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in a stochastic environment**

**Sackson, Marian V., Ph.D.**

**City University of New York, 1990**

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THE USE OF AN EXPERT SYSTEM TO SIMULATE GROUP DECISION MAKING  
IN A STOCHASTIC ENVIRONMENT

by

Marian V. Sackson

A dissertation submitted to the Graduate Faculty in Business in partial  
fulfillment of the requirements for the degree of Doctor of Philosophy, The  
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## Abstract

### THE USE OF AN EXPERT SYSTEM TO SIMULATE GROUP DECISION MAKING IN A STOCHASTIC ENVIRONMENT

by

Marian V. Sackson

Advisor: Professor George Schneller

This thesis presents an expert system model developed to simulate group decision makers engaged in a strategy and policy making task whereby, on a quarterly basis, they evaluate strategic scenarios and then execute a set of interrelated decisions. Can the expert system model make meaningful decisions? Can the expert system "learn" from previously executed decisions? Can the expert system compete? Answers to these questions are formulated through the specification of an operationally deed expert system model based on the decision making processes of a panel of experts.

A "management game" computer program implemented in an undergraduate university is used as the setting for the strategic task. The game environment offers the opportunity to test the expert system model in a stochastic decision making environment and at the same time to have some control over the limits of the experimental domain. In addition, the management game incorporates a number of hypothetical

relationships that represent a conceptualized view of how a company and its environment might behave.

The development process of the expert system simulation of group decision makers was pursued by: (1) Using a group of management faculty members who are both game administrators and real world business consultants as the panel of experts. They were given a set of thirty possible variables and relationships that are indigenous to the game. They then rated the importance of the variables, listed the interdependences and relationships affecting these variables, and estimated the likelihood that the relationships would influence different decisions and chose a fixed strategy. (2) Incorporating the responses from the expert panel into the knowledge base of the expert system model along with decisions and results for a hypothetical company during four years of operation; a standard synthetic history included in the management game by its authors. (3) Validating and then testing the decision making performance of the expert system in a "live" environment as it competes with five other student teams of decision makers while playing the management game extending over a simulated three year period.

This research, as a first step, will attempt to give some insight into the process of group decision making and to present an operational basis for further research.

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## CHAPTER 1

### INTRODUCTION

Decision making is fundamental to human existence. We are continually faced with problems that need solutions. How we solve these problems, the relationship between intelligence and problem solving, and the characteristics of the decision process are subjects of continual research.

Decision making is a very complex activity. The process often poses alternative courses of action, each of which must be evaluated for its relative merits. Sometimes the decision depends upon the reactions of others or past decisions; sometimes chance factors are involved; often, decision making is accompanied by perplexing mixtures of success and failure. Decision making involves many different kinds of knowledge and planning behavior. Past experiences may play a role in the decision process. Decision making entails cognitive activity and is psychological in nature. Decisions can be made by an individual or by a group.

The history of computing has been a two-way street, in that the field has benefited dually from the analogy between the human brain and the various types of programs and machines. The exercises in early Artificial Intelligence (AI) taught psychologists a great deal about the nature of human intelligence, (MYCIN, CADUCEUS, ELIZA, etc), and, conversely the continuing studies of the human brain, physiology, and psychology have given impetus to improve computing hardware (e.g. neural networks architecture) and software

(Artificial Intelligence). Heretofore, Expert Systems (ES) have been used primarily in applications within a limited field where they seek to produce decisions close to optimal and/or analyses close to reality, as perceived by the best human analyst. The author intends a different use of an expert system; that of realistically simulating group decision making behavior in a competitive and interactive environment. In the process of pursuing this endeavor, some questions arise. Can an expert system be developed to simulate the group making process? Can an expert system "learn" from previously made decisions? Can an expert system compete? Answering these questions requires knowledge of the group decision process, the significance of expertise, and the effect of experiential learning.

The objective of this thesis is to provide a portion of this knowledge. The thesis will focus on the development and use of an expert system for simulating group decision making for a management decision making application that evaluates strategic scenarios, extends over time, and can be affected by experiential learning. A "management game" package implemented in an undergraduate curriculum of an urban university will be used as the setting for the management decision making application. This thesis will explore the issues of group decision making that are frequently encountered in the evaluation of strategic scenarios and describe the process through an operationally defined model. This model will specify the various elements and aspects of the group decision making process such as:

- the decision variables in the group decision making process for the specific task
- the components/structure required to perform the decision making task

- the time dimension of the decision making task
- the organizational and decision making environment
- the decision rules of the decision makers and the expert system
- the modification of the decision rules of the decision makers and the expert system as a consequence of gaining experience and 'learning' over time

The research questions to be studied are:

- a. How will the expert system react to a stochastically changing environment of the management game?
- b. How and to what extent will the expert system modify the decision rules?
- c. As the expert system simulates group decision making over time, will its decisions be affected by experiential learning?
- d. How will the expert system perform relative to other live group decision makers in the same arena?

Obviously, no single study can fully examine all the components of group decision making, definitively describe the group decision process or specify the most appropriate decision rules for evaluating strategic scenarios. This research will attempt to give some insight into the process and to present an operational basis for further research.

A prerequisite for any such research is the availability of appropriate tools. Such tools have recently become available as a result of more than thirty years of research in the areas of cognitive process of decision making, artificial intelligence, and management gaming.

The simulation of group decision making using an expert system has been chosen for several reasons. There has been extensive research attempting to

diagnose the process of individual decision making, but less in group decision making. At the same time, of the many existing expert system applications, few models have been developed that simulate group decision making in a dynamic environment. The process of evaluating strategic scenarios involves group decision making and necessitates a time factor.

The choice of the task environment was made because of the author's familiarity with business gaming, computers, expert systems, and the availability of data and subjects. The management game environment offered the opportunity to test the expert system model in a stochastic decision making environment while at the same time controlling the limits of the experimental domain.

### 1.1 Decision Making Behavior

The seminal research in the cognitive process of decision making by Newell and Simon (1972) emanated from the study of elementary tasks such as cryptarithmic puzzles, logic problems, and game playing such as chess and checkers. These efforts have resulted in an extensive and detailed theory in human problem solving. In particular, the research by Newell and Simon of human problem solving was replicated by Bouwman ten years later. Bouwman (1983) developed a diagnostic computer program based on human decision making behavior. His computer program, written in a general purpose language called ALGOL, simulated the diagnostic behavior of actual student decision makers who were judging the financial position of a company. His analysis of the behavior was built on the model of problem solving and decision making developed by Newell and Simon.

In turn, the field of artificial intelligence evolved as a result of an interest in making machines smarter and a desire to understand intelligent

behavior. Artificial intelligence research has progressed along a number of different tracks, (e.g. natural language processing, robotic sensory interpretation, and so forth) but one of the most far ranging has concerned the development of programs for solving problems that are difficult enough to require the specific knowledge of human expertise for their solution. These programs are called "expert systems" or "knowledge-based systems".

Another perspective on decision making was provided by the research conducted by Meier, Newell and Pazer (1969) into the development of gaming techniques. Such games are a form of simulation in which human beings make decisions at various stages and the game model simulates the interactions between the simulated environment and the decisions of the participants.

Cohen and Rhenman (1985) stated that management games provide an environment that gives participants an opportunity to compare their decision making assumptions with those of the game model, to discuss and evaluate both, and to compare them critically. The simulated "real world" environment of the games contributes to the development of decision-making skills which can be practiced in the game environment and are not dependent upon practice in a realistic environment. Thus management games have seen widespread use in recent years in various educational and training environments

Our research will use Simon's taxonomy of decision types, Newell and Simon's theory of human problem solving, Bouwman's research in human diagnostic reasoning, and his computer program simulation of human decision making behavior, as a basis for examining the information processing aspect of decision making by groups of humans. It will attempt to assess the generality of their theories in conjunction with the analysis of decision types by Newell and Simon and transfer them from human group decision making to an expert

system's decision making ability. The decision making expert system, will simulate human group decision making performance where the groups are competing in a management game.

### 1.2 Research Philosophy

The research which is presented here is based on the Simon postulate that humans, in their thinking and decision making activities, are information processors. The information processing system is both cognitive and psychological in the same sense that the resulting behavior is dependent upon the decision maker's view of the task. This postulate has stood the test of thirty years of research, examination and critical review. This view of a human as an information processing system has significant impact on the direction of the research, as one's philosophy as to how a human decision maker operates strongly influences the model. Further, it influences the method or design by which this process is replicated on a computerized information system. More specifically, the resultant decision model will be the basis for the development of an expert system to simulate human group decision-making in a particular task domain.

### 1.3 Research Methodology

A management game that has been played by student teams at Pace for six years was chosen as an experimental setting, as it was thought that this would provide an adequate test environment for an expert system designed to simulate group decision making and to incorporate experiential learning. The game affords the opportunity for the expert system to develop operating decisions and monitor the competition while it gives the experimenter control over the experimental task domain parameters.

The general method that the research of this paper used is as follows:

1. Develop a set of decision rules for the expert system based on testimony of an eight member group of expert administrators (management faculty managers) of the management game which has been used for over six years in an undergraduate Business Policy and Strategy course at Pace University. They will provide the expertise necessary for developing the causal/correlational structure of the decision rules. In addition to administering the management game, these faculty members have been and are presently consultants to business organizations. The development method used to build the rule set was a modified Delphi technique. By "modified" we mean that the written responses from the panel, when questioned about the variables that influence good game decisions, were only circulated twice. Then, their responses were used to form a consensus on the rule structure.

2. Build a knowledge data base containing initially the four year history of operating decisions made by one company of the game industry that is precisely the data presented to all game participants at the outset.

3. Develop the expert system model to incorporate the decision rules of the experts and knowledge base mentioned above.

4. After the expert system model is built, it will be tested for validity by using a set of data from a recently completed three year game iteration. This test will be implemented by taking the results of this game, replacing one of the student teams that participated in the game with the expert system, and rerunning the game period-by-period starting with the initial historical data and continuing for seven quarters. The student team participants in the game chosen will all have competed with relatively similar performance outcomes, meaning the best and least well performing companies were not outstanding in either direction. Performance outcomes are measured by a

combination of profit on sales ratio, quick ratio, earnings per share, loan and bond interest rate, percentage share of the market, and productivity (units produced per hour). The specific student team to be replaced was judged as an average performer by the group of experts. The choice of both the game and the student team to be substituted for was based on the belief that the student teams were engaged in "fair" competition. There had been some instances of "contaminated" games, where one or more teams gained unfair advantage due to external help. The test used "real world decisions" previously made by participating student teams and the new decisions developed by the expert system. However, it should be noted that the decisions that the five remaining student teams had made were held constant during this test despite the changed environment of replacing the one team by the expert system.

5. The results obtained when the game was played by all student teams will be compared to the results obtained when the one student team was replaced by the expert system.

6. If the expert system's decision making and performance outcomes are unsuccessful, based on the criteria usually employed by the expert game administrators to evaluate the student teams' performance, then the expert system model will be refined using the original expertise from the faculty Delphi survey. The game will be replayed with the refined expert system replacing the same student team. Again, the experimental performance will be evaluated. This process is repeated until the expert system model is considered capable of making acceptable decisions as judged by the game administrators' performance measures.

7. The expert system model will be used in an actual class, where the system competed against live teams for twelve competitive quarters (game iterations). The human student teams will not be made aware that they are competing with an expert system team; they will be told there was a team from another class.

8. Finally, the students involved will be individually surveyed to see if they perceived anything unusual or different about the decision making behavior of the expert system or any other company. Some of the estimated decisions amounts and limited performance outcomes of the competing teams appear in the industry average industry average reports issued after each decision cycle (business quarter). (See Appendix 4 for the industry average reports.)

#### 1.4 Relevance of the Research

There has been much research during the past thirty years in Artificial Intelligence (AI). There have been some successful commercial applications notably in the expert system category. Interest in AI applications has increased (and decreased) several times. Current attempts to develop AI applications are much broader and more intensive than at any time in the past, and few, if any, expect the interest to revert to its previous status of a mere academic curiosity. Expert systems have evolved from one of the fundamental concerns of AI researchers for knowledge representation, and currently expert system tools exist which simplify the task of developing such a system and greatly reduce the labor involved.

The abundance of current literature on expert systems, the introduction of Artificial Intelligence courses in Business School curricula, and the availability of conferences and seminars for exposing the business

community to expert systems are evidence of the business community's interest in the application of expert systems to business problem solving and decision making. A recent study of business implications of knowledge-based systems stated:

"Interest in creating expert systems (ES) for use in business organizations has increased dramatically. Although the number of publicized, commercial successes is small, the potential for augmenting human expertise with ESs is noteworthy. Furthermore, the competitive implications of ES, seen through the lens of competitive strategy, suggest opportunities for expertise intensive industries to create a competitive advantage in using ES technology."

(Sviokla, 1986 page 5)

Fordyce, Nordon and Sullivan (1987) noted that venture capitalists had invested large sums of money into many small companies bent on commercializing AI and the areas where current applications were being developed: these include financial services, medicine, equipment maintenance, manufacturing and defense. Among the many existing expert systems, to our knowledge, none exist that simulate group decision making. The task environment of strategic planning and policy making followed by decision making for a period of years in a competitive industry can be simulated in a matter of weeks by a management game. Management gaming has also evolved and the games have become more realistic during the last thirty years that they have been used in the academic and business communities as documented in papers cited by Faria (1987).

As noted earlier, the choice of the task environment was largely determined by the author's familiarity with business gaming, computers, and the availability of data and subjects. However, the management game environment really did offer the opportunity to test the proposed expert system in a real competitive decision making environment while at the same time, it allowed some control over the limits of the experimental domain. In

addition, it was hoped that the exercise of developing this expert system to simulate group decision making in a changing competitive environment over time, would provide some insight into the decision making capabilities of expert systems and of humans.

Experiential learning is considered an important component of the learning process. An expert system that considered previous decisions, modified its own decision rules and improved its performance, would reveal new perspectives on experiential learning.

### 1.5 Outline of the Dissertation

The main body of this dissertation begins, in Chapter 2 with a survey of the relevant literature on the decision making process, group decision making, expert systems, and management games. Chapter 3 integrates the findings of the literature search into the initial model of group decision making for the strategy and policy task of evaluating strategic scenarios and performing operating decisions. This is the starting point of the actual research.

The management simulation game, the variables utilized to represent decision making in a business environment and the procedures followed to implement the game are described in chapter 4. A framework is presented for classifying the operating decision variables of the game. Chapter 5 discusses the development of the expert system decision making model. The description of the validation process and performance of the expert system in the controlled business game setting is covered in chapter 6. In chapter 7 the "live" experiment results are presented and the expert system's performance is compared with that of the student groups with which it competed by the use of the mathematical method of cluster analysis and a graphical analysis. The cluster analysis methodology will examine whether or not the expert's overall

decision making and performance profile were similar to any subset of the competing companies or resemble them as a class. In addition, cluster analysis will be used to provide an insight into any experiential "learning" by the expert system. A graphic analysis of the expert system's performance and that of the competing companies will examine both specific and subgroups of decisions and the resultant performance outcomes. This chapter concludes the thesis with a summary and discussion of the implications of using an expert system to simulate group decision makers engaged in evaluating strategic scenarios and executing operating decisions.

## CHAPTER 2

### RESEARCH ON DECISION MAKING

Expert systems are computer programs that are developed to contain the knowledge and decision making methodology of human experts within a well-defined and limited knowledge area. The resultant computer programs ideally have the ability to make decisions and solve problems in much the same manner as the human experts. In order to understand the decision making methods of experts for solving problems, the literature survey begins by reviewing theories of decision making including the general decision making process, the types of decisions faced by decision makers, and the cognitive performance of the decision maker. This order was chosen based on the historical progression of these topics and their significance to the current development of expert systems. Next, the research on group decision making as a guide for the expert system model and the comparative human groups is examined. Following that the literature on expert systems as decision making simulators will be reviewed. Finally we examine the current usage of management gaming for enhancing the effectiveness of decision making and experiential learning, as it relates to "learning" in expert system models.

#### 2.1 Individual Decision Making

##### 2.1.1 Decision Making Process

Almost thirty years ago Simon (1960), in his writings on management decisions, expressed his view of decision making as an activity performed in a

stepwise process rather than instantaneously at a specific time. From this he outlined the process in terms of three basic phases. He designated them 1) intelligence; the process of finding occasions for making a decision, 2) design; the process of finding possible courses of action, 3) choice; the process of choosing among courses of action. Simon wrote that each phase of the decision process is in itself a composite of the other phases as well as a repetition of other phases until the decision resolution.

About ten years later, Eilon (1969) also described the decision process as a sequence of steps that are similar to computer information processing. The steps are: entry of information, the sequencing of it, the analysis of the information and finally the output of a decision. Radford (1977) defined a three phased decision process similar to that of Simon but, he added bargaining and communication with other decision makers as part of the choice phase. The writings by Eilon and Radford did not significantly change the analysis of the decision process originally developed by Simon.

#### 2.1.2 Decision Types

Simon's theory of the decision process led to his introduction of a method for defining types of decisions. Simon viewed them on a continuum with structured and unstructured decisions at the extremities. In his same writings on management decisions Simon (1960) described structured decisions as repetitive, routine and those for which a definite procedure can be developed for handling them. These decisions evolve primarily in two ways; one, as habits, meaning they are internalized and acquired through training and experience, and two, as standard operating procedures which are formal and written.

Simon followed with his description of unstructured decisions as being novel, often critical, and consequential. He stated there is no prescribed method for handling these decisions and that their nature and structure are often elusive or complex. Simon, using a cognitive view, said the decision maker's ability to successively make these decisions depends on whatever general capacity one has for intelligent, adaptive, problem-oriented action. But Simon added that man is never completely helpless in a new or complex situation. He wrote that the decision maker, when faced with unstructured decision situations, seeks to reduce the complexity to a set of subdecisions which, in turn, are factored into familiar structured elements.

Almost ten years later, Newell (1969) expressed a more precise version of the concept of decision types. He specified that the three criteria for his definition of a structured decision: 1) the presence of numerical variables, scalars, and vector quantities, 2) goals that can be specified in terms of a well-defined objective function, and 3) algorithmic routines that permit solutions to be found and state in numerical terms. The absence of any of these criteria determines an unstructured decision. Like Simon, Newell employed a cognitive paradigm to describe complex decision making. Newell, and subsequently Luconi et al. (1985) defined unstructured decisions as all the negations of structured decisions because of the numerous combinations of ways the criteria for structure could fail to be met. Newell added that as knowledge increases, problem structure increases and the decisions become increasingly structured in the mind of the decision maker. For example, ordering and maintaining appropriate inventory levels was considered an art, an arcane, difficult and complex decision making task, until the economic order quantity (EOQ) formula was developed in the 1920's. From that point on, the

task of ordering inventory became more of a structured task though certainly not wholly structured in all cases.

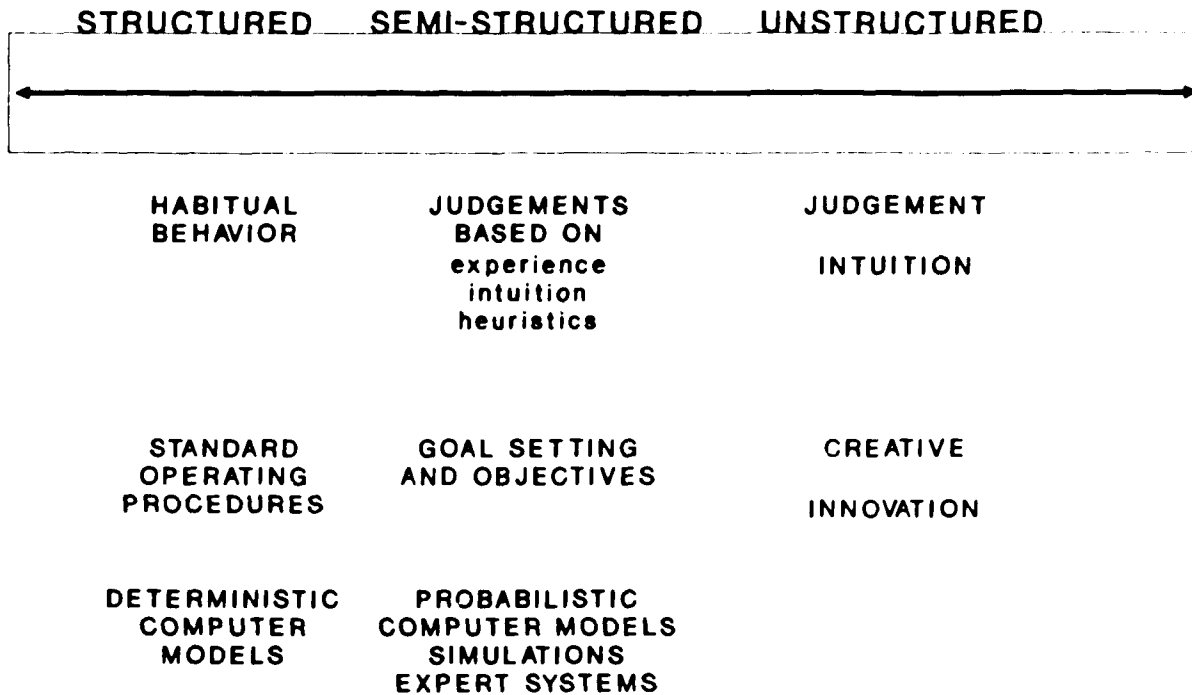
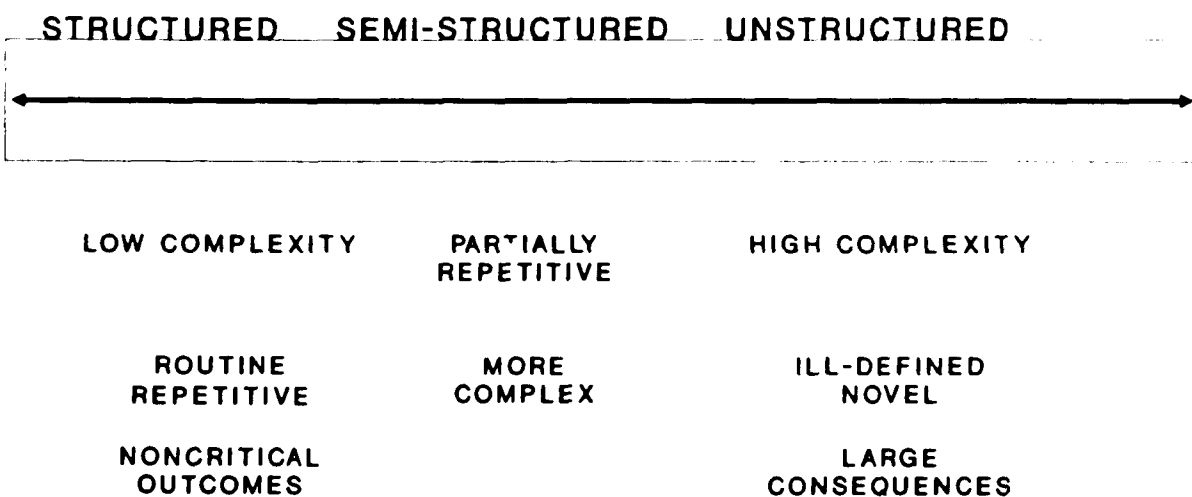
Scott Morton (1971) expanded Simon's original classification of decision types by the addition of a third class that he calls semi-structured decisions. Scott Morton wrote that decisions are semi-structured when a decision maker accepts a certain data set or certain procedures as being relevant to a problem solution. Table 2.1 is a schematic of the decision types developed by Simon and expanded by Scott Morton.

Classification of decision types in terms of management levels as suggested by R.N. Anthony (1965) is also relevant to this research. It provided a framework for combining the taxonomy of decision types with the tasks of organizational decision makers. Anthony proposed that managerial activities fall into three categories and each is sufficiently different to require distinctive planning and control behavior. This determines the nature of the decision type where each managerial activity predominates.

Anthony's first category is strategic planning. He described this as "the process of deciding on objectives of the organization, or changes in these objectives, and the policies that are to govern acquisition, use, and disposition of resources" (Anthony, 1965 page 24). Creativity, intuition and innovation are part of the strategic planning process and characteristic of unstructured decision making.

His second category is management control: "the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives" (Anthony, 1965 page 27). This category primarily fits Scott Morton's middle range of semi-structured decisions.

Table 2.1 - Decision Type Continuum

**DECISION METHODOLOGY COMPONENTS****DECISION CHARACTERISTICS**

Anthony's third category is operational control: the process of assuring that specific tasks are effectively and efficiently carried out.

Operational control is concerned with following predefined activities requiring less judgment than managerial control. Thus the decision types are predominately structured.

The decision type taxonomies of Simon and Anthony, Simon's theory of the decision process, and the concept that knowledge contributes to a problem's structure have helped define the concept of expert systems and provide a focus for their development. If expert systems can or have become a tool to enhance structure in an unstructured or semi-structured decision making task, then it becomes necessary to understand the representation of the problem solving task by an expert system. Thus, the next section focuses on problem solving.

### 2.1.3 Cognitive Aspects of Decision Making

Newell and Simon (1972) spent seventeen years researching and developing a theory of human thinking and problem solving. Their research was postulated on the belief that the human operates as an information processing system (IPS). The IPS is a combination of a cognitive processor and the psychology of the problem solver. The thrust of their research in support of their theory has been on human performance while engaged in specific task environments. Even though the research of Newell and Simon concentrated on problem solving, solving problems requires that one makes a sequence of decisions. The significance of their research to this thesis was their profound description of the problem solving and decision making process and the subsequent adaptability of their theory to the model development for the author's expert system.

Briefly, the theory of Newell and Simon stated that one inputs a set of symbol structures, which are external stimuli from the task environment, and stores them as a problem space in short term memory. There are a variety of problem spaces for a given situation, which are chosen as a function of the individual decision maker, indicating that person's knowledge representation. The cognitive processor uses both predetermined information processing sequences stored in short term memory and groups of associated facts called "chunks", that are retrieved from long term memory, to encode and interpret the input symbol structures. The cognitive processor continues in this manner using procedures such as hypothesis formulation, condition-action pairs and heuristic search among alternative choices for the encoding and interpretation of the input information until the problem is terminated. The psychology of the person determines the "problem space" which is the internal representation of the task environment and the sequence of the information processes is related to this problem space.

The theory of Newell and Simon focused on two dimensions of the problem solving process, the task environment and the human psychology.

"To the extent that the behavior is precisely what is called for by the situation, it will give us information about the task environment..... To the extent that the behavior departs from perfect rationality, we gain information about the psychology of the subject, about the nature of the internal mechanisms that are limiting his performance."

(Newell and Simon, 1972 page 55)

Luger and Stubblefield (1989), in their discussion of the problem solving theory of Newell and Simon, state that humans generally consider a number of alternative strategies on their way to solving a problem. For example, a chess player typically considers a number of moves, selecting what they consider the best according to such criteria as the opponent's possible responses or some

global strategy. Likewise, a mathematician will choose from a different set of strategies to find a proof for a difficult theorem. In both examples the person defines the problem space and the state space search.

Research conducted by Rowe (1985), based on the information processing theory of Newell and Simon, empirically studied the performance of humans while engaged in specific tasks. The significance of this research was the concentration on the role of intelligence, the capacity to acquire and apply knowledge, and its impact on the determination of the internal decision process. The findings of the study specified that "the internal differences in problem solving competence, measured intelligence, speed of performance and educational attainment are reflected in the process of performance and in the actual operations and strategies used by the individuals during their work on a task." (Rowe, 1985 page 332).

Another view of information processing is revealed through a literature search and study by Payne (1982). His analysis of the literature supported the proposition that information processing is contingent on the demands of the task. Payne proposed three frameworks consisting of 1) a rational cost/benefit approach, 2) the perceptual unconscious or "hardwired" response, and 3) the adaptation of a series of "if-then" production systems based on the problem solving theory of Newell and Simon (1972). After developing the frameworks, he concluded that there is less experimental or theoretical support for the existence of adaptive production systems, but that the wide ranging properties of this method of processing information could encompass elements of the other frameworks. Payne's observations concerning production systems supported their adaptation as the basis of the structure of the inference section of many expert systems. He further stated that the development of a

time-dependent view of decision behavior could result in a better understanding of the significance of the task. This statement by Payne suggested a need for developing a dynamic expert system.

Isenberg (1984) also studied the cognitive aspects of human information processing. His field study of the thinking process of senior managers concentrated on how this specific group of people make decisions. His study revealed the unstructured nature of many of their decision tasks and their intuitive approach to problem solving. He conducted interviews, observed senior managers on the job and used exercises in which they recounted their thoughts as they worked. He observed that senior managers do not exclusively follow a sequential process of first classifying a goal, assessing the situation, formulating strategies, determining their choice, and finally taking action to implement the decision. Instead they rely on their ability to holistically analyze a problem. Isenberg further wrote that they use a mix of intuition and individual sequential analysis in their decision making and incorporate their actions on a problem into their diagnosis of it. Managers rely on intuition to rapidly determine the appropriate well-learned sequence of behaviors to respond to a problem situation, synthesize isolated pieces of data, and develop an integrated scenario of the problem environment. Isenberg's study showed that some managers use intuition to evaluate the results of a rigorous and systematic analysis. They combine the results with their intuition until they find a match between their "gut feeling" and their "head". Intuition is used by other managers to bypass in-depth analysis and move rapidly to a plausible solution.

Isenberg described intuition as the "aha!" one feels when a decision seems right. It is the synthesizing of data and experience into a picture of

the problem, similar to the development of heuristic reasoning as a result of experience and knowledge. He said

"intuition is not the opposite of rationality nor is it a sequence of random guesses. Rather, it is based on a specific extensive experience in both analysis and problem solving and implementation, and to the extent that the experience is logical and well-founded, then so is the intuition. Further, managers combine intuition with systematic analysis, quantified data and thoughtfulness."

(Isenberg, 1984 page 86)

The contribution of Isenberg's analysis of the reliance by senior managers on intuition for decision making specified that they do analyze information, but have developed the skill to quickly appraise the significance of that information. Intuition provides the cues that evoke knowledge from long term memory, determine the "problem space" and affect the choice of problem solving search procedures.

