, advertising, R&D, and inventory set by each firm each quarter. Given the actions of the five competitors with respect to each of the decisions, finding an optimal set of decisions for the firm is a formidable search problem in a non-linear space, especially when longer decision horizons are adopted. The space is essentially infinite. Analytic solution techniques for non-linear surfaces of this nature are not available.

The problem becomes even more difficult when the time horizon is lengthened. It is related to the sequential interdependencies between quarters. The feasible set of decisions for price, advertising and R&D in any one quarter is based upon those of last quarter and should include consideration of expected consequences in future quarters.

Clearly, the analysis must account for dynamic interdependencies; that is, sets of decisions must be optimal with respect to each over an appropriate decision horizon. A four quarter decision horizon was chosen in the analysis. This horizon matches the planning horizon each team used during the game. Moreover, sensitivity studies indicated it was the more appropriate horizon given the prevalent seasonal sales patterns in the market.

The objective function for finding firm profitability is to maximize

$$\sum_{q}^{q+4} P_q = \sum_{q}^{q+4} ((p_q - m) * s_q - c_1 * a_q - c_2 * r_q - c_3 * i_q)$$

over a rolling four quarter decision horizon. The procedures are explained in later sections.

As noted above, complete search across all variables in the static (one quarter decision horizon) case is formidable. For the dynamic case the task is clearly not feasible. Even partial search is extremely difficult, costly and time consuming. There are three basic ways to reduce search: (1) reduce the number of variables over which search takes place, (2) reduce the increment size used for each variable, (3) learn what solutions are dominant and thus be able to disregard significant parts of the space.

It became clear that price was the most sensitive decision variable because its effect was not smoothed and it was the main determinant of potential contribution. Because of the smoothing effects on advertising and R&D, the results of changes in these variables effects sales much less than does a small change

in price in the quarter in which all decisions are made. For this reason advertising and R&D expenditures were accepted as given for all firms and all search was confined to the price/inventory variables. This decision substantially reduced the required search to a manageable level and produced reasonable estimates for potential profitability.

Domestic Market Non-Aided Decision Making

	12	13	14	15	16	17	18	19	Actual
12	6.20 895	6.40 906	6.40 906	6.40 906	6.40 906	6.40 906	6.40 906	6.40 906	6.40 906
13	6.70 964	6.50 987	6.25 1022	6.25 1022	6.25 1022	6.25 1022	6.25 1022	6.25 1022	6.25 1022
14	6.80 1160	6.80 1129	6.70 1129	6.25 1265	6.25 1265	6.25 1265	6.25 1265	6.25 1265	6.25 1265
15	9.00 4435	9.65 4355	9.31 4321	9.02 4298	5.80 1758	5.80 1758	5.80 1758	5.80 1758	5.80 1758
16	9.00 3549	9.15 3473	9.31 3448	9.68 2817	7.49 1777	7.00 1550	7.00 1550	7.00 1550	7.00 1550
17	9.00 3172	9.15 3185	9.31 3171	9.68 2709	7.00 1693	7.00 1695	7.20 1548	7.20 1548	7.20 1548
18	9.00 2880	9.15 2893	9.31 2884	7.00 1661	7.00 1697	7.00 1699	7.20 1597	7.20 1422	7.20 1422
19	7.50 2834	7.44 2883	7.26 2759	7.00 2565	7.00 2560	7.00 2561	7.20 2519	7.20 2333	6.20 2099

12	15.37 1106	8.50 420	8.50 420	8.50 420	8.50 420	8.50 420	8.50 420	8.50 420	8.50 420
13	11.27 1407	11.25 1404	8.40 834	8.40 834	8.40 834	8.40 834	8.40 834	8.40 834	8.40 834
14	11.27 1340	10.18 1187	10.10 832	8.50 885	8.50 885	8.50 885	8.50 885	8.50 885	8.50 885
15	11.27 1737	10.40 1501	10.10 1411	9.62 1309	9.50 1305	9.50 1305	9.50 1305	9.50 1305	9.50 1305
16	10.20 1173	10.00 1074	9.90 1033	9.62 991	9.50 987	9.50 987	9.50 987	9.50 987	9.50 987
17	10.20 1173	10.00 1063	9.90 1024	9.62 991	9.50 987	9.50 987	9.50 987	9.50 987	9.50 987
18	10.20 1173	10.00 1130	9.90 1095	9.62 1067	9.50 1059	9.50 1059	9.50 1059	9.50 1059	9.50 1059
19	9.63 1535	9.63 1530	9.63 1516	9.62 1531	9.60 1461	9.60 1461	9.60 1461	9.60 1461	9.60 1461

Foreign Market Aided Decision Making

Figure 5.3 Analysis Sheet

5.2.1 Procedures for Measuring Decision Quality

The easiest way to understand all of the procedures used to find the dynamic optimal decisions and their associated potential contributions is in reference to the analysis sheet shown in Figure 5.3. The upper half is the analysis for the Domestic Market and the lower half is the analysis for the Foreign Market.

Above the diagonal step-lines and at the extreme right are the actual decisions and contributions earned each quarter. Below this line are the optimal sequences of decisions given the "state of the world" as it appeared in the quarter in which the optimal sequence starts.

For example, in the Domestic Market in the column labelled Q15, the optimal pricing policy for quarters 15 through 19 is shown below the diagonal. This is the optimal policy given that the firm had charged \$6.40, \$6.25 and \$6.25 in quarters 12, 13 and 14 respectively. By looking to the right of the \$9.02 optimal price on the line for quarter 15 in the column labelled Q16, it can be seen that the firm actually charged \$5.80 and in the process stocked out. Note that the optimal sequence of prices for quarter 16 to 19 given that the firm actually charged \$5.80 in quarter 15 is given below the diagonal in column labelled Q16 is different from the sequence with an optimal Q15 decision.

To find the sequence of dynamically optimal decisions and the corresponding potential contributions for each quarter the objective function

$$\sum_{q}^{q+4} P_q = \sum_{q}^{q+4} ((p_q - m)*s_q - c_1 * a_q - c_2 * r_q - c_3 * i_q)$$

was used to guide sequential search through the price/inventory space until the sequence of prices that maximized the objective function was found. The procedure was repeated beginning in each subsequent quarter thus producing the sequences of optimal decisions below the diagonal line for both markets. In moving from quarter to quarter the firm's actual decisions which

determine the "state of the world" were taken as the starting point in finding the new optimal sequence.

The potential contribution that could have been earned by the firm each quarter is shown below the box under the appropriate quarter. It is the sum of the actual contributions and the optimal contributions shown above in the column. It represents the potential contribution which was lost due to non-optimal (actual) decision making. For example, in Q15 the difference in the two sequences is the difference between the optimal price of $9.02 in quarter 15 and the actual price of $5.80 and the effects of this mistake in subsequent quarters. Because $9.02 was not changed in Q15, the firm's inventory was sold out at the lower actual price of $5.80. In addition, the firm lost the opportunity to sell at a higher price of $9.60 in the subsequent quarters which accounts for the shift to $7.49 for the optimal sequence once the decision to set the actual price at $5.80 was made.

The analysis is identical for both markets and proceeds from quarter to quarter finding the optimal sequence of prices for the remaining quarters and the associated potential contributions. Subtraction of the summed contribution determines the dollar loss due to non-optimal (actual) decision making for any quarter. The ratio of potential to actual contribution are the quality indices reported in Table .

In summary, the dynamic analysis determines quite accurately the loss due to non-optimal decision making for each quarter by considering the future impact of present decisions. All things considered, this analysis provides reasonable estimates for determining quality indices.

5.2.1 Quality Indices

The quality indices for every firm for each quarter were determined by the procedure. The results are shown in Table 5.2.

TABLE 5.2

Quality Indices

Quality Indices for Non-Aided Decision Making

Domestic Market - Control Condition

Quarter	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
12	0.985	0.974	0.989	0.981	0.988	0.970
13	0.989	0.961	0.997	0.992	0.976	0.988
14	0.925	0.890	0.918	0.919	0.936	0.956
15	0.580	0.617	0.603	0.623	0.613	0.521
16	0.855	0.807	0.971	0.817	0.820	0.870
17	0.937	0.932	0.947	0.950	0.912	0.940
18	0.981	0.939	0.853	0.943	0.958	0.872
19	0.935	1.000	0.732	0.680	1.000	0.792

Quality Indices for Aided Decision Making

Foreign Market - Experimental Condition

Quarter	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
12	0.748	0.742	0.706	0.726	0.759	0.769
13	0.791	0.819	0.795	0.809	0.798	0.761
14	0.937	0.954	0.970	0.945	0.943	0.975
15	0.876	0.920	0.995	0.981	0.971	0.643
16	0.988	0.850	1.000	1.000	0.959	0.978
17	0.994	0.992	1.000	1.000	0.981	1.000
18	0.993	0.961	1.000	1.000	0.986	1.000
19	0.978	0.990	1.000	1.000	0.910	1.000

5.3 Implications for Procedural Validity

This section discusses the issues related to procedural validity. The purpose here is to explore factors which have the potential to influence the quality of the measurements and, therefore, jeopardize procedural validity. Procedural validity concerns the quality of the measures and procedures used in the study. Measures, in this case, are quality indices and relate to the analytical procedures. These procedures determine the reliability of the measurements. This section is divided into two parts; (1) issues related to measures, and (2) issues related to procedures. Issues related to methods are discussed. The relevancy and reliability of the measures is discussed before the reasonableness of the procedure for finding quality indices is evaluated.

5.3.1 Issues Related to Measures

There is consensus in the literature,(20),(47), (87) that validity requires measures be relevant and reliable. These criteria are used to structure the following discussion.

Relevance

Measures must be pertinent to the experiment. For this experiment, this implies that decision quality should be measured in terms directly related to the goals of each firm. Moreover, the measures should reflect how decision making effectiveness might be measured in the real world. It seems reasonable, therefore, to measure the quality of decision making by its effects on the profitability of the firm. This recognizes the interrelationship of marketing decision and profits and is a reflection of the goals set by the firms in the game.

Table5.2 shows the importance of each goal to the firm.

TABLE 5.2

WEIGHTING OF FIRM GOALS

	Market Share (1)	Change in Net Worth (2)	Earning/ Share (3)	Return on Equity (4)	Market Value of Firm (5)
Firm 1	1	3	5	4	2
Firm 2	3	1	2	4	5
Firm 3	2	1	5	3	4
Firm 4	1	2	4	5	3
Firm 5	1	2	5	3	4
Firm 6	1	2	3	4	5

The table shows that most firms emphasized profit related goals. The firms realized that goals 2 to 5 were directly related to profitability, because they knew how goal attainment was evaluated by the Game Administrator.

Firms were required to weight each goal on the Firm Goal Form shown in Appendix H. These goal weights were used to evaluate each firm's performance in the game. Actual rank in the Game with respect to these goals was multiplied by goal weights. These products were summed for each firm to create an index of performance Total points represented by the index determines relative rank among the six firms.

The important question is how these goals influenced firms. In other words, to what extent did profit goals guide decision making strategy of each firm? Evidence is shown in Figures 5.4 to 5.6 . Goals clearly served as objectives for the firms as evidenced by the questionnaire and interview data shown below.

(Questionnaire, item)

Did the firm's goals which you submitted to the game administrator guide your decision making?

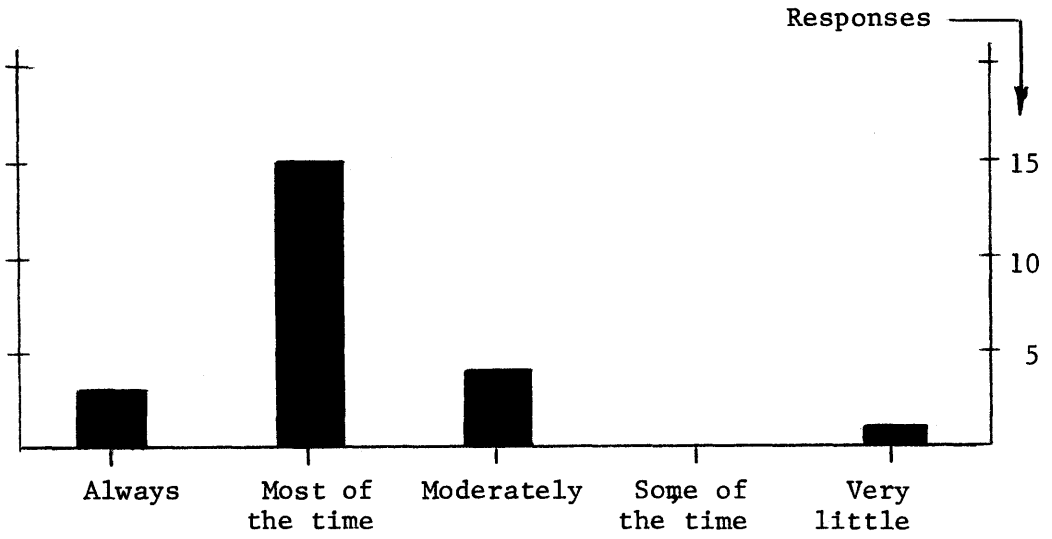


Figure 5.4 Influence of goals on decisions

(Questionnaire, item)

Was the goal conflict among team members, if it existed, detrimental to your firm? Yes __ or No __? Did it interfere with attainment of firm goals? Yes __ or No __?

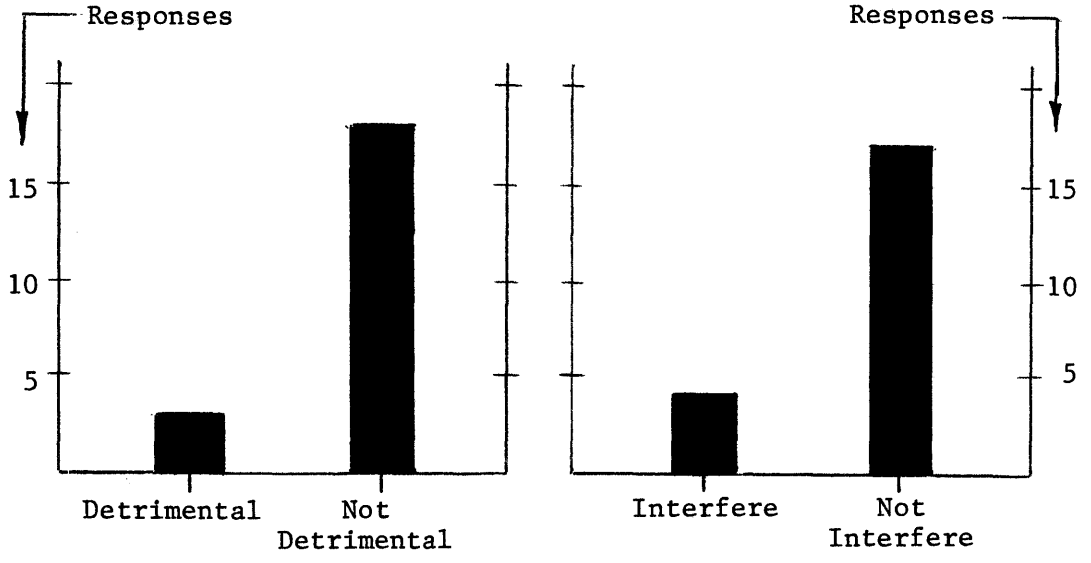


Figure 5.5 Influence of goal conflict

Interview data confirmed these responses to the questionnaire. Some conflict was considered normal but not detrimental to the firms nor did it interfere with goal attainment. The concensus was that any goal conflicts reflected healthy differences of opinion much like what the decision makers experienced in the real world.