O'Reilly (1982) likewise studied information processing but focused on the decision maker's use of information sources. He conducted a field study of decision makers with an average of two years of higher education and job tenure of the same length in a county welfare agency. These individuals represented Anthony's category of operations control managers. He concentrated on the relationship between the quality and accessibility of information and decision making performance. The results of his study showed that for most tasks decision makers use a combination of information acquired from experience or education and other information sources that are both accessible and have a high perceived quality. But, if decision makers are faced with decision tasks that are vague or undefined, they will more often than not use only the most accessible information sources and not evaluate the quality of the information. This work's viewpoint resembled the decision type continuum of Newell, Simon and Scott Morton but it classified the decision

makers use of information sources as a function of the task requirements ranging from structured to unstructured tasks. O'Reilly's study showed that the choice of information sources was a key input to the human information processing and decision making system.

Another group of researchers focused on the quantity of input, meaning the description of the input as a set of symbol structures unique to each decision maker, to the human information system. Both the study by Bonczek, Holsapple and Whinston (1979) of a computer-based support system for organizational decision making and McIntosh's (1982) work on an executive information system for decision making used as a basis for their work the premise that human decision makers operate as information processing systems. They concentrated on the manner in which the human information system gathers inputs from the task environment. These two studies emphasized the increasing amounts of available information to decision makers and the need to explore ways to assist them in the processing of this information glut. They cite this need as a background for the development of their computer-based support for organizational decision making. These studies were less concerned with the judgmental and intuitive aspects of decision making, and instead concentrated on "information overload". Bonczek et al. specified that human and computer information processing have a basis in common. The increasingly powerful computer-based techniques for information processing are used to assist the decision making process. McIntosh said managers and executives spend more than half their time gathering, synthesizing, manipulating, analyzing and disseminating information. Toffler (1980), with his perspective on the human information processing dilemma, summarizes the problem by saying "An information bomb is exploding in our midst, showering us with a shrapnel of

images... We are besieged and blitzed by fragments that come to us in the form of broken and disembodied blips." (Toffler, 1980 page 172)

The literature covered in this section has emphasized four aspects of individual decision making behavior:

1) Human decision makers operate as an information processing system.

2) Decision making can be described by a three-phased cyclical process.

And as decision makers are engaged in this iterative process, they analyze and synthesize information, use judgment, intuition, and heuristics.

3) The decisions themselves can be placed in a framework of structured, semi-structured and unstructured decisions. Intelligence and experience, as ways of gaining knowledge, affect the decision making process and they are reflected in the approach to the semi-structured and unstructured decisions.

4) The role of the decision maker in the organization delineates the types of decisions that the decision maker will face. Each decision maker's internal representation of the decision task environment in turn affects the use of information sources and the decision process.

## 2.2 Group Decision Making

The clear understanding of the decision making process and the performance of the individual decision maker is basic to the study of collective decision making, a composite of individual decision makers. Senior management and those faced with unstructured decisions such as strategic decisions, often make their decisions as a group. Complex problems require considerable information and expertise, sometimes more than one person usually has. Likewise, the success of implementing some decisions is enhanced by the participation of all those affected by the decision process.

The literature reviewed pertaining to group decision making falls into two broad research categories. One group investigated the comparisons between individual and group decision making, an analysis of the phenomena of group decision making, and the benefits of using different methods for groups participating in decision making. The other group of researchers concentrated on computer-based support for organizational group decision making. The researchers of both groups adhered to the iterative decision process paradigm and the significance of the task domain originally attributed to the research of Newell and Simon (1972).

#### 2.2.1 Group Process

Holloman and Hendrick (1972) wrote that much of the earlier research on group problem solving concentrated on comparisons between individual and groups decisions when working on tasks which require a single correct or common solution. Most of the earlier studies cited found group performance to be superior on the basis of a social interaction hypothesis. Their research focused on the human interaction component. They investigated six different group decision techniques ranging from minimal group interaction that averaged private decisions to a maximum group interaction through group majority vote followed by group consensus. They believed their study offered evidence that the quality of the group decision making is positively related to the amount and quality of the interaction among group members. More importantly, their study suggested that the error-correcting property of interaction is the primary reason that groups are superior to individual problem solving.

At the time Mintzberg, Raisinghani, and Theoret (1976) developed their model of the strategic decision process, the research on group decision making was carried on by social psychologists and centered on the

interactions of the group participations, as seen in the research of Holloman and Hendrick (1972). In contrast, Mintzberg's study concentrated on the process of group decision making. Mintzberg et al. analyzed data collected over a five year span from teams of students interviewing and observing different groups of decision makers in different organizations either engaged in the process of determining a specific organizational strategic decision or recollecting the process followed after they had made a specific strategic decision. The initial descriptions showed the decision process is characterized by

"novelty, complexity and open-endedness, by the fact that the organization usually begins with little understanding of the decision situation it faces or the route to its solution and only a vague idea of what the solution might be and how it will be evaluated when it is developed".

(Mintzberg et al, 1976 page 250)

Figure 2.1 presents an adaption of their diagram based on their model of the group strategic decision process. Before discussing this diagram, two remarks: first, Mintzberg et al. based their model on Simon's trichotomy of the decision process, but changed the terms to identification, development and selection. Second, the model is a generalization of one-time strategic decisions and does not consider the group decision process for an ongoing sequence of interrelated decisions. However, it appears to have the potential for being extended to a model for sequential, interconnected, and dynamically changing decisions, which is central to the goal of this thesis.

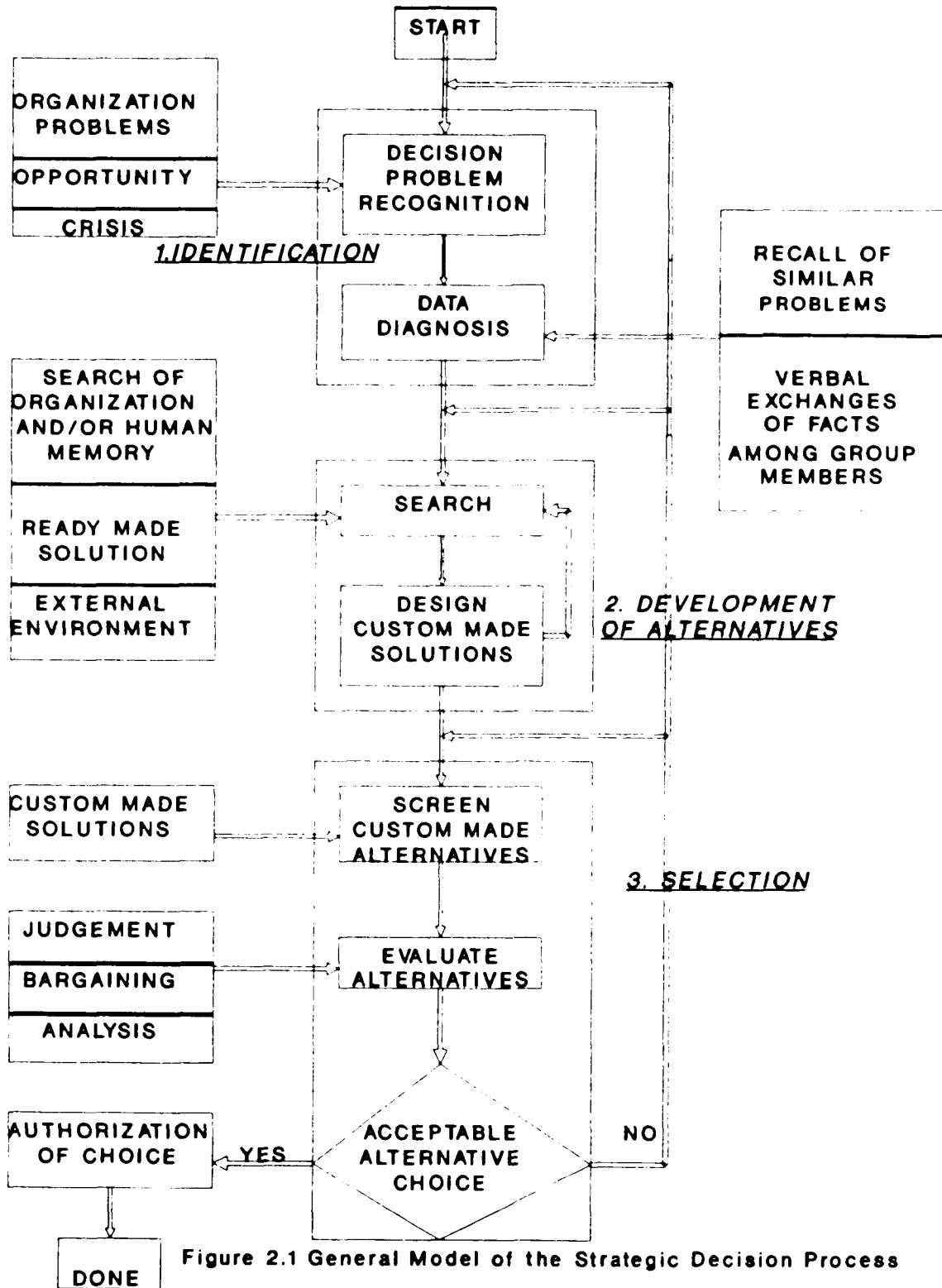


Figure 2.1 General Model of the Strategic Decision Process

### 2.2.2 Group Decision Models

The model of Mintzberg et al. is described as follows:

Step 1. Identification Process. The first step involves two parts: recognition of a problem, opportunity or crisis and diagnosis. Once the decision process is initiated, the next part of the identification is some form of diagnosis. This can be a formal activity with a diagnostic team or a mental reflection of similar decisions and the development of a hypothesis.

Step 2. Development Process. The authors considered this step to be the heart of the decision-making process. The greatest amount of decision-making resources is consumed in this process. The search part of the development process usually begins with scanning of both human memory and the organization's paper memory sources followed by pursuing familiar sources seeking ready-made solutions. If both of the preliminary search attempts fail, then the search becomes more active.

The active search includes what Mintzberg refers to "search generators" that delve into more remote and less familiar areas such as alerting other organizations that solutions are needed for specific problems. Active search also includes direct seeking of alternatives through scanning a wide area, (i.e. external environment) or focusing on a narrow one (i.e. similar product or problem solution). The design section takes the result of the search and develops custom-made alternatives from either the ready-made solutions or the actively pursued solutions.

Step 3. Selection Process. Mintzberg's literature search showed that most researchers and writers focused on the selection process, yet his own field work implied that this process is far less significant in the overall process of making strategic decisions. The selection process is composed of

four steps: screening, evaluation, choice and authorization. The screening step examines the alternatives, reduces the number considered by eliminating both inappropriate custom-made solutions that are too time consuming and/or nonfeasible solutions. The remaining alternatives are evaluated as possible acceptable problem solutions. Evaluation and choice occur in one of three ways. The first, judgment, uses procedures that cannot be explained, but have been acquired by experience and intuition. The second method is bargaining when there are conflicting goal systems. The third method is analysis, performed by other analysts and then presented to the strategic decision makers for judgment or bargaining. Since the development process frequently factors one decision into a series of subdecisions, selection is a process of iterating until a complete or acceptable solution is developed. If the decision makers do not have the authority to commit the organization to a course of action, then authorization is sought from the appropriate hierarchical organizational level.

Many, but not all of the subsequent studies of group decision making cited in this chapter either used laboratory studies as the vehicle for investigating group decision making, analyzed the literature on group decision making, or developed computerized decision support systems. No studies replicated the field study of Mintzberg et al. or reexamined its validity, and this author knows of no work to date in this realm.

### 2.2.3 Benefits of Group Decision Making

White, Dittrich & Lang (1980) conducted an exploratory laboratory research study to investigate the effects of the group problem solving method and problem situation complexity on the implementation of group solutions. Their results indicated that structure in group decision-making processes

increased the rates of implementation attempts. They used structured discussions and nominal group techniques, whereby the views of each individual member of the group are written down, as the group decision-making process progresses. Even though the focus of their research centered on decision implementation, they contributed some insights into the relationship between the group decision-making process and the problem situation complexity. They concluded from an analysis of their findings, that as the degree of problem complexity increased, the need for sufficient structure in the group decision-making process to reach an acceptable solution to the problem increased as well.

Murnighan (1981) and Stephenson and Franklin (1981) focused their research on managerial group decision making. They concluded that managers who are physically separated, who dislike committee groups or diverse groups, will tend to benefit from the Delphi and statistical aggregation techniques. Fusfeld and Foster (1971) stated that the Delphi method is an effective technique for consensus decision making in a complex decision environment.

Adizes and Turban (1985) stated that even though many management decisions are made collectively due to the complexity of the problems and need to share considerable information and expertise, managers either resist the trend toward group decision making or consider it a waste of time. Therefore, they proposed a framework for effective group decision making as a function of the quality of the decision and the probability of implementation of the proposed solution. Adizes and Turban specified that there are three factors to consider: 1) the nature of the problem, 2) the composition of the decision making team, 3) and the decision-making process and tools. If the problem requires a group solution, then the team is developed. Adizes and Turban claim

Turban claim that a team composed of persons who assume four complementary roles is most successful. They suggest that a structured decision making process such as the Nominal Group Process is essential for effective group decision making. The management game, used for the experimental setting of the research for this thesis, likewise has four person teams in just such complementary roles as described in appendix 1, table A1.4.

Miner (1984) provided another perspective on group decision making. He investigated prior research findings on group versus individual decision making performance. He noted that the findings were fraught with inconsistencies such as one group claiming that individual decision making was more effective while another group claimed the reverse. Minor believed that much of the confusion in results was due to the lack of an agreed upon definition of the dependent variable. Therefore, Minor conducted research that differentiated along the dimensions of task, process, individual differences, and methodology. Then he utilized a variety of such groups in a multistage decision task. He wrote that some solved the problem as individuals first and groups second and others reversed the process. He concluded that initial individual decision making followed by group decision making is the most effective due to a process gain when co-acting individuals solve problems prior to group decision making.

#### 2.2.4 Computer-based Support for Group Decision Making

The next concern was the body of research that focused on the possible enhancements to the group decision making through the application of computers. Steeb and Johnson (1981) designed a computer-based interactive system for group decision making using decision tree analysis. For their experiment they developed a specific complex problem and compared the

performance, behavior, and responses of aided and non-aided groups to this problem. They stated that because decision analysis is a highly personal and time consuming process, they believed it was more worthwhile to develop a methodology to aid the group process rather than that of each individual decision maker. Steeb and Johnson concluded the group-decision-aided system provided a systematic, useful and easily accepted tool in the experimental test scenario. Even though their experimental problem was artificially derived, it was a step in the direction of valid computerized assistance in decision making. This experiment lent support to the claim that there is value in developing a computerized simulation of group decision making.

Huber (1984), prior to the similar study by Adizes and Turban (1985), studied the inherent problems of group decision making such as the amount of time spent in such a collective endeavor due to individuals of the group possessing different expertise, assumptions, and information. Thus, he proposed using a computer system to minimize the impact of these problems on the group decision makers. He addressed problems faced by managers such as the fragmented decision environment as well as the need for the sharing of information and expertise. He also claimed that many feel the excessive amount of time spent in meetings detracts from other important managerial activities; thus they resent the time commitment. Like Steeb and Johnson, he was concerned with the quality of the decision outcome rather than the decision making process. Huber emphasized the need to develop a computerized method for facilitating more information sharing while providing a rich verbal interchange. Subsequently he and other researchers have developed a computer system called Group Decision Support System (GDSS) which at that time supported group decision making for only a very small set of tasks. It is

relatively rudimentary, but he expected that future systems will be markedly superior.

Another study of the use of GDSS by DeSanctis and Gallupe, (1985), also emphasized the need for developing methods to enhance group decision making. They believed that as organizations become increasingly complex, fewer decisions are made by single individuals, thus, the need to concentrate on group decision making.

Huber and McDaniel (1986) developed a decision-making paradigm that stated that when designing organizations it is crucially important to create structures and processes that facilitate the making of organizational decisions. They believed current and future organizational environments face more turbulence and uncertainty than past and current organizational environments and that organizations will thus increasingly rely on group decision making. The increased competitiveness, size and complexity of organization structures requires more emphasis on incorporating expertise within the computer-based information systems to support these group decision makers.

#### 2.2.5 Summary of Group Decision Making

Reviewing the literature on group decision making leads one naturally to several observations: first, it seems apparent that the multi-staged, iterative decision process paradigm is common to most decision research studies. Further, as real organizations increase in size, group decision making appears more prevalent for complex and multi-stage decision making. Some computer-based systems have been developed to aid group decision makers for specific problems within narrow domains and the thrust is in this direction. These observations and Mintzberg's general model of the strategic group

decision process were part of the group decision model for the specific strategic task of this thesis.

## 2.3 Expert Systems

### 2.3.1 Early Period

The field of artificial intelligence can be traced back to Charles Babbage and Ada Lovelace with their work on his inference engine. They were intrigued with the potential of their invention and speculated whether the machine would ever be as smart as people or if it could "think". Perhaps within this century the first person to see clearly the possibility of computer intelligence was Alan Turing. He put forth the idea that a computer could be programmed so as to exhibit intelligent behavior. His famous "Turing Test" as described by Luger and Stubblefield (1989) says that a machine and a human counterpart are placed in rooms apart from a second human being, referred to as the interrogator. The human interrogator is not able to see or communicate directly with either of them, only by using a textual device such as a terminal. The interrogator is asked to distinguish between the human and the machine based solely on their answers to questions. If the interrogator is unable to reliably do that, then Turing says the machine is intelligent. Hertz (1985) related a description of artificial intelligence taken from a discussion with Norbert Wiener.

"A reasonable description is that it is a manifestation of complex information handling processes which increase the probability of successful responses by an entity, or group of entities, to threats and opportunities in the environment. To the extent that machines accomplish this their actions can be termed intelligent".

(Hertz, 1985 page 2).

By the mid 1950's numerous scientists across the United States had access to mainframe computers which enhanced their research. The seminal work

in developing general principles of problem solving was performed by Newell, Simon and Shaw with a computer program called the Logic Theorist. This program, written in 1956, produced the first successful proof of a geometric theorem from Russell and Whitehead's Principia Mathematica. Additional early endeavors included a program developed to solve geometric analogy problems like those that appeared on intelligence tests and another program that performed symbolic mathematics (MACSYMA) originally developed at MIT in 1968.

Newell and Simon (1972) also developed the General Problem Solver (GPS) during the time period of the late 1950's. This program solved cryptarithmic puzzles, block puzzles, and other similar tasks. They had at first thought that a few laws of reasoning coupled with powerful computers would result in expert and superhuman performance. Instead, as time and effort accrued, they recognized the limitations of a general purpose problem solving strategies. They succeeded for easily definable tasks, but GPS was too weak to solve complex problems. They concluded that without advances in theory or program design, GPS, or any program based on its approach, would not be capable of "general problem solving". With the limits of GPS made clear, research shifted directions from general problem solving to that of problem solving within narrowly defined application areas.

The early achievements, albeit simplistic, have spawned further interest in artificial intelligence resulting in the development of computer programs that became known as "expert systems" or "knowledge-based system". These computer programs are designed to represent and apply factual knowledge and problem solving expertise in specific task domains. One of the early expert system successes was the work done by a group of researchers led by Edward Feigenbaum. Their program, DENDRAL, was able to deduce the structure of an

organic molecule using the heuristic search method of an expert who had a sophisticated knowledge of mass spectrographic and other relevant chemical data.

"The behavior of the best general problem solvers we know, human problem solvers, is observed to be weak and shallow, except in the areas in which the human problem solver is a specialist. And it is observed that the transfer of expertise between specialty areas is slight".

(Feigenbaum, 1977 page 1017).

### 2.3.2 Heuristics and Expert Systems

Various descriptions of heuristic reasoning are described in this section. They range, in a time sequence, from Simon (1960) to Luger and Stubblefield (1989), which also parallels the closer identification of heuristics with expert system program development. Simon discussed the decision making technique used as a response to a nonprogrammed decision that is novel, unstructured, and consequential as follows:

"By nonprogrammed I mean a response where the system has no specific procedures to deal with situations like the one at hand, but must fall back on whatever general capacity it has for intelligent, adaptive, problem-oriented action...exercise judgment and this judgment depends, in some undefined way, upon experience, insight, and intuition."

(Simon, 1960 page 6).

Reitman (1964) specified that heuristic reasoning means bringing as much intuition and plausible argument as possible to bear on problems which were described as to be either computationally intractable or for which inadequate theory existed. Heuristics, as stated by Keen and Scott Morton (1978) are a compromise between the demands of the problem and the capabilities and commitment of the decision maker. To understand the decision process of individuals or of groups it is essential to know the heuristics used.

Hayes-Roth et al. (1983) stated that human expertise consists of knowledge about a particular domain, understanding the domain problems, and

skill at solving some of these problems. Human experts generally possess large amounts of knowledge that consists largely of heuristics which enables the expert to make educated guesses when necessary, recognize promising approaches to problems and deal effectively with erroneous or incomplete information.

Winston and Prendergast (1984) pointed out that human experts specialize in relatively narrow problem solving tasks. They said that experts learn from experience, change their point of view to suit a specific problem, and are able to transfer knowledge from one domain to another. An expert's knowledge source is a combination of published materials, facts, theories about specific domains of study and experience, and "rules of thumb" that are referred to as heuristics. Winston and Prendergast state that an expert system is a computer program that behaves like a human expert in some useful ways, but they claim, the present state of the art is such that expert systems are successful for simpler problems for the most part.

Luger and Stubblefield (1989) state that much of what we call intelligence resides in the heuristics used by humans to solve problems. They also claim heuristics are not foolproof, but they add, while they do not guarantee the best solution to a problem, a good heuristic can come close most of the time. Additionally, they state that if the state space search (see the description by Newell and Simon in section 2.1.3) give us a way of formalizing the problem solving process, then heuristics allows the infusion of that formalization with intelligence. They conclude that expert systems research has affirmed the importance of heuristics as an essential component of problem solving. The "rules of thumb" that a human expert uses to solve

problems efficiently are largely heuristic in nature and that these heuristics are extracted and formalized by expert system designers.

The next section reviews a group of papers which claimed that knowledge, rather than sophisticated problem solving skills, determines the quality of the expert system performance.

### 2.3.3 Expert System Knowledge Base

Rauch (1984) wrote that the term "expert system" exists because this class of computer programs addresses problems which are normally thought to require human specialists for solution. The programs are also called "knowledge-based" because researchers have found that accumulating and correctly representing large amounts of knowledge, rather than sophisticated reasoning techniques, is the key factor in the success of these computer programs. These computer programs provide the user with a context for specifying courses of action. The user is able to project a scenario beginning from that action, and to estimate its likely consequence. It is the responsibility of the user to determine each specific alternative to be assessed.

Harmon and King (1985) noted three different methods for representing knowledge; semantic networks, developed by Daniel Bobrow in 1968, production rules, introduced by Edward Feigenbaum in 1969, and frames, developed by Marvin Minsky in 1975. A description of the methods illustrates the basic differences. The expert system developed for this thesis used a form of production rules in the knowledge base. (See chapter 5 for development of the expert system model).

Semantic networks, which were the oldest knowledge representation, are a collection of objects called nodes, connected together by links. Examples of

nodes are names of entities such as different birds or characteristics of birds. The links are word groups depicting relationships between nodes using word groups such as "is-a", "has-a" and so forth. Thus if the expert system was queried "is a canary a bird", the response might also reveal general traits of flying and breathing.

Production rules represent knowledge through the use of condition-action relationships. The rules are expressed as if-then statements that are checked against a collection of facts or knowledge about a specific situation. The factual knowledge is expressed as an object-attribute-value triplet. Production rules seem to provide a powerful model of human thought. An external stimulus activates the "if" portion and the internal mental processes result in the "then" portion in forward chaining, or an external stimulus describes a goal, a desired "then" state and seeks to find a "if" state that will activate the goal in backward chaining.

Frames are descriptions of objects that contain slots for the information associated with the objects. Slots are similar to attributes and can contain all the important features of an object. The information within the frames are attached by using procedural statements. Frames gain power, generality, and popularity as a knowledge base through their ability to integrate both declaratives and procedural representations.

Harmon and King (1985) compared the human cognitive behavior in the information processing model of Newell and Simon to information processing in a computer. They stated that to the human the external stimuli from the task environment are similar to standard input to the computer. The human short term memory is analogous to cache and buffer memories of the computer and the long term memory is analogous to the secondary storage devices such as

readily accessible disk devices. The cognitive processor, like the central processing unit (CPU) of the computer, cycles periodically through a "fetch-execute" process encoding and interpreting the contents of the buffer memories. As more input is placed in memory, the central processing continues. Harmon and King say that simple, habitual tasks such as reaching to turn off a light switch can be compared to computer information processing. More complex tasks require more information and elaborate human cognitive processor will call on long term memory. They suggest that a production system consists of two parts: production rules, or "if-then" statements, and a working memory. Production rules are applied to working memory and if they succeed in contributing new information, then it is stored in working memory. A production system provides an extremely powerful model for human thought because it is simple, discrete and flexible.

Reitman (1982) used artificial intelligence to develop a computer program based on the oriental board game GO. The program determines plausible goals, ascertains available resources, locates constraints, and matches resources to options. The search for each player's move is restricted to very small subset of good alternatives. His computer program is only capable of playing GO, a game of strategy whereas chess is more tactical. Reitman claimed the success of the GO program in managing its search and decision problems is attributable to the highly selective character of the search, similar to an expert using heuristics for problem solving. Reitman's approach was derived from the work of Simon and Newell, who introduced heuristics and satisficing into programs capable of independent thinking and problem solving. Reitman claimed the ability of the GO program to selectively construct good alternatives can

provide a framework for examining and rationalizing strategic analysis and planning in business.

#### 2.3.4 Expert Systems in Management

The studies reviewed in this section presented an overview of the application of expert systems to management decision making tasks. Currently there are expert system models that have been developed for limited number of particular business applications, but collectively these studies highlight the need to develop others. Holsapple and Whinston (1987) claim that the increase in knowledge management tools, specifically expert system tools (described in Chapter 5) will enhance the development of expert systems for an increased number of business applications.

Blanning (1984) wrote that the successful expert systems for various constrained decision making domains, such as game playing, medical diagnosis, chemical structure analysis, geological exploration, computer configuration selection, and computer fault diagnosis, have given rise to the possibility that expert systems can be developed for managers to capture their specialized decision tasks. An expert system for managers would diagnose potential or actual problems, recommend strategies, and offer, on demand, explanations for its diagnosis and recommendations.

Blanning (1985) followed with an analysis of research areas for expert systems in management. He stated that decision models are primarily causal models of a real world system that a manager is trying to influence or control while expert systems are models of the judgment and decision processes of an experienced manager. Blanning further stated that the idea of capturing expert judgment in a knowledge system is not new. Management scientists have developed numerous heuristic models in such areas as production scheduling

and marketing. However, in his opinion, the design of a management expert system should place emphasis on the acquisition, representation and processing of expert knowledge. A comment by Blanning pertinent to this thesis, is that recent development of a number of expert system "shells" that contain the ability to transform functional relationships into predetermined inference rules, has accelerated the growth of management expert systems (see Chapter 5, section 5.1 for a description of expert system shells).

Sviokla (1986) surveyed features of expert systems. He stated that expert systems cannot begin to solve all unstructured problems, but, they are often the best available tool to enhance the decision structure for the manager. He wrote that structure pertains to the task itself, independent of the computer program and each expert system is a particular representation of the task and its solutions. Sviokla's distinction between program and problem structure is based on the theory of problem solving developed by Newell and Simon. He stated that the problem solver, human or expert system, has a set of operators that can be applied to the variables in the problem in order to change their content or structure. The task's problem space is defined by the complete set of problem-solving procedures generated by the interaction of the problem solver and the task environment. The degree to which the expert system can capture the "true" problem space indicates how well it represents the task. Sviokla stated that, if part of the task domain is unstructured and the representation of the problem retains some of the unstructured parts, then it may still be an expert system. Otherwise, if the program oversimplifies the problem space, then the program is not an expert system, but is merely a model which simply approximates the problem to some degree.

He referred to Anthony's dimension of management levels as similar to the dimension of the problem structure. Sviokla believes the development of expert systems at different management levels bring structure to the task being supported and, over time, these tasks may migrate from unstructured to structured. For example, a current strategic task such as cash management, with an expert system support, may change from a strategic level to an operational one.

#### 2.4 Management Games

Current use of games are extensions of war games which have been utilized since the seventeenth and eighteenth century. In the early post WW II period the computer was employed in war gaming with the computer doing all the data reduction and analysis. Aside from military applications, the most extensive efforts to utilize games and gaming techniques has been in business related areas. An inventory management game developed at RAND in 1955 to simulate the US Airforce logistics had more in common with modern management games than it did with earlier war games.

A survey of the use of management games by Faria (1987) stated one of the first uses of a management game on a university campus was the Top Management Decision Game developed by Schreiber at the University of Washington in 1957. At the same time UCLA, Carnegie-Mellon University, IBM, and other companies constructed management games. Following the introduction of management games, their number and use expanded rapidly, so that by 1961 there were over one hundred games in existence and over 30,000 people had participated in playing the games. Currently Faria estimates three million company employees have participated at one time or another in various management games. His survey revealed the business firms that responded

indicated they used simulation games in training programs for managers ranging from trainees to top level management groups. This would tend to indicate that these firms felt there was value added to the decision making behavior of the personnel in such exercises.

Mehrez, Reichel, and Olami (1987) compared a management game simulation of a fictitious company to a real company in the same industry. The performance results of their study revealed similarities in environmental variables, interest rates, and industry structure. They concluded that even though the range of decisions were constrained in the simulated firm, the management game yielded results that were very similar to the "real" firm they studied. This study provided evidence that management games can be constructed to realistically simulate an actual company's environment.

### 2.5 Experiential Learning

Although the literature pertaining to experiential learning focused on human learning, some aspects of this learning can apply to the concept of an expert system.

Kolb (1984) defined learning as "the process whereby knowledge is created through the transformation of experience". (Kolb, 1984 page 38). He also compared the learning process as a sequence of phases similar to the decision-making process of Simon (1960). Kolb's experiential learning model has four stages: concrete observation and reflective observation which resemble Simon's intelligence stage, abstract conceptualization, analogous to Simon's design stage, and active experimentation which corresponds to Simon's third phase that he called choice.