To this point, it has been shown that (1) goals relate directly to profitability and (2) goals guided the firm's decision making and (3) any conflict which existed did not have a detrimental effect or interfere in any substantial way with goal attainment.

Two important questions remain: (1) did firms attempt to maximize marketing profits and, if it is clear that they did, (2) did firms attempt to maximize profits on a quarterly basis or over some longer decision horizon? Figures and provide data related to these questions.

(Questionnaire, item)
If you had perfect knowledge and information, would your primary goal have been profit maximization: Yes or No ? If yes, would the primary approach have been to maximize marketing profits: Yes or No . If no, what would you have done?

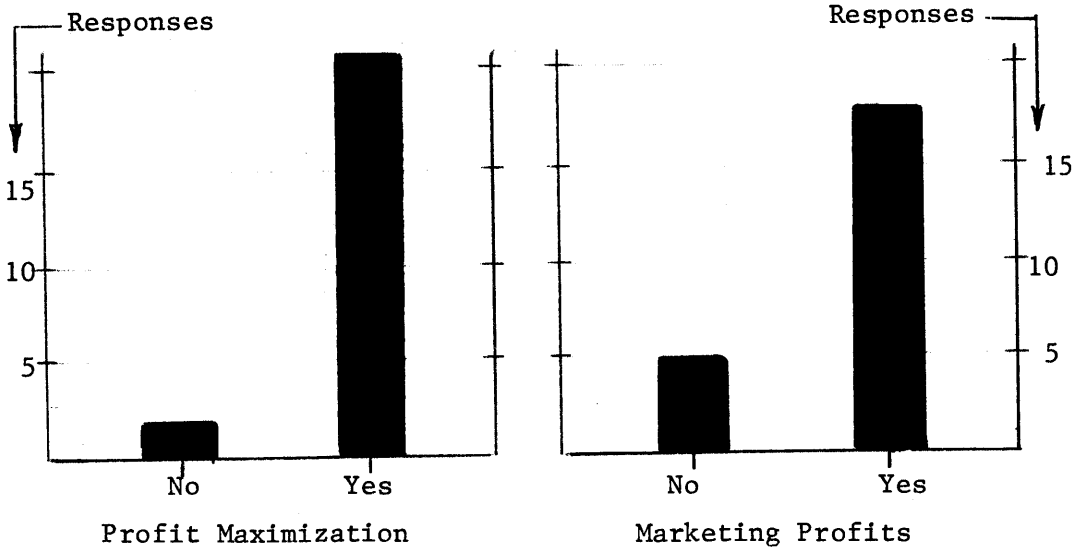


Figure 5.6 Primary goals

Three of the five "no" responses to the last question commented on their reasons.

> "the marketing decisions were certainly important but the capacity decisions are more important - we missed the timing on expansion."
> "I believe the production decisions were more important - maybe because my background is in this area - what I wanted to do was run the plant at maximum efficiency."
> "The financial decisions were my main concern. I did little in the marketing area."

(Questionnaire, item)
Over what number of quarters did you realistically try to maximize the results of your marketing decisions?

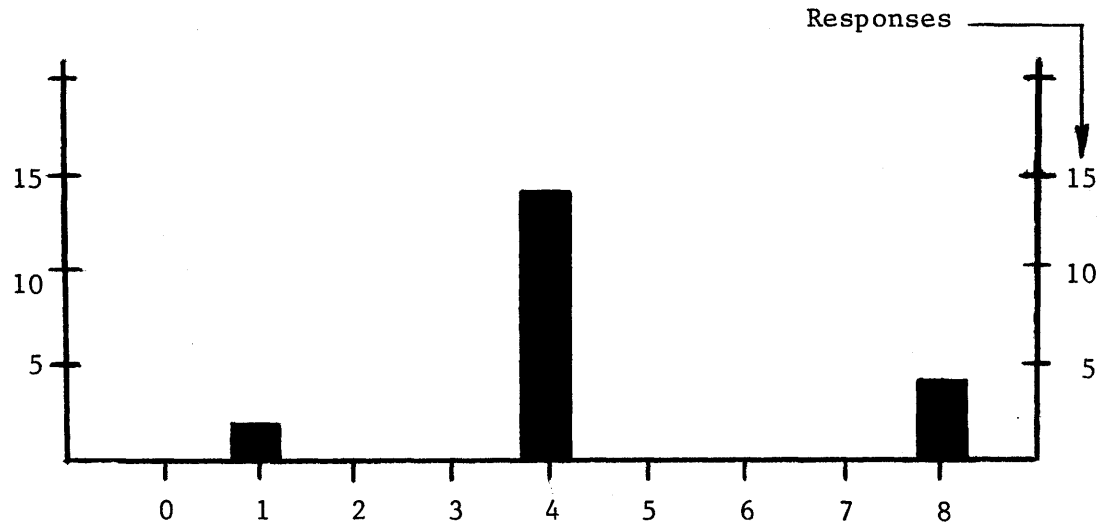


Figure 5.7 Marketing Decision Horizons

All of this data suggests that the primary goal of the firm was to maximize marketing profits, if possible, over a decision horizon that averaged four quarters since the responses to the last question were evenly distributed among firms.

Reliability

The reliability of measurement means that values found for a certain measure recurs in repeated measurements under the same circumstances. Kerlinger (59) suggests that a measurement is highly reliable if replication produces the same or similar results. Reliability of measures in the game is related to actual results and to the analytical procedures used to derive the standards of comparison. Therefore, the reliability of the measures has two components which must be considered - the quality of actual results and the quality of potential results.

The quality or accuracy of actual results is not open to question. The Game had been used previously and the accuracy of reported results verified on a number of occasions. In addition, before the game was run, all input data was checked by the Game Administrator and his assistants, as was the output returned to the firms. The researcher also reran the entire eight quarters of play for the experiment on a different machine (larger word size) and computed various critical results by hand. In all these tests no error in actual results was detected.

The quality of potential results rests on the analytical procedures. Due to the complexity and the number of relevant issues, the procedures are discussed in detail in the next section, which demonstrates that quality of potential results is high, judged by any reasonable set of criteria. Moreover, these results are objective and quite accurate, as repeated checks have indicated. Therefore, measurements of quality indices can be considered highly reliable.

The reliability of measures also relates to the level of measurement attained. Siegel (102) identifies four levels of measurement: nominal, ordinal, interval and ratio. Each is related to the appropriate choice of the statistical test used in the study. An interval level of measurement for the quality indices is obtained by the analytical procedures.

5.3.2 Issues Related to Analytical Procedures

The analytical procedures are the basis of measurement. They provide the standards of potential profitability for each firm each quarter which are used as the denominators of the quality indices. Parsons (82) and Mester and Rabideau (67) have identified three criteria associated with analytical procedures that are particularly important in man/machine research: applicability, reasonableness and reliability of the procedures. These criteria are used to structure this discussion.

Applicability

Applicability relates to the appropriateness of a specific technique for achieving useful results. The usefulness of results must be judged in light of the needs of the study. The research required the determination of the potential profits each firm could have realized in each quarter in the Foreign and Domestic Market. Potential profits were the denominators of the quality indices and, therefore, required sufficient accuracy to allow meaningful comparisons between firms.

To determine potential profits requires an appropriate analytical procedure The choice centers on the tradeoff between the power of the technique and the realism it could handle. Certainly, optimizing models are preferred if their use is possible. The requirements for using optimizing models are recognized by Emery (40):

> "It must be possible to duplicate the real world in mathematical form with sufficient accuracy that results from the model to make sense and there must be available a computationally feasible procedure for finding optimal solutions."

The use of a formal optimizing model was not feasible for finding profit potentials. To have done so would have required many compromises and, therefore, results would have been unrealistic.

The problem involved finding a series of interdependent integer decisions for a game world characterized by discontinuities in non-linear relationship, high uncertainty with respect to various estimates and essentially an infinite number of feasible solutions. Several formal techniques were reviewed: linear and non-linear programming, integer programming and dynamic programming. These efforts showed that to reduce the problem to a representation for which optimizing techniques were feasible required compromises which would have made the results rather meaningless. It was clear that accurate representation of the situations facing each firm was mandatory for obtaining useful results.

Fortunately, the problem was amenable to a search procedure without having to oversimplify the unique situation facing each firm in the complex decision environment. Search occurred over the surface representing the unique conditions created by the firm and its competitors. A measure of effectiveness that accounted for all of the firms' decision variables was used to guide the search. The procedure provided good estimates of the potential profits that firms could have achieved had their decisions been optimal or near-optimal for the complex situations facing firms each quarter.

Reasonableness

The reasonableness of the estimates for potential profits relate to the measure of effectiveness, the procedures and the problem representation. As noted, the procedures did not require simplifying the problem but certain features of the analyses deserve further consideration.

The measure of effectiveness used to guide search was:

$$\sum_{q}^{q+4} P_q = \sum_{q}^{q+4} ((p_q - m) * s_q - c_1 * a_q - c_2 * r_q - c_3 * i_q)$$

This expression was used to evaluate actual and potential profits for both the Foreign and Domestic Markets by searching over the price-inventory surface assuming the advertising and research

and development expenditures were given.

The price-inventory space was searched because price was the primary determinant of sales in each quarter. Its effects were immediate rather than smoothed, as were the advertising and R&D effects. Moreover, advertising and R&D decisions were established by policy and thus tended to change less frequently than price.

Firms identified the pricing decision as the critical decision in marketing strategy each quarter and noted in the interview that advertising and R&D decisions were essentially policy based decisions which tended to remain stable for longer periods of time.

Questionnaire, item)
What was the most important marketing decision your firm made each quarter?

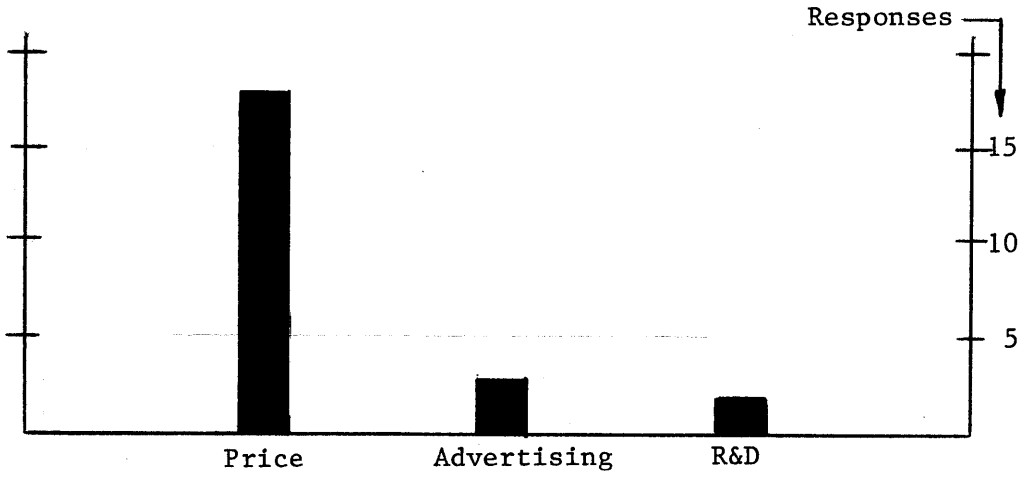


Figure 5. 8 Perceived importance of marketing decisions

Even more important, to have searched advertising and R&D in addition to the price and inventory variables would have made the search unmanageable. A number of sensitivity studies were carried out early in the research which indicated that profit potentials were not significantly affected by confining the search to only the two most critical variables. To use more variables would have increased the search time substantially without a concomitant effect on results.

The measure of effectiveness is based on profitability. Four out of five firm goals directly related to profitability and the weights firms placed on these goals indicated that achieving high profits was the route that all firms adopted in attaining their goals. Moreover, firms attempted to set prices so that profits would be"maximized" in the longer run rather than on a quarterly basis. Therefore, using a measure of effectiveness based on profitability is relevant.

The measure of effectiveness was used to find price-inventory decisions which achieved the highest potential profits over a four quarter decision horizon. Firms implicitly adopted a similar decision horizon because substantial seasonal peaks occurred every four quarters. The firms stated in the questionnaire that their goal was to look four quarters ahead, on the average.

(Questionnaire, item)

How many quarters ahead do you feel that your firm should have looked in evaluating the effets of each quarter's decisions?

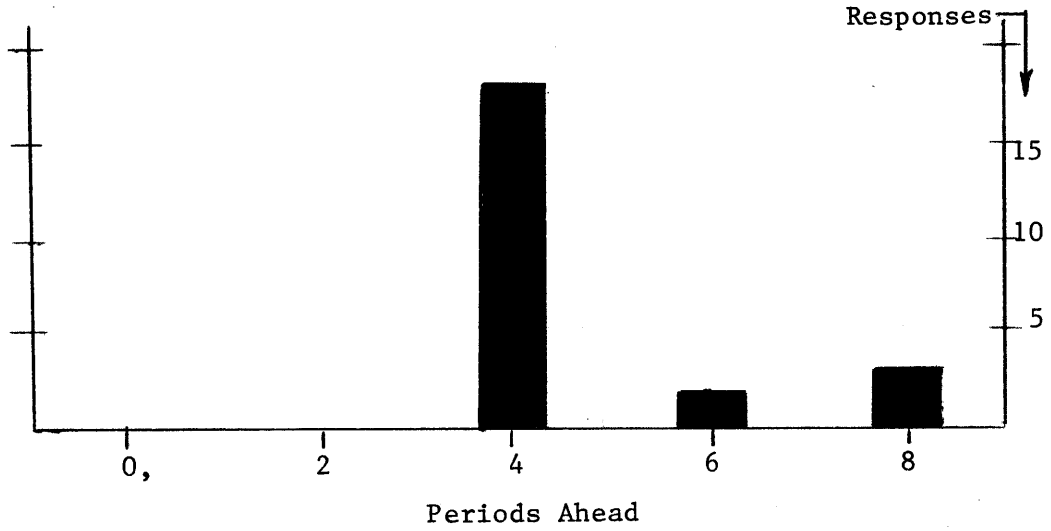


Figure 5. 9 Decision Horizons

The console trace and responses in the interview confirm that the actual decision horizons adopted were shorter in some cases and in addition, decision horizons in the Foreign Market were greater than their counterparts in the Domestic Market.

The effects of different decision horizons were studied by the researcher. These studies were based on one, two, three, four, five, six and eight quarter decision horizons. Decision horizons greater than four quarters clearly required excessive computation and unwarranted assumptions for ending conditions.

The one quarter decision horizon was helpful in that it provided a static analysis. Two and three quarter horizons were not long enough to recognize the seasonality in the markets. Therefore, a four quarter decision horizon seems the better choice given the seasonality of the environment, the actions of the firms and the increased search required if longer horizons were adopted.

The experiment formally ended in quarter 19; actual data beyond this point is not available. To maintain a consistent four quarter decision horizon, firms were asked during the interview to develop a plan for three succeeding quarters. Results were recorded and used as the basis of estimating effects in the last quarters. Prior work had shown that this alternative was preferable to using shorter planning horizons for attributing potential profitability to quarters 17, 18, and 19. This procedure may understate potential profits and thus provides conservative estimates of quality indices for the later quarters.

The effects of previous decision in any quarter determines what is feasible in the next quarter. Therefore, prior decisions determine the "state of the world" at the beginning of the decision sequence and are taken as a given for purposes of analysis. All firms had to do this in the game.

This assumption is needed because past decisions effect future results in the game. For example, given a price of $7.00 in period t would result in a quadratic decrease in repeat customers in period t. If the price in period t - 1 had been $8.00, the same percentage increase in price over the $8.00 base would result in the same loss of repeat customers. Similar effects occur for both advertising and R&D. This is the main reason why the optimal sequences of decisions in the dynamic analysis change from quarter to quarter.

The method of determining potential profit for each quarter is particularly important. Actual profits were determined for each quarter by substituting the real price, advertising, R&D, sales and inventory into the expression to measure actual profitability. Determining potential profitability for any quarter was more complicated. The sequence of four price-inventory decisions that maximized the contribution measure over the decision horizon was found relative to each quarter by taking the previous quarters conditions as a starting point. Then the

summed potential profitability relative to a quarter was compared to the equivalent potential profitability of the succeeding quarter and the difference attributed to the specific quarter under consideration. Since both sequences of decision are optimal with respect to the starting quarter, the difference represents the potential profits for that quarter.

The researcher assumed that the competitors' decisions regarding price, advertising, R&D and inventory were known rather than use the estimates supplied by firms. In the game, each firm estimated for each quarter each of these decision variables for its competitors. The average percentage error was small; it varied by firm but was well below eight percent which was not enough to effect results. By using the actual decisions rather than the estimates, the data bases supporting the interactive search procedures were cut by four fold and estimates of potential profitability were more consistent.

Certain parameter (C_i) values were required to use the measure of effectiveness for both the Foreign and Domestic Market.

C_1 (Advertising multiplier)= 1 for both markets.

This has the effect of charging advertising expenditure against the period in which they are incurred. In the game the effects of advertising and R&D are smoothed in such a way that there is substantial effects of a present expenditure on future periods. However, in the reports that firms received both advertising and R&D expenditures were recorded as expenses for the period in which the decision was made. Therefore, this procedure was adopted even though the results of advertising and R&D expenditures are, in a sense, a capital investment.

C_2 (R&D multiplier)= 1 for Domestic Market
0 for Foreign Market

This has the effect of charging all R&D expenditures against the domestic branch of the company as was done in the game.

Because R&D expenditures determine the product quality in both markets, this introduces very slight inaccuracies in each analysis. These inaccuracies are not significant enough to justify the substantial increase in search time and money which would be required to eliminate this slight inaccuracy.

C_3 (Inventory carrying cost)= \$0.10 per unit with a doubling of this cost in excess of 375,000 in the Domestic Market and 35,000 in the Foreign Market. These were the actual values and breakpoints used in the game; therefore, they are appropriate parameters to use in the contribution measure.

Reliability

Procedural reliability relates to the ability to duplicate results in repeated application of the procedure. The procedures for determining profit potentials are more objective than procedures used in some experiments. Meister and Rabideau ( ) have noted:

> "...objectivity and subjectivity represent a continuum, not a diochotomy...One objection to using subjective judgments as measures is that they tend to be unreliable...Lack of reliability threatens internal validity."

The procedures used here are more reliable because the measure of effectiveness was quantifiable and, therefore, did not require subject judgment to evaluate whether one series of decision was better than another. It was possible to determine profit potentials with a high degree of confidence.

Finding the 96 profit potentials required 14 months. Ten months were used to find the 96 sequences while 4 months were used for verification and accuracy checking. The interactive search procedure was directed from the console by the experimenter. Over 18,000 sequences of decisions were tested before this phase of the experimentation was completed.

Search was not ended until the experimenter was confident that only insignificant increase in potential profits might be found for any of the 96 solutions. The judgment was made using a number of criteria developed in living with the problem for over a year. During that time, the experimenter became intimately familiar with translating different combinations of conditions into decisions which would realize potential profits. As a check in 12 trials beyond a point where continued search did not seem feasible, additional work increased profits less than 1/50 of 1 percent.

On the whole, the search procedures produced sufficiently precise standards of comparison. Because the technique did not require any appreciable simplification; potential profits are directly comparable to actual profits. The procedures were applied consistently in both markets so that no bias was introduced. Since exhaustive search was prohibitive, results can not be proven optimal; this accuracy, however, is more than adequate for purposes of this study.

5.4 Chapter Summary

This chapter documents the measures of performance and methods of analyses. Implication for procedural validity are examined to determie the quality of results. The objectives of performance measurement and the actual measures used in this study are described. The procedure for measuring decision quality and the quality indices for aided and non-aided decision making are derived.

As the chapter indicates the problems involved in measuring the quality of non-structured decision making are formidable. To the experimenter's knowledge, it has never been attempted for decision making situations of this complexity. This chapter outlines the rationale and procedures and problems that encountered in measuring the quality of executive decision making.

The quality of the measures and procedures determines the procedural validity are discussed. Questionnaire data demonstrates the relevance and reliability of the measures. The applicability and reasonableness contribute to procedural reliability of the study.

It is fair to conclude that the procedures used here produced measures of decision quality - the quality indices - which are accurate and reliable. The verifability of the procedure contributes to the objectivity of the measures. This is in sharp contrast to the subjective measure used in prior studies of simple decision making.

CHAPTER 6

RESULTS OF THE EXPERIMENT

Each of the preceeding chapters has laid the groundwork for this chapter. The credibility of the results of an experimental study is based on the quality, care and thoroughness with which the entire study was conceived, designed and conducted. Prior chapters have established the quality of the study; unusual features contribute to the exceptionally high external, internal and procedural validity. Consequently, the results of the study reported in this chapter can be viewed with a high degree of confidence.

This chapter presents the results of the study. The organization and contents of the chapter are shown in Figure 6.1.

Figure 6.1 Contents of Chapter 6

The first section reviews hypotheses and discusses the reasons for using nonparametric statistical tests. Later sections present the data and hypotheses tests. Information concerning the use of decision aids is related to each of the hypotheses in this study. The final section draws conclusions for the entire study.

6.1 Review

This section reviews the hypotheses and the statistical tests that are used in the study. Two types of nonparametric tests are used. Their appropriateness is determined by the design of the experiment and the level of measurement achieved. The hypotheses are reviewed first because they indicate the comparative nature of the study and the need for tests for related samples.

6.1.1 Hypotheses

The hypotheses presented in Chapter 2 are reviews prior to the formal tests presented in this chapter.

Effectiveness Hypothesis

The effectiveness hypotheses are:

> For non-structured managerial tasks, DSS-aided decision making will result in decisions whose:
>
> (H1) - quality is higher
>
> (H2) - quality is more consistent
>
> (H3) - quality has a higher rate of improvement
>
> than non-aided decision making in similar, controlled circumstances.

Each of these hypotheses relates to the level or pattern of decision quality represented by the table of quality indices found in Chapter 5.

Efficiency Hypotheses

The efficiency hypotheses are:

> For non-structured managerial tasks, DSS-aided decision making will result in:
>
> (H4) - lower resource use
>
> (H5) - shorter resolution time
>
> than non-aided decision making in similar, controlled circumstances.

These hypotheses relate to different aspects of decision time - contact time and elapsed time. Resource use is a measure of the man-hours used in DSS-aided and non-aided decision making and, therefore, represents contact time. Resolution time is a measure of the elapsed time from the beginning of the decision period to the final choice of an alternative.

6.1.2 Statistical Tests

The use of statistical tests is related to the level of measurement achieved and the design of the experiment. An interval level of measurement for quality indices was obtained by the analytical procedures. Interval data allows the researcher to use either parametric or nonparametric statistical tests. An ordinal level of measurment was achieved for man-hours and resolution time. This requires the use of nonparametric tests.

Certain assumptions must be met to use parametric tests. The requirements for the use of parametric tests are:

(1) Observation be independent,

(2) Observation be drawn from normally distributed population, and

(3) Population must have the same variances.

The meaningfulness of the result of a parametric test depends hevily on the validity of these assumptions. These requirements are highly restrictive and cannot be assumed with any confidence in this study. Therefore, nonparametric tests are used for testing hypothesis. Siegel (102) claims

> "A nonparametric statistical test is a test whose model does not specify conditions about the parameters of the population from which the sample was drawn. Certain assumptions are associated with most nonparametric statistical tests, but these assumptions are fewer and much weaker than those associated with parametric tests."

Nonparametric tests are useful when the assumption and requirements of parametric tests are unrealistic for the data, which is the case in this experiment. Because nonparametric tests require fewer assumptions, external validity and generality of results are increased.

The nonparametrical statistical tests used in this study are the appropriate tests for two related samples involving means, variances and differences for aided and non-aided decision making. The use of these tests is noted in Sellitz (98):

> "The two-sample statistical tests are used when the researcher wishes to establish whether two treatments are different, or whether one treatment is better than another...In each case, the group which has undergone the treatment is compared with one which has not, or which has undergone a different treatment."

Comparative tests for two related samples are appropriate for data involving subjects that act as their own controls or for matched-pairs experimentation because these tests do not assume that all pairs are drawn from the same population.

The nonparametric tests used in this study are the:

(1) Wilcoxon Matched-Pairs Signed Rank Test

(2) The Sign Test

Complete documentation is given in Siegel (102).

6.2 Tests for Effectiveness Hypotheses

Each hypothesis will be tested using the Wilcoxon Matched-Pairs Signed-Rank Test. This nonparametrical test for related samples is the appropriate test to use because the quality indices can be ranked on an ordinal scale both within and between teams; and the parent population is assumed to be non-normal which precludes parametrical tests. The procedure for using the Wilcoxon test is given in Siegel (102). This method is fairly standardized and adapts nicely to the work that follows.

The appropriate data for these hypotheses are the quality indices shown in Table 6.1. The table shows the quality indices for each firm for both the non-aided and aided decision making conditions. The table indicates that there were six matched-pairs involved in the experiment - Firms 1 to 6. Each group was involved in eight replications of the experiment; that is each quarter amounted to a replication of the experiment under different sets of conditions. Therefore, each quality index represents a "raw" data point.

Summary statistics are shown in Table 6.2. These statistics are based on the quality indices for quarters 13 to 19 because the Marketing Decision System was not available for use in quarter 12. Each set of statistics are used in the three tests for effectiveness hypothesis.

TABLE 6.1

Quality Indices

Quality Indices for Non-Aided Decision Making

Domestic Market - Control Condition

Quarter	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
12	0.985	0.974	0.989	0.981	0.988	0.970
13	0.989	0.961	0.997	0.992	0.976	0.988
14	0.925	0.890	0.918	0.919	0.936	0.956
15	0.580	0.617	0.603	0.623	0.613	0.521
16	0.855	0.807	0.971	0.817	0.820	0.870
17	0.937	0.932	0.947	0.950	0.912	0.940
18	0.981	0.939	0.853	0.943	0.958	0.872
19	0.935	1.000	0.732	0.680	1.000	0.792

Quality Indices for Aided Decision Making

Foreign Market - Experimental Condition

Quarter	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
12	0.748	0.742	0.706	0.726	0.759	0.769
13	0.791	0.819	0.795	0.809	0.798	0.761
14	0.937	0.954	0.970	0.945	0.943	0.975
15	0.876	0.920	0.995	0.981	0.971	0.643
16	0.988	0.850	1.000	1.000	0.959	0.978
17	0.994	0.992	1.000	1.000	0.981	1.000
18	0.993	0.961	1.000	1.000	0.986	1.000
19	0.978	0.990	1.000	1.000	0.910	1.000

TABLE 6.2

Summary Statistics for Quality Indices

Statistics for Non-Aided Decision Making

Domestic Market - Control Condition

Firm	Mean	Median	Variance	Std. Dev.
1	0.886	0.935	0.0201	0.142
2	0.878	0.932	0.0170	0.130
3	0.860	0.918	0.0208	0.144
4	0.847	0.919	0.0208	0.144
5	0.888	0.936	0.0181	0.134
6	0.846	0.872	0.0251	0.159

Statistics for Aided Decision Making

Foreign Market - Experimental Condition

Firm	Mean	Median	Variance	Std. Dev.
1	0.936	0.937	0.00595	0.0772
2	0.927	0.954	0.00462	0.0680
3	0.966	1.000	0.00579	0.0761
4	0.962	1.000	0.00497	0.0705
5	0.936	0.959	0.00434	0.0659
6	0.908	0.978	0.00211	0.1452

6.2.1 Decision Quality Hypothesis

(H1) - For non-structured managerial tasks, DSS-aided decision making will result in decisions whose quality is higher than non-aided decision making in similar, controlled circumstances.

This hypothesis can be tested by establishing the null hypothesis:

H_n: The decision quality for the experimental condition does not differ from the decision quality for the control condition.

and the alternative hypothesis:

H_a: The decision quality for the experimental condition is better than the decision quality for the control condition.

The appropriate data for this test are either the means or the medians of the quality indices for each firm for both the control and experimental conditions. The use of means to measure average quality for each team is more appropriate and, in fact, is a better measure of decision quality because it adequately captures the range of quality for a variety of circumstances that existed during the experiment.

The data is shown in Table 6.3. The means for each firm are identical to those shown in Table 6.2 These means represent the average quality for each firm for DSS-aided and non-aided decision making from quarter 13 to 19.