Cell (1984) stated that there are four kinds of experiential learning that reflect stages of human development. The first two, 1) response and 2)

situation learning are the result of interaction with the environment. The other two stages, 3) transsituation and 4) transcendent learning, occur when one interprets the environmental interaction and subsequently changes the interaction and adapts to the environment.

Sims (1983) used Kolb's experiential learning theory as a model and developed a framework for relating job demands with learning competencies. He included strategic planners in a class of jobs that require a perceptual orientation, understanding of the present and ability to focus on the future, thus he proposed that the experiential learning appropriate to this group is the gathering and organizing of information.

Simon referred to learning as "any change in a system that produces a more or less permanent change in its capacity for adapting to its environment". (Simon, 1981 page 118). Simon wrote that cognitive simulations in the form of expert systems that have been modeled as production systems can be endowed with learning capabilities and are called adaptive production systems. Since the knowledge base of these expert systems is a sequence of "if..then" rules, these rules could be modified by adding new ones or deleting or modifying existing ones as a consequence of "learning".

Luger and Stubblefield (1989) outlined a list of five training and learning themes that compare human and machine learning and training. The first and simplest type, rote learning requires no modification of input, solutions are stored and recalled when the same problem instances arises. The second, learning by examples is the induction of general principles from a set of examples either incrementally, modifying concepts in response to each training instance or in a single trial, forming concepts once in response to all the data. Thirdly, learning from advice involves improving performance using

explicit advice from a "teacher". This learning requires a correct understanding of the advice, correct translation into the internal representation, and integration of this knowledge into a current knowledge base. Learning from analogy applies existing knowledge to a new problem instance on the basis of similarities between them. They compare this learning to case-based reasoning, utilizing a knowledge base that is a set of relevant examples rather than general rules. The last, learning by observation and discovery, is unsupervised learning. There are either large amounts of unstructured scientific data or data produced by experimentation. Much work in learning by discovery is done in the areas of scientific and mathematical discovery. These domains have fit well into AI research. They conclude, the first four learning or training experiences can occur from a teacher or the outside environment while the last training experience has been by expert system computer programs.

## 2.6 Conclusion

The review of the research in expert systems, and in individual and group decision making suggested a number of observations. First, structured decisions have well defined decision rules; thus they can be easily adapted to a computer program. On the other hand, semi-structured decisions contain some well-defined and ill-defined decision rules while unstructured decisions are ill defined and complex. Intuition, judgment and heuristic reasoning are usually required to make these latter two type of decisions with any success. Secondly, group decision makers are more often faced with semi-structured and unstructured decision tasks and their more extreme consequences. Another observation suggested by this literature pertains to the structure of expert system programs that are modeled on human expertise. Hayes-Roth et al. (1983)

wrote that human experts generally possess large amounts of knowledge that consists largely of heuristics which enables them to make educated guesses, recognize promising approaches to problems and deal effectively with erroneous or incomplete information. Next, we recall that Simon (1981) claimed an expert system model that contains production system rules in the knowledge base has the potential to exhibit the effects of experiential learning. Lastly, management games constructed to simulate a real world competitive and interactive environment appear to provide a convenient and appropriate setting for research into group decision making.

When all of these observations were combined with the model of the strategic decision making process developed by Mintzberg et al. (1976), they provided a theoretical framework for the research of this thesis.

## CHAPTER 3

### AN INITIAL MODEL OF THE GROUP DECISION PROCESS

The survey of the literature in Chapter 2 showed a concurrence of opinion on the description of the individual decision process. The research and conclusions pertaining to the group decision making process assumed some common understanding of the individual decision making process. Mintzberg and his colleagues, using Simon's trichotomy of the decision process, presented a general model for a one-time strategic decision process that could extend from one to more than four years before resolution. The remaining studies focused on the comparisons between individual and group decision makers. Even though there was some agreement, the surveyed studies of both individual and group decision making had different perspectives, assumptions and variables and were not always expressed in comparable terms. In this chapter, therefore, the purpose is to integrate the findings and develop an initial model of the group decision process for a specific strategic task that will attempt to show the interrelationships among the decisions pertaining to the task.

#### 3.1 The Decision Process

The initial model is illustrated in figure 3.1. This model pertains to decision makers interacting in a group process while formulating their decisions for the management game task environment of evaluating strategic scenarios and making operating decisions. The development of an initial model for a specific task domain, rather than a general model, is in accord with our

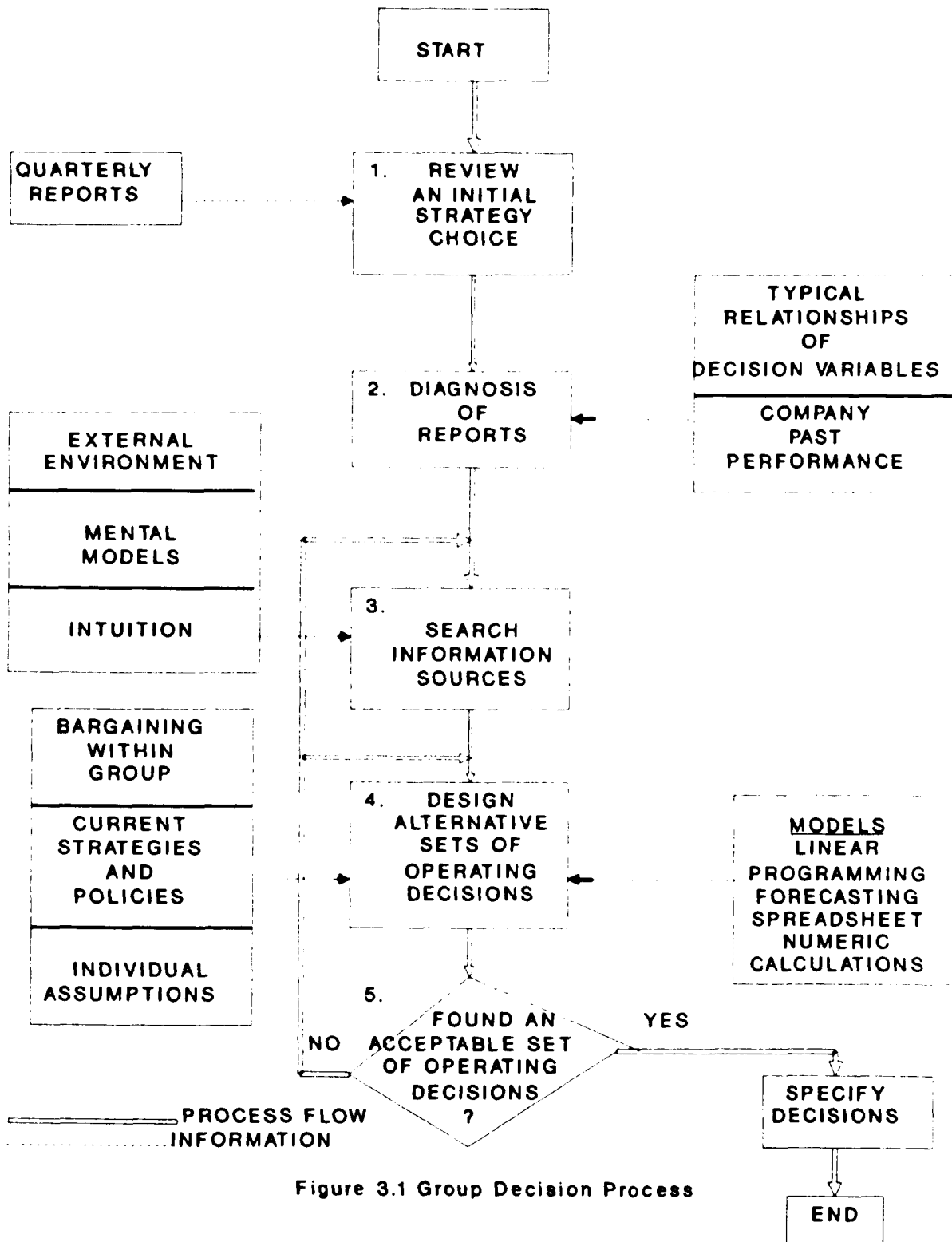


Figure 3.1 Group Decision Process

goal to employ an expert system to simulate this group decision process. Prior to discussing this diagram, the following two facts relevant to the management game environment are as follows: first, in the implementation of the management game in the undergraduate curriculum of an urban university, specifically Pace University, classes are divided by the instructor into four-member teams. Each team member is assigned a functional role within his/her "company"; (Vice President (VP) of Marketing, VP of Finance, VP of Production, and Chief Operating Officer (CEO)). To the extent possible, the roles are assigned to match the students major study concentration. Second, as they assume their roles initially, all the team decision makers review identical reports pertaining to four years of past history of a specific company and develop the initial strategies and policies for their company. The experience of the game administrators has indicated that three basic strategies work best in the game's simulated market place: high volume - low price, product differentiation, and reactive. Thus, each team's choice is from these three strategies and affects the pattern of the quarterly operating decisions. (See Chapter 4, section 4.2 for a detailed description of these strategies.) The numbers in the following text refer to the diagram.

1. Review of initial strategy choice. This step begins the process: The decision makers, portraying their functional roles, receive quarterly reports showing the state of their "company" which is the accepted way the decision makers in this game environment receive the initial information. As they review, via quarterly reports, the decisions and resulting outcomes from the previous quarter they analyze how these decisions affected their company in the competitive environment, the estimated performance of the other companies in the same industry, and the general state of the economy. From this analysis

the decision makers review their initial strategy choice and either continue with the initial choice or decide to change to another.

2. Diagnosis of reports. The decision makers use their personal knowledge, acquired through their business education and any business exposure, to highlight specific decisions and develop some basic relationships between the variables for other decisions. Typical information that would be considered are the sales volumes and demands, finished goods inventory, production efficiency, stock price and earnings per share. The game's quarterly reports have five separate subreports (see samples in appendix 1 table A1.2) that contain information pertaining to last quarter decisions, production and sales, associated operating costs, financial statements, econometric and stock market data, and estimates of the performance of the competing companies in the industry.

The game decision makers review each of the subreports, assess their company's performance by posing and answering questions such as:

Did the firm run out of finished goods inventory?

Did we pick up another firm's unfilled demand?

Why didn't we produce what we expected?

How does our price compare to other companies in the same industry?

What was the unit cost of our product?

3. Search information sources. The decision makers of each group use their individual internal model (Simon's "problem space") to develop values for the decision variables. They also use intuition, predetermined perceptions of the task environment, and call upon experience and acquired knowledge that pertains to their particular decision task. The preliminary search may be sufficient. If more information is needed, then the decision makers' search

becomes more active. They scan a wide range of information sources such as; reviewing the current data, the historical data, curriculum-specified reference materials, and other related resource documents.

4. Design alternative sets of operating decisions. The results of the information search are used by the decision makers, either as a complete or partial group or individually, to design alternative sets of operating decisions. They may use analytical models such as linear programming and forecasting software packages. They may also develop spreadsheet models and computer programs to perform basic numeric calculations they feel will be useful. Some of the structured production decisions might be fully determined by calculations. The semi-structured and unstructured decisions require the use of analytical and heuristic models; some may require intuition in specialized areas. The decision makers, either collectively or individually, review the sets of decision alternatives, eliminating those that are inappropriate based on their current strategy choice.

5. Evaluate new operating decisions. The remaining sets of alternative operating decisions are reviewed by the group decision makers to determine which, if any, are acceptable. If all the decisions for next quarter's operations are acceptable as a group consensus, they then specify the game decisions for the upcoming quarter. The group decision makers usually do not work in unison or automatically agree. Their individual responsibilities and interests as production, marketing and finance executives can result in conflicts. If the decisions are not acceptable, they then re-examine the current strategy choice and individual assumptions or repeat the search process. Each individual step may be recycled several times as well as the

total process. This iterative process is very similar to what Simon (1960) describes as "wheels within wheels".

### 3.2 Elements of the Information Processing System

The basic research philosophy of this thesis is the generally accepted information processing theory of Newell and Simon as outlined in Chapter 2, section 2.1.3. The elements of information processing in the model developed in this chapter that are similar to their theory are the input sources from the task environment, the quarterly reports, and they are the external stimuli. The specific educational and/or experiential background of the members of the group define their initial individual problem space. These quarterly reports are available on a regular basis and become a more reliable information source over time. This regularity reinforces the typical interrelationships of the decisions and changes the problem space for each of the decision makers. As the individual decision makers interact to form group decision making teams, the periodic group interaction for each quarter's decisions could either have a positive affect on the group consensus, if they have developed similar problem spaces, or result in a dominant decision maker in the group.

The analysis of the differences between the experts described in the Mintzberg et al. strategic decision model and the students indicates two things: experts possess a "richer" information source for the problem space and their recall of similar problems and ready-made solutions exceeds that of the students due to their expertise. Nevertheless, the information sources for the specific task of the management game will be sufficiently "rich" to simulate group decision making in a competitive environment and demonstrate experiential learning. In addition, the roles played by the members of the student groups are chosen to match their educational background, if possible,

thus another component of the game environment will attempt to move the game simulation closer to reality.

### 3.3 The Present Research

The literature survey of the preceding chapter covered both individual and group decision making while the initial model developed in this chapter (see figure 3.1) pertained to the group decision process. The implication is group decision making is an amalgamation of individual decision makers. This thesis seeks to simulate the process of group decision making in a management game context through the use of an expert system. Survey information on the causal structure of the decision variables from the expert faculty panel provide the expertise. Given this, the type of expert system shell chosen for the research uses historical examples of decisions mapped onto the expertise to quantify the relative causal/correlational relationship as the initial knowledge base. These examples are used to generate production rules for the inference mechanism and to meld them into a decision tree. Examples of the expert system decisions are added to the knowledge base as the management game proceeds from quarter to quarter and the inference rules are regenerated to reflect the current knowledge base. The chosen expert system shell seemed suitable for the combination of structured and unstructured decision variables that are part of developing and evaluating strategic alternatives within the management game. The game was chosen because of the author's familiarity with it and its availability, as well as the accessibility to a group of expert subjects. In addition, the management game contained a set of stochastic parameters, provided a dynamic environment for experiential "learning" and lastly, the author had the ability to exercise control over the experimental task domain.

## CHAPTER 4

### THE BUSINESS POLICY AND STRATEGY GAME EXPERIMENT

As the objective of the present research is to develop an operationally defined model of the group decision process in the form of an expert system computer program, it is not sufficient to simply develop the expert system. The system that results must be able to react to stochastic parameters and exhibit "learning". To accomplish this objective, knowledge collection and a suitable decision environment are essential. Thus the management game environment was a natural choice as an experimental setting in which to adequately test the expert system that was designed to react to a decision making environment containing stochastic parameters. Further, the game presented a sequence of twelve periods, and thus a reasonable test of the ability of the expert system to react to the changes in the competitive environment and "learn" from experience.

#### 4.1 Experiment Conditions

##### 4.1.1 Experimental Setting

There are various ways that one can choose to simulate group decision making. One possibility would be to conduct a study on an actual organization engaged in a group decision process and then attempt to construct the same decision environment in a lab setting. This way, one might be able to study a real-life decision environment, instead of a simplified game environment, assuming the faithfulness of the laboratory reconstruction. Furthermore, one would be studying the established, well developed group decision making

process of professionals; people who as a matter of course execute these kinds of group decisions for a wide variety of tasks. There are, however, some distinct disadvantages to this method. With a real-life company inevitably comes the choice of an appropriate group decision. Companies face numerous decisions during any period in many different places within the organization. Also, in order to experience learning, one would have to afford the decision makers of the study an extended and uncertain length of time. This length of time cannot be controlled and could extend over a period of years. It may, of course, be argued that the goal should be to simulate a real company's group decision making with an expert system. This study is, however, an exploratory study, a first step. At the moment, very little is known about the reactions of an expert system in a group decision making environment that contains stochastic parameters. Should such an exploratory study then try to deal with the complexity of a real company over a long uncertain time period?

The answer, of course, depends on the approach one intends to take: basically the choice lies between simulating the actual decision making of experienced experts in a real organization or a simplified task (with the essential characteristics of a real organization) at a low level of simulation. In this research, the second, more controlled approach has been taken, because one of our main (methodological) objectives is to assess the decision making process of an expert system and examine how it performs with imperfect information and how well it fits the presently existing body of research on group decision making and expert systems.

However, a major disadvantage of a field study is the reduced control over the experimental conditions and the actual content of the task; it would be difficult to isolate the specific decision components from the

organizational environment and other simultaneously occurring tasks. A second disadvantage of a field study is the inability to replicate the experiment. Furthermore there might be interruptions that would change the decision making environment, or change the decision makers, or lengthen the time from the beginning to the end of the decision making period. In addition, there are many assumptions and particular views of the environment which vary with each decision maker. Thus, much of the field research on group decision making has concentrated on interviewing people after the decision process, studying different group processes such as nominal decision making, or studying computer-based support for organizational group decision making as stated in Chapter 2. This after the fact survey can only introduce more potential for distortion of the decision process.

For these reasons, and for the more pragmatic ones of availability of decision makers and a body of experts as well as a suitable environment, the management game setting was decided on. The decision makers competing with the expert system in this experiment were undergraduate business students in the last year of their degree program who were taking the policy making class as the capstone course of their curricular programs. Although they were not specifically trained in strategy development and policy making per se, they had all taken a sufficient number of business courses to understand the functional areas and decision making process in organizations.

#### 4.1.2 Instrument Used.

It is clear from the preceding discussion that group decisions, as made by real companies, are too complex, varied, and numerous. Clear too, is the need to measure the longitudinal impact of competitive decision making and "learning", which necessitates observing a sequence of decisions over time.

Lastly, stochastic parameters, external econometric values, and industry performance reports are part of any real organizational environment.

For these reasons: (the required flexibility, the time sequencing element, degree of decision complexity, interdependence of functional business areas, econometric values and industry reports,) the author chose a simulated model of companies whose managers would be making specific operating decisions in a competitive environment.

The chosen simulation was the Business Strategy and Policy Game (BUSPOG) of Eldredge and Bates (1984). It has been used for at least six years in the capstone course in both the graduate MBA and the undergraduate program at Pace University. BUSPOG is also in use in forty-six other colleges and universities across the country. The BUSPOG is a management exercise involving three levels of managerial activities: functional (marketing, production, personnel, and finance), coordinative, and organizational.

The BUSPOG deals with a hypothetical refrigeration industry made up of as many as seven companies that compete within three markets. Each company produces two products: refrigerators, which are marketed as a consumer product, and refrigeration units, which are marketed to other manufacturers as an industrial product. The management teams of each company make a set of operating decisions for each quarter of the year. The particular decisions involved include selling price, product research and development budget, scheduled production work week, raw materials ordered, profit sharing and dividends. The full list of the decisions made for each quarter is in appendix 1 table A1.1.

The decisions of all the competing groups are processed through the game computer program, and the estimated results of the competition for the

quarter are reported to each company in the form of computer printouts. These reported results depend not only on a management team's internal decisions but also on the external environment which includes the company's customers, competitors, and the economic situation. The reports include the operating decisions the company itself has made, a production and sales report, a cost report, a financial statement report, an economy and stock market report, and an industry estimate report which is how it is informed on the action and outcomes of each of its competitors for that period. Appendix 1 table A1.2 contains the full set of reports of a company's quarterly performance.

The BUSPOG computer program incorporates a number of hypothetical relationships. These relationships represent a conceptualized view of how such an industry and its environment might behave. In the real world, the forms of some relationships are known with a high degree of certainty while those of others are only vaguely known. This is also the situation of the game. The simulated economic environment of the game is determined by six variables: Gross National Product (GNP), personal consumption expenditures for durable goods, number of household formulations, bond interest rate, loan interest rate and raw material cost. The complete list of external stochastic parameters are also listed in appendix 1 table A1.3.

#### 4.2 Design of the experiment

The management game provided the means for studying management decision making in three levels of managerial activities within a controlled experiment. First, at the functional level, it requires decision makers to make decisions in each of three areas of marketing, production, and finance. Second, at the coordinative level, these three sets of functional area decisions must be coordinated with each other to insure the organization's

goals and objectives. Finally, at the organizational level, the decision makers must design and formulate their strategy in relation to the simulated external environment of the game.

The research design planned to initiate and maintain a specific strategy for the duration of the game. More importantly, the effectiveness of the strategy chosen for the expert system computer program could be tested in a simulated environment containing other firms using the same or different strategies within a realistic time period. Strategy, as described by Christensen and Andrews (1978) means the pattern of decisions in a company that:

1. Shapes and reveals its objectives, purposes, or goals.
2. Produces the principal policies and plans for achieving these goals.
3. Defines the business the company intends to be in and the kind of economic and human organization it wants to be.

The experience of the game administrators has indicated that the three basic strategies which work best in the game's simulated market place are:

High Volume - Low Price: This approach seeks overall cost leadership using high volume sales coupled with low cost production. In turn, this low cost will enable the company to set a lower selling price resulting in raising market share. Margins are usually small but through high volume this strategy usually gives the firm the above average return in its industry despite the presence of competitive forces.

Product Differentiation: This approach will entail the production of a differentiated product that will culminate in the attainment of a steady market share while achieving a high profit margin. The firm benefits by reducing the

impact of price competition and establishing a recognized perception of the product characteristics and quality.

Reactive: This approach is followed by the firm that does not take an initial leadership position in the market place. The firm does not usually take any kind of pioneering or unique action, but instead reacts so as to conform to the behavior of the other companies in the competitive environment. This approach is taken by companies that are conservative and adverse to risk. The firm benefits by reducing costs in order to compensate for the possible limited market share.

The expert system model could have been developed with an initial strategy choice and as the game progressed information relating to its performance, that of the competition, and the external econometric indicators could have been added. After "evaluating" this information, the expert system could then, if it seemed appropriate, change strategies in the same manner as the human student teams. The strategy change option necessitates a combination of three separate knowledge bases and three different perspectives for determining the operating decisions based on the strategy choice. This implies actually developing a meta-expert system for the strategy choice with three expert systems for the possible strategies. Waterman (1986) writes that expert system tools, as a research system are relatively slow and inefficient; commercial systems that are polished, streamlined, well-supported and fast are limited in number and expensive. Since the objective of this thesis is to focus on the use of an expert system for simulating group decision making in a specific task domain and not an emphasis on developing a multi-level, rigorous, and robust expert system, an expert system program that satisfies the requirements of the research direction is sufficient. In

addition, the uncertain epistemology of group decision making, simulation of human decision making, learning, expert systems in general and the labor intensity even with computer assistance are significant constraints upon this research.

Instead, since this experiment was to be a first step investigating the success of an expert system that simulates group decision making in a stochastic environment, the strategy change option would alter the direction of the experiment from the original planned research. Thus, the knowledge base of the expert system will be developed to make decisions based on a fixed strategy choice. Likewise, some of the competing student teams, as the expert system, select an initial strategy that they also follow for the duration of the management game.

#### 4.2.1 Description of the experiment

The instrument used has been described as the management game BUSPOG. The general method that the experiment followed is illustrated in figure 4.1. (the numbers in the following text refer to this figure).

1. Elicit expertise from the panel of experts. The eight person panel of experts chosen are faculty members who administer the management game BUSPOG and were considered the experts for two reasons: first, they have administered the game for at least eight semesters as well as full time management faculty and second, they have been or are active consultants to business organizations. This panel was given a Delphi questionnaire in the form of thirty possible variables and relationships that might influence the decisions made while "playing" the game. In addition, the questionnaire stated that their responses would be used to form decision rules for an expert system computer program (see Appendix 2, table A2.1). They rated the

importance of the variables, listed the interdependencies and causal relationships affecting these variables, and estimated the likelihood that the relationships would shape different decisions, and choices of an overall strategy. These panel responses were compiled, recirculated to the panel, new responses elicited, etc. for two iterations: a truncated Delphi technique. From this process, a set of specific relationships among the decision variables was obtained. Table A2.2 in appendix 2 lists the final panel responses used for the decision rules.

2. Choose a fixed strategy. The author examined the expert testimony developed by the Delphi questionnaire, discussed the resulting variable relationships with a few members of the expert panel and selected the reactive strategy for two reasons. First, these relationships that represent the different variables that were considered, by the expert panel, pertinent to meaningful decision making for each of the twenty-nine operating decisions in each business quarter always included both a company's previous operating decisions and those of the competition. This decision behavior that monitors the competing companies decisions as well as its own previous decisions seems to correspond to the reactive strategy as described in section 4.2. Second, the reactive strategy is best suited to the type of expert system shell, Expertease, that is used in this experiment to develop the expert system model that simulates group decision making. (For a further explanation, see Chapter 5 for a discussion of this specific expert system shell).

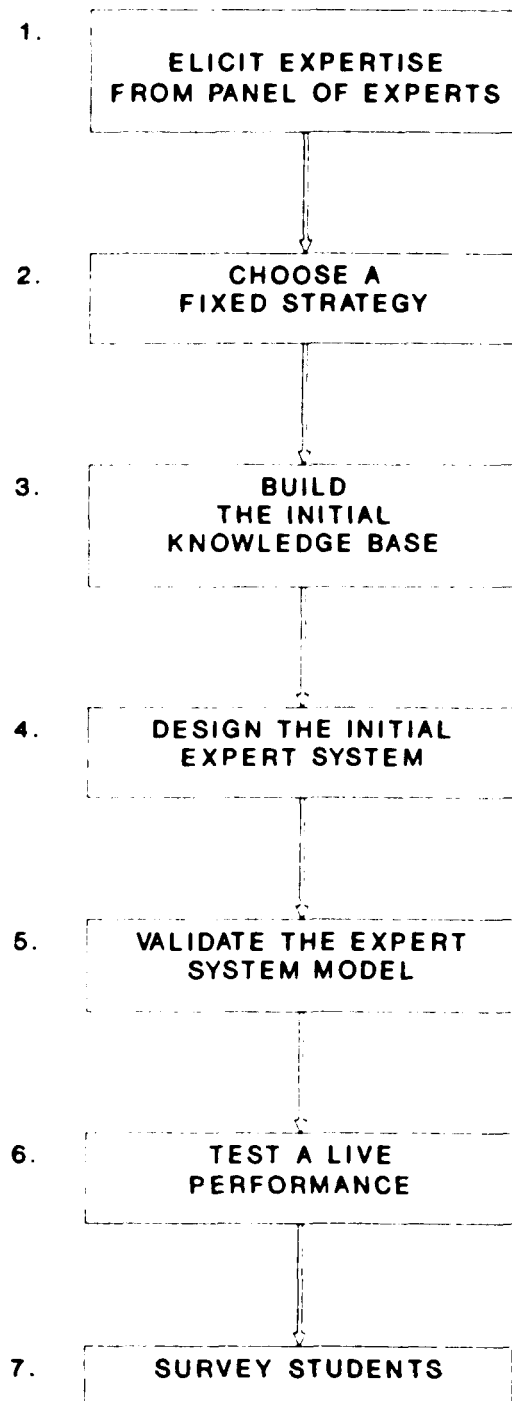


Figure 4.1 Experimental Design

3. Build the initial knowledge base. The decision relationships developed from the Delphi questionnaire and the data from four business years of quarterly historical reports of one hypothetical company were incorporated into the initial knowledge base of the expert system model. The data in these reports included the operating decisions made by this specific company, its production, sales, costs, and financial data, general econometric and stock market data, as well as estimates of performance measures of competing companies. These reports were identical to those given to the student teams so that they could try to note recurring trends or cyclical patterns, as well as all the companies represented by the student teams and the expert system would begin with identical histories so as to eliminate any one company having an unfair advantage over the others. No significant business crisis occurred in this four years of data and the specific company's performance gradually improved over time. In addition, the historical data could be used by the student teams and the expert system for forecasting future unit demand.

4. Design the initial expert system model. The combination of the decision relationships and the historical data are used by the expert system shell to build a tree of alternative sequences of specific if-then rules which ultimately determined a set of operating decisions for any given period. More precisely, the causal relationships elicited from the panel of experts decided the initial tree branching structure while the historical data yielded numerical cutoff points between alternative branches. The chosen expert system shell, a commercially available expert shell is called Expertease. (Chapter 5 discusses the design and development of the expert system model).

5. Validate the expert system model. After the initial model was developed, it was tested using a set of data from a recently completed three

year game iteration. This test proceeded by replacing one of the teams that participated in the game with the expert system and rerunning the game period-by-period starting with the initial historical data and continuing for at least eight quarters. After each active quarter of game playing, the decisions made during each business period were added to the original knowledge base. This detailed process of the steps by which the expert system model modified itself is discussed in Chapter 5. The team that was replaced by the expert system was chosen as that team which best represented average play and is described in Chapter 6, section 6.1. The experiment used "real world decisions" previously made by participating student teams and new decisions developed by the expert system. The results, in the form of the game output reports, obtained when the game was played with all the student teams was compared with the results obtained when the one student team was replaced by the expert system. The benchmark was the same set of performance criteria used by the game administrators (the instructors using the BUSPOG in their classes) to evaluate the student team's performance. These criteria included measures such as percent market share, productivity (number of products that can be produced in one hour), stock price, price-earning ratio, earnings per share, quick ratio, profit-on-sales ratio, and bond and loan interest rates. The bond and loan interest rates are reflections of an overall good performance for two reasons; 1) if a company runs out of cash, these rates are raised significantly, or 2) if a company rates better or worse than the industry average in ten or more of the thirteen financial ratios computed by the BUSPOG program, the rates are correspondingly lowered or raised. A combination of significantly good performance on these scales of measure would indicate a well performing company.

If the expert system model made erratic decisions or its performance was inferior to the competition based on these benchmark criteria, the management faculty experts were consulted for recommended changes and the relationships between the variables that formed the decision rules for the expert system's model were accordingly adjusted. Replaying the game again and evaluating the performance of the expert system continued until it was considered capable of making acceptable operating decisions similar to those of the student team that was replaced by the expert system.

6. Test a "live" performance of the expert system. Finally, the expert system was run "live" in an actual game iteration where the system competed against live student teams. The game comprised twelve actual competitive cycles covering three business years.