TABLE 6.3

Index of Mean Quality

Quarters 13 - 19

For Each Firm

Firm	Index of Mean Quality for DSS-Aided Decision Making	Index of Mean Quality for Non-Aided Decision Making
Firm 1	0.936	0.886
Firm 2	0.927	0.878
Firm 3	0.966	0.860
Firm 4	0.962	0.847
Firm 5	0.936	0.888
Firm 6	0.908	0.846

Result:

The index of mean quality for DSS-aided decision making is higher for each firm than the comparative index for non-aided decision making. The Wilcoxon matched-pairs, signed-rank test accepts the alternative hypothesis at least at the 0.025 level. This result implies that quality for DSS-aided decision making is significantly better than the quality for non-aided decision making.

6.2.2 Test of Decision Consistency

(H2) - For non-structured managerial tasks, DSS-aided decision making will result in decisions whose quality is more consistent than non-aided decision making in similar, controlled circumstances.

This hypothesis can be tested by establishing a null hypothesis:

H_n: The consistency of quality for the experimental condition does not differ from the consistency of quality for the control condition.

and the alternative hypothesis is:

H_a: The consistency of quality is better (shows smaller variations) for the experimental condition than the consistency of quality for the control condition.

To test this hypothesis requires a measure comparing variations in quality. An adequate indicator of the spread of the quality is the variance or standard deviation of each quality indices. Table 6.2 lists the measures for both DSS-aided and non-aided decision making for each firm. The data chosen for this test are the standard deviations shown in Table 6.4. The standard deviations represent this consistency of quality for each firm for DSS-aided and non-aided decision making from quarters 13 to 19.

TABLE 6.4

Standard Deviation of Quality

Quarters 13 - 19

For Each Firm

Firm	Standard Deviation for DSS-Aided Decision Making Quality	Standard Deviation for Non-Aided Decision Making Quality
Firm 1	0.0772	0.142
Firm 2	0.0680	0.130
Firm 3	0.0761	0.144
Firm 4	0.0705	0.144
Firm 5	0.0659	0.134
Firm 6	0.1452	0.159

Result:

The table shows that the standard deviation for each team is smaller in the experimental condition than in the control condition. The Wilcoxon matched-pairs, signed-rank test accept the hypothesis at a level of significane of at least θ.025. This implies that DSS-aided quality is significantly more consistent than non-aided decision quality.

6.2.2 Test of Rate of Decision Quality Improvement

(H3) - For non-structured managerial tasks, DSS-aided decision making will result in decisions whose quality has a higher rate of improvement than non-aided decision making in similar, controlled circumstances.

This hypothesis can be tested by establishing a null hypothesis:

H_n: The rate of improvement for the experimental condition is equal to (or less than - i.e.negative) the rate of improvement for the control condition.

and the alternative hypothesis:

H_a: The rate of improvement for the experimental condition is greater than the rate of improvement for the control condition.

The basic problem in testing this hypothesis stems from the fact that all teams experienced large fluctuations in decision quality. These variations are both increases and decreases in quality over the previous quarters and are much more pronounced in the Domestic Market than in the Foreign Market. This problem can be minimized by using the net rate of change over the game as a measure of change in quality levels for each firm.

To calculate the net rate of change, the first step is to determine quarterly differences in decision quality for each team for every quarter. These differences are given in Table 6.5. A plus indicates an increase in quality over the previous quarter while a minus indicates a reduction in quality over the previous quarter. The magnitude of the signed numbers indicate the size of the increase or reduction in quality relative to the previous quarter.

TABLE 6.5

Changes in Decision Quality

Rate of Change in Decision Quality

Domestic Market - Control Condition

Quarter From-To	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
12 - 13	+0.004	-0.013	+0.008	+0.011	-0.012	+0.018
13 - 14	-0.064	-0.071	-0.079	-0.073	-0.040	-0.032
14 - 15	-0.345	-0.273	-0.315	+0.296	-0.323	-0.435
15 - 16	+0.275	+0.190	+0.368	+0.194	+0.307	+0.349
16 - 17	+0.082	+0.125	-0.024	-0.133	-0.008	+0.070
17 - 18	+0.044	+0.007	-0.094	-0.007	+0.046	-0.068
18 - 19	-0.046	+0.061	-0.121	-0263	+0.042	-0.080

Rate of Change in Decision Quality

Foreign Market - Experimental Condition

Quarter From-To	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
12 - 13	+0.053	+0.047	-0.011	-0.083	+0.039	-0.008
13 - 14	+0.143	+0.135	+0.175	+0.136	+0.145	+0.214
14 - 15	-0.058	-0.034	+0.025	+0.036	+0.028	-0.332
15 - 16	+0.112	-0.070	+0.005	+0.019	-0.012	+0.335
16 - 17	+0.046	+0.142	0.000	0.000	-0.022	+0.022
17 - 18	-0.001	-0.031	0.000	0.000	+0.005	0.000
18 - 19	-0.015	-0.029	0.000	0.000	-0.076	0.000

The signed numbers in Table 6.5 are true rates of change for decision quality over each quarter because they are, in fact, the slope of the decision quality graphs. The net rate of change can then be calculated for each team by determining the algebraic sum of the increases in quality, less all decreases in quality. If this sum is positive, the decision quality would show an increase, but if the sum is negative, the decision quality would show a decrease.

To compare the rates of change in decision quality between the two markets, requires computing the algebraic sum for the net difference score for the Wilcoxon test. This comparison is given in Table 6.6:

TABLE 6.6

Net Rates of Change of Decision Quality

Firm	Net Rate of Change for DSS-Aided Decision Making	Net Rate of Change for Non-Aided Decision Making	Signed Difference
Firm 1	+0.227	-0.054	+0.281
Firm 2	+0.113	+0.039	+0.074
Firm 3	+0.205	-0.245	+0.450
Firm 4	+0.191	-0.327	+0.518
Firm 5	+0.068	+0.024	+0.044
Firm 6	+0.239	-0.196	+0.435

Result:

All of the signed differences are positive. This could only occur if the rate of improvement of decision quality is greater for the experimental condition than for the control condition. The Wilcoxon matched-pairs signed-rank tests reflects this fact by accepting the hypothesis at the 0.025 level. The analysis and hypothesis test suggest that the rate of improvement in decision quality is significantly higher for DSS-aided decision making than for non-aided decision making.

6.3 Tests for Efficiency Hypotheses

Each hypothesis will be tested using the Sign Test. This nonparametrical test for related samples is the appropriate test to use because the data can be ranked on an ordinal scale both within and between teams while the parent population is assumed to be non-normal, thus precluding parametrical tests. The procedure for using the Sign Test is given in Siegel (102). This test adapts nicely to the work that follows.

The appropriate data for these hypotheses are required for man-hours and resultion time making foreign and domestic marketing decisions. Tables 6.7 and 6.8 show the data for each firm for both the non-aided and aided decision making conditions. The tables are set up to show that there were six matched-pairs involved in the experiment. Each group was involved in eight replications of the experiment; that is, each quarter amounted to a replication of the experiment under different sets of conditions. Therefore, each sign represents a "raw" data point.

Summary statistics are shown in Tables 6.7 and 6.8. These statistics are based on data for quarters 13 to 19 because the Marketing Decision System was not available for use in quarter 12.

6.3.1 Resource Use Hypothesis

(H4) - For non-structured managerial tasks, DSS-aided decision making will result in lower resource use than non-aided decision making in similar, controlled circumstances.

This hypothesis can be tested by establishing a null hypothesis:

H_n: The number of man-hours required for Foreign Marketing decisions is equal to the number of man-hours required for Domestic Marketing decisions

and the alternative hypothesis:

H_a: The number of man-hours required for Foreign Marketing decision is less than the number of man-hours required for Domestic Marketing decision.

The data for this test are shown in Table 6.7 These entries are estimates of the man-hours used in making the Domestic and Foreign Marketing decisions. Since an ordinal level of measurement is achieved, the appropriate statistical test is the sign test for related samples. These data can, at best, be only partially ordered. The most important requirement for use of sign test is that it must be possible to rank the two values of each pair with respect to each other. This requirement was met for the data. Thus, the information contained in the estimates is saved by expressing the difference as a sign.

TABLE 6.7

Estimated Man-Hours for Marketing Decisions

Quarter	Firm 1			Firm 2			Firm 3		
	Dom.	For.	Sign	Dom.	For.	Sign.	Dom.	For.	Sign
12	3.7	4.0	-	4.8	3.8	+	3.3	3.0	+
13	2.7	1.2	+	0.5	0.5	=	1.6	2.3	-
14	2.0	1.3	+	0.5	0.5	=	1.3	1.4	-
15	3.5	1.7	+	2.7	1.5	+	2.1	2.0	+
16	1.7	1.2	+	2.0	3.8	-	1.3	1.3	=
17	1.7	1.5	+	1.8	1.6	+	1.3	0.7	+
18	1.0	1.2	-	1.9	1.3	+	1.8	0.7	+
19	1.7	1.0	+	0.6	1.2	-	1.2	0.8	+

Quarter	Firm 4			Firm 5			Firm 6		
	Dom.	For.	Sign	Dom.	For.	Sign	Dom.	For.	Sign
12	3.4	3.1	+	4.0	3.0	+	2.1	1.7	+
13	2.4	1.9	+	3.0	2.3	+	1.2	1.6	-
14	1.8	1.2	+	1.7	2.0	-	1.7	1.3	+
15	2.7	1.3	+	3.0	2.7	+	2.8	2.4	+
16	1.9	1.0	+	2.0	1.2	+	1.7	1.4	+
17	1.6	2.0	-	1.6	1.2	+	1.6	1.0	+
18	1.1	1.4	-	1.3	1.2	+	1.2	1.2	=
19	1.0	0.7	+	1.3	0.9	+	1.0	0.8	+

The signs to the right of each matched-pair indicate:

Sign	Meaning
+	Man-hours required for Domestic Marketing Decisions were greater than those required for Foreign Marketing Decisions
=	Man-hours required in both markets were equal
-	Man-hours required for Domestic Marketing Decisions were less than those required for Foreign Marketing Decisions.

Result:

The data shows a preponderance of plus signs which indicate that in most quarters the number of man-hours devoted to Domestic marketing decision making was greater than the number of man-hours devoted to Foreign marketing decision making. The formal sign test confirms the fact by accepting the hypothesis at the 0.05 level of significane. These results suggest that teams required fewer man-hours to make marketing decisions in the Foreign Market than in the Domestic Market.

6.3.2 Resolution Time

(H5) - For non-structured managerial tasks, DSS-aided decision making will result in shorter resolution time than non-aided decision making in similar, controlled circumstances.

This hypothesis can be tested by establishing a null hypothesis:

H_n: The clock time to final choice for Foreign Marketing decisions is equal to the time required for Domestic Marketing decisions

and the alternative hypothesis:

H_a: The clock time to final choice for Foreign Marketing decision is less than the time required for Domestic Marketing decision

The data for this test are shown in Table 6.8. These entries are estimates of resolution time for the Domestic and Foreign Marketing decisions. The appropriate statistical test is, once again, the sign test for related samples because this data can be only partially ordered.

The signs to the right of each matched-pair indicate:

Sign	Meaning
+	Resolution time for Domestic Marketing decision was greater than Foreign Marketing decisions
=	Resolution time in both markets were equal
-	Resolution time for Domestic Marketing decisions was less than Foreign Marketing decisions.

TABLE 6.8

Resolution Time for Marketing Decisions

Quarter	Firm 1			Firm 2			Firm 3		
	Dom.	For.	Sign.	Dom.	For.	Sign.	Dom.	For.	Sign.
12	3	0	+	0	3	-	2	2	=
13	3	0	+	3	3	=	0	4	-
14	0	3	-	3	3	=	2	2	=
15	2	1	+	2	1	+	4	0	+
16	2	1	+	3	0	+	4	4	=
17	3	3	=	3	0	+	4	0	+
18	3	0	+	3	0	+	4	0	+
19	3	0	+	0	3	-	4	0	+

Quarter	Firm 4			Firm 5			Firm 6		
	Dom.	For.	Sign.	Dom.	For.	Sign.	Dom.	For.	Sign.
12	4	0	+	2	1	+	3	0	+
13	3	1	+	3	0	+	0	3	-
14	2	2	=	3	3	=	0	3	-
15	3	1	+	3	3	=	3	1	+
16	4	0	+	3	0	+	2	1	+
17	2	2	=	3	0	+	3	0	+
18	0	4	-	3	1	+	3	3	+
19	4	0	+	3	0	+	3	0	+

Result:

The data shows a greater number of plus signs. This indicates that Domestic Marketing decisions require more time to resolve. The formal sign test confirms this fact by accepting the hypothesis at the 0.05 level of significance. These results suggest that teams arrive at Foreign marketing decisions faster than in the Domestic Market.

6.4 Decision Aids Use

The Interactive Systems available to each firm were:

MDS - Marketing Decision System

FPS - Financial Planning System

SAS - Statistical Analysis System

MDS could only be used to aid the decision maker in the Foreign Market; its use was prohibited in the Domestic Market. FPS could be used to aid making financial decisions in both markets. SAS could be used to develop models and analyses in either market.

In the true technical sense marketing decision in the Domestic Market was not strictly unaided. Even though FPS and SAS were available, the Domestic Market is considered non-aided in that no true Decision Support System was provided to directly aid non-structured decision making. Specifically, no formal system was available in the Domestic Market in which a decision maker could work directly with the decision variables under his control. In other words, formal models were not provided in SAS; only the capability to perform statistical analyses.

In contrast, MDS was a system in which a formal interactive simulation model was available to evaluate alternative strategies concerning the firm's decision variables and the effects of competitive and economic changes. It dealt directly with the firms marketing decision variables; Price, Advertising, R&D and Inventory for the Foreign Market.

6.4.1 Statistics of Use

The use of each package was measured in the following way. For MDS the number of completed runs were tallied for the Modeler (M) option and the Future (F) option. For FPS the number of completed runs were tallied for the Planner (P) option and the Forward (F) option. The Forward option results are not reported because this feature was used only once. For SAS the number of transformations (T) entered, plots (P) requested and regression (R) runs completed were tallied by team by quarter. Only the regression results are reported in the Table . A dash indicates that the package was not used during the quarter. All firms attempted runs which were not completed due to either computer system failures and/or mistakes made by the firms. In either case runs were aborted; these attempts are not tallied.

MDS was not available for use during quarter 12 due to technical difficulties; therefore, the dash indicates no use - not because firms neglected to use the package but simply because it was not available. MDS was available from Quarter 13 through Quarter 19. Thus, some of the early runs, especially those in Quarter 13 may have been used by the firms to familiarize themselves with MDS operations. Figures 6.2to 6.6 compare the fequency use of these systems. The frequency of use is a rough indicator of the decision makers' need for the particular support package. Given this background it can be seen that firms used both MDS and FPS extensively. In fact, one member of each four-man team spent the majority of the three-hour console session at the terminal. No console session was less than three hours in length and many sessions were extended for the convenience of the teams.

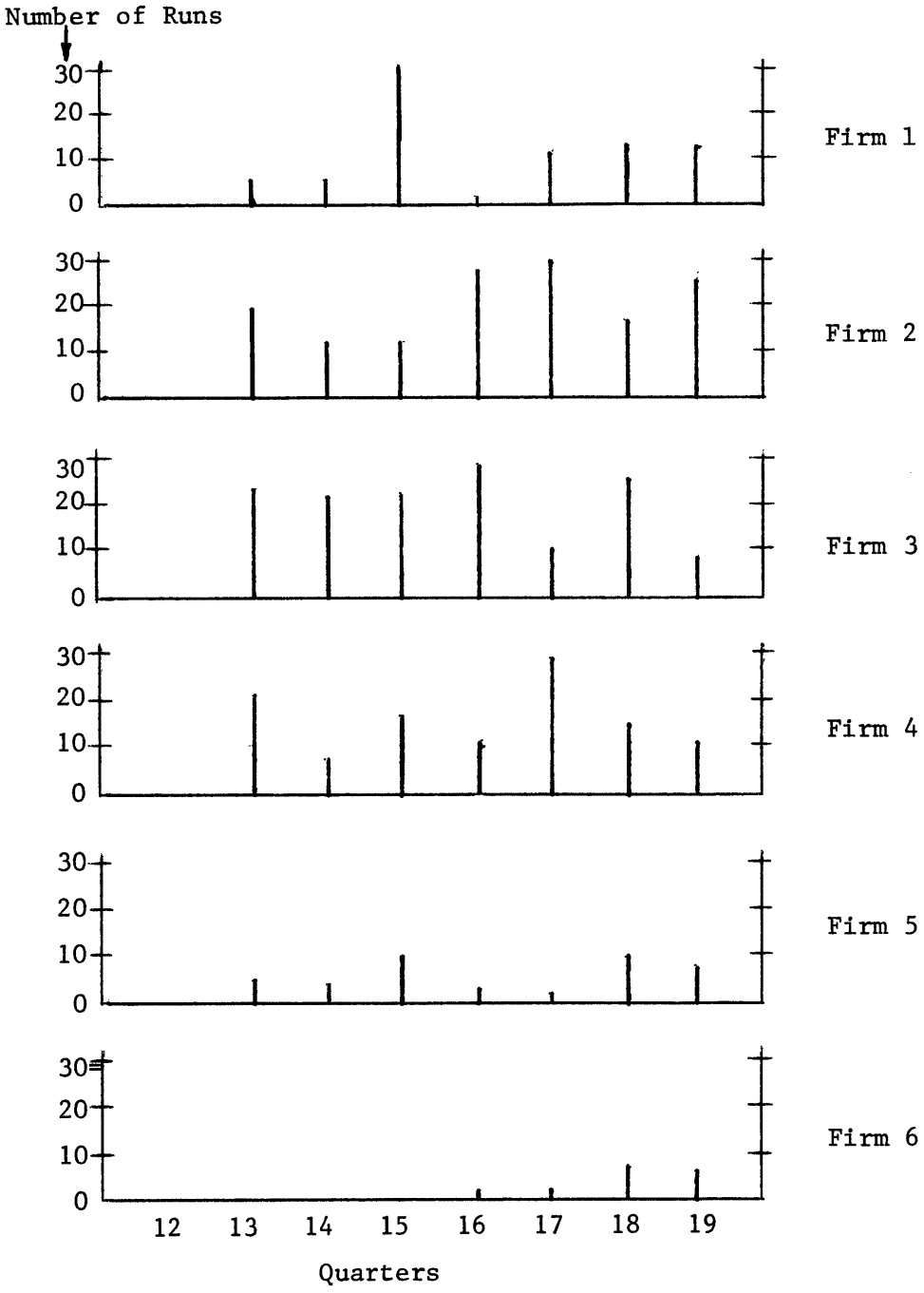


Figure 6.2 Use of Marketing Decision System Total Modeler and Future Runs

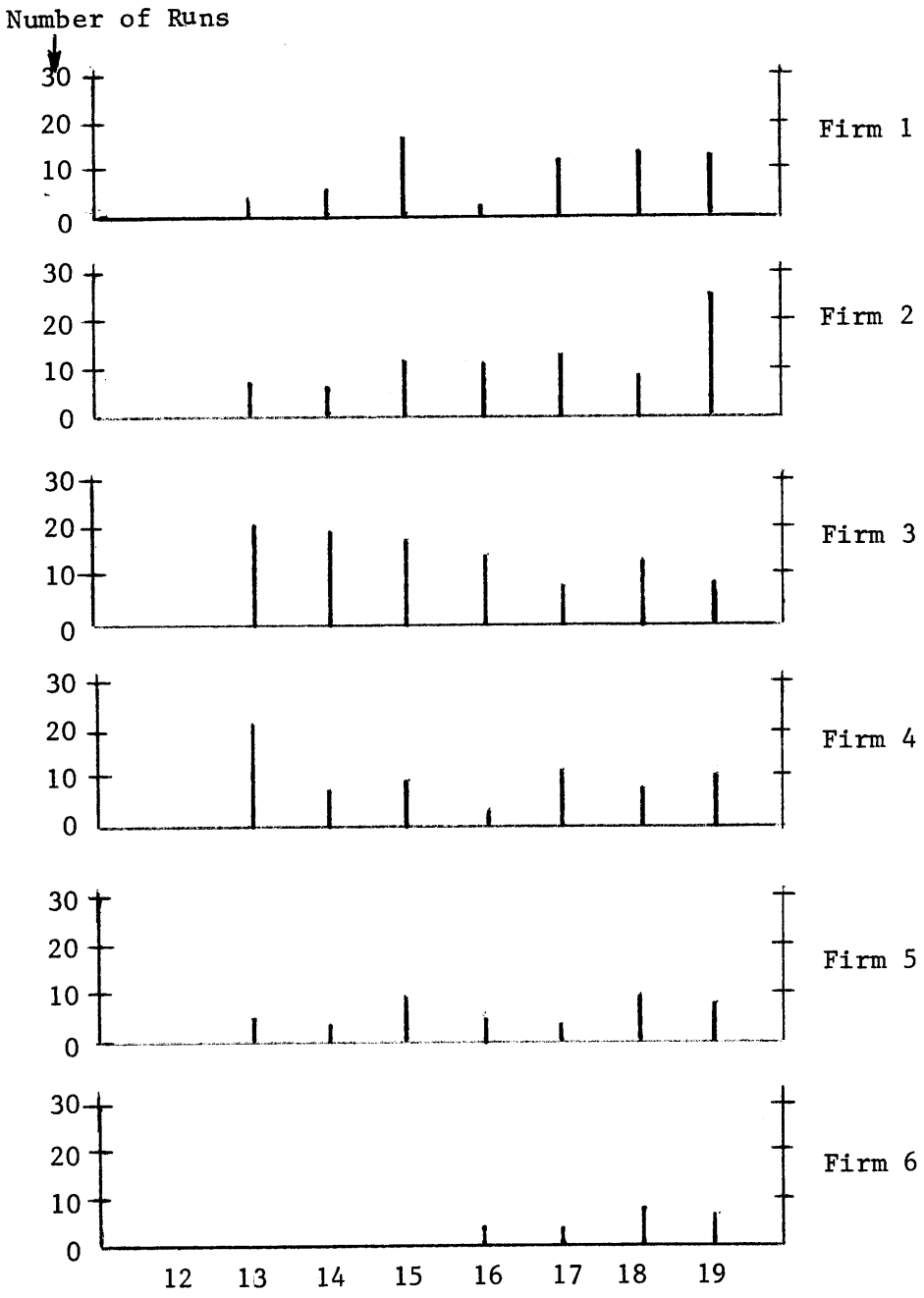


Figure 6.3 Use of Marketing Decision System Modeler Option

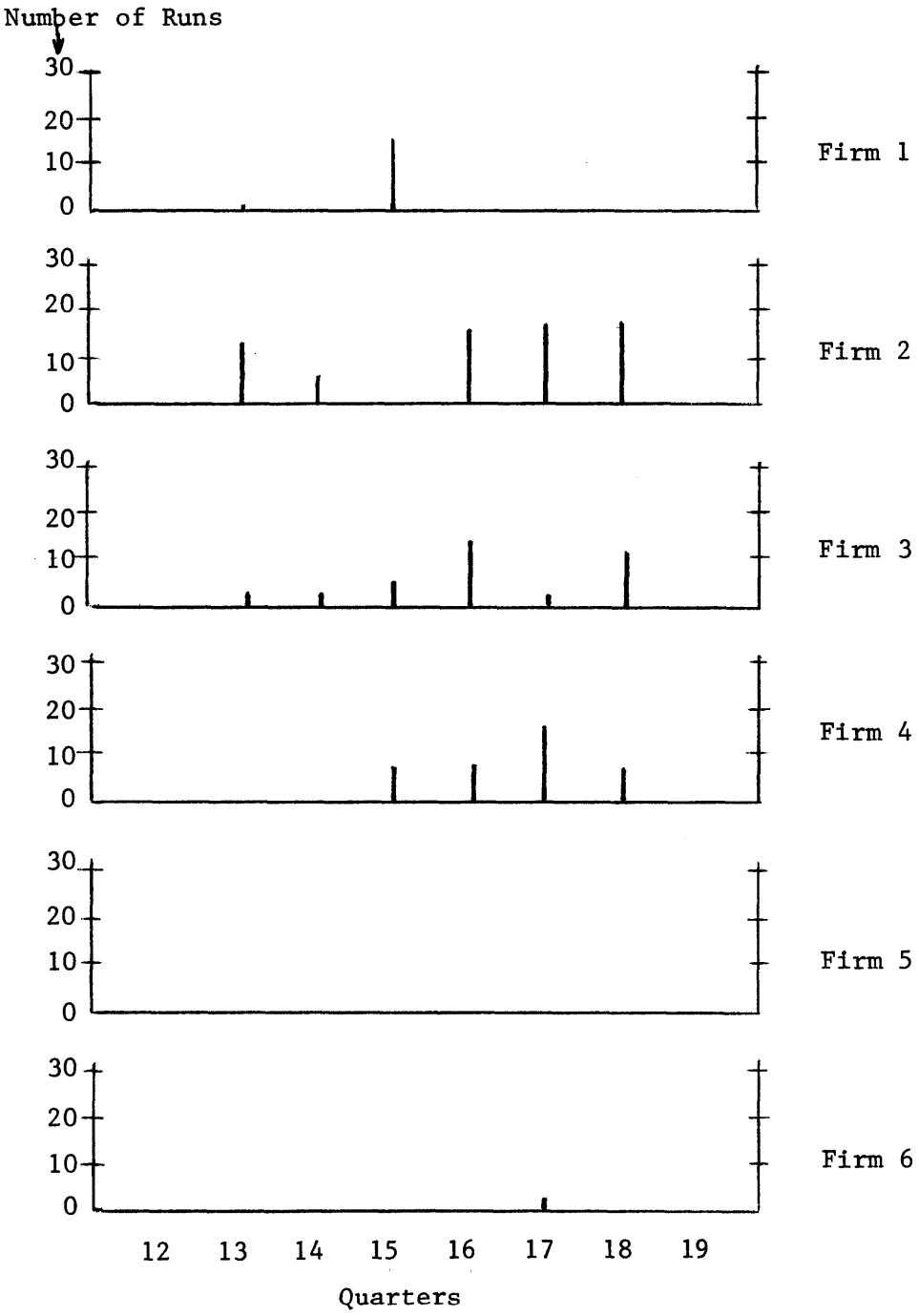


Figure 6.4 Use of Marketing Decision System
Future option

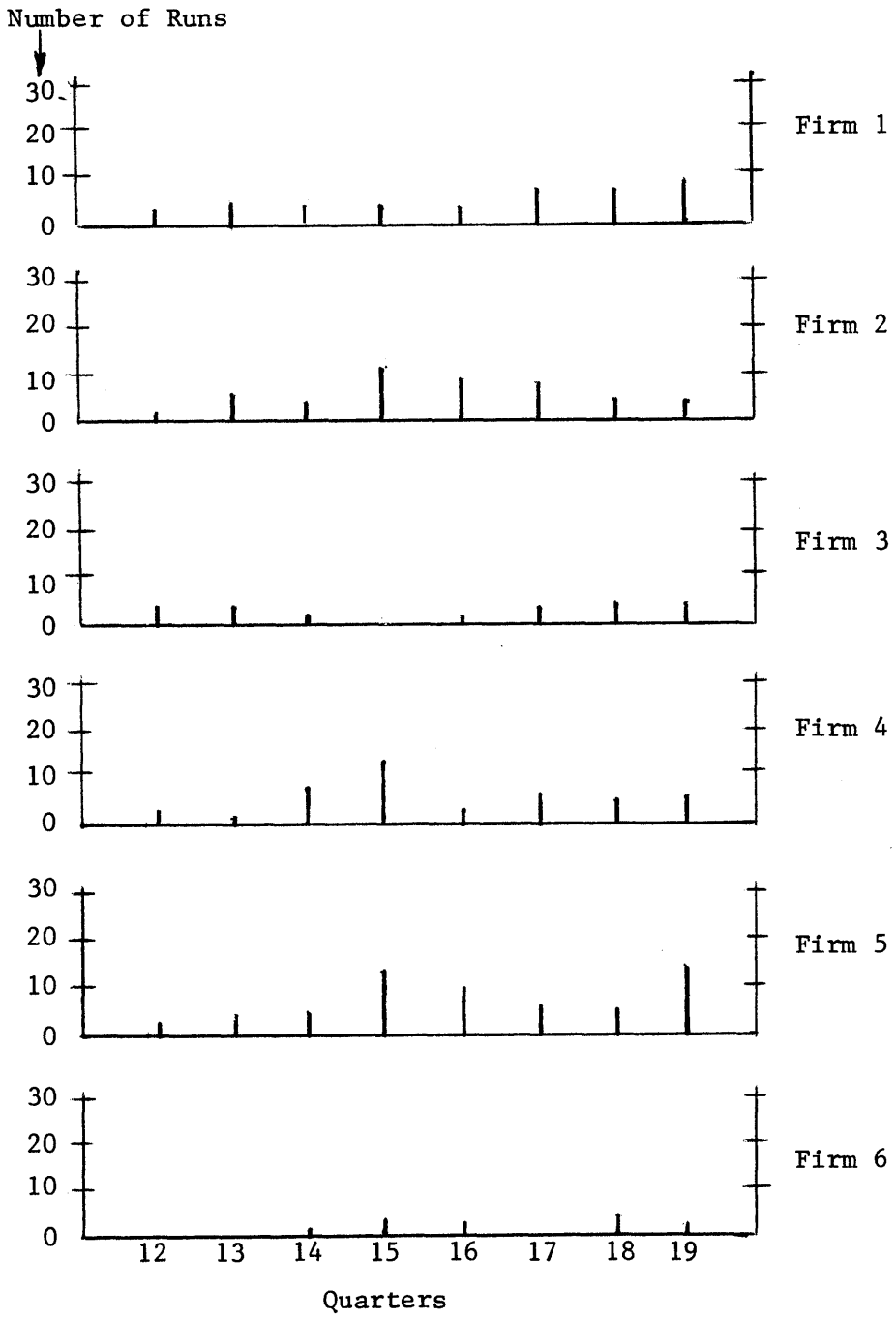


Figure 6.5 Use of Planning System
Planner option

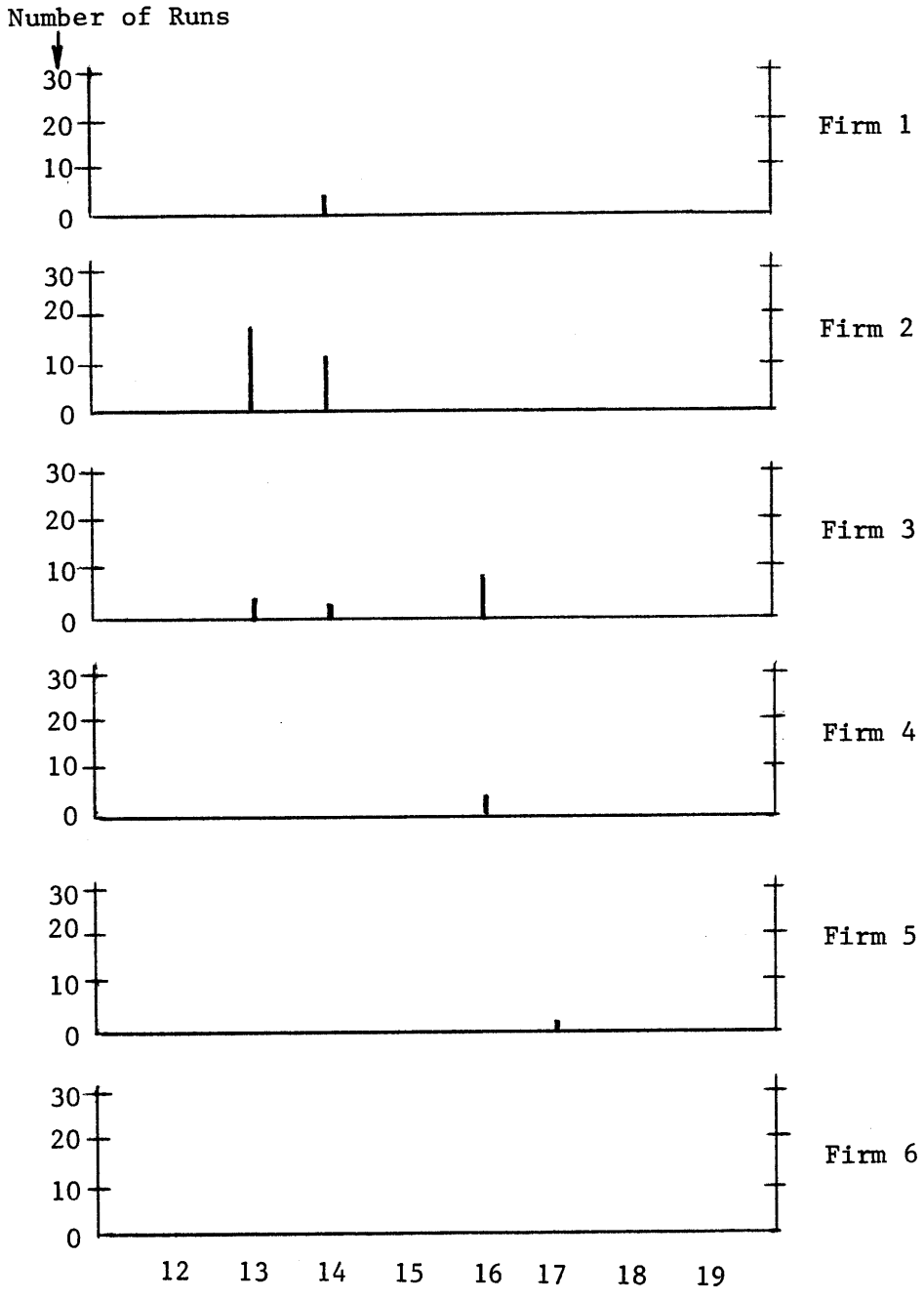


Figure 6.6 Use of Statistical Analysis System Regression Option

6.4.2 Quality of Aid

Figures 6.2 to 6.6 showed that the MODELER and FUTURE option of MDS were used extensively. The only question which remains to be answered is whether this use directly aided the Foreign marketing decision making. Some or all of the runs may have been "playing with the system", although there is a low probability that this occurred. Each firm indicated on the questionnaire that the MDS was used as an aid in making marketing decisions in the Foreign Market. This response, however, does not detail the quality of the aid provided by the MDS.

A better indication can be obtained by comparing the actual Foreign marketing decisions of Price, Advertising, R&D, and Inventory with those that were used as input to MODELER. Because decisions were not finalized until the end of the console sessions, a direct comparison indicates the system was used to aid in making the decisions for that quarter.

Table 6.9 provides data on the comparisons of actual marketing decisions for the quarter and the closest complete MDS runs that were found in the trace.

TABLE 6.9

Degree of Correspondence between MDS Runs and Actual Decisions.

Firm	Three Variables	Two Variables			One Variable			Qtr
	P/A/R	P/A	P/R	A/R	P	A	R	Used
Firm 1	4	1	1	1	-	-	-	7
Firm 2	4	2	1	-	-	-	-	7
Firm 3	2	1	1	-	2	-	1	7
Firm 4	3	-	2	1	-	-	1	7
Firm 5	3	1	-	1	2	-	-	7
Firm 6	2	2	-	-	1	-	-	5

It should be clear from this exhibit that all decisions were DSS-aided. The degree of aid which the system provided is shown by the number of exact and partial correspondences between MDS runs and actual decisions of Price Advertising and R&D.

6.5 Conclusions

As stated earlier, for decision making to be judged more effective required the acceptance of each of the decision quality hypotheses. Each hypothesis has been formally accepted in this section. In particular, decision making in the Foreign Market resulted in decisions whose:

(H1) quality is higher

(H2) quality is more consistent

(H3) quality has a higher rate of improvement

Therefore, it is fair to conclude that decision making in the Foreign Market is significantly more effective than in the Domestic Market. In addition, the hypothesis (H4, H5) related to decision efficiency were also accepted. Significantly fewer man-hours were devoted to making Foreign marketing decisions than to Domestic marketing decisions. Foreign marketing decisions also require less resolution time.

This compound result is highly significant. The efficiency and effectiveness of decision making in the Foreign Market are substantially better.

Alternative Explanations of Derived Results

There are several factors which had the potential to influence the results and thus serve as the basis for alternative explanations of the hypotheses. These factors are discussed in this section.

Concerning hypotheses 1, 2, 3, there are two possibilities to consider. One factor is that there might have been less difficulty facing the decision makers in the Foreign Market than in the Domestic Market. Considerable detail related to the game is needed to evaluate this contention. A complete discussion is provided in Appendix

The conclusions reached in the appendix can be summarized succinctly. In no quarter was the difficulty in the Foreign Market less than the difficulty faced in the Domestic Market. On the contrary, the Foreign Market was considerably more difficult to play. It is fair to say that the difficulty in the Foreign Market completely dominated the difficulty faced in the Domestic Market. In other words, the lack of comparative difficulty can be ruled out as an explanation of increased decision effectiveness in the Foreign Market. In fact, the higher difficulty in the Foreign Market provided a more rigorous test for the three hypotheses by biasing the results toward rejecting the hypotheses.

Another factor to consider is that there might have been transfer of knowledge between the markets. This was a serious concern during the design of the experiment. Therefore, a number (7) of different questions were asked in the questionnaire to determine if transfer of knowledge took place. Results shown in Chapter 3 can be summarized by stating that

(1) No decision maker on any team suspected, even remotely, that the markets were structurally identical.

(2) Every decision maker felt that any transfers which may have occurred were not very significant.