7. Survey the students. During the live game the student teams were not told that they were competing with an expert system; but that one of the teams came from another class. The students competing in the industry with the expert system were issued a questionnaire at the end of the game playing. Part of this questionnaire was used as a quasi-Turing test. If the expert system displayed a sufficiently normal (human group-like) competitive performance, the results of the questionnaire should indicate whether or not the students continued to assume that the expert system was another "live" team. The questionnaire also recorded the various strategies of the competing teams, and their observations of, and their reactions to the competition.

#### 4.3 The Group Decision Makers

In the real world, management is either the greatest strength or greatest weakness an organization possesses because the organization's overall activities are the responsibility of management. Thus, the roles of the

decision makers are an important component in the experiment. At the initiation of competition, the only differences among the competing companies are their management teams. Therefore, the individual role players and their interaction in group decision making are significant and should attempt to simulate real organizational decision makers.

Each team has four members who are assigned by the game administrator to the roles of Production, Financial, and Marketing Vice Presidents. The fourth member of the team is the President of the company. The students are informed in class, before the game playing, as to the characteristics of each of these roles. In addition they receive two student game manuals, (Ritchings and Berry (1984) and Eldredge and Bates(1984)), that contain detailed descriptions of the roles that they will assume. These student roles are described in appendix 1 table A1.4.

The student teams interact both inside and outside the classroom. Student teams, in the past, have taken their team roles very seriously for two main reasons. 1) their class grade depends upon their team's performance and 2) the students enjoy the feeling of accomplishment they experience if their company performs well in the competitive environment. The author has observed several classes with teams participating in the management game BUSPOG. The student groups do engage in adversarial discussions in the process of deciding their operational decisions. There can be instances of discharging a member of the group if they are non-performers. The student teams are composed of students with a variety of business curriculum concentrations such as Marketing, Accounting, Finance, Management, Management Science and so forth.

#### 4.4 The Decisions

The decisions in the group making process are the strategy, policy and operating decisions made by the teams participating in BUSPOG and assuming the roles of real organization decision makers. These decisions can be placed on Simon's decision continuum, ranging from structured to unstructured decisions, and they can also be arranged within a functional organization structure. In table 4.1 we have constructed a taxonomy of these decisions incorporating the testimony of the experts and also modeling the functional organization structure.

Ideally, each team's production decisions are made by considering the factors such as productivity, last quarter company decisions, estimated industry average decisions, relationship between unit sales and production, depreciation and so forth. Some of these decisions can be precisely calculated and others are simply estimates.

Financial decisions depend upon factors such as gross profit, cash balance, net income, bank loan interest rate, debt/equity ratio and so forth. Some of these factors can be calculated, others are known from financial reports. The precise relationships among some of these factors is known while others that interact with the production and marketing decisions require intuition and judgment.

Market decisions rely on the interaction of factors such as product unit cost, forecast of the expected unit demand for the next business quarter, the company's last quarter marketing decisions, the performance of the salespersons, and the estimated industry expenditures for these operating decisions. Some of these can be calculated and others are estimated.

Table 4.1 Taxonomy of the Decisions

70

| DECISIONS         | <u>STRUCTURED</u>                                                                                                                              | <u>SEMI-STRUCTURED</u>                                                                                                                                                                                                                                    | <u>UNSTRUCTURED</u>                         |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|
| FUNCTION          |                                                                                                                                                |                                                                                                                                                                                                                                                           |                                             |
| <u>PRODUCTION</u> | <ol style="list-style-type: none"> <li>1. LABOR FORCE CHANGE</li> <li>2. RAW MATERIAL REQUIREMENTS</li> <li>3. PRODUCT DISTRIBUTION</li> </ol> | <ol style="list-style-type: none"> <li>1. PROCESS R&amp;D</li> <li>2. HOURLY WAGES</li> <li>3. PRODUCTION TRAINING</li> <li>4. NEW PLANT &amp; EQUIPMENT</li> <li>5. PRODUCTION HOURS</li> </ol>                                                          |                                             |
| <u>FINANCE</u>    |                                                                                                                                                | <ol style="list-style-type: none"> <li>1. PROFIT SHARING</li> <li>2. BONDS SOLD OR REDEEMED</li> <li>3. BONDS ISSUED</li> <li>4. DIVIDENDS</li> <li>5. NEW STOCK</li> <li>6. LONG-TERM DEPOSIT OR WITHDRAWAL</li> </ol>                                   | <p>MARKET STRATEGY AND COMPANY POLICIES</p> |
| <u>MARKETING</u>  |                                                                                                                                                | <ol style="list-style-type: none"> <li>1. PRODUCT PRICES</li> <li>2. ADVERTISING BUDGET</li> <li>3. HIRE/FIRE SALESPERSONS</li> <li>4. PRODUCT R&amp;D</li> <li>5. SALES COMMISSION</li> <li>6. SALESPERSON SALARY</li> <li>7. TRAINING BUDGET</li> </ol> |                                             |

The unstructured decisions do not rely on the interaction of specific factors but are long range decisions that affect many of the quarterly operating decisions. They require the use of intuition, judgment and an understanding of the economic factors and the competitive behavior of the industry.

Chapter 5 will describe the development of the expert system computer program used to simulate group decision making for the duration of the business game.

## CHAPTER 5

### DEVELOPMENT OF THE EXPERT SYSTEM MODEL

The development of the expert system model, the validation and testing methodology, and implementation in a "live" business game are important components of the experiment. Chapter 4 described the management game experiment and the roles of human group decision makers participating in the management game. This chapter will describe the process followed to develop a simulation of the group decision makers in the form of an expert system. First, a general discussion of expert systems, followed by a description of the knowledge acquisition process, and lastly the method by which the expert system program shell, Expertease, is used to simulate the group decision makers for the management game task. The expert system will not be measured on how well it plays the management game, described in Chapter 4, but how closely it imitates group decision making ranging from average success to successful.

#### 5.1 Expert Systems

Expert systems are one of the application areas developed during the early stages of the research in artificial intelligence. The importance of domain specific knowledge in expert systems, called expertise, was a significant insight that was also developed during the same time from early work in attempting to understand human problem solving.

In Harmon and King (1985), Professor Feigenbaum of Stanford University defined an expert system as:

"...an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. Knowledge necessary to perform at such a level, plus the inference procedures used, can be thought of as a model of the expertise of the best practitioners of the field.

The knowledge of an expert system consists of facts and heuristics. The "facts" constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in the field. The "heuristics" are mostly private, little discussed rules of good judgment (rules of plausible reasoning, rules of good guessing) that characterize expert-level decision making in the field. The performance level of an expert system is primarily a function of the size and quality of a knowledge base it possesses."

(Harmon and King, 1985 page 5).

Waterman (1986) stated that expert systems have many useful features. The most important feature is the high-level expertise that often represents the best thinking of top experts in a particular field and provides aid in problem solving. He says that another useful expert system feature is its predictive modeling power; thus, an expert system can act as an information processing model of problem solving in a given task domain and provide the desired answers for a given problem situation. Expert systems can also be used to provide training due to the knowledge it contains and the ability to state its reasoning process. The final useful feature expressed by Waterman is that an expert system knowledge base developed through the interactions of key individuals in an institution becomes the consensus of high-level opinion and is a record of the best strategies and problem solving methods of the group. This last feature, expressed by Waterman, is the most significant one for the knowledge collection process of the expert system model developed for this research to simulate group decision making.

Knowledge engineers are the computer experts that collect and translate human expertise into the knowledge base of an intelligent computer program, an expert system. The computer languages used by knowledge engineers are sophisticated language systems for developing expert systems. They are categorized as either general purpose systems or expert system shells. The expert system shells, originally developed from general purpose systems and referred to as knowledge-based expert systems, provide structure and built-in facilities that make system development easier and faster than general purpose languages. The built-in facilities are the basis for an inference rule structure. These initial expert systems shells are the result of general purpose systems stripped of the original task domain knowledge and left with the inference mechanism called the "inference engine". A typical example is MYCIN that was written in a general purpose language called INTERLISP (a dialect of the LISP programming language) and EMYCIN, the expert system shell. MYCIN was the first large expert system to perform at the level of a human expert in aiding the diagnosis and treatment of a particular class of medical disorders. Subsequent to its development in the 1970's which required over fifty man-years of effort, researchers realized they could remove the specific knowledge base for medical diagnosis and retain the inference engine, the general-purpose chaining rule evaluator. This was the first expert system shell called EMYCIN. Using EMYCIN, knowledge engineers implemented PUFF, another medical diagnostic program, in about five man-years of effort. Expert system shells have become increasingly common, with commercial products available for all classes of computers.

Luger and Stubblefield (1989) wrote that there are some deficiencies in expert systems such as 1) the difficulty in capturing "deep" knowledge of the

problem domain, 2) expert systems lack robustness and flexibility compared to humans who can examine first principles and develop some strategy for solving a problem that can not be solved immediately, 3) inability to provide deep explanations meaning they can describe the steps they took in finding a solution, but not tell "why" a certain approach was taken, 4) difficulties in validating in contrast with algorithmic computer programs, and 5) little learning from experience since many expert systems are developed with a set knowledge base.

In spite of these limitations, as stated by Luger and Stubblefield, expert systems have proven valuable for many task domains. In addition, the expert system model developed for this thesis followed a rigorous validation process (described in chapter 6) and attempted to exhibit experiential learning (described by the evaluation of the "live" experiment in chapter 7).

### 5.2 Knowledge Acquisition Process

The heart of an expert system is the knowledge it accumulates during the system development. "The accumulation and codification of knowledge is one of the most important aspects of an expert system" (Waterman, 1986 page 7). Knowledge in an expert system may originate from many sources, such as reports, empirical data, textbooks, personal experience, and so forth. However the dominant source of knowledge is the domain expert. A knowledge engineer usually obtains this knowledge through direct interaction with an expert. The interaction could consist of a prolonged series of interviews that extends over a period of many months or years.

The knowledge acquired for the expert system model developed for this thesis came from two sources. First, the management faculty who participated as the expert panel, responded to a Delphi questionnaire and provided the

qualitative, causal, interrelationships and dependencies for the variables that were considered meaningful to the decision making for the business game task domain (see chapter 4, section 4.2.1 for a description of the Delphi questionnaire). The second source was the set of quarterly reports that contained decisions and performance measures for one hypothetical company during a four year span (see chapter 4, section 4.2.1 for a more complete discussion of these reports).

The author, as the knowledge engineer, could have conducted separate extensive interviews with each faculty member of the expert panel to obtain their set of the most significant factors that they consider meaningful and influence the decisions making while "playing" the business game. This process may have provided a "large" knowledge base, but, for this thesis it was not the most appropriate method. Since the objective of the expert system was a simulation of group rather than individual decision making, it was more meaningful to gather the expertise from the faculty members of the expert panel as a group. The research studies of Murnighan (1981), Stephenson and Franklin (1981), and Adizes and Turban (1985) all concurred that managers who are physically separated dislike group decision making meetings thus, they suggested the use of the Nominal Group Process or the Delphi technique. If we assume that the faculty members are the managers and being "physically separated" is similar to the faculty members presence at Pace University on different days and times of the day then, the use of the Delphi technique to acquire the expertise seemed to be a suitable choice. In addition, the author had sufficient knowledge and exposure to the BUSPOG management game to combine the expert testimony of the faculty and the data from the historical reports into the initial knowledge base.

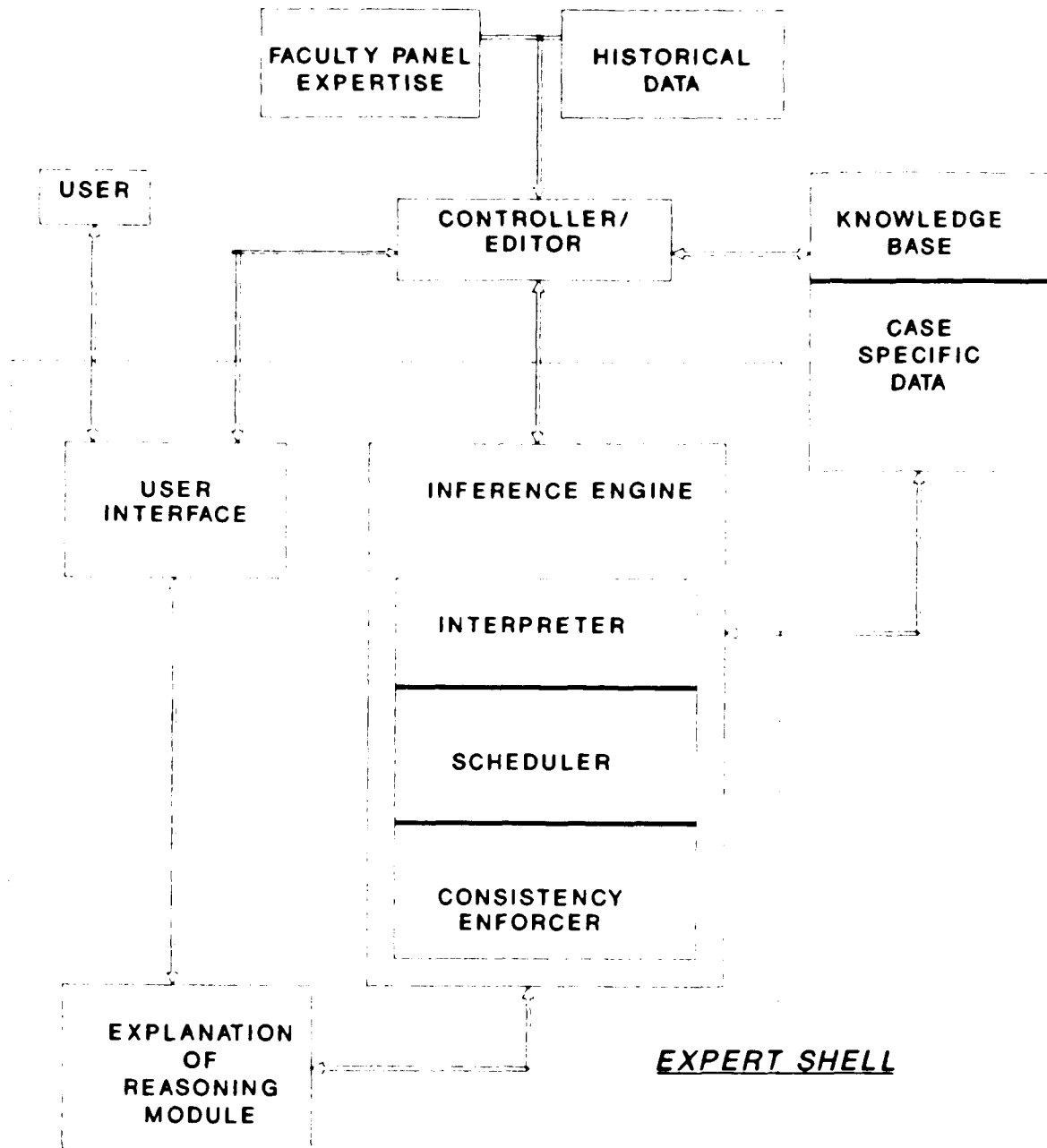


Figure 5.1 Expert System Model

### 5.3 Expertease - An expert system shell

Expertease, the expert system program selected for this research, is an example-based production rule expert system shell that is implemented as a microprocessor-based computer program. Figure 5.1 is a general model of an expert system. The dotted lines within the figure indicate the expert system shell modules. The heart of an expert system is the general knowledge base. It and the controller are separated to allow the same inference engine, interface, and reasoning explanation computer program modules to be used in a variety of systems. The case-specific data is empty until the expert system is actively used. Expert system developers can use the shell modules and create a new knowledge base appropriate to their application. Expertease consists of three stand-alone pieces of software: 1) an editor that processes the initial and subsequent expertise and historical data for the general knowledge base, 2) a rule set manager that generates rule sets within the general knowledge base, and 3) a controller that interprets the rule sets built by the rule set manager and then "fires" the inference engine.

A user has a particular problem that relates to the knowledge base that exists in the expert system task domain. The user sits in front of a computer and invokes an expert system program that initiates a dialogue. The user responds, through the user interface, to the questions asked by the expert system in order to describe the problem to be analyzed. These responses become part of the case-specific data, then are accepted by the controller/editor and "fire" the inference engine. The expert system executes the three parts: interpreter - applies the case-specific data to the rules and then arranges them in a logical sequence, scheduler - determines the most likely set of internal conclusions, and the consistency enforcer - checks the

logic of the inferences and conclusions. If the expert system needs more input in order to conclude its internal knowledge search, it will ask the user for more input responses and repeat the cycle. The particular expert system used for this research, Expertease, continues to request more input values until it can reach a conclusion. This cyclical pattern will conclude when the expert system can respond to the specific problem. A user is able to elicit a statement of the logical steps (rules) the expert system followed to arrive at its conclusion.

The knowledge base of Expertease, is a matrix containing the complete set of variable relationships for some decision making process expressed as columns and non-numeric and/or numeric attributes as rows. The attribute values are "examples" of the decision making process for a single decision. The variable relationships (see appendix 2, table A2.2) were developed from the testimony of the panel of experts as described in chapter 4, section 4.2.1.

Table 5.1 illustrates this matrix for the Product Research and Development Budget decision. Each row contains different attribute values for each variable (column) that the panel of experts felt impacted on this specific decision. In this example, the first four columns, after the data list, are the variables that affect the fifth column which is the operating decision. The rows illustrate the initial historical data base composed of sixteen examples of this operating decision made by one company over a period of four business years (sixteen quarters). All the team players in the business game use this same company as the basis for their initial set of operating decisions during the game playing. The historical data was described in chapter 4, section 4.2.1 and the decision process is illustrated in figure 3.1 of chapter 3. Each of the twenty-nine decisions made in the business game is a separate matrix,

yet, related decisions can contain the same variables that appear in other matrices. In addition, one decision can be chained to sub-decisions that can simplify the knowledge search.

Table 5.1 - Expertease Initial Knowledge Base

EXPERT-EASE Example Listing: PRODUCT RESEARCH AND DEVELOPMENT BUDGET

| DATA LIST | COMPANY PRODUCT R&D | COMPANY UNIT SALES | INDUSTRY AVE SALES/ IND AVE PRICE | COMPANY SALES/ COMP AVE PRICE | PRODUCT R & D DECISION |
|-----------|---------------------|--------------------|-----------------------------------|-------------------------------|------------------------|
| 1         | 85                  | 4979               | 171                               | 172                           | \$85                   |
| 2         | 85                  | 4151               | 142                               | 143                           | 85                     |
| 3         | 85                  | 5230               | 182                               | 181                           | 90                     |
| 4         | 90                  | 6045               | 210                               | 210                           | 90                     |
| 5         | 75                  | 3271               | 109                               | 109                           | 75                     |
| 6         | 75                  | 4011               | 135                               | 135                           | 75                     |
| 7         | 75                  | 4511               | 152                               | 152                           | 78                     |
| 8         | 78                  | 4177               | 142                               | 142                           | 80                     |
| 9         | 80                  | 3443               | 116                               | 116                           | 80                     |
| 10        | 80                  | 4257               | 144                               | 144                           | 80                     |
| 11        | 80                  | 4828               | 164                               | 164                           | 80                     |
| 12        | 80                  | 4481               | 152                               | 152                           | 80                     |
| 13        | 80                  | 3714               | 127                               | 127                           | 80                     |
| 14        | 80                  | 4636               | 159                               | 159                           | 85                     |
| 15        | 85                  | 5310               | 182                               | 182                           | 85                     |
| 16        | 90                  | 5718               | 199                               | 199                           | 300                    |

Product R & D is scaled by 1000, unit sales is scaled by 10)

The rule set manager of Expertease uses the Shannon information theoretical measure, entropy, to determine which of the variables, with the examples of previous decisions, have the "best" values (least random or lowest entropy measure) thus establishing their relative importance in the rule generation. The numeric attribute values for each variable are placed in increasing order and partitioned into subranges. Frequency values are

established for the subrange and then an informational entropy value is calculated for each subrange. This process of splitting subranges and deriving an entropy measure before and after each partition and finding the difference, produces a measure of the usefulness of the variable. The variable with the lowest entropy measure becomes the most significant variable. Some variables, as illustrated in figure 5.2, are not considered useful indicating that their entropy values are relatively high thus signifying randomness. In figure 5.2 only the "Company Product R&D" and "Company Unit Sales" (as seen in table 5.1) were considered useful variables. The "useful" variables are arranged in a decision tree (see figure 5.3) which is the rule set built by the rule set manager and this tree is the basis of the inference engine. The dollar outcomes are what the Product R&D Budget should be set to for the next quarter.

As more examples are added during the game playing, representing more recent decisions, the entropy values are remeasured and some previously unused variables can become part of the decision tree as others can drop out, and changes in the state conditions of the decision tree can occur also. The same response values to the user interface at different business quarters can produce different answers for the operating decisions because the decision tree has changed. Hopefully, the later operating decisions will show a pattern of improving performance by the expert system company comparable to that of human decision makers making group decisions as a result of "learning" from past performance.

## EXPERT-EASE Rule Listing, Problem: PRODUCT RESEARCH AND DEVELOPMENT BUDGET

## COMPANY R&amp;D

```

<83:      COMPANY R&D
          <77:      COMPANY UNIT SALES
                <4621:    $75
                >=4621:   $78

          >=77:     COMPANY UNIT SALES
                <4559:    $80
                >=4559:   COMPANY UNIT SALES
                        <4732:    $85
                        >=4732:   $80

>=83:     COMPANY R&D
          <88:      COMPANY UNIT SALES
                <5105:    $85
                >=5105:   COMPANY UNIT SALES
                        <5270:    $90
                        >=5270:   $85

          >=88:     COMPANY UNIT SALES
                <5882:    $300
                >=5882:   $90

```

Figure 5.2 Rule Set for Initial Knowledge Base

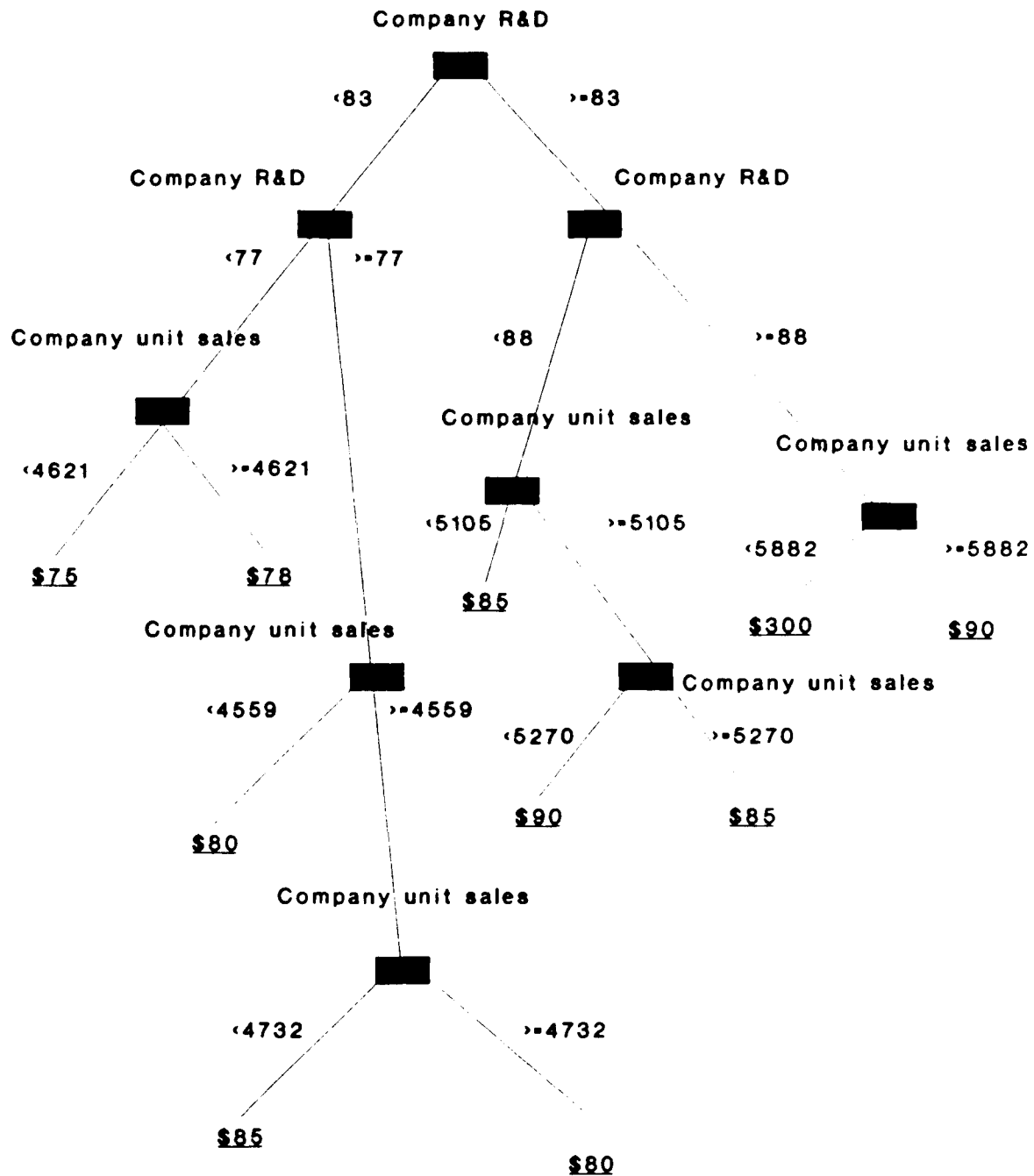


Figure 5.3 Decision Tree for  
Product R&D Budget

The same Product Research and Development Budget operating decision, examined in table 5.1 and figure 5.2, with an additional twenty-one decision examples that were added over time and the rule set for this updated version appear in table 5.2 and figure 5.4. As can be seen, the additional attribute values resulted in more variables appearing in this rule set than the illustration in figure 5.2 for the initial historical sixteen examples.

After each quarter during the active game playing, the operating decisions of the expert system "company" and the aggregated decisions of the other competing companies are added as new examples and new decision rule sets are generated through the rule set manager. As stated previously, these new examples may be considered akin to experiential "learning" and thus, change the values for the operating decisions which in turn will change the expert system's performance each quarter. Appendix 3 contains illustrations of other decisions that contain knowledge base and rule set listings that change from one quarter to the next.

Chapter 6 is an explanation of the validation method used followed by the validation process. The performance of the expert system will be monitored through each phase of the validation tests.

Table 5.2 - Expanded Expertease Knowledge Base

EXPERT-EASE Example Listing: PRODUCT RESEARCH AND DEVELOPMENT BUDGET

| DATA LIST | COMPANY PRODUCT R & D | COMPANY UNIT SALES | (RATIO A) INDUSTRY AVERAGE UNIT SALES/ AVERAGE PRODUCT PRICE | (RATIO B) COMPANY UNIT SALES/ COMPANY AVERAGE PRODUCT PRICE | PRODUCT R & D DECISION |
|-----------|-----------------------|--------------------|--------------------------------------------------------------|-------------------------------------------------------------|------------------------|
| 1         | 85                    | 4979               | 171                                                          | 172                                                         | \$ 85                  |
| 2         | 85                    | 4151               | 142                                                          | 143                                                         | 85                     |
| 3         | 85                    | 5230               | 182                                                          | 181                                                         | 90                     |
| 4         | 90                    | 6045               | 210                                                          | 210                                                         | 90                     |
| 5         | 75                    | 3271               | 109                                                          | 109                                                         | 75                     |
| 6         | 75                    | 4011               | 135                                                          | 135                                                         | 75                     |
| 7         | 75                    | 4511               | 152                                                          | 152                                                         | 78                     |
| 8         | 78                    | 4177               | 142                                                          | 142                                                         | 80                     |
| 9         | 80                    | 3443               | 116                                                          | 116                                                         | 80                     |
| 10        | 80                    | 4257               | 144                                                          | 144                                                         | 80                     |
| 11        | 80                    | 4828               | 164                                                          | 164                                                         | 80                     |
| 12        | 80                    | 4481               | 152                                                          | 152                                                         | 80                     |
| 13        | 80                    | 3714               | 127                                                          | 127                                                         | 80                     |
| 14        | 80                    | 4636               | 159                                                          | 159                                                         | 85                     |
| 15        | 85                    | 5310               | 182                                                          | 182                                                         | 85                     |
| 16        | 90                    | 5718               | 199                                                          | 199                                                         | 300                    |
| 17        | 300                   | 4596               | 177                                                          | 160                                                         | 305                    |
| 18        | 125                   | 4417               | 177                                                          | 154                                                         | 125                    |
| 19        | 100                   | 5088               | 169                                                          | 193                                                         | 200                    |
| 20        | 160                   | 4592               | 175                                                          | 160                                                         | 175                    |
| 21        | 95                    | 4863               | 174                                                          | 177                                                         | 97                     |
| 22        | 250                   | 5398               | 168                                                          | 213                                                         | 250                    |
| 23        | 95                    | 4709               | 175                                                          | 170                                                         | 125                    |
| 24        | 305                   | 5524               | 227                                                          | 192                                                         | 325                    |
| 25        | 125                   | 5229               | 229                                                          | 185                                                         | 205                    |
| 26        | 175                   | 5566               | 226                                                          | 200                                                         | 180                    |
| 27        | 97                    | 6079               | 223                                                          | 223                                                         | 100                    |
| 28        | 250                   | 7143               | 213                                                          | 281                                                         | 280                    |
| 29        | 124                   | 5956               | 222                                                          | 222                                                         | 250                    |
| 30        | 300                   | 4620               | 177                                                          | 161                                                         | 305                    |
| 31        | 305                   | 5627               | 232                                                          | 211                                                         | 305                    |
| 32        | 205                   | 6256               | 276                                                          | 232                                                         | 225                    |
| 33        | 500                   | 8209               | 261                                                          | 318                                                         | 600                    |
| 34        | 180                   | 7395               | 265                                                          | 292                                                         | 190                    |
| 35        | 100                   | 6993               | 271                                                          | 258                                                         | 150                    |
| 36        | 280                   | 7680               | 262                                                          | 302                                                         | 280                    |
| 37        | 250                   | 7134               | 268                                                          | 271                                                         | 375                    |

EXPERT-EASE Rule listing, Problem:PRODUCT RESEARCH AND DEVELOPMENT BUDGET

COMPANY R&D

```

<93: COMPANY R&D
  <83: COMPANY R&D
    <77: COMPANY UNIT SALES
      <4261: $75
      >=4261: $78
    >=77: COMPANY UNIT SALES
      <4559: $80
      >=4559: COMPANY UNIT SALES
        <4732: $85
        >=4732: $80
  >=83: COMPANY R&D
    <88: COMPANY UNIT SALES
      <5105: $85
      >=5105: COMPANY UNIT SALES
        <5270: $90
        >=5270: $85
    >=88: COMPANY UNIT SALES
      <5882: $300
      >=5882: $90
  >=93: RATIO B
    <212: COMPANY R&D
      <143: COMPANY UNIT SALES
        <4786: $125
        >=4786: COMPANY R&D
          <98: $97
          >=98: COMPANY R&D
            <113: $200
            >=113: $205
      >=143: COMPANY R&D
        <238: COMPANY R&D
          <168: $175
          >=168: $180
        >=238: COMPANY R&D
          <303: $305
          >=303: CO UNIT SALES
            <5576: $325
            >=5576: $305
      >=212: COMPANY UNIT SALES
        <7064: COMPANY R&D
          <113: COMPANY R&D
            <99: $100
            >=99: $150
          >=113: COMPANY UNIT SALES
            <6106: $250
            >=6106: $225
        >=7064: RATIO A
          <264: COMPANY R&D
            <390: $280
            >=390: $600
          >=264: COMPANY R&D
            <215: $190
            >=215: $375

```

Figure 5.4 Rule Set with Additional Examples

## CHAPTER 6

### EXPERT SYSTEM VALIDATION

A review of the literature on expert systems that referred to testing and evaluation leads to the conclusion that validating an expert system is a difficult task. It is further complicated by the possibility that there are many different approaches depending on the developed expert system. Waterman (1985) implied that evaluating an expert system is difficult because there may be no formal way to prove a given answer is correct or the best possible choice. Holsapple and Whinston (1987) suggested that a human expert test the expertise that has been captured in a rule set. The developer and expert look for indications that the rule set may be inaccurate, incomplete, or inconsistent. If this is so, the rule set should be appropriately adjusted and reviewed again. Blanning (1984) claimed that validating an expert system can be accomplished with a "blind Turing test". Both the expert system and a human expert evaluate and respond to the same problem. If a third party human expert determines both responses are acceptable, then the expert system is valid. Weiss and Kulikowski (1984) said that there are two extremes in evaluating expert system performance: anecdotal and empirical. The anecdotal approach implied that the model designers describe their good experiences or the situations when the program performed well. The empirical approach, the one used in this expert system research, placed its emphasis on the empirical evaluation of performance over many problem cases stored in a data base. When

using this approach, one seeks to have firm end points; that is, knowledge of what constitutes correct conclusions for each case used. Weiss and Kulikowski concluded that the primary direction for research and development of expert systems has been the acquisition, capture, and valid representation of knowledge.