There is a paradox here. Any transfer which may have occurred would, more than likely, have been from the Foreign to the Domestic Market rather than the reverse because results were superior in the Foreign Market. Thus, transfers of knowledge would have biased the experiment, once again, toward rejecting the hypothesis.

Concerning hypothesis H4, one factor to consider is that the relative size of the markets and potential profits might have influenced the number of man-hours devoted to decision making in each market. The Domestic Market was larger than the Foreign Market, therefore, more man-hours might be allocated to the Domestic marketing decisions at the expense of the Foreign marketing decisions.

There is no doubt that all firms were cognizant of the difference in market sizes and that this had an influence on the man-hours allocated to each. This fact is apparent from responses to both the questionnaire and the interview why fewer man-hours were devoted to making marketing decisions in the Foreign Market relative to the Domestic Market, each firm stated, categorically, that the main reason for the reduction in time was the availability of the Marketing Decision System. In addition, they also expressed the opinion that the number of hours would have been approximately equal had no Decision Support System been available. The reason given for this was that the Foreign Market was more attractive because:

(1) the profit margins in the Foreign Market were higher and
(2) the Foreign Market was growing faster than the Domestic Market,

Although it is not possible to demonstrate that the only reason fewer man-hours were devoted to Foreign marketing decisions was the availability of the Decision Support System, there are sufficient reasons to believe that this was the primary factor.

To summarize, the preceding discussion has shown that factors which had the potential to influence the outcome of the experiment had either a negligible effect or actually strengthened the results by making the acceptance of the hypotheses more difficult.

APPENDIX A
DATA INPUT FORM

MARKETING FORECASTS AND PLANS

Domestic Mkt.	this QTR.	QTR.	QTR.	QTR.
Industry's Total Mkt.	_____	_____	_____	_____
Firm's Pot. Mkt.	_____	_____	_____	_____
Firm's Sales Plan	_____	_____	_____	_____
Foreign Mkt.				
Industry's Total Mkt.	_____	_____	_____	_____
Firm's Pot. Mkt.	_____	_____	_____	_____
Firm's Sales Plan	_____	_____	_____	_____

PRODUCTION/CAPACITY PLANS

Total Prod.	_____	_____	_____	_____
Dom. Prod.	_____	_____	_____	_____
For Ship.	_____	_____	_____	_____
Machine Cap.	_____	_____	_____	_____
Labor Force	_____	_____	_____	_____

INFORMATION ESTIMATES

Domestic Mkt. GNPD _____ SEAS _____

	Price	Promotion	Production	Inventory
Firm 1	_____	_____	_____	_____
Firm 2	_____	_____	_____	_____
Firm 3	_____	_____	_____	_____
Firm 4	_____	_____	_____	_____
Firm 5	_____	_____	_____	_____
Firm 6	_____	_____	_____	_____

Foreign Mkt. GNPF _____ SEAS _____

	Price	Promotion	R & D	Inventory
Firm 1	_____	_____	_____	_____
Firm22	_____	_____	_____	_____
Firm 3	_____	_____	_____	_____
Firm 4	_____	_____	_____	_____
Firm 5	_____	_____	_____	_____
Firm 6	_____	_____	_____	_____

DECISIONS THIS QTR.

Marketing Decisions

1. Domestic Price _____
2. Foreign Price _____
3. Domestic Promotion _____
4. Foreign Promotion _____
5. R & D Expenditure _____

Production Decisions

6. Units Produced _____
7. Units Shipped _____
8. Machine Capacity _____
9. Labor Force _____

Finance Decisions

10. Cash Remitted _____
11. Domestic Securities _____
12. Foreign Securities _____
13. Domestic Loans _____
14. Foreign Loans _____
15. Shares Outstanding _____
16. Dividends _____

APPENDIX B

MARKET SUMMARY REPORT
Quarter 11

DOMESTIC MARKET REPORT
MARKET 1 GNP=503.30 TOTAL UNITS = 3113000.

FIRM	UNITS	PRICE	LOST SALES	%THIS	%TOTAL
1	532000.	6.00	94000.	17.1	14.9
2	508000.	6.00	79000.	16.3	14.2
3	464000.	6.00	96000.	14.9	13.0
4	609000.	6.00	90000.	19.6	17.0
5	507000.	6.00	105000.	16.3	14.2
6	493000.	6.00	96000.	15.8	13.8

FOREIGN MARKET REPORT
MARKET 2 GNP=181.50 TOTAL UNITS = 464000.
GNP PROJECTIONS: 191.0 196.0 202.0 209.0

FIRM	UNITS	PRICE	LOST SALES	%THIS	%TOTAL
1	65000.	8.00	44000.	14.0	1.8
2	83000.	8.00	58000.	17.9	2.3
3	91000.	8.00	105000.	19.6	2.5
4	80000.	8.00	67000.	17.2	2.2
5	71000.	8.00	88000.	15.3	2.0
6	74000.	8.00	44000.	15.9	2.1

SUMMARY INFORMATION ON INDUSTRY

FIRM	CASH	SECURITIES	INVENTORY	OTHER	LOANS	ACCRUED TAXES
1	1541294	200000	2354999	10350000	0	496200
2	1548859	200000	2354999	10375000	0	496200
3	1535855	200000	2354999	10325000	0	496200
4	1549932	200000	2354999	10350000	0	496200
5	1540500	200000	2354999	10350000	0	496200
6	1532608	200000	2354999	10350000	0	496200

FIRM	COMMON STOCK	NET WORTH	DIVIDENDS	DOMESTIC ADV.	FOREIGN ADV.	R&D
1	10000000	3950093	50000	90000	0	250000
2	10000000	3952658	50000	80000	0	200000
3	10000000	3969654	50000	90000	0	210000
4	10000000	3958731	50000	100000	0	170000
5	10000000	3949299	50000	130000	0	130000
6	10000000	3941407	50000	100000	0	130000

FIRM	STOCK PRICE	MARKET VALUE	TOTAL NET
1	27.17	13585342	13950093
2	28.85	14426055	13952658
3	31.26	15631568	13969654
4	28.94	14468292	13958731
5	29.26	14630744	13949299
6	28.31	14154090	13941407