O'Leary (1987) stated that if expert systems and other computer systems are similar to each other then the same validation process for both types of systems is appropriate. However, he specified that four characteristics of expert systems distinguish them from other computer-based systems. The four characteristics are:

- 1)...."expert systems process symbolic information (e.g., "If...then" rules) rather than just numeric information....experience with representing knowledge shows that a fraction (less than ten percent) of this knowledge escapes standard representation schemes and requires special "fixes" to make it accessible.
- 2) ....expert systems directly influence or make decisions. Other systems simply support decision making or have an indirect impact on decisions.
- 3)....expert systems often are developed using a "middle-out" design rather than the traditional data processing approach of top-down or bottom-up design. A middle-out design philosophy rather than the traditional philosophy starts with a prototype and gradually expands to meet the needs of the decision.

4)...some domain characteristics of one decision system often distinguish these decisions from decisions made in other domains and specific decisions generally do not have a single solution. A decision reached often can be evaluated only by how similar it is to decisions other decision makers develop (i.e. by consensus); there may be no way to rank the decisions a priori."

(O'Leary, 1987 page 470)

He said that validation is critical to the design and implementation of decision making expert systems. He specified that there are four requirements of the validation process. First, it is important to ascertain what the system knows, does not know, or knows incorrectly. That is, one should compare responses of the expert system to expected human responses to the same problem to correct errors or omissions. Second, the requirement of ascertaining the level of expertise implied determining the type of problems the system can solve and the quality of its solution. O'Leary stated that the third requirement is to determine if the system is based on a theory for decision making. This requirement analyzed the reliability of the expert system by insuring that it gave similar responses to similar sets of test problem. Thus, O'Leary developed a validation framework for expert systems that includes content, criterion, and construct validity, systematic, extraneous, and error variance, objectivity, and reliability.

#### 6.1 Validation Criteria

"Content validity is the representativeness or sampling adequacy of the content - the substance, the matter, the topic - of a measuring instrument. If it is not possible to satisfy the definition of content validity, how can a reasonable degree of content validity be achieved? Content validation consists essentially in judgment. Alone or with others, one judges the representativeness of the items."

(Kerlinger, 1986, page 417).

O'Leary stated that content validity for expert systems, as written in his first requirement, is establishing what the expert system knows, does not know, or knows incorrectly. O'Leary suggested that content validity for expert systems can be operationalized in three ways: 1) direct examination of the expert system components, 2) testing the system against human experts, or 3) test the expert system against other models.

The validation process for this experiment implemented content validity in two ways. The first was a display of the decision rules generated by rule set manager of Expertease as a method for examining the components of the expert system prototype. These rules were then checked for logic and consistency by the chairperson of the management department, who did not participate in the Delphi questionnaire, and the author. Secondly, the expert system's overall decision making behavior was compared to that of the average of the human decision making teams during the validation testing game iterations. The evidence of similarity between the expert system's decisions and the student teams was the other component of content validation. A test against other models was not possible due to the non-existence of a comparable model.

"Criterion-related validity is studied by comparing test or scale scores with one or more external variables, or criteria, known or believed to measure the attribute under study".

(Kerlinger, 1986, page 418)

O'Leary wrote "In expert system validation, this refers to the criteria used to validate the system, for example, to ascertain the level of the system's expertise" (O'Leary, page 475). He further stated that the primary criterion for an expert system validation is the comparison between an expert system's decisions and those developed by experts. In artificial intelligence this process is implemented by the use of a Turing test. However, this

approach for decision making relationships presented difficulties such as defining the level of expertise, the particular knowledge-based criteria, and the uncertainty about what is being evaluated. Therefore, O'Leary stated that an alternative method for determining the level of an expert system's expertise is to measure its performance on a set of problems. He wrote that if in analyzing a human's knowledge, the problems that the person can solve determine one's level of accomplishment, then the same criteria can be adapted to evaluating an expert system's expertise.

For this expert system validation process, the criteria for determining the level of the expertise of the expert system were the decisions and the performance outcomes of the human student team that had received the highest grade for the BUSPOG game iteration that was used for the validity testing game. (The game choice was described in section 6.2). The criteria measure for the decision validity was the similarity between the expert system's decisions and those of the "best" team. Performance outcome criteria were the measures chosen by the game administrators, after eight years of experience with the BUSPOG management game, to determine the grades of the student teams. In addition, the less-experienced game administrators also adapted the same criteria. The criterion-related validity test was the similarity between the decisions and performance outcomes of the expert system and that of the "best" student team at the end of each testing iterations.

"Construct validity refers to those constructs or factors that the test is designed to discover. The significant point about construct validity, that which sets it apart from other types of validity, is its preoccupation with theory, theoretical constructs, and scientific empirical inquiry involving the testing of hypothesized relations".

(Kerlinger, 1986, page 420)

O'Leary stated that for expert systems, this type of validity implied the importance of some theoretical basis for the expert system.

This expert system was a prototype and "first study" of an expert system's success in simulating group decision making. Therefore, the expert system model was developed by using the results of the Delphi questionnaire that revealed the importance of specific variables, the interdependencies and causal relationships affecting these variables, and estimates of the likelihood that these relationships would shape different decisions of the expert system. The construct validity for this experiment was, at best, an empirical approach. If, after the validity testing iterations, the expert system made meaningful decisions, then there is some sense that it had been "successful" in simulating group decision making.

Objectivity, in variance terms, as stated by O'Leary referred to minimizing judgmental variance by the developer of the expert system. Again, similar to construct validity, because this expert system was a prototype and "first study" it was difficult to establish unbiased independent judgments. Therefore, to both minimize the author's evaluation of the expert system and establish some objectivity, the game administrators were the independent participants. They contributed to the expert system knowledge base, however, they were not involved in the expert system program development nor had biases or vested interest in the experiment results. They reviewed the expert system's decisions and performance outcomes at the end of each validation test iteration.

O'Leary stated that reliability refers to the stability of the expert system and its ability to generate identical solutions given identical inputs. Thus, if the expert system, during the validity testing iterations, maintained the same knowledge base, then the decisions could be analyzed using sensitivity analysis. However, this experiment included changes to the

knowledge base each business quarter to reflect "experiential learning". O'Leary stated that if revising expert system prototypes adds new knowledge to the knowledge base, then the outcomes will change. Therefore, assessment of the stability of this expert system was difficult to measure.

"If the independent variable does not vary substantially, there is little chance of separating its effect from the total variance of the dependent variable. It is necessary to give the variance of a relation a chance to show itself, to separate itself, so to speak, from the total variance, which is a composite of variances due to numerous sources and chance"  
(Kerlinger, 1986, page 287)

O'Leary stated that for expert systems the form and number of the test problems allowed the validator to distinguish between systematic variance and chance. In addition, he also specified that a major problem of prototype and experimental expert systems was the small number of test problems used as well as the use of test problems that examined the system's overall behavior from a "middle of the road" perspective. O'Leary wrote that enlarging the range of the test problem parameters could overcome some of the limiting factors for experimental expert systems.

In this experiment, the choice of an actual BUSPOG game iteration and extending each testing iteration for seven quarters was a measure of the degree of changes in the decisions and performance outcomes primarily related to the expert system's meaningful decision changes rather than chance. However, the purposeful adjustments to the expert system's knowledge base during each testing iteration affected the decision and performance changes. This phenomenon minimized the ability to distinguish between system variance and chance. Nevertheless, at the end of each testing iteration, the graphic displays of the decision changes and performance outcomes were used by the author and some of the experts to assess these changes.

"The control of extraneous variance means that the influences of independent variables extraneous to the purposes of the study are minimized, nullified or isolated".

(Kerlinger, 1986 page 287)

O'Leary stated that the research performed on the validation processes of prototype expert systems revealed that the location of the expert system, number of fixes to the system, and the effect of learning by the judges of the system were possible extraneous variables.

This experiment attempted to control extraneous variance in the following ways. The experiment was conducted in a laboratory setting to control the expert system environment. A well-known management game, BUSPOG, was chosen as a way of controlling the experimental conditions. Likewise, the changes to the expert system's knowledge base, after each testing iteration, were only made to a subset of operating decisions each time. Lastly, since the "judges" of the expert system's performance were the game administrators (management faculty) who are experienced users of the management game; therefore, learning by the judges was not a significant concern.

In a discussion of error variance, Kerlinger noted "There are a number of determinants of error variance, for instance, factors associated with individual differences among subjects. Ordinarily we call this variance due to individual differences "systematic variance." But when such variance cannot be, or is not identified and controlled, we have to lump it with error variance."

(Kerlinger, page 289).

O'Leary stated that the minimization of error variance in expert systems could occur by 1) using proven measurement scales and 2) unambiguous questions.

The administrators of the BUSPOG management game, used in the expert system experiment, all received the same set of reports during the game playing and generally adhered to a uniform set of measurement criteria for judging the performance of the student teams. (See section 4.2.1 ) This

uniformity resulted from the eight years that BUSPOG has been used at Pace University combined with the administrator's manual. The use of these measurement scales provided one method for minimizing error variance. In addition, the expert system's user interface was developed to eliminate ambiguous questions as seen in Figure 6.1.

EXPERT-EASE Query Listing. Problem: PRODUCT RESEARCH AND DEVELOPMENT BUDGET

QUESTIONS:

What is the current company Product R&D budget?  
 What is the current company total unit sales (scaled by 10)?  
 What is ratio A (Current industry average unit sales/industry average product price)?  
 What is ratio B (Current company total unit sales/company average product price)?

DECISION:

The Product R&D budget is:  
 Product R&D of 305 (\$1000/qtr)

Figure 6.1 Expertease User Interface

The paucity of attention paid to evaluation and testing in the literature surveyed, except for this 1987 article by O'Leary, largely left the determination of the method to the researcher. Thus, O'Leary's validation framework was used as a basis for the validation of the expert system. His framework also suggested testing the expert system against a human expert, but not the expert or experts who provided the original expertise since they have a bias in the system. The human "experts" were the competing student teams.

## 6.2 Experimental Validation Process

The first step, prior to the validation testing iterations, was the substitution of the expert system for one of the student teams in a recent management game iteration, the previous semester. The particular game chosen was composed of seven student teams participants that had all competed with relatively similar performance results, meaning the best and least well performing companies were not outstanding in either direction. The particular student team chosen exhibited an average performance based on the performance criteria as originally described in chapter 4, section 4.2. These criteria are percentage market share, productivity, stock price, P/E ratio, earnings per share, quick ratio, profit on sales ratio, and bond and loan interest rates. The validation testing iterations held the decisions of the six remaining student teams constant despite the changed environment of replacing the one team by the expert system and replaying the game period-by-period. However, the original limited range in decision choices by the competing teams during their actual game playing, minimized the effects of the expert systems decision choices on the competition's performance outcomes as seen in table A4.1 in appendix 4. This table lists the range of the operating decisions made by the original seven competing student teams for the first quarter and the seventh quarter. The numbers in parentheses indicate the ratios of the ranges to the average operating decisions.

The second step was determining an initial strategy and eliminating the ability to change strategies during the management game playing. This decision to maintain a fixed strategy was made by the author to simplify the expert system as well as the validation process. If the expert system had the ability to change strategies in the same manner as the human student teams, the

expert system would have required a separate knowledge base for each different strategy as well as a meta expert system. Furthermore, many student teams have maintained a fixed strategy choice.

Once these two steps were in place, each of the testing game iterations for the validation process proceeded for seven quarters of the total twelve quarters of game playing. This number was chosen by the author, after consulting with the original management faculty experts, for three reasons; 1) there was sufficient time (almost two business years) for the student teams to experience the cyclically changing business patterns, and thus learn to make their decisions more appropriate for performing in a competitive environment, 2) the unit demand forecast, computer program calculations, and business game playing were extremely time consuming and labor intensive, that is, the elapsed time between each set of twenty-nine decisions for each quarter was at least one week. The validation process, if possible, needed to be completed in sufficient time to be ready to begin the "live" game by the start of the next academic semester. 3) The author, along with the panel of experts, believed that the number of necessary validation testing replays of the management game by the expert system before it was considered performing satisfactorily at mimicking the student team it replaced, could be accomplished by reducing the total number of quarters of each of the successive replays from twelve to seven. In addition, the game playing, in some class sessions, extended for eight rather than twelve quarters. An illustration of the Expertease expert system decision making model and the procedures for each game playing business cycle is shown in figure 6.2.

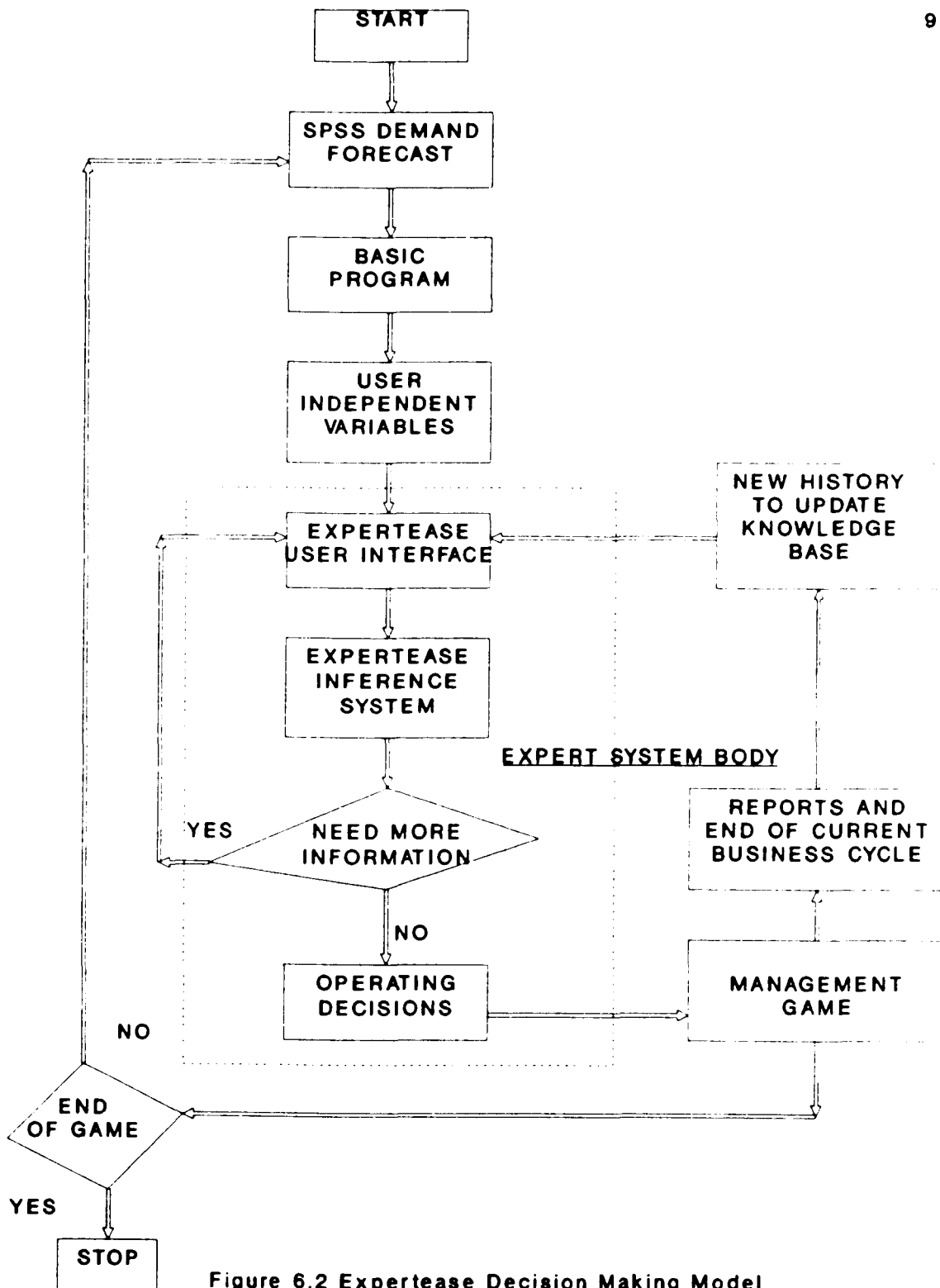


Figure 6.2 Expertease Decision Making Model

Some of the operating decisions have decision rules that are specifically defined in the student manual for BUSPOG, Richings and Berry (1984). They are the change in the size of the production workforce, the percentage allocation of finished products to the three markets, and the raw material requirements. Therefore, the author wrote a program in the BASIC computer language to calculate each of these, the industry averages (computed from the industry estimates in the quarterly reports exhibited the appendix 1, table A1.2), and the several ratios exhibited in appendix 2, table A2.2. A multiple regression technique in Statistical Programs for the Social Sciences (SPSS) was used to calculate forecasts for each next quarter's product demand. The student manual for BUSPOG suggested a list of possible independent variables for the multiple regression. They included price of the product, advertising expenditure, sales force size, product R&D, sales commissions, sales training budget, personal consumption of durables, GNP, household formations, previous quarter sales, quarter number, and seasonal index. In order to avoid multicollinearity, only five of the independent variables were used in the multiple regression program for the unit demand forecast of the expert system; price of the product, advertising expenditure, sales force size, household formations, and seasonal index. These five are the ones suggested by the experienced game administrators. The multiple regression program was also used by most of the student teams. Table 6.1 lists the mean absolute deviations (MAD) of the demand forecast of the expert system in the two consumer markets and the industrial market for all validation testing iterations and the "live" game. The values in the table illustrated the effects of the modifications to the decision making behavior of the expert system during the tests as well as the accuracy of the demand

forecasts. The numbers in the parentheses are the percentage deviations of MAD from the actual average demand in each market.

Table 6.1 Mean Absolute Deviation of the Demand Forecast

| Validation<br>Test | Consumer<br>Market 1 | Consumer<br>Market 2 | Industrial<br>Market |
|--------------------|----------------------|----------------------|----------------------|
| 1                  | 4717 (.28)           | 2208 (.11)           | 6814 (.32)           |
| 2                  | 4889 (.21)           | 3580 (.16)           | 4687 (.29)           |
| 3                  | 3323 (.14)           | 3375 (.15)           | 4350 (.25)           |
| Live Game          | 2035 (.08)           | 1690 (.09)           | 1713 (.10)           |

The decision rules generated by the expert system were checked at the end of each validation testing iteration for logic and consistency by the chairperson of the management department and the author. In addition, the expert system's decision choices were compared to the decisions of the student team it replaced. These two steps were part of the content validity. Likewise, its performance, at the end of each iteration, was measured by using the predetermined benchmark performance criteria. If its performance was inferior to the competition and dissimilar to that of the student team that the expert system replaced then, the relationships between the variables that formed the decision rules were adjusted. This process was repeated after each modification to the operating decision during the validation testing game iterations.

### 6.3 The Expert System Validation Performance

#### 6.3.1 First Validation Testing Iteration

During the first test the expert system's behavior was monitored after each quarter of play. The expert system used the historical data for its first set of operating decisions. Initially, as demonstrated in appendix 4 figures A4.5a and A4.5b, the expert system priced its products above those of the average price of the competition in the consumer market (market 1 and 2) and

lower in the industrial market. It continued this product pricing scheme for the seven quarters. The expert system seemed to have made this choice because the industrial market was not pursued by the competition in the game played. Figures A4.5c and A4.5d (see appendix 4) indicated that the expert system gradually lost its share of the consumer market as its consumer product price remained higher than the competition. The reverse phenomena occurred for the industrial market. As the expert system lowered its prices it initially gained a larger percentage of the industrial market share and then maintained almost an equal percentage share as that of the competition.

In appendix 4, figures A4.6a, through A4.6d, one sees that the productivity of the expert system was initially low in comparison to that of the competition; therefore, the expert system reacted by slightly increasing the production wage rate for a short span. However, the significantly larger process research and development budget of the competition and the lower amount of raw material requirements seemed to have had more impact on the expert system's lower relative productivity performance, particularly in later stages.

The financial outcomes apparent in figures A4.7a through A4.7d of appendix 4 showed that the expert system, at first, had a large increase in net income but subsequently it decreased to a level well below that of the competition average. The price earnings ratio (P/E) and the profit on sales ratio performance measures were lower than the competition, yet the graphs revealed that the expert system's performance did "track" that of the competition from the second to the sixth quarter. The relatively poor financial performance of the expert system could be partially attributed to cash flow and the P/E ratio. In addition, changes in the cost model could improve the

expert system's performance. The dividends payments decision affected the cash flow, thus needed to be changed to reflect some consideration of the industry dividend payments.

The evaluation of the first test by the author and the panel of experts determined that the expert system consistently reacted too slowly to changes in the competitive arena. Modifications to the pricing model that made it more sensitive to the industry averages prices could improve the expert system's performance. Nevertheless, in the opinions of the author and the expert panel, the expert system seemed to assume "human" decision making behavior as it made operating decisions during the seven quarters of the first test. Its operating decision choices appeared to be interrelated and it tried, with limited success, to improve its performance each subsequent quarter.

As a result of the first validation test of the expert system the author, after consulting with the expert panel members, made changes to the relationships of variables for the product pricing and dividend payment decisions. Some variables were added, others were removed, and some were changed thus, the attribute values representing past decisions were likewise changed to reflect the variable changes. Specifically the product unit cost amount and industry average price were removed from the prior product pricing decision for each market. Instead, the prices chosen by the expert system with two variables removed were then compared to the industry average prices. If the industry average prices were lower than the first price choices of the expert system and also higher than the unit cost, then an industry average price was chosen, otherwise, the first price choice was used. In addition, for the dividends paid decision rule, the industry average stock price variable was changed to the industry average dividend price.

### 6.3.2 Second Validation Testing Iteration

The same seven quarters were rerun starting with the original historical knowledge base. As in the first validation test, the six other competing companies made the same decisions they had made when the game was run "live" with all the student teams. The new decisions of the expert system for each quarter of the second game became part of the knowledge base of the expert system and a new rule set was generated each quarter.

The expert system's second set of quarter performance results were compared with the first test performance based on the selected benchmark criteria referred to in section 6.2. This time, as displayed in appendix 4 figures A4.8a through A4.8d, the expert system's product pricing decisions in both the consumer and industrial market were comparable to the competition product prices. The expert system was able to maintain a larger consumer market share than during the first test. The expert system did not seem to concentrate on the industrial market, as it did in the first game, because its other product prices were competitive in the two consumer markets. Nonetheless, the expert system's market share gradually decreased during subsequent quarters.

Figure A4.9a in appendix 4 illustrates that the explanation for this phenomena appeared to be directly related to the expert system's erratic raw materials level which, in turn, affected the expert systems production capacity. Likewise, figure A4.9b in appendix 4 demonstrated that the expert system also hired and fired production workers in quick order, changing the size each quarter in contrast to the student teams that either steadily increased or maintained a fairly consistent workforce. The expert system seemed to react too quickly to changes in the product demand forecast and

the finished products inventory. These problems influenced the plant operation resulting in less efficiency as seen in figure A4.9c and A4.9d (see appendix 4); therefore, the expert system was unable to decrease the product prices and the product demand suffered.

The illustrations in appendix 4 figures A4.10a through A4.10d showed that there had been some changes in the decision behavior of the expert system. Even though the performance measures of P/E ratio and profit-on-sales ratio were only slightly better, the dividends paid and net income showed that some of the modifications improved the expert system's decision behavior.

The second test still displayed evidence that revisions should be made to the expert system's operating decisions. An attempt was made by the expert system to plan a production level that reflected the anticipated demand and maintained a sufficient safety stock, but the determination of raw material requirements was inadequate. Thus, the raw materials ordering sub-system required modification. During the second test the raw materials ordered was a function of demand, raw materials required per unit, safety stock, and the current raw materials inventory. The modifications changed the method for determining the current raw materials inventory and increased the safety stock from twenty to twenty-five percent of the demand forecast.

The production workforce staffing model was changed to eliminate wide swings in production work levels. The operating decision that changed the labor force size was initially a function of planned production level, productivity and the current workforce. The modification to the workforce staffing decision added changes to the production level that would more closely react to that of the previous quarter as well as either maintain the

same, or minimize the adjustments to the size of the production workforce. These changes in the variable relationships were designed to yield better control over the hiring and firing of production workers.

### 6.3.3 Third Validation Test Iteration

The figures A4.11a through A4.11d in appendix 4 compared the performance of four groups: 1) the original team that was replaced for this validation test 2) its original competing companies 3) the expert system in the third game, and 4) the competition of the third game. As seen from these graphs, the third test revealed that the expert system's performance was still more competitive and generally similar to the average of all teams in performance; better than some, worse than others. Its product price decisions in both markets were comparable to those of the competition as well as its percent market share. Likewise, the expert system's overall decision behavior was similar to the student team it replaced.

Figures A4.12a through A4.12d in appendix 4 illustrated that the expert system raised its productivity above the levels of previous test runs. Also, as seen in these figures, the net income of the expert system exceeded that of the average of the competition, its profit on sales ratio performance measure was the best, and its P/E ratio measure was better than either of the previous two tests. Similarly, all these performance measures were comparable to those of the team originally replaced by the expert system. Likewise, as seen in table 6.1 the MAD measures of the forecast demand for all three tests in the two consumer markets and the industrial market indicated performance improvement.

After three validation testing iterations, the panel of experts determined that the expert system's performance was sufficiently modified to

satisfy their performance criteria. The illustrations, previously described, revealed that the expert system made operating decisions that closely mimicked the student group it replaced, and thus reinforced the expert panel's decision to approve of the expert system's decision behavior. They agreed that the expert system seemed able to compete in the limited test setting.

In summary, the author decided to change relatively few of the variable relationships for each test run to maintain control during the validation phase. The specific variable relationships that changed were; product pricing and dividend payments after the first test, followed by level of raw materials ordered, planned production level, and adjustments to the size of the production force after the second test. These modifications made prior to each subsequent test run, were closely interrelated and only impacted a few of the twenty-nine total operating decisions at one time. The object of this validation methodology was to maintain control of the expert system's rule set manager in the knowledge base by instituting only a few changes at one time, monitor the changed decisions, the other decisions, and the performance outcomes. Table A4.2 in appendix 4 lists nineteen operating decisions. These were the validity-related criteria used to compare the expert system's decisions to those of the "best" student team at the end of each of the three testing game iterations. Another criterion validity is illustrated by the performance measures in Table A4.3 in appendix 4. The numbers in parentheses are the percentage differences between the "best" team and the expert system at the end of the validation testing iterations.

The next chapter described and analyzed the "live" decision behavior and performance outcome of the expert system as it reacted to a competitive environment.

## CHAPTER 7

### THE LIVE EXPERT SYSTEM EXPERIMENT

At this point the expert system model had completed three validation tests with subsequent modifications. The third set of performance results of the expert system model had been shown to the management faculty members who had originally contributed their expertise toward the development of the knowledge base. They agreed that the expert system was capable of making meaningful operating decisions and appeared sufficiently astute to compete with student groups in a live BUSPOG game iteration.

The expert system model, along with the five competing student teams, used the same four year history of decisions made by one company as the basis for the first set of operating decisions. The expert system was designed to follow a strategy that reacted to the behavior of the other companies in the competitive environment as was explained in Chapter 4, section 4.2.1. The BUSPOG game simulated twelve successive business quarters during an eight week classroom session. Once a week (occasionally twice a week) the teams, including the expert system, produced decisions for the game. The expert system's decision and resultant performance measures from a previous decision period were added to the knowledge base. Then, new rules were generated that became the basis for the expert system's next set of operating decisions. This chapter uses two methods for analyzing the decisions and performance outcomes of the expert system and the competing student teams. First, a

graphic analysis is used to examine and compare the expert system's individual and sub-groups of decisions and performance measures with that of the competition. Second, cluster analysis methodology combines set of decisions and performance outcome measures from each competing team and the expert system and provides, as a composite measure over time, a means for placing the teams including the expert system that have common attributes into specific classes.

### 7.1 Graphic Analysis of the Expert System Performance

#### 7.1.1 Marketing Performance Measures

The changes that were made to the pricing model (see Chapter 5 Section 5.3) caused the expert system to begin the game with product prices that were competitive with the industry prices, but slightly higher, as seen in appendix 5 figures A5.1a and A5.1b. The initial higher product prices chosen by the expert system for both the consumer and industrial markets allowed the competition to immediately establish a larger market share in both these markets (see appendix 5 figures A5.1c and A5.1d). The expert system reacted by continually decreasing its prices close to those of the competition and was therefore able to maintain its market share for the first four quarters, but its ability to respond to price and market changes was too slow. This sluggish response is illustrated in the net change columns in table 7.1(a) and table 7.1(b).

Table 7.1 - Product Prices

## (a) Consumer Market Prices

| QTR | COMPETITION<br>UNIT PRICE | EXPERT<br>UNIT<br>PRICE | COMPETITION<br>NET CHANGE | EXPERT<br>NET<br>CHANGE | COMPETITION<br>CUMULATIVE<br>CHANGE | EXPERT<br>CUMULATIVE<br>CHANGE |
|-----|---------------------------|-------------------------|---------------------------|-------------------------|-------------------------------------|--------------------------------|
| 1   | 269                       | 288                     |                           |                         |                                     |                                |
| 2   | 262                       | 270                     | -7                        | -18                     | -7                                  | -18                            |
| 3   | 260                       | 262                     | -2                        | -8                      | -9                                  | -26                            |
| 4   | 260                       | 258                     | 0                         | -4                      | -9                                  | -30                            |
| 5   | 210                       | 258                     | -50                       | 0                       | -59                                 | -30                            |
| 6   | 205                       | 220                     | -5                        | -38                     | -64                                 | -68                            |
| 7   | 194                       | 207                     | -11                       | -13                     | -75                                 | -81                            |
| 8   | 184                       | 190                     | -10                       | -17                     | -85                                 | -98                            |
| 9   | 184                       | 183                     | 0                         | -7                      | -85                                 | -105                           |
| 10  | 172                       | 183                     | -12                       | 0                       | -97                                 | -105                           |
| 11  | 155                       | 173                     | -17                       | -10                     | -114                                | -115                           |
| 12  | 151                       | 169                     | -4                        | -4                      | -118                                | -119                           |

## (b) Industrial Market Prices

| QTR | COMPETITION<br>UNIT PRICE | EXPERT<br>UNIT<br>PRICE | COMPETITION<br>NET CHANGE | EXPERT<br>NET<br>CHANGE | COMPETITION<br>NET CHANGE | EXPERT<br>CUMULATIVE<br>CHANGE |
|-----|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|--------------------------------|
| 1   | 260                       | 285                     |                           |                         |                           |                                |
| 2   | 253                       | 263                     | -7                        | -22                     | -7                        | -22                            |
| 3   | 250                       | 251                     | -3                        | -12                     | -10                       | -34                            |
| 4   | 250                       | 251                     | 0                         | 0                       | -10                       | -34                            |
| 5   | 215                       | 251                     | -35                       | 0                       | -45                       | -34                            |
| 6   | 202                       | 219                     | -13                       | -32                     | -58                       | -66                            |
| 7   | 188                       | 206                     | -14                       | -13                     | -72                       | -79                            |
| 8   | 179                       | 188                     | -9                        | -18                     | -81                       | -97                            |
| 9   | 178                       | 176                     | -1                        | -12                     | -82                       | -109                           |
| 10  | 152                       | 176                     | -26                       | 0                       | -108                      | -109                           |
| 11  | 152                       | 173                     | 0                         | -3                      | -108                      | -112                           |
| 12  | 148                       | 169                     | -4                        | -4                      | -112                      | -116                           |

Table 7.2 - Percent Market Share

## (a) Consumer Market

| QTR | COMPETITION<br>MARKET<br>PERCENT | EXPERT<br>MARKET<br>PERCENT | COMPETITION<br>NET CHANGE | EXPERT<br>NET<br>CHANGE | COMPETITION<br>CUMULATIVE<br>CHANGE | EXPERT<br>CUMULATIVE<br>CHANGE |
|-----|----------------------------------|-----------------------------|---------------------------|-------------------------|-------------------------------------|--------------------------------|
| 1   | 16.92                            | 15.38                       |                           |                         |                                     |                                |
| 2   | 17.02                            | 14.90                       | 0.1                       | -0.48                   | 0.1                                 | -0.48                          |
| 3   | 17.06                            | 14.77                       | 0.04                      | -0.13                   | 0.14                                | -0.61                          |
| 4   | 17.13                            | 14.31                       | 0.07                      | -0.46                   | 0.21                                | -1.07                          |
| 5   | 17.62                            | 11.91                       | 0.49                      | -2.40                   | 0.70                                | -3.47                          |
| 6   | 19.74                            | 10.63                       | 2.12                      | -1.29                   | 2.82                                | -4.75                          |
| 7   | 19.68                            | 9.83                        | -0.06                     | -0.80                   | 2.76                                | -5.55                          |
| 8   | 18.08                            | 9.58                        | -1.60                     | -0.25                   | 1.16                                | -5.80                          |
| 9   | 17.77                            | 10.18                       | -0.13                     | 0.60                    | 0.85                                | -5.20                          |
| 10  | 19.20                            | 8.61                        | 1.43                      | -1.57                   | 2.28                                | -6.77                          |
| 11  | 18.38                            | 7.74                        | -0.82                     | -0.87                   | 1.46                                | -7.64                          |
| 12  | 18.62                            | 6.882                       | 0.24                      | -0.92                   | 1.70                                | -8.56                          |

## (b) Industrial Market

| QTR | COMPETITION<br>MARKET<br>PERCENT | EXPERT<br>MARKET<br>PERCENT | COMPETITION<br>NET CHANGE | EXPERT<br>NET<br>CHANGE | COMPETITION<br>CUMULATIVE<br>CHANGE | EXPERT<br>CUMULATIVE<br>CHANGE |
|-----|----------------------------------|-----------------------------|---------------------------|-------------------------|-------------------------------------|--------------------------------|
| 1   | 17.01                            | 14.92                       |                           |                         |                                     |                                |
| 2   | 17.23                            | 13.81                       | 0.22                      | -1.11                   | 0.22                                | -1.11                          |
| 3   | 17.22                            | 13.90                       | -0.01                     | 0.09                    | 0.21                                | -1.02                          |
| 4   | 17.33                            | 13.36                       | 0.11                      | -0.54                   | 0.32                                | -1.56                          |
| 5   | 17.78                            | 11.10                       | 0.45                      | -2.26                   | 0.77                                | -3.82                          |
| 6   | 18.02                            | 9.59                        | 0.30                      | -1.51                   | 1.07                                | -5.33                          |
| 7   | 18.27                            | 8.64                        | 0.19                      | -0.95                   | 1.26                                | -6.28                          |
| 8   | 18.37                            | 8.13                        | 0.10                      | -0.51                   | 1.36                                | -6.79                          |
| 9   | 18.18                            | 8.64                        | -0.19                     | 0.51                    | 1.17                                | -6.28                          |
| 10  | 18.37                            | 8.07                        | 0.19                      | -0.57                   | 1.36                                | -6.85                          |
| 11  | 19.57                            | 7.08                        | 1.20                      | -0.99                   | 2.56                                | -7.84                          |
| 12  | 19.61                            | 6.92                        | 0.04                      | -0.16                   | 2.60                                | -8.00                          |

In the fifth quarter the average product prices of the competition were decreased by a significant amount, fifty dollars, in the consumer market and thirty-five dollars in the industrial market while the expert system maintained the same prices as in the previous quarter in both markets. Responding to the price reductions of the competition, the expert system, one period later, decreased its prices by thirty-eight dollars and thirty-two dollars in the consumer and industrial markets, respectively. This lag response behavior of the expert system continued through the twelve periods of the business game as seen in both table 7.1(a) and 7.1(b).

As seen in net change columns of table 7.2(a) and table 7.2(b), the initial lower prices and price-decrease initiative by the competition resulted in market share gains during the comparable six quarters in contrast to the expert system losses. In fact, the competition exhibited 2.12 and 0.3 percentage point gains in the consumer and industrial markets, respectively, while the expert system experienced significant losses of 2.4 followed by 1.29 percent market share in the consumer market and 2.26 and 1.51 in the industrial market. Subsequently, the cumulative change columns of table 7.2(a) and table 7.2(b) show that the competition continued increasing its market share of both markets as the expert system exhibited a steady decline.

A team's decision process for determining the product prices depends on the team's demand forecast, estimates of the competition's product prices, and other variables. The unit demand forecast, in turn, is influenced by stochastic quantities such as the game's econometric and industry measures (as seen in the variable relationships in appendix 2, figure A2.2) and, thus, the product pricing can not be specifically controlled by a team vice-president or president. These stochastic components and estimates of

the competition's pricing decisions are difficult to predict and are influenced by the vagaries of a competitive market. If the expert system shell, Expertease, had the facilities to incorporate and adjust probabilistic weights to interact with the stochastic components in the rule structure, the expert system model might have reacted more quickly and effectively to the performance changes of the competition or even affect product price reductions at the same time as the competition. Similarly, if there were separate knowledge bases for all the strategies and it was possible for the expert system to appropriately decide to switch strategies (as the humans teams were able to and in some cases, did) then, the expert system's market performance might have been better.

#### 7.1.2 Cost Model

Even though the competition continued to chip away at the expert system's total market share, appendix 5 figures A5.2a and A5.2b show that both the net income and profit margin on sales ratio performance measures of the expert system were always higher than those of the competition. Since these performance measures are indications of profits after costs and profit per dollar of sales, a plausible explanation for this outcome is that the expert system had a better cost model. This is reasonable because the expert system's knowledge base was originally developed from the panel of faculty experts who, from real life experience, knew that a low cost structure is essential in a competitive manufacturing environment.

The cost model of the expert system was based on three variable factors; raw material requirements, raw materials inventory, and the production costs attributed to labor, maintenance, production training, plant, and equipment investment. Since these factors are deterministic, they can be

calculated by the expert system using specific decision rules. Significant barometers of a well developed cost model are the ability to maintain low and non-fluctuating costs along with a consistent and minimal level of raw materials inventory without significant negative impact on profitability.

The first factor, the amount of raw material required per unit partly reflects the production efficiency. The business game placed a lower level of ninety-four pounds per unit as the minimal amount of raw materials required. All the companies, including the expert system, attained this lower level by the fourth quarter of the first year as depicted in appendix 5 figure A5.3a. However, the expert system showed an increase in raw materials required at the start of the ninth quarter and continued to do so through the end of the game. This increase appeared to have been caused by its loss in productivity, as displayed in figure A5.3b in appendix 5. The impact of this productivity loss and its relevance to the expert systems performance is discussed later in the Production Performance Evaluation Section.

The second component in a cost model is the amount of the raw material inventory. The historical data initialized the expert system and the competing student teams at the same raw material inventory level. Appendix 5 figure A5.3c tracks for twelve quarters the raw material inventory normalized by the total production amount. This graph revealed that the expert system lowered its raw material inventory ratio during the second quarter and maintained this level through the eighth quarter followed by a slight increase in the raw materials inventory until the end of the game. In contrast, the competition exhibited higher and much more variable raw material inventory from quarter to quarter. Furthermore, figure A5.4a in appendix 5 graphically illustrates the

variations in raw materials inventory ratio for each of the competing student companies.

The third factor, the total production cost of labor, production training, maintenance, and investment in plant and equipment is tracked in appendix 5 figure A5.3d. This graph showed that the average production costs of the competition intermittently rose and sank during the twelve quarters, while the expert system maintained a low, steady cost profile. Again, figure A5.4b in appendix 5 emphasized the contrast between the cost profile of the expert system and each of the individual student companies.

In all of the above mentioned cost areas, the expert system performed better than the competing companies. The expert system's performance results tended to support the original contention that the panel of experts, who were the source of the original knowledge base, developed an appropriate cost model for a manufacturing industry and that this model was maintained by the expert system through the course of the twelve competitive business cycles. On the other hand, the competing student teams seemed to concentrate on market share development rather than cost containment.

### 7.1.3 Production Performance Measures

The set of operating decisions that have an effect on the manufacturing productivity measure (units produced per hour) include employee profit sharing percentage, a production training budget, and process research and development budget. The productivity measure is one of the key performance measures used by the game administrators to assess the quality of production operating decisions.

The expert system initially displayed a productivity profile similar to that of the competition for the first four quarters as shown in appendix 5

figure A5.5a. However, during the next four quarters the average productivity measure of the competition increased at a faster rate than that of the expert system. Subsequently the last four quarters showed that the expert system productivity trended downward suggesting that this was simply a lag effect due to its drastic sixth quarter decrease in the employment profit sharing percentage and its consistently lower investment in process research and development and production training (see appendix 5 figures A5.5b, A5.5c, and A5.5d). At the same time, the competition maintained or slightly increased their budget allocations for these expenses. This combination of decisions appeared to have caused, after a brief time lag, the relatively inferior productivity exhibited by the expert system in the final four quarters of the game. It is possible that since the expert system was designed to focus so strongly on costs and to, in a sense, play for just the three years that it did play and not beyond, that this caused the end-of-game decline. However, this decline did not seriously affect the competitive position of the expert system as measured by profitability.

The profit margin on sales ratio (discussed in section 7.1.2 as part of the cost model), seen again in appendix 5 figures A5.6a and A5.6b, is used widely by the game administrators as a measure of company effectiveness. The first figure demonstrated the overall superior performance by the expert system and confirmed the earlier remarks on the focus of the cost model rather than the preservation of the market share. The second figure illustrated that the expert system's performance was similar to Company 3, which was considered by the game administrator for this experiment to be the "best" performing company, and was better than the other four. In the area of

profit on stockholders equity ratio (see figures A5.6c and A5.6d in appendix 5) the expert system performed similarly.

#### 7.1.4 Financial Performance Measures

The quick ratio, return on assets, interest rates for bonds and bank loans, price earning ratio (P/E), earnings per share, cash flow, and stock price, are criteria used by the game administrators to evaluate the financial condition of each company. The financial ratios are analyzed by 1) comparing the expert to the competition to indicate the comparative financial conditions of the expert system and 2) comparing the trends in the expert system performance over time to provide insight into the financial condition of the expert system itself.

The quick ratio, defined as  $(\text{current assets} - \text{inventories}) / \text{current liabilities}$ , represented in appendix 5 figure A5.7a, is a liquidity measure. At the end of first year the quick ratio of the competition was 20.45 and for the expert system 16.26, a difference of four. During the subsequent quarters of the business game, the quick ratio of the competition increased its lead to eight points at the end of the eighth quarter, and to a twenty point lead by the end of the game. This seemed to imply better financial management policies were followed by the student teams than by the expert system. The quick ratio of the expert system followed a downward trend until the sixth quarter and was then able to level off its quick ratio at approximately 9.0 until the end of the business game.

The return on total assets, as seen in appendix 5 figures A5.7b is a profitability ratio. Even though the expert system captured a smaller market share than the competition, it exhibited a better performance for this ratio than that of the competition, right up to the last period, apparently due to

its more effective cost model. This ratio decreased over time for all six companies which seemed to reflect the lowering of profit margins as a result of competition.

The loan and bond interest rates are manipulated by the business game to reflect the overall creditworthiness of each company as well as its cash flow position. The interest rates are changed in either of two situations; 1) a company runs out of cash or 2) if a company rates better or worse than the industry average in ten or more of thirteen ratios computed by the BUSPOG program. The ratios are as follows:

Profits on Sales

Profits on Stockholders Equity

Sales to Stockholders Equity

Sales to Net Working Capital

Sales to Inventory

Fixed Assets to Stockholders Equity

Current Debt to Stockholders Equity

Stockholders Equity to Total Debt

Net Working Capital to Inventory

Inventory to Current Debt

Net working Capital to Funded Debt

Current Assets to Current Debt

Figure A5.7c in appendix 5 illustrated that the combined interest rates of the expert system were lower than the industry average for the first eight quarters (two years) indicating the financial decisions of the expert system were initially viable. By the third year the competition improved their performance and their interest rates decreased while those of the expert

system rose. One plausible explanation for this behavior was cash management. A comparison of figure A5.7c to figure A5.7d suggested a likely relationship between interest rates and cash flow.

The cash flows of the expert system and the competition were similar for the first six quarters. Subsequently the competition improved their cash flow position at an increasing rate while the expert system exhibited a gradual decrease in its cash flow position until the end of the game. The decrease in the bond and loan interest rates of the competition to a lower level than those of the expert system trailed the changes in cash flow by two quarters indicated a delayed reaction. The student teams were advised that successful business game decision making required cash planning to ensure a company had sufficient cash available and they appeared to make use of this advice.

If a company had a negative cash balance BUSPOG automatically executed a bank loan for the duration of only one business quarter to cover the cash deficit, and subsequently raised the bank and interest loan rate. Funds could be obtained by selling bonds, issuing stock or making a withdrawal from the company's savings account. Even though all the financial decisions of the expert system included a consideration of the cash balance, the decision behavior of the expert system program did not seem to capture the significance of a cash flow analysis and secure sufficient funds to improve its cash flow. One explanation for this decision behavior was the decision rule generated by EXPELTEASE for selling or redeeming bonds to secure funds. The cash balance and bonds outstanding are the only significant variables in the decision rule. Since the history data that was part of the initial knowledge base of the expert system maintained a constant outstanding bond amount of

\$10400 for all cash balance amounts followed by the constant decision not sell any more bonds, this decision strongly influenced the expert system's inability to acquire additional cash when it was needed. In addition, BUSPOG allowed bonds to be issued or redeemed, but stock can only be sold; therefore, the student teams sold bonds to acquire cash rather than stock. The combination of higher loan rates, decreased funds, and reduced market share could not be offset by the low cost model of the expert system. Even though the panel of experts seemed to have specified variables for a good cash flow analysis, a weakness in the expert system shell, EXPELTEASE, did not interpret them to produce the same.

In appendix 5 figures A5.8a, A5.8b and A5.8c, the P/E (price earnings) ratio, earnings per share, and stock price performance measures of the expert system were shown to be generally better than those of the competition. The significantly improved stock price of the expert system over that of the competition was an indication of attention to cost control. Stock price maximization required efficient, low-cost operations that produced the desired quality and quantity of products at the lowest possible costs. It appeared that the BUSPOG stock price model perceived the expert system to have either better growth prospects or to be a lower risk investment. Due to the fixed reactive strategy choice of the expert system and its focus on the cost model, the lower risk scenario seemed to more likely to account for the performance outcomes. It should be noted that P/E and earnings per share are short-term measures.

#### 7.1.5 Survey Responses of the Student Teams

The student questionnaire (described in appendix 2, table A2.3) was presented to the students at end of the business game simulation. The answers

to the questionnaire, exhibited in appendix 5 figure A5.9, show that their initial strategies ranged from high-volume and low cost to price differentiation. They monitored the performance measures of the competition and considered, as well as attempted to understand, the strategies of the other companies. The last question, presented as a modified Turing test, asked if the students noted any unusual performance by the other competing teams. With the exception of questioning the performance of the "best" team, the expert system was perceived as being just another student team. One team remarked on the consistently inferior sales of the "absent" team; the expert system.

### 7.2 Cluster Analysis of the Expert System Performance

The original research questions, introduced in Chapter 1, asked; can an expert system "learn" from previously made decisions; does experiential learning improve the group performance; and how will the expert system perform relative to other live decision makers in the same arena? In the preceding sections of this chapter, the graphic analysis of the expert system's performance in a "live" competitive business environment focused on both individual and groupings of graphs of decision making and performance measures. This analysis partially responded to the last question when it revealed that the expert system and the competition displayed occurrences of better and worse decision making and resultant performance measures by both. Given these disparate phenomena and the vast amount of dissimilar data collected, cluster analysis was chosen as a method for determining whether or not the expert system's overall decision making and performance profiles were similar to any subset of the five competing companies or resemble them as a class.

Cluster analysis uses data matrices whose columns, for this data set, stand for the six competing companies whose similarities we want to estimate. The rows are examples of the properties (attributes) of the companies which are the operating decisions determined by the companies and performance measures generated by the business game. The first step of cluster analysis, as described by Romesburg (1984), begins with the development of the data set for the data matrices.

There are twenty-nine separate and interrelated decisions made prior to each quarter of the business game, five performance reports available to the the game participants, and approximately thirty performance criteria presented to the game administrators (as described in Chapter 4, Section 4.2). After conferring with the panel of experts and using the list of operating decisions (see Appendix 1, Table A1.1), twenty operating decisions and eight important performance measures were used as the attribute data for the cluster analysis. Since the product price, advertising budget, and numbers of salespersons are aggregate operating decisions for the three markets, this reduces the original twenty-nine decisions to twenty-three. In addition, the percentage allocation of finished products to the aggregated markets is one hundred percent, thus further reduces the operating decision number to twenty. The eight performance measures chosen are those consistently used by the game administrators for evaluating the performance of the student teams. The two data sets, decisions and performance measures, were analyzed both separately and combined. Table 7.3 lists the operating decisions and performance measures selected for the cluster analysis.

Table 7.3 - Operating Decisions and Performance Measures

| Operating<br>Decisions                     | Performance<br>Measures     |
|--------------------------------------------|-----------------------------|
| Product Price                              | Percentage Market Share     |
| Advertising Budget                         | Productivity                |
| Product R&D Budget                         | Quick Ratio                 |
| Salesmen Commission                        | Profit on Sales Ratio       |
| Process R&D Budget                         | Stock Price                 |
| Sales Training Budget                      | Earnings per Share          |
| Production Wage Rate                       | Bank Loan and Interest Rate |
| Profit Sharing Percentage                  | Price Earning (PE) ratio    |
| Production Training Budget                 |                             |
| Labor Force Size Change                    |                             |
| Production Work Week                       |                             |
| Raw Material Purchased                     |                             |
| Number of Salespersons                     |                             |
| Salesperson Salary                         |                             |
| Bank Loans Requested                       |                             |
| Bonds Sold or Redeemed                     |                             |
| New Stock Issued                           |                             |
| Long term Investment Deposit or Withdrawal |                             |
| Dividends Paid                             |                             |
| Plant and Equipment Investment             |                             |

Additionally, the scales of measure for these operating decisions and performance criteria range from one digit to thousands of dollars, percentages, ratios, numbers of people, and pound weights. The variations in the range differences of this data set can possibly arbitrarily affect the similarities among the companies. Thus, the second step of cluster analysis, as described by Romesburg, provides a procedure for standardizing (normalizing) the data to transform it into dimensionless units to remove the arbitrary affects. The standardizing function chosen for the decisions and performance measure data was the Z score type, the most commonly used.

The second step is computing a resemblance coefficient that measures the degree of similarity among pair companies. The measure chosen is called

the Average Euclidean distance coefficient. It is a dissimilarity coefficient that is sensitive to size displacement and shape, a natural characteristic of the different decisions and performance measures. The "smaller" the value, the more similar the pair companies are. The formula for this resemblance coefficient is the literal distance between two objects (companies) when viewed as points in a two-dimensional space formed by two attributes. However, for "n" attributes, the formula is the square root of the sum of the squares of the differences of the values on the "n" attributes as follows:

$$d_{jk} = \left[ \sum_{i=1}^n (x_{ij} - x_{ik})^2 / n \right]^{1/2}$$

The dissimilarity coefficients for the six companies forms a matrix containing fifteen values that measures the resemblance between pairs of companies. The concept of resemblance is symmetric, thus only the lower-left half of the matrix contains values.

The third step determined the clustering methodology. The hierarchical agglomerative methods are the most frequently used methodology. They produce a visualization process, called a tree or dendrogram, that shows at a glance the degree of similarity between all the pairs of objects (companies). Gnanadesikan and Kettenring (1989) described three clustering methods. The first, single linkage method (SLINK) measures the similarity between two clusters in terms of the most similar resemblance coefficient (maximum value) of objects between the two separate clusters. Members are admitted to clusters by lowering the criteria for admission. That is, if at least one member of an existing cluster has the level of similarity as the case under consideration,

then it joins the cluster. SLINK tends to chain or produce elongated clusters and the dendrograms appear compacted. The second, complete linkage method (CLINK) is the reverse of single linkage and more rigorous. It takes the similarity between two clusters to be the most dissimilar resemblance coefficient (minimum value) of objects spanning two clusters. Members are admitted to clusters by increasing the criteria for admittance. Thus, a member joins a cluster only if it is highly similar to all members of the group. CLINK produces clusters that have highly similar members and extended dendrograms. The last, unweighted pair-group method using arithmetic averages (UMPGA), calculates resemblance coefficients and uses the same criteria for admittance whether a similarity or dissimilarity coefficient is used. The UMPGA method was chosen because it produces less distortion in transforming the similarities between objects into a dendrogram, is a compromise to the extremes of both single and complete linkage, and is the most often method used by researchers.

At the start of the clustering, each company is regarded as being in a singleton cluster. The method begins by selecting the pair of companies that have the smallest resemblance coefficient and then places these in a single cluster. The Average Euclidean distance coefficients are recalculated and placed in a revised and reduced resemblance matrix of the remaining objects (including the cluster with the two objects in it). The distance of some objects transcribed from the original matrix remain unchanged while the objects affected by the previous clustering are those that are recalculated. Each successive resemblance matrix is mapped into a tree called a dendrogram that illustrates the clusters. This process is repeated until all the groups form one cluster. Figure A5.10 in appendix 5 is an example of a dendrogram.

The clustering method used in this thesis is called the unweighted pair-group method using arithmetic averages (UPGMA).

The number of clusters needed for the analysis determines where to cut the dendrogram. The choice is either a matter of judgment, if the classification is for a specific purpose, or determined by measurements taken from the dendrogram for a general-purpose classifications. The first method may seem to be an unscientific way of proceeding, but informed subjective judgments do play a crucial role in all research. Since there were six groups (the six competing companies), it was possible to have from one to six clusters. However, if all six groups were forced to be together, the distances at which the groups would be joined would be quite high. Therefore, a goal of three clusters was initially selected and the cut or separation point that resulted for the first dendrogram was consistently followed for each of the succeeding periods in the business game. The goal of three clusters is the same number of common viable strategic postures as judged by the expert panel. In addition, the number three corresponds classifying all six competing companies as exhibiting the best, average, or least successful performance outcomes. However, after scanning the dendrograms, the original choice of three clusters changed to a predominance of four clusters for the decisions, three for the performance, and two for the combined data.

To support a judgmental choice and determine a precise cut-off point, a heuristic classification method cuts the tree at the points, using the resemblance coefficient, where the number of clusters change. This determines different ranges before new information enters the clustering. This widest range indicates that the clusters are well separated in the attribute space. Table 7.4 illustrates the heuristic method for determining the best suitable

number of clusters by using different ranges of the Euclidean distance coefficient (resemblance coefficient). The asterisks indicate the widest ranges for all three dendrograms. These cutoff points, (11.9135 for decisions, 6.897 for performance measures, and 27.32 for the combined data), were held constant for all the time periods (quarters) even though, over time, it resulted in two-group to four-group clusters.

Table 7.4 - Determine Cluster Choices and Cut-off Points

(a) Operating Decisions Dendrogram

| Number of clusters | Range of coefficient | Width of range |
|--------------------|----------------------|----------------|
| 4                  | 8.539-9.1555         | 0.6165         |
| 3                  | 4.1555-11.9135       | 2.7528 *       |
| 2                  | 11.9135-13.793       | 1.8795         |

(b) Performance Measures Dendrogram

|   |             |         |
|---|-------------|---------|
| 5 | 0-2.586     | 2.586   |
| 3 | 2.586-6.897 | 4.331 * |
| 2 | 6.897-0.483 | 2.586   |

(c) Combined Operating Decisions and Performance Measures Dendrogram

|   |               |          |
|---|---------------|----------|
| 6 | 0-9.935       | 9.935    |
| 4 | 9.935-16.5035 | 6.5685   |
| 3 | 16.5035-19.87 | 3.3665   |
| 2 | 19.87-27.3205 | 7.4505 * |

\* The largest range that results in the best classification

The last step in the cluster analysis methodology is the development of the cophenetic correlation coefficient (also known as the Pearson product-moment correlation coefficient). While the dendrogram is a graphical mapping of the resemblance matrix, it is not an exact "like" the data it represents. The cophenetic correlation coefficient gives a partial answer to how well the dendrogram and the resemblance matrix "say the same thing". The larger the coefficient the less the distortion. Romesburg states that a

coefficient near to 0.8 or more says the distortion is not great. Figure A5.12 in appendix 5 illustrates the method for calculating the cophenetic correlation coefficient. Table 7.5(a), 7.5(b), and 7.5(c) contain the cophenetic correlation coefficients in addition to an illustration of the cluster membership for the operating decision, performance measures, and combined data dendrograms during the twelve business periods. These tables copied the company numbers directly from the dendrograms. The order of the numbers across the rows, from left to right, reflects their similarity and approximate distance from each other. Company 6 is the expert system.