APPENDIX C

REPORT FOR QUARTER 11

DOMESTIC PROFIT AND LOSS

SALES REVENUE		3270000	
COST OF GOODS SOLD		1907500	
GROSS MARGIN			1362500
MANUFACTURING OVERHEAD	57500		
OVERTIME	39000		
HIRING	80000		
OVERHEAD EXPENSE		61500	
SHIPPING	20000		
PROMOTION	100000		
R&D EXPENSE	200000		
SELLING AND ADMINISTRATIVE EXPENSE	159000		
OPERATING EXPENSES		479000	
TOTAL EXPENSES			540500
OPERATING INCOME			822000
INTEREST INCOME	1625		
NET INTEREST		1625	
NET INCOME BEFORE TAX			823625
TAXES		395340	
NET INCOME AFTER TAX			428285

REPORT FOR QUARTER 11

DOMESTIC BALANCE SHEET

CASH		1070573	
SECURITIES		100000	
WORK IN PROCESS	2354999		
TOTAL INVENTORY		2354999	
PLANT	13000000		
DEPRECIATION	2650000		
NET BOOK VALUE OF PLANT		10350000	
INVESTMENT IN FOREIGN OPERATION		478499	
TOTAL ASSETS			14354071
ACCRUED TAXES		395340	
COMMON STOCK		10000000	
NET WORTH		3958731	
TOTAL LIABILITIES			14354071

APPENDIX C

REPORT FOR QUARTER 11

DOMESTIC SOURCES AND USES OF FUNDS

SOURCES		
CHANGES IN RETAINED EARNINGS	487550	
DEPRECIATION	325000	
CHANGES IN ACCRUED TAXES	240470	
TOTAL SOURCES		1053020
USES		
CHANGES IN CASH	896255	
CHANGES IN INVENTORY	103500	
CHANGES IN FOREIGN INVESTMENT	53265	
TOTAL USES		1053020

REPORT FOR QUARTER 11

DOMESTIC RECONCILIATION OF RETAINED EARNINGS

NET INCOME AFTER TAX	428285	
INCREASE IN FOREIGN RETENTIONS	53265	
SHIPMENTS OF GOODS	344000	
REMITTANCES	400000	
DIVIDENDS	50000	
CHANGE IN RETAINED EARNINGS		487550
RETAINED EARNINGS BEGINNING OF PERIOD		3471181
RETAINED EARNINGS END OF PERIOD		3958731

REPORT FOR QUARTER 11

DOMESTIC INVENTORY RECONCILIATION

	UNITS	VALUE
INVENTORY BEGINNING OF PERIOD	0	0
RECEIPTS	545000	1907500
SALES	545000	1907500
INVENTORY END OF PERIOD	0	0
WORK IN PROCESS	550000	1925000
AVAILABLE FOR SALE NEXT PERIOD	550000	1925000

APPENDIX D

REPORT FOR QUARTER 11

FOREIGN PROFIT AND LOSS

SALES REVENUE		640000	
COST OF GOODS SOLD		344000	
GROSS MARGIN			296000
TARIFF	16000		
PROMOTION	10000		
SELLING AND ADMINISTRATIVE EXPENSE	62000		
OPERATING EXPENSES		88000	
TOTAL EXPENSES			88000
OPERATING INCOME			208000
INTEREST INCOME	2125		
NET INTEREST		2125	
NET INCOME BEFORE TAX			210125
TAXES		100860	
NET INCOME AFTER TAX			109265

REPORT FOR QUARTER 11

FOREIGN BALANCE SHEET

CASH	479359	
SECURITIES	100000	
TOTAL ASSETS		579359
ACCRUED TAXES	100860	
NET WORTH	478499	
TOTAL LIABILITIES		579359

APPENDIX D

REPORT FOR QUARTER 11

FOREIGN SOURCES AND USES OF FUNDS

SOURCES		
CHANGES IN RETAINED EARNINGS	53265	
TOTAL SOURCES		53265
USES		
CHANGES IN CASH	43665	
CHANGES IN ACCRUED TAXES	9600	
TOTAL USES		53265

REPORT FOR QUARTER 11

FOREIGN RECONCILIATION OF RETAINED EARNINGS

NET INCOME AFTER TAX	109265	
SHIPMENTS OF GOODS	344000	
REMITTANCES	400000	
CHANGE IN RETAINED EARNINGS		53265
RETAINED EARNINGS BEGINNING OF PERIOD		425234
RETAINED EARNINGS END OF PERIOD		478499

REPORT OF QUARTER 11

FOREIGN INVENTORY RECONCILIATION

	UNITS	VALUE
INVENTORY BEGINNING OF PERIOD	0	0
RECEIPTS	80000	347500
SALES	80000	347500
INVENTORY END OF PERIOD	0	0
WORK IN PROCESS	100000	435000
AVAILABLE FOR SALE NEXT PERIOD	100000	435000

APPENDIX E

Profile of Participants

Senior Executive	Education	Company Position
Atkins, M. A.	Roosevelt Aviation School Washington Preparatory University of California at Loss Angeles	Work Manager Bell Helicopter Company
Blackadder, T.S.	University of Glasgow - B. Sc.	Managing Director Diamond Power Specialty Ltd.
Brockmeier, K.H.	Techn. Hochschule Braunschweig	General Manager Industrial Furnace Division of Brown, Boveri & Cie, AG
Burn, J.A.S.	Trinity College Pembroke College	Group Technical Services Manager Imperial Tobacco Group Limited
Clark, D.R.	Texas Technological College - B.S.	Assistant General Manager of Marketing Continental Oil Company
Dickson, R.S.	University of Tulsa - B.S.	Manager, Operations Division Computing Department Phillips Petroleum Company
Finegan, C.	University College in Dublin - Diploma in Social Science College of Marketing in London- Diploma in Marketing	Chief Marketing Officer Irish Dairy Board

APPENDIX E

Profile of Participants (continued)

Senior Executive	Education	Company Position
Fligny, G.P.	Faculty of Law in Paris - Bachelor	Long Term Planning Director Savonneries Lever
Flint, R.D.	Bordesley Green Technical University of Aston -B.Sc. University of Birmingham - Diploma	Production Engineer Joseph Lucas Limited
Gailey, J.S.	University of Missouri - B.S.	Plant Manager Corning Glass Works
Haeffner,Jr.,P.C.	Williams College - B.A.	Vice-President Real Estate & Mortgage Loan Department Chase Manhattan Bank
Hall, Jr., J.N.	University of Texas - B.A.	Vice President Lone Star Gas Company
LeMasters, G.E.	University of Kentucky B.S.M.E.	Executive Assistant to Executive Vice President - Indiana & Michigan Electric
Lewis, W.E.	Oklahoma State University - B.S.	Assistant General Manager, Room Air Conditioning Division Westinghouse Electric Corporation
Loton, B.T.	Melbourne University - B.Met. Eng.	General Manager The Broken Hill Proprietary Coy.Ltd.
Lubben, H.E.	Bergakademie Clausthal - Engineering and Ph.D	Operations Manager Brigitta - Elwerath

APPENDIX E

Profile of Participants (continued)

Senior Executive	Education	Company Position
Kossov, O.H.	Moscow Power Institute - Post Doctoral	Head of group for R&D Institute for Control and Management Problems
Meyer, G.C.W.	Swiss Federal Institute of Technology - Electrical Engineering	Director of Central Organization of the group Swiss Aluminium Ltd.
Petersen, W.E.	Iowa State University - B.S.	Vice President of Marketing-Residential Division Honeywell Inc.
Rives, J.R.	Texas Technological University - B.S.	Vice President-Manager, Equipment Division J.M.Huber Corporation
Sedgley, G.H.	University of Toronto - B.Sc.	Vice President, Marketing Control Systems Group Honeywell Limited
Steck, R.J.	Technical University Berlin - Ph.D	Assistant Vice President - Research Production & Engineer Henkel-CIE-GMB H Corp.
Tevoedjre, A.	University of Toulouse - d'enseignement plus CAPES Graduate Institute of International Studies- post graduate diploma University of Fribourg - doctorate	Assistant Director-General International Labour Office

APPENDIX E

Profile of Participants (continued)

Senior Executive	Education	Company Position
Trippe, K.A.B.	University of Missouri - LL.B. Kansas University - B.S.	Assistant Treasurer Corporate and International Utilities Financing Corporation
Wells, J.L.	Yale University - B.A. University of Virginia Law School - LL.B.	Vice President and Secretary CIBA-GEIGY Corporation

APPENDIX F

Senior Executive
Management Game Schedule

Date	Time	Activity
Thursday 30 March	7.30 p.m.	Game Manuals distributed
Saturday 1 April	2.00 p.m.	Demonstration of Console Use
Tuesday 4 April	2.00 p.m.	Introduction to Game
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 12 data input form
Wednesday 5 April	3.30 p.m.	Individual goal due
		Quarter 12 results returned
Thursday 6 April	2.00 p.m.	Firm goals due
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 13 data input form
Friday 7 April	2.00 p.m.	Quarter 13 results returned
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 14 data input form
Monday 10 April	2.00 p.m.	Quarter 14 results returned
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 15 data input form
Tuesday 11 April	2.00 p.m.	Quarter 15 results returned
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 16 data input form
Wednesday 12 April	2.00 p.m.	Quarter 16 results returned
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 17 data input form
Thursday 13 April	2.00 p.m.	Quarter 17 results returned
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 18 data input form
Friday 14 April	2.00 p.m.	Quarter 18 results returned
	2.00-5.00 p.m.	Console session
	5.00 p.m.	Quarter 19 data input form
Tuesday 18 April	2.00-5.00 p.m.	Debriefing session

APPENDIX G

Contents of the MIT Management Game Manual

Management Game Notes

Brief introduction to game and performance evaluation.

Schedule

Detailed schedule of activities for the game.

Overview

Complete description of the details of the game.

Explanation of Report Items

Capsule summary of the meaning of items contained in the reports.

Market History

Summary history of the markets during quarters 2 through 11.

Firm History

Full financial reports covering operation of a firm in quarters 2 through 11.

Console Input

Description of data input and command use common to all systems.

Marketing Decision System (MDS)

Description of Marketing Decision System.

Financial Planning System (FPS)

Description of Financial Planning System.

Statistical Analysis System (SAS)

Description of Statistical Analyses System.

Computer System Characteristics

Description of some pertinent characteristics of the computer.

Flow Charts

Capsule descriptions of MDS, FPS and SAS in flow chart form.

Goals and Decision Questionnaires

Forms to be completed and returned to game administrator.

Paper

Graph and accounting paper for the convenience of the team.

APPENDIX H

Firm Goals

The firm should complete this form. In order to determine performance relative to desired goals, we would like you to establish your corporate objectives. Five factors should go into this determination.

Market value of stock at end of last period
Return on net equity over last four periods
Market share at end of last period
Total earnings over total simulation
Earnings per share

Fifteen points are to be assigned to a combination of these five factors. Rank each factor from 5 to 1, 5 being the most important, 1 being the least. Each factor must be assigned a unique number from the set (1 to 5). No equal rankings are allowed.

Factor	Points Assigned
Market value of stock	_____
Return on equity	_____
Market Share	_____
Cumulative earnings	_____
Earnings per share	_____

BIBLIOGRAPHY

1. Aaker, David A., "Toward A Normative Model of Decision Making," Management Science, Vol. 19, No. 6 February, 1973, pp. 593-603.

2. Ackoff, Russell L., "Towards a System of Systems Concepts," Management Science, Vol. 17, No. 11, July 1971, pp. 661-671.

3. Ackoff, Russell L., "Management Misinformation Systems," "Management Science, December, 1967, pp. B-147-56.

4. Amstutz, Arnold, "The Computer: A New Partner in Investment Management," Alfred P. Sloan School of Management at M.I.T., Working Paper 283-67, September, 1967.

5. Anthony, Robert N., Planning and Control Systems: A Framework for Analysis, Division of Research, Harvard Business School, 1965.

6. Argyris, Chris., "Management Information Systems: The Challenge to Rationality and Emotionality," Management Science, Vol. 17, No. 6, February 1971, pp. B-275-292.

7. Babb, E. M. and Eisgruber, L. M., Management Games for Teaching and Research, Chicago, Illinois: Educational Methods, Inc., 1966.

8. Baker, J. D., "Quantitative Modelling of Human Performance in Information Systems," Ergonomics, 1970, Vol. 13, No. 6, pp. 645-664.

9. Bass, Bernard M., "Business Gaming for Organizational Research," Management Science, Vol. 10, No. 3, April 1964, pp. 545-555.

10. Bellman, R. E., Zadeh, L. A., "Decision-Making in a Fuzzy Environment," Management Science, Vol. 17, No. 4, December, 1970.

11. Beged-Dov, Aharon G., "An Overview of Management Science and Information Systems," Management Science, Vol. 13, No. 12, August, 1967.

12. Beville, James, Wagner, John H., Zannetos, Zenon S., "An Experiment with Interactive Planning Models," Alfred P. Sloan School of Management at M.I.T., Working Paper 503-70, December 1970.

13. Blumenthal, Sherman C., Management Information Systems: A Framework for Planning and Development, Prentice-Hall, 1969.

14. Boulden, James B., Buffa, Elwood S., "Corporate Models: On-line, Real-Time Systems," Harvard Business Review, July-August 1970, pp. 65-81.

15. Boulding, Kenneth, "General System Theory: The Skeleton of Science," Management Science, April, 1956.

16. Bowman, E. H., "Consistency and Optimality in Managerial Decision Making," in Industrial Scheduling, J. L. Muth and G. L. Thompson, Eds., Prentice-Hall, 1963.

17. Brady, Rodney H., "Computers in Top-Level Decision Making," Harvard Business Review, July-August, 1967, pp. 67-76.

18. Bruner, Jerome, Goodnow, Jacqueline, and Autin, George, A Study of Thinking, Wiley, 1956.

19. Bruner, J. S., "The Course of Cognitive Growth," Journal of the American Psychology Association, Vol. 19, 1964, pp. 1-15.

20. Campbell, D. T., Stanley, J. C., Experimental and Quasi-Experimental Designs for Research, Rand McNally, 1966.

21. Carroll, Donald C., "Man-Machine Cooperation on Planning and Control Problems," Industrial Management Review, Vol. 8, No. 1, Fall, 1966.

22. Carroll, Donald C., "Implications of On-Line Real-Time Systems for Managerial Decision-Making," from The Management of Aerospace Programs, Vol. 12, Science and Technology Series, 1967, American Astronautical Society, pp. 345-367.

23. Chapanis, A., "The Relevance of Laboratory Studies to Practical Situations," Ergonomics, 1967,Vol. 10, No. 5.

24. Charnes, A., and Cooper, W. W., "Data, Modeling, and Decisions," Management Sciences Research Report No. 43, Carnegie Institute of Technology, June, 1965.

25. Cohen, Kalman J., Rhenman, Eric, "The Role of Management Games in Education and Research," Management Science, Jan. 1961.

26. Cohen, K. J., Dill, W. R., Kuehn, A. A., Winters, P. R., The Carnegie Tech Management Game, Homewood, Illinois, Richard D. Irwin Inc. 1964.