Table 7.5 - Cluster Membership

## (a) Operating Decisions

| Quarter | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cophenetic Correlation |
|---------|-----------|-----------|-----------|-----------|------------------------|
| 1       | 6,2,1     | 3         | 5,4       | *         | 0.8810 *               |
| 2       | 5,4,2     | 6,1       | 3         | *         | 0.6910                 |
| 3       | 5,1,6,3   | 2         | 4         | *         | 0.8401 *               |
| 4       | 2,4       | 5,1       | 6         | 3         | 0.6161                 |
| 5       | 5,1       | 2,3       | 4         | 6         | 0.7056                 |
| 6       | 2,4       | 5,1       | 6,3       | *         | 0.6455                 |
| 7       | 2,3,5,1   | 4         | 6         | *         | 0.7734 *               |
| 8       | 1,4,5,2,3 | 6         | *         | *         | 0.9198 *               |
| 9       | 2,4,1     | 5,3       | 6         | *         | 0.7270 *               |
| 10      | 2,3       | 1,4,5     | 6         | *         | 0.8581 *               |
| 11      | 1,2,3     | 5         | 4         | 6         | 0.8342 *               |
| 12      | 2,3,5,4   | 6         | 1         | *         | 0.6167                 |

## (b) Performance Criteria Variables

| Quarter | Cluster 1 | Cluster 2 | Cluster 3 | Cophenetic Correlation |
|---------|-----------|-----------|-----------|------------------------|
| 1       | 2,5,1,6,3 | 4         | *         | 0.8886 *               |
| 2       | 2,4,5     | 1,6       | 3         | 0.7954 *               |
| 3       | 2,4,5     | 1,6       | 3         | 0.6850                 |
| 4       | 4,5       | 1,2       | 3,6       | 0.5939                 |
| 5       | 1,2,5     | 3,6       | 4         | 0.8046 *               |
| 6       | 2,5,6,3   | 4         | 1         | 0.6369                 |
| 7       | 2,6,3     | 1,5,4     | *         | 0.5800                 |
| 8       | 1,5,4     | 2,6,3     | *         | 0.6615                 |
| 9       | 2,5,4,3   | 6         | 1         | 0.7922 *               |
| 10      | 2,4,3     | 5,6       | 1         | 0.8368 *               |
| 11      | 2,3,5,4   | 6         | 1         | 0.8781 *               |
| 12      | 2,3,4     | 1,5,6     | *         | 0.6864                 |

## (c) Combined Decisions and Performance Criteria Variables

| Quarter | Cluster 1 | Cluster 2 | Cluster 3 | Cophenetic Correlation |
|---------|-----------|-----------|-----------|------------------------|
| 1       | 1,6,5,2,3 | 4         | *         | 0.8597 *               |
| 2       | 4,5,2     | 1,6,3     | *         | 0.8144 *               |
| 3       | 1,5,2,4   | 3,6       | *         | 0.6078                 |
| 4       | 1,6,5,2,3 | 4         | *         | 0.7419 *               |
| 5       | 1,5,2,3,6 | 4         | *         | 0.7349 *               |
| 6       | 2,5,4,1   | 3,6       | *         | 0.6432                 |
| 7       | 2,3,6     | 1,5,4     | *         | 0.5559                 |
| 8       | 2,3,6     | 1,4,5     | *         | 0.6604                 |
| 9       | 2,3,5,4   | 1         | 6         | 0.6840                 |
| 10      | 2,3,5,4,1 | 6         | *         | 0.7466 *               |
| 11      | 2,3,5,1,4 | 6         | *         | 0.8541 *               |
| 12      | 2,3,4     | 1,5,6     | *         | 0.6778                 |

\* signifies concordance between resemblance matrix and dendrogram

### 7.2.1 Operating Decisions

The initial pricing strategies of companies 5 and 1 selected product prices based on costs and industry pricing while companies 2 and 3 started with a low-price, high-volume strategy. Company 4 began with a product differentiation strategy and thus, chose high prices. The expert system also selected high prices due to the initial high unit costs and industry average prices in the historical data. Table 7.5(a) reveals that during the first three quarters, the initial strategies of companies 2,3,4, and 5 did not influence the clustering, but company 1 and the expert system (company 6) were in the same cluster. Since the other companies had chosen different strategies, their initial decisions choices were dissimilar. During the business game playing companies 1,4, and 5 changed their strategies to the similar high-volume, market-oriented strategy adapted by companies 2 and 3 while the expert system continued with its original cost-oriented reactive strategy (see appendix 5 figure A5.9). As the operating decisions of these companies became more similar to each other, they appeared in same clusters. In the eleventh and twelfth quarters, the decisions of the competing companies separated into three clusters and the expert system appeared in the fourth cluster. By the end of the game, companies 2, 3, the most successful companies, made similar decisions, followed by 5 and 4 in another cluster. Company 1, the least successful company, and the expert system were in singleton clusters.

The overall cluster membership implied that some of the student teams exhibited more experiential learning than the expert system as they grouped together in two clusters and the expert system in another. During the overall game iteration, company 4 was in its own cluster for four quarters (thirty-three percent); companies 2 and 3, the "better" performing companies

clustered together six times (fifty-percent); companies 5 and 1, the least successful companies, appeared in the same cluster seven times (fifty-eight percent); and the expert system was alone for eight quarters (eighty-seven percent). These clustering patterns, that mainly evolved after the first year, indicated consistency in the decision choices of the competing companies as they determined their final strategy choices and were either in lone or grouped clusters. The fixed strategy of the expert system appeared to control its decisions from the initial quarter and continued throughout the game.

#### 7.2.2 Performance Outcome Measures

The cluster analysis for the performance criteria measurements, as displayed in Table 7.5(b), showed that three separate clusters were maintained across all the twelve business quarters with the exception of two clusters during quarters one, seven and eight. The expert system appeared in the same cluster with companies 2 and 3, the "better" performing companies for six quarters. As in the decision clustering, the performance changes occurred midway through the game possibly related to the pricing strategy changes of the human teams. In the last quarter, the better performing companies were in one cluster and the less successful companies in another along with the expert system. Again, this performance cluster membership seemed to be related to the similarity between the initial strategy choices of companies 1, 5 and the expert system. Even though companies 1, 4, and 5 changed their initial strategies to the similar strategy followed by companies 2 and 3, there was a delay in the resulting performance effect. At the end of the game, companies 1 and 5 clustered with expert system while the consistent strategies of companies 2 and 3, along with the changed company 4, resulted in the performances of these latter three being the most similar.

### 7.2.3 Combined Decisions and Performance Outcome Measures

The combined decision and performance outcomes data, as seen in table 7.5(c), represented the decisions prior to any quarter and the performance measures at the end of that quarter. The combined data clusters were more similar to the clusters of the performance measures than those of the operating decisions with the exception of quarters three, four and five. Overall, six of the twelve clusters in the performance outcomes were the same as those of the combined data. The first two quarters of both these cluster analyses displayed clustering changes. In addition, companies 1, 4, and 6 appeared in single clusters. There was congruence between the clustering of the performance measures outcomes and those of the combined data as both annexed the lone objects. As before, the last quarter of the combined data clusters included companies 2, 3, and 4 in one cluster and companies 1, 5, and 6 in another.

### 7.2.4 Conclusions of the Clustering Analysis

All the clusters that evolved in the three data sets developed some specific patterns as the management game progressed. The clustering of all three data sets, independent of the separation into specific cluster groups, displayed similarities during the twelve quarters. The combined data and the decisions were the same twice; the combined data matched the performance measures six times; and all three data sets were similar three times as seen in table 7.6.

Table 7.6 Comparative Clustering

| Quarter | Combined Data | Performance Measures | Decisions |
|---------|---------------|----------------------|-----------|
| 1       | 162354*       | 241634               | 621354*   |
| 2       | 452163*       | 245163*              | 542613*   |
| 3       | 152436*       | 245163*              | 516324    |
| 4       | 165234        | 451236               | 245163    |
| 5       | 152364*       | 125364*              | 512346*   |
| 6       | 254136*       | 256341               | 245163*   |
| 7       | 236154*       | 263154*              | 235146    |
| 8       | 236145*       | 154236*              | 145236*   |
| 9       | 235416        | 254361               | 241536    |
| 10      | 235416        | 243561               | 231456    |
| 11      | 235146*       | 235461*              | 123546    |
| 12      | 234156*       | 234156*              | 235461    |

\* similar clustering

The decisions clusters implied that the group decision teams, including the expert system, did "learn" from their own previously made decisions and thus consistently made the same decisions. How the companies that clustered together for decision making directly affected the isolated performance measures clusters was less obvious. Nevertheless, the decision data combined with the performance measure clusters followed a pattern that matched their performance improvements. Thus, the responses to "experiential learning improving the group performance" was partially answered by these analyses. The cluster analysis revealed that the expert system made decisions and exhibited performance measures that matched human teams. Therefore, the expert system succeeded in the competitive arena as a company with credible group decision making.

#### 7.2.5 Graphic Profiles

The graphs, shown in appendix 5, figures A5.11a and 5.11b, used the original distance measure data from the resemblance matrices for each quarter

of the business game as a way to illustrate the cluster membership profile for the decision variables and performance measures. The expert system is used as the base line and the distance of the other competing companies from the expert system is plotted for each quarter of the business game.

Figure A5.11a (see appendix 5) illustrated that for the first three quarters, group 1's decisions were closest to that of the expert system and subsequently became more distant. At the same time, the decisions of group 3, the better performing company, became closer to those of the expert system until the seventh quarter. From then on until the end of the game, the decisions of all the companies, including the expert system, changed relative to each other. At the last quarter, the decisions of companies 1 and 5 were close to each other and closest to those of the expert system, the decisions of companies 2 and 3 were similar, and the decisions of company 4 were the most unique and most distant from the expert system. After analyzing these results there seemed to be three possible explanations; 1) the decisions of the expert system did not change significantly while those of the competing companies did change, thus only the competition was exhibiting experiential learning, 2) the competition followed a market-oriented strategy and reacted to changes to secure their market share, while, the expert system followed a cost-oriented strategy and did not react to market changes, or 3) the expert system followed a cost-oriented strategy and was less affected by the competition behavior, then displayed some experiential "learning" when it clustered with other companies for the last four quarters.

The graph in appendix 5 figure A5.11b seemed to support explanations 2 and 3 above for the following reasons. The performance measures profile showed 1) during the business game simulation it takes time for the operating

decisions to affect performance outcomes due to a natural lag effect and the performance of the companies became more similar as the decisions reflected the strategy changes and 2) the conservative, cost-oriented strategy of the expert system, despite the apparent "learning" in the last four quarters was too late to change its performance to be similar to any of the other companies. The combined data profile (see appendix 5 figure A5.11c) displayed the least degree of fluctuations in the distance measures from that of the expert system. This profile suggested some degree of similarity between the behavior of the expert system and human decision makers. Finally, the game administrator of the "live" management game experiment evaluated the performance of the companies 3, 4, and 2 as the most successful in that order, companies 5 and 1 as the least successful followed by company 6 (the expert system) as an average performer. The last profile, figure A5.11d in appendix 5, compared the combined decisions and performance measures data of the best (company 3) and least successful (company 1) companies to the expert system. Over the twelve quarters, the profiles of the best company corresponded more closely to that of the expert system than the least successful company. This assessment, albeit subjective, suggests that the expert system exhibited success in mimicking the performance of an average human team.

### 7.3 Conclusions

The research and tests conducted in this dissertation have generated a large amount of information. A crucial point at this time is whether the research questions have been answered. As may be recalled from the introduction the task of the research was to provide some knowledge to answer the questions; how will the expert system react to a stochastically changing

environment of the management game? How will and to what extent will the expert system modify the decision rules? As the expert system simulates group decision making over time, will its decisions be affected by experiential learning? And lastly, how will the expert system perform relative to other live group decision makers in the same arena? If one takes into account the information presented in the previous chapters and accepts as plausible the case the author has made that the expert system has exhibited the ability to capture some elements of group decision making, the conclusions are:

1. The reactive fixed strategy of the expert system influenced its conservative decision making behavior. Nevertheless, the expert system exhibited meaningful and interrelated decisions as evidenced in the analysis of the different categories of performance measures earlier in this chapter.
2. The structure of the expert system shell, Expertease, that regularly uses past decisions as input to each set of current operating decisions influenced the expert system's reliance on past performances of the industry. As a result of this, and the inability to change the fixed strategy, in mid stream, the expert system was less likely to exhibit the decision making behavior of an entrepreneur and become a leading company in the industry. Nevertheless, the expert system was able to compete with modest success in the stochastically changing competitive environment as an "average" performing company in most areas that were important to the game administrators.
3. Since the expert system model was developed using an expert system shell, it followed a rule structure inherent in its inference system. As a result, it took longer and was more difficult for the expert system than human

decision makers to perform sudden modifications to their decision making behavior as a reaction to changes in the competitive market area.

4. The changes in the decision rule structure of the expert system, as more examples were added, displayed a pattern of improving performance for some measurement criteria and the reverse for others. Some of the human decision making teams exhibited the same type of performance; therefore, it is possible to assume that the expert system exhibited some minimal "learning" from past performances. The expert systems' "view" of the competition performance was the average performance of all competitors; therefore, the expert system did not "know" the behavior of each individual competing company. In comparison, the human teams were able to observe the approximate decisions and performance behavior of each individual company after each quarter as shown in their quarterly company reports (see appendix 1, table A1.2).

5. At the beginning of the business game simulation, the student teams were told an additional group from another similar class would be part of their industry and would compete with them. Nothing in the behavior of the expert system appears to have altered their original assumption that the absent team was not another student team.

In summary, there are some suggestions for further research. This initial model of an expert system revealed that with a richer set of features in an expert shell, allowing more flexibility in the rule structure, would improve the expert system's decision making performance. Likewise, the next developmental step might be one that would extend the decision making ability of an expert system to dynamically modify an initial strategy as a reaction to the competition and changes in the market place. Cluster analysis could be

used as a methodology to compare an expert system program to the performance of human experts and students to reveal whether or not the expert system performance is closer to that of experts or to student decision makers. The time frame of the business game could be arbitrarily determined and not known to the game players, thus the game playing strategy would not be influenced by the knowledge of a specific stopping point in the game. Lastly, from what has been examined, analyzed, and specifically discussed in Chapter 5 and 6, this thesis has shown that it is possible to simulate a particular kind of group decision making behavior within a competitive environment.

## APPENDIX 1

### Description of BUSPOG Management Game

Table A1.1 - Quarterly Decisions

The simulated competition of BUSPOG requires that the management team for each company make the following set of operating decisions once each quarter of a year. The particular decisions are:

#### Marketing

1. Selling price for each of the three markets.
2. Advertising budget for each of the three markets.
3. Salespersons hired or discharged in each of the three markets.
4. Product research and development budget for the company.
5. Sales commission for the company

#### Production

1. Scheduled production work week for the company.
2. Change in the production labor force for the company.
3. Allocation of finished product to the three markets.
4. Process research and development budget for the company.
5. Raw materials ordered for the company.
6. Plant investment budget for the company.

#### Personnel \*

1. Sales salaries for the company.
2. Sales training budget for the company.
3. Production wage rate for the company.
4. Production training budget for the company.
5. Profit sharing for the company.

#### Finance

1. Bonds sold or redeemed for the company.
2. Bank loan requested for the company.
3. Dividends paid by the company.
4. Stock issues by the company.
5. Long term savings account deposit or withdrawal for the company.

\* As our four person student teams had a President role, the decisions under Personnel were allocated between marketing, production, and finance as follows:

1. and 2. went to Marketing
3. and 4. went to Production
5. went to Finance

Table A1.2 - Company Quarterly Reports

COMPANY 6 INDUSTRY 1 YEAR 4 QUARTER 1 SECTION D-45 SEMESTER FA87

| 1. DECISIONS                     | MARKET 1 | MARKET 2 | MARKET 3 |       |
|----------------------------------|----------|----------|----------|-------|
| PRICE(\$/UNIT)                   | 288      | 288      | 285      |       |
| ADVERTISING (\$1000/QTR)         | 350      | 300      | 135      |       |
| SALES FORCE CHANGE (NO.)         | 3        | 0        | 5        |       |
| PRODUCT R&D (\$1000/QTR)         | 300      |          |          |       |
| SALES COMMISSION                 | 3.5      |          |          |       |
| PRODUCTION SCHEDULED (HRS/WK)    | 40       |          |          |       |
| LABOR FORCE CHANGE (NO)          | 0        |          |          |       |
| ALLOCATION TO MARKET (%)         | 35       | 34       | 31       |       |
| PROCESS R&D (\$1000/QTR)         | 300      |          |          |       |
| RAW MATERIALS ORDERED(1000LBS)   | 12400    |          |          |       |
| SALES SALARIES (\$/MONTH)        | 1025     |          |          |       |
| SALES TRAINING (\$1000/QTR)      | 30       |          |          |       |
| PRODUCTION TRAINING(\$1000/QTR)  | 100      |          |          |       |
| PRODUCTION WAGES (\$/HR)         | 4.20     |          |          |       |
| PROFIT SHARING (%)               | 2.5      |          |          |       |
| BONDS SOLD OR REDEEMED (\$1000)  | 0        |          |          |       |
| BANK LOAN REQUESTED (\$1000)     | 0        |          |          |       |
| DIVIDEND PAID (\$1000)           | 1300     |          |          |       |
| STOCK ISSUED(1000 SHARES)        | 0        |          |          |       |
| LONGTERM INVEST. (\$1000)        | 0        |          |          |       |
| PLANT INVESTMENT (\$1000)        | 1800     |          |          |       |
| 2. PRODUCTION AND SALES          | MARKET 1 | MARKET 2 | MARKET 3 | TOTAL |
| PRODUCTION WORKFORCE (NO)        | 1294     |          |          |       |
| PRODUCTIVITY(UNITS/MAN-HOUR)     | 0.0919   |          |          |       |
| RAW MATERIAL REQUIRED(LBS/UNIT)  | 123      |          |          |       |
| PRODUCTION OUTPUT (NO OF UNITS)  | 21636    |          |          |       |
| FIN PROD INVENTORY (NO UNITS)    | 21636    | 21018    | 19164    | 61818 |
| RAW MAT INVENTORY(END) (1000LBS) | 15532    |          |          |       |
| DEMAND (NO OF UNITS ORDERED)     | 17419    | 15201    | 12131    | 44751 |
| SALES (NO OF UNITS SOLD)         | 17419    | 15201    | 12131    | 44751 |
| SALES (\$1000)                   | 5017     | 4378     | 3457     | 12852 |
| SALESMEN ACTIVE (NO)             | 14       | 14       | 12       | 40    |
| SALES TRAINEES (NO)              | 3        | 0        | 5        | 8     |

Table A1.2 Continued

## 3. COSTS

| PRODUCTION (\$1000) |      | MARKETING (\$1000) |      | OTHER (\$1000)    |      |
|---------------------|------|--------------------|------|-------------------|------|
| LABOR               | 2826 | ADVERTISING        | 785  | R & D             | 600  |
| MATERIAL            | 2809 | SALARIES           | 148  | CARRY-FIN PROD    | 39   |
| MAINTENANCE         | 424  | COMMISSIONS        | 450  | CARRY-RAW MAT     | 32   |
| TRAINING            | 100  | TRANSPORTATION     | 396  | BOND INTEREST     | 156  |
| PROD LEVEL CHANGE   | 0    | ADMINISTRATIVE     | 288  | LOAN INTEREST     | 0    |
| EQUIPMENT           | 1800 | SALESFORCE CHANGE  | 41   | ADMINISTRATIVE    | 925  |
| ADMINISTRATIVE      | 164  | TRAINING           | 30   | BOND CALL PREMIUM | 0    |
| DEPRECIATION        | 1339 |                    |      | FORECASTING COST  | 0    |
| TOTAL               | 7662 |                    | 2137 |                   | 1752 |

## 4. FINANCIAL STATEMENTS (\$1000)

| INCOME STATEMENT    |       | FLOW OF FUNDS      |       | FINANCIAL POSITION |       |
|---------------------|-------|--------------------|-------|--------------------|-------|
| GROSS SALE REVENUE  | 12852 | ACCOUNTS COLLECTED | 14069 | CASH BALANCE       | 101   |
| BEGINNING INVENTORY | 1774  | BANK LOANS REQUEST | 0     | ACCOUNTS REC.      | 4284  |
| TOTAL PROD COST     | 7662  | BONDS SALE RETURN  | 0     | INV-FIN PROD       | 3733  |
| GOODS AVAILABLE     | 9435  | LT INVEST-INT&WITH | 35    | INV-RAW MAT        | 5865  |
| END INVENTORY       | 3733  | STOCK SALE RETURN  | 0     | LONGTERM INVEST    | 2000  |
| COST GOODS SOLD     | 5702  | BEGINNING CASH     | 1597  | TOT CURR ASSETS    | 15983 |
| GROSS PROFIT        | 7149  | READY CASH INV     | 6     |                    |       |
|                     |       | RETURN PLANT SALE  | 0     |                    |       |
|                     |       | TOTAL SOURCE       | 15707 | PLANT&EQUIP VALUE  | 54006 |
| TOTAL MARKET COST   | 2137  |                    |       | TOTAL ASSETS       | 69989 |
| PROFIT ON SALES     | 5013  | TOTAL PROD COST    | 8226  |                    |       |
|                     |       | TOTAL MARKET COST  | 2137  | BANK LOAN BAL      | 0     |
|                     |       | TOTAL OTHER COST   | 1752  |                    |       |
| TOTAL OTHER COST    | 1752  | DIVIDENDS PAID     | 0     | BONDS OUTSTAND     | 10400 |
| LT INVEST INCOME    | 35    | LOAN REPAYMENT     | 0     |                    |       |
| READY CASH ACCT     | 6     | BONDS REDEEMED     | 0     | CAPITAL STOCK VAL  | 36000 |
| NET PROFIT BEFR TAX | 3302  | INCOME TAXES       | 1651  | ACCUM RET EARNING  | 23589 |
|                     |       | PROFIT SHARE COST  | 41    | TOT STOCK EQUITY   | 59589 |
| INCOME TAXES        | 1651  | PLANT&EQUIP INVEST | 1800  | TOT LIABILITIES    | 69989 |
| PROFIT SHARE COST   | 41    | TOTAL DISBURSEMENT | 15607 |                    |       |
| NET INCOME          | 1610  |                    |       |                    |       |
| DIVIDENDS PAID      | 0     | CASH AVAILABLE     | 101   |                    |       |
| RETAINED EARNING    | 1610  | EMERG BANK LOAN    | 0     |                    |       |
|                     |       | CASH BAL ENDING    | 101   |                    |       |

Table A1.2 continued

## 5. ECONOMY AND STOCK MARKET

GROSS NATIONAL PRODUCT 1055(\$BILLIONS) PERSONAL CONSUMPTION EXP 90(\$BILLIONS)  
 NO HOUSEHOLD FORMATIONS 1504(1000,S) RAW MATERIALS COST .37(\$/LB)

| COMPANY            | STK PRICE | EARNGS | DIVIDS | SHARES | BOND INT | LOAN INT |
|--------------------|-----------|--------|--------|--------|----------|----------|
| ALASKA DEEP FREEZE | 9.74      | 0.27   | 0.21   | 6000   | 6.0      | 6.0      |
| INTERNTL COOLING   | 8.90      | 0.19   | 0.22   | 6000   | 7.2      | 7.2      |
| BREEZLY BRUIN      | 9.65      | 0.22   | 0.23   | 6000   | 6.0      | 6.0      |
| MR DEEP FREEZE     | 8.25      | 0.09   | 0.22   | 6000   | 6.9      | 6.9      |
| ICECON INC         | 9.26      | 0.18   | 0.27   | 6000   | 6.9      | 6.9      |
| EXPERTCORP         | 7.09      | 0.27   | 0.0    | 6000   | 6.0      | 6.0      |

## 6. INDUSTRY ESTIMATES

| COMPANY            | MARKET PRICES |     |     | AVERAGE<br>ADVERT | SALES<br>COMM | PROFIT<br>SHARE |
|--------------------|---------------|-----|-----|-------------------|---------------|-----------------|
|                    | 1             | 2   | 3   |                   |               |                 |
| ALASKA DEEP FREEZE | 279           | 280 | 268 | 213               | 3.3           | 2.3             |
| INTERNATL COOLING  | 257           | 273 | 254 | 254               | 3.6           | 2.5             |
| BREEZLY BRUIN      | 261           | 252 | 253 | 304               | 3.7           | 0.0             |
| MR DEEP FREEZE     | 256           | 262 | 254 | 325               | 3.5           | 2.3             |
| ICECON INC         | 291           | 293 | 287 | 263               | 3.1           | 2.5             |
| EXPERTCORP         | 284           | 293 | 287 | 263               | 3.4           | 2.5             |

| COMPANY            | SALES<br>SALARY | PROD<br>WAGES | PROD<br>WKFC | PROD<br>OUTPUT | SALES<br>FORCE | UNIT<br>SALES |
|--------------------|-----------------|---------------|--------------|----------------|----------------|---------------|
| ALASKA DEEP FREEZE | 1033            | 4.31          | 1514         | 71802          | 39             | 48780         |
| INTERNATL COOL     | 1107            | 4.08          | 1805         | 81935          | 40             | 50516         |
| BREEZLY BRUIN      | 1032            | 4.14          | 1202         | 58546          | 39             | 50516         |
| MR DEEP FREEZE     | 1321            | 5.03          | 1928         | 84799          | 41             | 52987         |
| ICECON INC         | 1209            | 4.31          | 2061         | 86124          | 40             | 45239         |
| EXPERTCORP         | 1030            | 4.26          | 1302         | 62843          | 40             | 44858         |

Table A1.3 - Stochastic Parameters

1. Manufacturing productivity
2. Raw material required per unit of finished product
3. Finished product demand
4. The number of salespersons who quit if their salary and/or profit sharing is less than the industry average
5. Values appearing in the industry estimates reports

1,2,3,5 use normal distributions and the standard deviation statistic can be changed by the game administrators.

4 uses a binomial distribution.

Table A1.4 - Student Roles

The student assuming the role of the Production Vice President (VP) is given the following description:

#### PRODUCTION VICE PRESIDENT

The role of the Production Vice President is, perhaps, the most important position one can hold in the firm. The duties of the Production VP touch on almost all parts of the firm, as well as set the foundation for many important decisions. Production itself is the transformation (through labor) of raw materials into a finished product. Since the existence of any manufacturing firm depends mainly on the products manufactured, the Production VP holds the success of the firm at his/her fingertips. The Production VP does not only deal with the materials needed to produce the product, he/she must also be concerned with the scheduling of the labor force that produces the product, distribution of the product to the three markets, and, finally, the research and development needed to advance the production and processing techniques of these firms. The Personnel Vice President role is eliminated and all the personnel responsibilities are separated into the production and marketing departments.

Table A1.4 continued

## FINANCIAL VICE PRESIDENT

The student role of the Financial Vice President is described in the student manual as follows:

Since the Financial Vice President oversees the sources and uses of funds, his function is critical to the liquidity of the firm. The Financial VP is not only responsible for the financial reporting of the company, it is also his duty to inform all other managers of the funds that are available for their use. The Financial manager must make sure that cash is available to meet all expenses resulting from decisions made by all departments. In addition to this, money must also be available to make interest payments, pay dividends to shareholders and any outstanding bank loans, and also pay income taxes. Having enough cash to meet all expenses is, as the Financial VP will soon realize, not an easy task. If the amount of cash needed by the firm is underestimated, the game automatically issues the firm an "emergency" bank loan to cover the expenses. If the amount of cash needed by the firm is overestimated, the firm will have excess cash lying around that could have been put to better use. So now the job of the Financial VP is clear; it is his/her responsibility to see that just the right amount of cash is available for the firm's use.

Table A1.4 continued

#### MARKETING VICE PRESIDENT

The last vice presidential role, that of marketing, is described in the following manner:

In any firm, the Marketing Department's main concern is the sale of the product. Marketing brings the finished product into the hands of the consumer using many different strategies. Some of the major aspects of the Marketing function include the advertising of the product, research and development of the product, the maintenance and training of a successful sales force, and most importantly the establishing of the product price. All of the above concerns are limited by the cash available to the Marketing Vice President and also restricted by the costs of the firm. For example, the Marketing Department should never set the price of the product at a level below what it costs to produce and sell it. The Marketing strategy is up to the individual firm. Some companies try for a low-cost price approach so as to bring their price lower than the rest of the industry, creating a high demand for their firm. On the other hand, some firms stick with a relatively high price and depend on advertising or research and development to bring in the customers. The above examples of Marketing strategies are only a few of the many different ways a firm can outsell its competitors. The decisions made by the Marketing VP are the means of executing the plan that your firm decides.

Table A1.4 continued

## PRESIDENT

The last role is that of the President of the firm who is the coordinator of the other three roles. This role does not have specific responsibilities, but must be filled by a student who shows leadership, can arbitrate disputes, quell destructive crises, or create constructive ones. The role is described in the following manner:

The President of any firm is the person upon whom most of the responsibilities fall. Unfortunately, the President is also the person that everyone blames if the operation of the firm does not run quite as smoothly as was expected. Why is this so? This question is answered by looking at the function of the President of the firm. The President is responsible for maintaining a "harmony" between all the departments of the firm. He/she supervises the actions and interactions of each segment of the company, and makes sure that all operations run as efficiently as possible. The President also must set the short term and long-term goals and objectives of the firm, and make sure that these goals are realistic and obtainable within the time period. Another important function of the President is to head the design of the strategies and policies of the corporation. What type of Marketing strategy should the firm follow for maximum exposure? What should the inventory policy be? How will debt be handled, and how much debt can the firm take on? All of these questions must be answered by the President. So you see, although the President is not directly responsible for any particular decisions on the decision sheet, he/she is actually responsible for all of the operating decisions. The President must be certain that all the decisions made by the students in the firm follow the plan and the policies of the firm.

He/she must always coordinate the decisions made by the Vice Presidents to ensure a smooth execution of the strategy that was laid out at the onset of the game.

## APPENDIX 2

### Expert System Model

Table A2.1 - Delphi Questionnaire

The answers that you provide to these questions will be used to form decision rules. These rules will then be programmed into an artificial intelligence software package.

Based on your experience, please list what main factors (variables) influence the following decisions that a person would make when playing the Management Game:

1. Pricing Decision
2. Advertising Budget
3. Product Research and Development Budget
4. Process Research and Development Budget
5. Sales Force Size
6. Sales Salary
7. Sales Training Budget
8. Sales Commission
9. Labor Force Size
10. Labor Force Salary (wage rate)
11. Production Training Budget
12. Profit Sharing Percentage
13. Number of Hours Worked per week
14. Allocation of Finished Products to the three Markets
15. Amount of Raw Materials Purchased
16. Plant and Equipment Investment
17. Amount of Dividends to Distribute
18. Decision to Sell or Redeem Bonds
19. Long-Term Investment/Withdrawal Decision
20. Stock Issue
21. What factors (variables) have an effect on demand?
22. What factors (variables) determine stock prices?
23. What factors (variables) effect Manufacturing productivity?