27. Conrath, David W., "Organizational Decision Making Behavior Under Varying Conditions of Uncertainty," Management Science, Vol. 13, No. 8, April 1967, pp. B-487-500.

28. Cravens, David W., "An Exploratory Analysis of Individual Information Processing," Management Science, Vol. 16, No. 10, June 1970, pp. B-656-670.

29. Cyert, Richard M., Simon, Herbert A., Trow, Donald B., "Observation of a Business Decision," Ch. 37 of Some Theories of Organization, Rubinstein, Albert H., and Haberstroh, Chadwick J., editors, Irwin, 1966.

30. Damon, William W., Schramm, Richard, "A Simultaneous Decision Model for Production, Marketing and Finance," Management Science,Vol. 19, No. 2, October 1972, pp. 161-172.

31. Davis, Ruth M., "Man-Machine Communication," Annual Review of Information Science and Technology, Editor C. A. Cuadra, Vol. 1, Interscience Publishers, 1966, pp.221-254.

32. Davis, Ruth, "Classification and Evaluation of Information System Design Techniques," Information System Science and Technology, Spartan Books, 1964.

33. Dickson, Gary W., "A Generalized Model of Administrative Decisions: An Experimental Test," Management Science, Vol. 17, No. 1, September 1970, pp. 35-47.

34. Dill, W. R., "Desegration or Integration? Comments About Contemporary Research on Organizations," In Cooper, W. W., Leavitt, H. J., and Shelly, M. W. (eds.), New Perspectives in Organization Research, Wiley, New York, 1964.

35. Ebert, Ronald J., "Time Horizon: Implications for Aggregate Scheduling Effectiveness," AIIE Transactions, Vol. 4, No. 4, December 1972, pp. 298-307.

36. Edstrom, Olof., Man-Computer Decision Making, Gothenburg, Seden, BAS, 1973.

37. Edwards, Ward, "The Theory of Decision Making," Psychological Bulletin, Vol. 51, No. 4, 1954, pp. 410-411.

38. Eilon, Samuel, "What is a Decision," Management Science, Vol. 10, No. 4, December 1969, pp. B-172-189.

39. Emery, James C., "Organizational Planning and Control: Theory and Technology," unpublished Ph.D. Dissertation, M.I.T., September, 1965.

40. Emery, James C., "Decision Models- Part I and II, Datamation, September 1 and 15, 1970.

41. Farris, G. F., "Executive Decision Making in Organizations: Identifying Key Men and Managing the Process," Working Paper No. 551-571, Alfred P. Sloan School of Management at M.I.T., June, 1971.

42. Forrester, Jay W., "Counterintuitive Behavior of Social Systems," Technology Review, Vol. 73, No. 3, January 1971, pp. 1-16.

43. Gebhard, J. W., "The Computers Role in Command Decision," Naval Institute Proceedings, Vol. 92.

44. Gerrity, Thomas P., "Design of Man-Machine Decision Systems: An Application to Portfolio Management," Sloan Management Review, Vol. 12, No. 2, Winter 1971, pp. 59-76.

45. Gerrity Jr., Thomas P., "The Design of Man-Machine Decision System," Unpublished Ph.D. dissertation, Alfred P. Sloan School of Management at M.I.T., June 1970.

46. Goffman, E., Encounters: Two Studies in the Sociology of Interaction, Bobbs-Merrill, 1961.

47. Gibson, R. S., Nicol, E. H., "The Modifiability of Decisions Made in a Changing Environment," USAF ESD Tech. Document Rep. No. 64-657.

48. Gorry, G. Anthony, "The Development of Managerial Models," Sloan Management Review, Vol. 12, No. 2, Winter 1971, pp. 1-16.

49. Gorry, Anthony G., Morton, Michael S.S., "A Gramework for Management Information Systems," Sloan Management Review, Vol. 13, No. 1, Fall 1971, pp. 55-70.

50. Green, P. E., Robinson, P. J., Fitzroy, P.T., Experiments on the Value of Information in Simulated Marketing Environments, Boston, Allyn and Bacon, Inc., 1967.

51. Hall, A. D., A Methodology for System Engineering, D. Van Nostrand Company, Princeton, N. J., 1962.

52. Haynes, R. J., "The Evaluation of Management Information Systems - Three Case Studies," Computing Science Report 18, Imperial College, January 1970.

53. Hedberg, Bo, On Man-Computer Interaction in Organizational Decision-Making: A Behavioral Approach, Gothenberg, Sweden, BAS, 1970.

54. Howard, John A., Morgenroth, William M., "Information Processing Model of Executive Decision," Management Science, Vol. 14, No. 7, March 1968, pp. 416-428.

55. Hunt, E. B., Concept Learning: An Information Processing Problem, Wiley, 1962.

56. Hunt, Earl B., Marin, Janet, and Stone, Philip J., Experiments in Induction, Academic Press, 1966.

57. Hunt, E. B., Makous, W., "Some Characteristics of Human Information Processing," In Tou, J. (ed.) Advances in Information Processing, Vol. 2, New York: Plenum Press, 1969.

58. Joyner, Robert, Tunstall, Kenneth, "Computer Augmented Organizational Problem Solving," Management Science, Vol. 17, No. 4, December 1970, pp. B-212-225.

59. Kerlinger, F. N., Foundations of Behavioral Research, Holt, Rinehart and Winston, New York, 1965.

60. Kunreuther, Howard, "Extensions of Bowman's Theory on Managerial Decision-Making," Management Science, Vol. 15, No. 8, April 1969, pp. B-415-439.

61. Licklider, J.C. R., "Man-Computer Symbiosis," IRE Transactions of Human Factors in Electronics, March 1960, pp. 1-10.

62. Licklider, J. C. R., "Man-Computer Partnership," International Science and Technology, May, 1965, pp. 18-26

63. Little, John D. C., "Models and Managers: The Concept of a Decision Calculus," Management Science, Vol. 16, No. 8, April 1970, pp. B-466-485.

64. MacKenzie, Kenneth D., Barron, F. Hutton, "Analysis of a Decision Making Investigation," Management Science, Vol. 17, No. 4, December 1970, pp. B-226-241.

65. Mason, Richard C., Mitroff, Ian I., "A Program for Research on Management Information Systems," Management Science, Vol. 19, No. 5, January 1973, pp. 475-487.

66. McKendry, J. M., "Utility of Information As a Predictor of Decision Adequacy in Ambiguous Situations," HRB-Singer Rep., 567-R-3.

67. McKenney, James L., Simulation Gaming for Management Development, Boston: Division of Research Graduate School of Business Administration, Harvard University, 1967.

68. Miller, G. A., "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," Psychological Review,1956m 63, pp. 81-97.

69. Miller, G.A., Galanter, E., and Pribram, K. H., Plans and the Structure of Behavior, Henry Holt & Company, New York 1960.

70. Miller, R. B., "Psychology for a Man-Machine Problem-Solving System," IBM Technical Report TR00.1246, February 19, 1965.

71. Miller, H. B., "Archetypes in Man-Computer Problem Solving," I.E.E.E. Trans. on Man-Machine Systems, December 1969, pp. 219-241.

72. Mintzberg, Henry, "Managerial Work: Analysis From Observation," Management Science, Vol. 18, No. 2, October 1971, pp. B-97-110.

73. Morris, William T., "On The Art of Modeling," Management Science, Vol. 13, No. 12, August 1967, pp. B-707-717.

74. Moskowitz, Herbert, "An Experimental Investigation of Decision Making in a Simulated Research and Development Environment," Management Science, Vol. 19, No. 6, February 1973, pp. 676-687.

75. Nickerson, R. S., "Man-Computer Interaction: A Challenge for Human Factors Research," Ergonomics, 1969, Vol. 12, No. 4, pp. 501-517.

76. Ness, David, Sprague, Christopher R., Moulton, Allen, "On the Implementation of Sophisticated Interactive Systems," Alfred P. Sloan School of Management at M.I.T., Working Paper 506-571, December 1971.

77. Ness, David, Sprague, Christopher R., "Application of a Flexible System to Retrieve, Manipulate and Display Information from a Stable, Questionnaire-Oriented Data Base to Social Science Research," Alfred P. Sloan School of Management at M.I.T., Working Paper 594- March 1972.

78. Ness, David, Sprague, Christopher R., "An Interactive Media Decision Support System," Sloan Management Review, Vol. 14, No. 1, Fall 1972, pp. 51-62.

79. Newell, A., Shaw, J. C., and Simon, H. A., "Elements of a Theory of Human Problem Solving," Psychological Review, 65, May, 1958.

80. Newman, J. R., and Rogers, M. S., "Experiments in Computer-Aided Inductive Reasoning," TM-3227, System Development Corporation, December 6, 1966.

81. Newman, J. Robert, "Extension of Human Capability Through Information Processing and Display System," SP-2560, System Development Corporation, December 7, 1966.

82. Parsons, Henry McIlvaine, Man-Machine System Experiments, John Hopkins Press, Baltimore, 1972.

83. Philippatos, G. C., Moscato, D. R., "Effects of Constrained Information on Player Decisions in Experimental Business Simulation: Some Empirical Evidence," Journal of the Association for Computing Machinery, Vol. 18, No. 1, January 1971, pp. 94-104.

84. Pitz, G. F., Downing, L., "Optimal Behavior in Decision Making Tasks," Journal of Experimental Psychology, 73.

85. Pounds, William F., "The Process of Problem Finding," Industrial Management Review, Fall 1969, pp. 1-19.

86. Powers, J. R., "The Investigation of Human Decision-Making by Means of Man-Computer Interaction," Ergonomics, Vol.11.

87. Raser, John R., Simulation and Society, Allyn and Bacon Inc., Boston, 1969.

88. Sackman, H., "Experimental Evaluation of Time-Sharing and Batch Processing in Teaching Computer Science," SP-3411, Systems Development Corporation, 24 October 1969.

89. Sackman, H., Erickson, W. J., and Grant, E. E., "Exploratory Experimental Studies Comparing Online and Offline Programming Performance," Communications of the ACM, Vol. II, No. 1, pp. 3-11, January 1968.

90. Sackman, H., and Gold, Michael M., "Time-Sharing Versus Batch Processing: An Experimental Enquiry into Human Problem-Solving," SP-3110, System Development Corporation, June 14, 1968.

91. Scott Morton, Michael S., "Interactive Visual Display Systems and Management Problem Solving," Industrial Management Review, Fall, 1967, pp. 69-81.

92. Scott Morton, Michael S., and MvCosh, Andrew M., "Terminal Costing for Better Decisions," Harvard Business Review, May-June, 1968, pp. 147-156.

93. Scott Morton, Michael S., "Strategic Planning and Management Information System - Some Implications of Present Research," Working Paper No. 439-70, Alfred P. Sloan School of Management at M.I.T., June 1968.

94. Scott Morton, Michael S., "Strategy for the Design and Evaluation of an Interactive Display System for Management Planning," Working Paper No. 439-70, Alfred P. Sloan School of Management at M.I.T., February 1970.

95. Scott Morton, Michael S., Management Decision Systems, Division of Research Graduate School of Business Administration, Harvard University, Boston, 1971.

96. Schroder, Harold, Driver, Michael, and Streufert, Siegfried, Human Information Processing, Holt, Rinehart and Winston, 1967.

97. Selltiz, Claire, Jahoda, M., Deutsch, M. and Cook, S., Research Methods in Social Relations, Holt, Rinehart and Winston, 1966.

98. Shackel, B., "Man-Computer Interaction - The Contribution of the Human Sciences," I.E,E.E. Trans. on Man-Machine Systems, December 1969, pp. 149163.

99. Shubik, Martin, "On the Scope of Gaming," Management Science, Vol. 18, No. 8, Part 2, January 1972, pp. P20-36.

100. Shubik, Martin, "Gaming: Costs and Facilities," Management Science, Vol. 14, No. 11, July 1968, pp. 629-660.

101. Shure, G. H., Rogers, M. S., Meeker, R. J., "Complexity, Realism and Simulation in Decision Research" Systems Development Corporation, Report FN-5768.

102. Siegel, Sidney, Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill Book Company, Inc., New York, 1956.

103. Simon, H. A., Models of Man, Wiley, 1957.

104. Simon, H. A. , The New Science of Management Decision, Harper and Brothers, New York, 1960.

105. Simon, Herbert A., The Shape of Automation, Harper & Row,1965.

106. Simon, H. A., "The Future of Information Processing Technology," Management Science, May 1968, pp. 619-24

107. Singleton, W. T., "Display Design: Principles and Procedures," Ergonomics, 1969, Vol. 12, No. 4, pp. 519-531.

108. Soelberg, P. A Study of Decision Making: Job Choice, Cambridge, Mass., M.I.T., 1966, pp. 19-29.

109. Souder, William E., "A Scoring Methodology for Assessing the Suitability of Management Science Models," Management Science, Vol. 18, No. 10, June 1972, pp. B-526-543.

110. Southard, J. F.,"An Application of Bayes Theorem as a Hypothesis Selection Aid in a Complex Information Processing System," USAF _ AMRL Tech. Document Report No. 64-51.

111. Swinth, Robert L., "Organizational Joint Problem-Solving," Management Science, Vol. 18, No. 2, October 1971, pp. B-68-79.

112. Trull, Samuel G., "Some Factors Involved in Determining Total Decision Success," Management Science, Vol. 12, No. 6, February 1966, pp. B-270-280.

113. Vaughn, F. T., "Information Processing Tasks and Performance," USAF-AMR-TDR 69-77

114. Westendorf, C. W., "A Test of Bowman's Theory Using a Management Game" Decision Application, Vol. 2.

115. Will, H. J., "Definition of Management Information Systems," excerpted in "Information Systems in Management Science," Management Science, pp. B-391-95, February, 1968.

116. Whitfield, D., "Human Skill as a Determinate of Allocation of Function," Ergonomics, 1969, Vol. 12, No. 4, pp. B154-60.

117. Yntema, Douwe B. and Torgerson, W. S., "Man-Computer Cooperation in Decisions Requiring Common Sense," Institute of Radio Engineers, Transactions on Human Factors in Electronics, 1961

BIOGRAPHICAL NOTE ON THE AUTHOR

Albert Andrew Marcotte was born in Abington, Massachusetts on August 11, 1939. He was educated in public schools and graduated from Abington High School in 1957. He then entered Northeastern University, where he received the S.B. in industrial engineering in 1963, the S.M. in 1965, and a M.B.A. in 1967. In 1968 he began doctoral studies in the Sloan School of Management at MIT.

Mr. Marcotte's business experience included an apartment house redevelopment project. He has taught industrial engineering at Northeastern University.

He is a member of Alpha Pi Mu and Sigma Xi honorary societies.