Table A2.2 - Variable Relationships

|                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PRICING DECISION [affected by]<br>unit cost<br>unit demand forecast<br>company price<br>industry ave price                                                                                                                                                                                               | SALES COMMISSION [affected by]<br>company sales commission<br>industry ave sales commission<br>company unit sales<br>industry ave unit sales<br>company sales salary<br>industry ave sales salary<br>company advertising budget<br>industry ave advertising budget |
| ADVERTISING BUDGET [affected by]<br>company ad budget<br>industry ave ad budget<br>company unit sales<br>industry ave unit sales<br>company sales commission<br>industry ave sales commission<br>company sales salary<br>industry ave sales salary                                                       | PROCESS R&D BUDGET [affected by]<br>company process R&D budget<br>raw material requirements<br>productivity<br>company unit sales/company workforce<br>industry ave unit sales/industry<br>ave workforce                                                           |
| PRODUCT R&D BUDGET [affected by]<br>company product R&D<br>company unit sales<br>industry ave unit sales/<br>industry ave unit price<br>company unit sales/<br>company unit price                                                                                                                        | LABOR FORCE SIZE = desired production<br>output next qtr/(productivity*40*13)<br>numerator = unit demand forecast +<br>desired finished good inventory -<br>current finished goods inventory<br>desired finished goods inventory =<br>25% of unit demand forecast  |
| SALES FORCE SIZE [affected by]<br>company unit sales<br>finished product inventory<br>unit demand<br>unit demand forecast<br>company sales force size<br>industry ave sales force size<br>company sales salary<br>industry ave sales salary<br>company sales commission<br>industry ave sales commission | PRODUCTION WAGE RATE [affected by]<br>company wage rate<br>industry ave wage rate<br>company prod training budget<br>company efficiency**<br>industry ave efficiency**<br>company workforce size<br>productivity                                                   |
| SALES SALARY [affected by]<br>company sales salary<br>industry ave sales salary<br>company sales commission<br>industry ave sales commission<br>company advertising budget<br>industry ave advertising budget<br>company unit sales<br>industry ave unit sales                                           | PRODUCTION TRAINING BUDGET[affected by]<br>raw materials requirements<br>company training budget<br>productivity<br>company efficiency**<br>industry ave efficiency**                                                                                              |
| SALES TRAINING BUDGET[affected by]<br>company training budget<br>company sales per salesperson**<br>industry sales per salesperson**                                                                                                                                                                     | RAW MATERIALS ORDERED = (1.25 *planned<br>production output*raw material<br>requirements per unit)-current raw<br>materials inventory                                                                                                                              |
|                                                                                                                                                                                                                                                                                                          | ALLOCATION OF FINISHED GOODS TO<br>THE THREE MARKETS = (unit demand<br>forecast for each market+1.25-finished<br>product inventory)/total planned<br>production                                                                                                    |

\*\* ratio

Table A2.2 continued

|                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>NUMBER OF HOURS WORK PER WEEK</b><br>[affected by]<br>company production**<br>industry ave production workforce<br>company production output<br>industry ave production output<br>productivity | <b>DIVIDENDS PAID [affected by]</b><br>cash balance<br>net income<br>company stock price<br>industry average dividends paid                                                                                                                                                                                                                             |
| <b>PLANT AND EQUIPMENT INVESTMENT</b><br>[affected by]<br>production laborforce size<br>productivity<br>company depreciation<br>production efficiency                                             | <b>BONDS SOLD OR REDEEMED [affected by]</b><br>cash balance<br>bonds outstanding<br>bond interest rate<br>debt/equity ratio                                                                                                                                                                                                                             |
| <b>PROFIT SHARING PERCENTAGE</b><br>[affected by]<br>industry ave profit sharing<br>company gross profit                                                                                          | <b>LONG-TERM INVESTMENT/WITHDRAWAL</b><br>[affected by]<br>cash balance<br>bonds outstanding<br>company bonds sold or redeemed<br>bank loans requested<br>company stock issued<br>company dividends paid                                                                                                                                                |
| <b>STOCK ISSUED [affected by]</b><br>cash balance<br>bonds outstanding<br>bonds sold or redeemed<br>debt/equity ratio                                                                             | <b>VARIABLES AFFECTING DEMAND</b><br>production price<br>advertising budget<br>salesforce size<br>product R&D<br>sales commission<br>sales salary<br>sales training budget<br>profit sharing percentage<br>personal consumption of durables<br>gross national product (GNP)<br>household formations<br>seasonal index<br>previous quarter company sales |
| <b>VARIABLES AFFECTING STOCK PRICE</b><br>earnings per share<br>dividends per share<br>dividends paid<br>process R&D<br>bank loans<br>company product price                                       |                                                                                                                                                                                                                                                                                                                                                         |
| <b>VARIABLES AFFECTING MANUFACTURING PRODUCTIVITY</b><br>workforce training budget<br>process R&D<br>plant and equipment/workforce                                                                |                                                                                                                                                                                                                                                                                                                                                         |

Table A2.3 - Student Questionnaire

Please answer the following questions on this sheet.

1. How many members in your BUSPOG team?
2. What was your initial pricing strategy?
3. Did your team consider the competition when making your operating decisions?
4. If, you had an initial strategy, did you stay with the strategy or change to another?
5. Did you attempt to understand or consider the strategy of the competing companies?
6. Did you think there was anything unusual about the performance of the competing companies? If so, identify the company by name or names.

# APPENDIX 3

## Expertease Decision Examples

Table A3.1 - Expertease Knowledge Base for Product Pricing Decision

### EXPERT-EASE Example Listing: PRODUCT PRICE FOR CONSUMER MARKET 1

| DATA LIST | COMPANY PRICE | UNIT COST | INDUSTRY AVE PRICE | FORECAST UNIT DEMAND | PRODUCT PRICE |
|-----------|---------------|-----------|--------------------|----------------------|---------------|
| 1         | 295           | 217       | 292                | 1616                 | \$295         |
| 2         | 295           | 228       | 292                | 2031                 | 290           |
| 3         | 290           | 212       | 288                | 2344                 | 290           |
| 4         | 290           | 209       | 288                | 2212                 | 290           |
| 5         | 290           | 198       | 288                | 2073                 | 295           |
| 6         | 295           | 220       | 277                | 2239                 | 295           |
| 7         | 290           | 207       | 279                | 2176                 | 285           |
| 8         | 265           | 206       | 283                | 2025                 | 260           |
| 9         | 287           | 209       | 281                | 2388                 | 275           |
| 10        | 279           | 202       | 280                | 1995                 | 279           |
| 11        | 255           | 199       | 284                | 2238                 | 255           |
| 12        | 275           | 207       | 282                | 1995                 | 270           |
| 13        | 300           | 272       | 298                | 1607                 | 300           |
| 14        | 300           | 251       | 298                | 1808                 | 300           |
| 15        | 300           | 245       | 298                | 1672                 | 298           |
| 16        | 298           | 250       | 295                | 1375                 | 298           |
| 17        | 298           | 259       | 295                | 1695                 | 298           |
| 18        | 298           | 247       | 295                | 1919                 | 298           |
| 19        | 298           | 238       | 295                | 1777                 | 298           |
| 20        | 298           | 236       | 295                | 1472                 | 295           |
| 21        | 295           | 245       | 293                | 1830                 | 295           |
| 22        | 295           | 232       | 292                | 2087                 | 295           |
| 23        | 295           | 220       | 292                | 1948                 | 295           |

## EXPERT-EASE Rule Listing, Problem: PRODUCT PRICE FOR CONSUMER MARKET 1

## COMPANY PRICE

```

<289:    COMPANY PRICE
          <270:    COMPANY PRICE
              <260 :$255
              >=260:$260

          >=270:    COMPANY PRICE
              <277: $270
              >=277:    COMPANY PRICE
                              <283: $279
                              >=283:$275

>=289:    COMPANY PRICE
          <297:    UNIT COST
              <208:UNIT COST
                              <203:  $295
                              >=203: $285

              >=208: COMPANY PRICE
                  <293: $290
                  >=293:  UNIT COST
                              <224:  $295
                              >=224:    UNIT COST
                                      <230:  $290
                                      >=230: $295

          >=297:    UNIT COST
              <237:  $295

              >=237: COMPANY PRICE
                  <299:  $298
                  >=299    UNIT COST
                              <248:  $298
                              >=248: $300

```

Figure A3.1 Rule Set for Quarter 2 Pricing Decision

Table A3.2 Expertease Knowledge Base with Additional Examples

EXPERT-EASE Example Listing: PRODUCT PRICE FOR CONSUMER MARKET 1

| DATA LIST | COMPANY PRICE | UNIT COST | INDUSTRY AVE PRICE | FORECAST UNIT DEMAND | PRODUCT PRICE |
|-----------|---------------|-----------|--------------------|----------------------|---------------|
| 1         | 295           | 217       | 292                | 1616                 | \$295         |
| 2         | 295           | 228       | 292                | 2031                 | 290           |
| 3         | 290           | 212       | 288                | 2344                 | 290           |
| 4         | 290           | 209       | 288                | 2212                 | 290           |
| 5         | 290           | 198       | 288                | 2073                 | 295           |
| 6         | 295           | 220       | 277                | 2239                 | 295           |
| 7         | 290           | 207       | 279                | 2176                 | 285           |
| 8         | 265           | 206       | 283                | 2025                 | 260           |
| 9         | 287           | 209       | 281                | 2388                 | 275           |
| 10        | 279           | 202       | 280                | 1995                 | 279           |
| 11        | 255           | 199       | 284                | 2238                 | 255           |
| 12        | 275           | 207       | 282                | 1995                 | 270           |
| 13        | 300           | 272       | 298                | 1607                 | 300           |
| 14        | 300           | 251       | 298                | 1808                 | 300           |
| 15        | 300           | 245       | 298                | 1672                 | 298           |
| 16        | 298           | 250       | 295                | 1375                 | 298           |
| 17        | 298           | 259       | 295                | 1695                 | 298           |
| 18        | 298           | 247       | 295                | 1919                 | 298           |
| 19        | 298           | 238       | 295                | 1777                 | 298           |
| 20        | 298           | 236       | 295                | 1472                 | 295           |
| 21        | 295           | 245       | 293                | 1830                 | 295           |
| 22        | 295           | 232       | 292                | 2087                 | 295           |
| 23        | 295           | 220       | 292                | 1948                 | 295           |
| 24        | 295           | 203       | 260                | 2001                 | 295           |
| 25        | 285           | 197       | 268                | 2091                 | 296           |
| 26        | 260           | 195       | 272                | 2674                 | 260           |
| 27        | 275           | 197       | 270                | 2236                 | 245           |
| 28        | 279           | 184       | 270                | 2107                 | 275           |
| 29        | 255           | 183       | 273                | 2871                 | 255           |
| 30        | 270           | 192       | 271                | 2552                 | 265           |
| 31        | 295           | 195       | 259                | 2188                 | 295           |
| 32        | 265           | 194       | 264                | 2171                 | 232           |
| 33        | 250           | 186       | 264                | 3259                 | 260           |
| 34        | 245           | 175       | 267                | 2962                 | 245           |
| 35        | 275           | 173       | 263                | 2165                 | 269           |
| 36        | 255           | 174       | 265                | 3631                 | 255           |
| 37        | 265           | 188       | 263                | 2572                 | 265           |

## EXPERT-EASE Rule Listing, Problem:PRODUCT PRICE FOR CONSUMER MARKET 1

```

COMPANY PRICE
  <289:
    COMPANY PRICE
      <268:
        COMPANY PRICE
          <258: COMPANY PRICE
            <250: $245
            >=250: $255
          >=258: IND AVE PRICE
            <264: $265
            >=264: COMPANY PRICE
              <263: $260
              >=263: UNIT COST
                <200: $232
                >=200: $260
          >=268: FORECAST DEMAND
            <2043: COMPANY PRICE
              <277: $270
              >=277: $279
            >=2043: COMPANY PRICE
              <277: COMPANY PRICE
                <273: $265
                >=273: UNIT COST
                  <185: $269
                  >=185: $245
              >=277: IND AVE PRICE
                <269: $265
                >=269: $275
          >=289: COMPANY PRICE
            <297: COMPANY PRICE
              <293: UNIT COST
                <208: UNIT COST
                  <203: $295
                  >=203: $285
                >=208: $290
              >=293: UNIT COST
                <224: $295
                >=224: UNIT COST
                  <230: $290
                  >=230: $295
            >=297: UNIT COST
              <237: $295
              >=237: COMPANY PRICE
                <290: $298
                >=290: UNIT COST
                  <248: $298
                  >=248: $300

```

Figure A3.2 Rule Set with Additional Examples for Quarter 4

Table A3.3 Expertease Knowledge Base for Process R&amp;D Decision

EXPERT-EASE Example listing: PROCESS RESEARCH AND DEVELOPMENT BUDGET

| DATA<br>LIST | COMPANY<br>BUDGET | RAW MATERIAL<br>REQUIREMENTS | COMPANY<br>SALES/<br>COMPANY<br>WORKFCE<br>(RATIOC) | INDUSTRY<br>AVE SALE/<br>INDUSTRY<br>WORKFCE<br>(RATIOD) | PRODUCTIVITY | PROCESS<br>R&D<br>BUDGET |
|--------------|-------------------|------------------------------|-----------------------------------------------------|----------------------------------------------------------|--------------|--------------------------|
| 1            | 210               | 160                          | 38                                                  | 38                                                       | .0760        | \$210                    |
| 2            | 210               | 155                          | 40                                                  | 40                                                       | .0780        | 215                      |
| 3            | 215               | 150                          | 42                                                  | 42                                                       | .0800        | 215                      |
| 4            | 215               | 145                          | 43                                                  | 43                                                       | .0830        | 215                      |
| 5            | 225               | 140                          | 44                                                  | 44                                                       | .0850        | 300                      |
| 6            | 300               | 128                          | 33                                                  | 40                                                       | .0910        | 305                      |
| 7            | 255               | 129                          | 39                                                  | 39                                                       | .0890        | 255                      |
| 8            | 400               | 136                          | 38                                                  | 39                                                       | .0910        | 500                      |
| 9            | 275               | 131                          | 41                                                  | 38                                                       | .0880        | 290                      |
| 10           | 250               | 136                          | 41                                                  | 38                                                       | .0930        | 260                      |
| 11           | 300               | 130                          | 42                                                  | 38                                                       | .0910        | 300                      |
| 12           | 226               | 138                          | 40                                                  | 39                                                       | .0850        | 260                      |
| 13           | 190               | 205                          | 33                                                  | 33                                                       | .0600        | 190                      |
| 14           | 190               | 204                          | 33                                                  | 33                                                       | .0600        | 192                      |
| 15           | 192               | 202                          | 31                                                  | 31                                                       | .0610        | 195                      |
| 16           | 195               | 200                          | 33                                                  | 33                                                       | .0610        | 195                      |
| 17           | 195               | 197                          | 34                                                  | 34                                                       | .0620        | 195                      |
| 18           | 195               | 193                          | 34                                                  | 34                                                       | .0630        | 200                      |
| 19           | 200               | 189                          | 33                                                  | 33                                                       | .0650        | 200                      |
| 20           | 200               | 184                          | 36                                                  | 36                                                       | .0660        | 200                      |
| 21           | 200               | 179                          | 35                                                  | 35                                                       | .0680        | 200                      |
| 22           | 200               | 173                          | 37                                                  | 37                                                       | .0700        | 200                      |
| 23           | 200               | 166                          | 39                                                  | 39                                                       | .0730        | 210                      |

## EXPERT-EASE Rule Listing : PROCESS RESEARCH AND DEVELOPMENT BUDGET

## RATIOC

```

<38:      RAW MATERIAL
          <195:    COMPANY BUDGET
              <250:  $200
              >=250: $305

          >=195:    COMPANY BUDGET
              <191:  RAW MATERIAL
                  <205:  $192
                  >=205: $190
              >=191:  $195

>=38:      COMPANY BUDGET
          <220:    RAW MATERIAL
              <158:  $215
              >=158: $210

          >=220:    RATIOC
              <40:    COMPANY BUDGET
                  <328:  $255
                  >=328: $500
              >=40:    RATIOC
                  <42:      COMPANY BUDGET
                      <263:  $260
                      >=263: $290
                  >=42:  $300

```

Figure A3.3 Rule Set for Process Research and Development Budget for Quarter 2

Table A3.4 - Expertease Knowledge Base with Additional Examples

EXPERT-EASE Example listing: PROCESS RESEARCH AND DEVELOPMENT BUDGET

| DATA<br>LIST | COMPANY<br>BUDGET | RAW MATERIAL<br>REQUIREMENTS | COMPANY<br>SALES/<br>COMPANY<br>WORKFCE<br>(RATIOC) | INDUSTRY<br>AVE SALE/<br>INDUSTRY<br>WORKFCE<br>(RATIOD) | PRODUCTIVITY | PROCESS<br>R&D<br>BUDGET |
|--------------|-------------------|------------------------------|-----------------------------------------------------|----------------------------------------------------------|--------------|--------------------------|
| 1            | 210               | 160                          | 38                                                  | 38                                                       | .0760        | \$210                    |
| 2            | 210               | 155                          | 40                                                  | 40                                                       | .0780        | 215                      |
| 3            | 215               | 150                          | 42                                                  | 42                                                       | .0800        | 215                      |
| 4            | 215               | 145                          | 43                                                  | 43                                                       | .0830        | 215                      |
| 5            | 225               | 140                          | 44                                                  | 44                                                       | .0850        | 300                      |
| 6            | 300               | 128                          | 33                                                  | 40                                                       | .0910        | 305                      |
| 7            | 255               | 129                          | 39                                                  | 39                                                       | .0890        | 255                      |
| 8            | 400               | 136                          | 38                                                  | 39                                                       | .0910        | 500                      |
| 9            | 275               | 131                          | 41                                                  | 38                                                       | .0880        | 290                      |
| 10           | 250               | 136                          | 41                                                  | 38                                                       | .0930        | 260                      |
| 11           | 300               | 130                          | 42                                                  | 38                                                       | .0910        | 300                      |
| 12           | 226               | 138                          | 40                                                  | 39                                                       | .0850        | 260                      |
| 13           | 190               | 205                          | 33                                                  | 33                                                       | .0600        | 190                      |
| 14           | 190               | 204                          | 33                                                  | 33                                                       | .0600        | 192                      |
| 15           | 192               | 202                          | 31                                                  | 31                                                       | .0610        | 195                      |
| 16           | 195               | 200                          | 33                                                  | 33                                                       | .0610        | 195                      |
| 17           | 195               | 197                          | 34                                                  | 34                                                       | .0620        | 195                      |
| 18           | 195               | 193                          | 34                                                  | 34                                                       | .0630        | 200                      |
| 19           | 200               | 189                          | 33                                                  | 33                                                       | .0650        | 200                      |
| 20           | 200               | 184                          | 36                                                  | 36                                                       | .0660        | 200                      |
| 21           | 200               | 179                          | 35                                                  | 35                                                       | .0680        | 200                      |
| 22           | 200               | 173                          | 37                                                  | 37                                                       | .0700        | 200                      |
| 23           | 200               | 166                          | 39                                                  | 39                                                       | .0730        | 210                      |
| 24           | 305               | 120                          | 37                                                  | 47                                                       | .0981        | 325                      |
| 25           | 255               | 127                          | 45                                                  | 46                                                       | .0904        | 265                      |
| 26           | 500               | 124                          | 52                                                  | 44                                                       | .1001        | 900                      |
| 27           | 290               | 120                          | 42                                                  | 47                                                       | .0953        | 295                      |
| 28           | 260               | 128                          | 47                                                  | 45                                                       | .1026        | 265                      |
| 29           | 300               | 126                          | 55                                                  | 44                                                       | .0909        | 350                      |
| 30           | 260               | 128                          | 45                                                  | 46                                                       | .0869        | 360                      |
| 31           | 325               | 113                          | 39                                                  | 54                                                       | .1059        | 500                      |
| 32           | 265               | 119                          | 48                                                  | 53                                                       | .0977        | 265                      |
| 33           | 900               | 114                          | 59                                                  | 50                                                       | .1102        | 1300                     |
| 34           | 295               | 113                          | 57                                                  | 51                                                       | .1011        | 310                      |
| 35           | 265               | 120                          | 59                                                  | 50                                                       | .1087        | 300                      |
| 36           | 350               | 120                          | 59                                                  | 50                                                       | .0985        | 350                      |
| 37           | 360               | 117                          | 45                                                  | 53                                                       | .0929        | 460                      |

## EXPERT-EASE Rule Listing: PROCESS RESEARCH AND DEVELOPMENT BUDGET

## RATIOC

```

<40:      RAW MATERIAL
          <170:    COMPANY BUDGET
                <278:  COMPANY BUDGET
                    <233:  $210
                    >=233: $255
                >=278: COMPANY BUDGET
                    <315:    COMPANY BUDGET
                        <303:  $305
                        >=303: $325
          >=170:    RAW MATERIAL
                <195:  COMPANY BUDGET
                    <191:    RAW MATERIAL
                        <205:  $192
                        >=205: $190
>=40:      COMPANY BUDGET
          <270:    RATIOC
                <44:    COMPANY BUDGET
                    <221:  $215
                    >=221: $260
                >=44:    PRODUCTIVITY
                    <.0877:    COMPANY BUDGET
                        <243:  $300
                        >=243: $360
                >=.0877:    RATIOC
                    <54:    $265
                    >=54:    $300
          >=270:    RATIOC
                <49:    COMPANY BUDGET
                    <295: COMPANY BUDGET
                        <283:  $290
                        >=283: $295
                    >=295: COMPANY BUDGET
                        <330:  $300
                        >=330: $460
                <49:    COMPANY BUDGET
                    <425:    COMPANY BUDGET
                        <298:  $310
                        >=298: $350
                    >=425:    COMPANY BUDGET
                        <700:  $900
                        >=700: $1300

```

Figure A3.4 Rule Set with Additional Example Decisions for Quarter 4

### GAME 1 CONSUMER MARKET PRICE

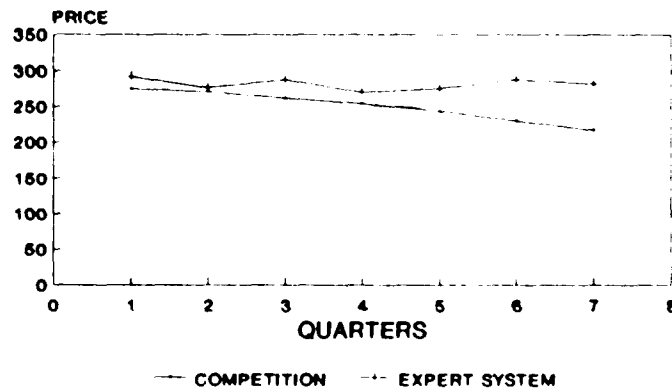


Figure A4.5a

### GAME 1 INDUSTRIAL MARKET PRICE

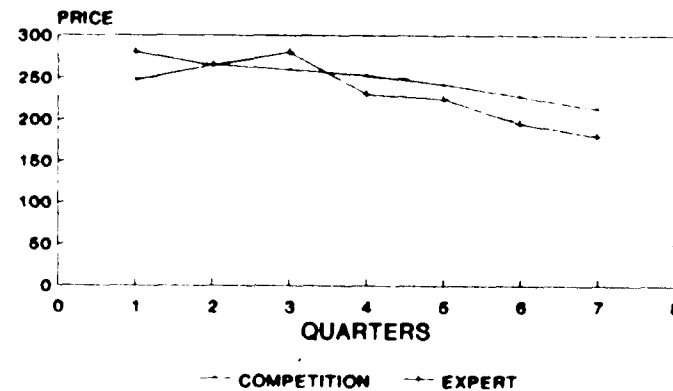


Figure A4.5b

### GAME 1 CONSUMER MARKET PERCENT SHARE

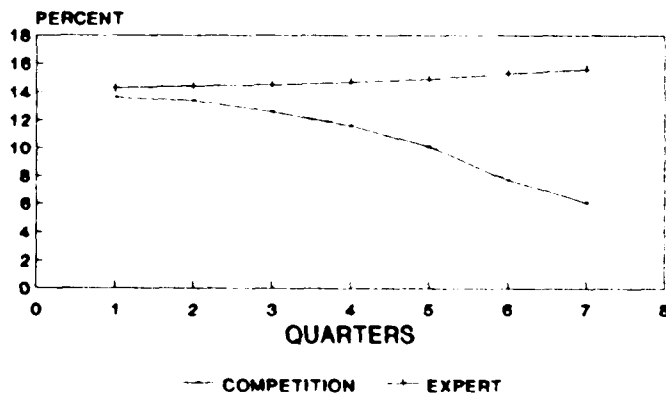


Figure A4.5c

### GAME 1 INDUSTRIAL MARKET PERCENT SHARE

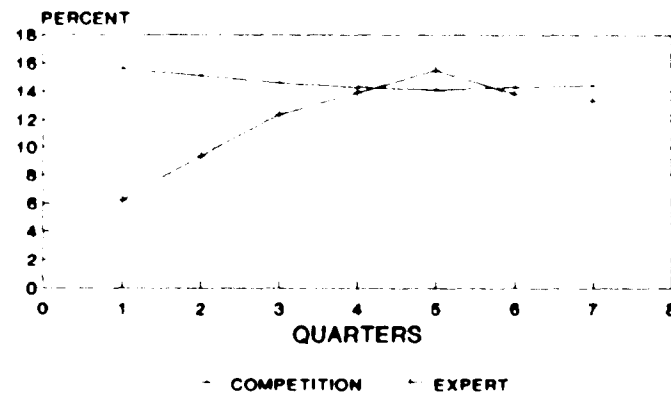


Figure A4.5d

### GAME 1 PROCESS R&D BUDGET

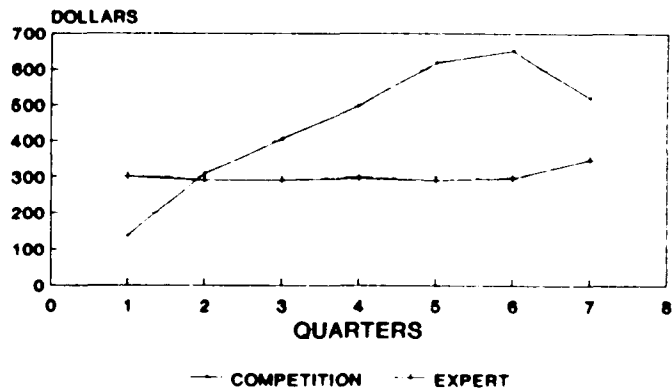


Figure A4.6b

### GAME 1 PRODUCTIVITY

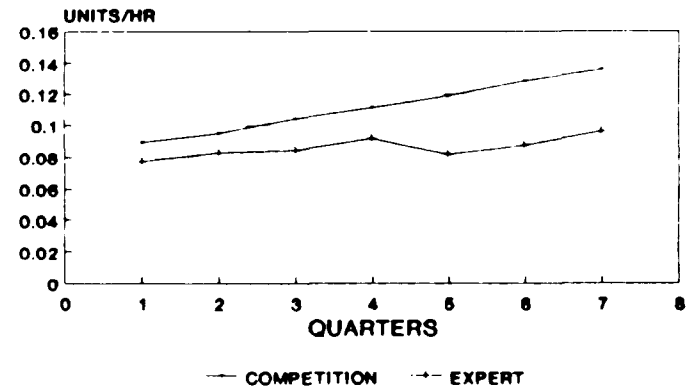


Figure A4.6a

### GAME 1 RAW MATERIAL REQUIREMENTS

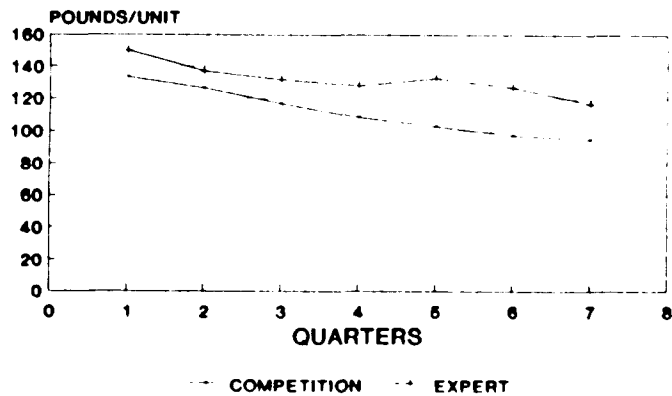


Figure A4.6d

### GAME 1 PRODUCTION WAGE RATE

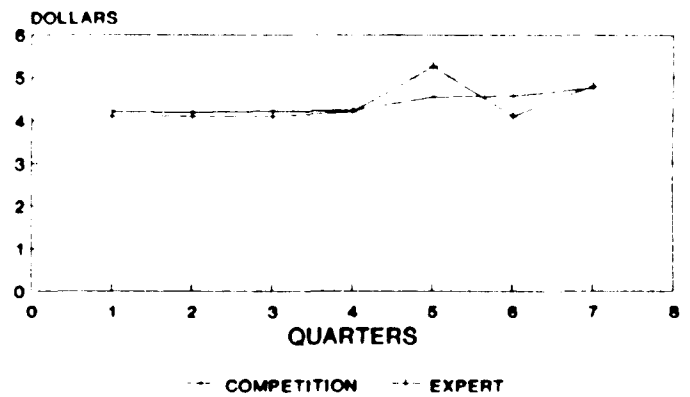


Figure A4.6c

### GAME 1 NET INCOME

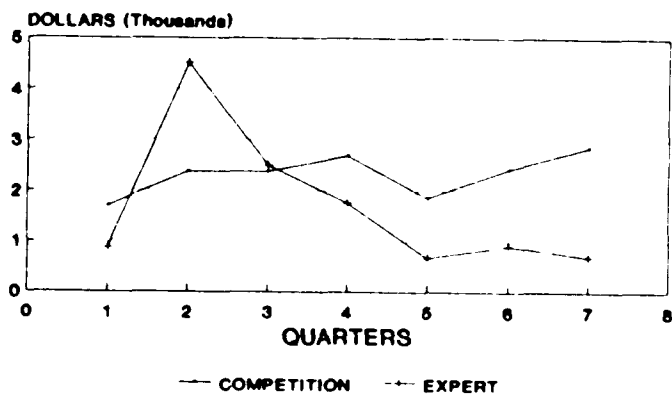


Figure A4.7a

### GAME 1 P/E RATIO

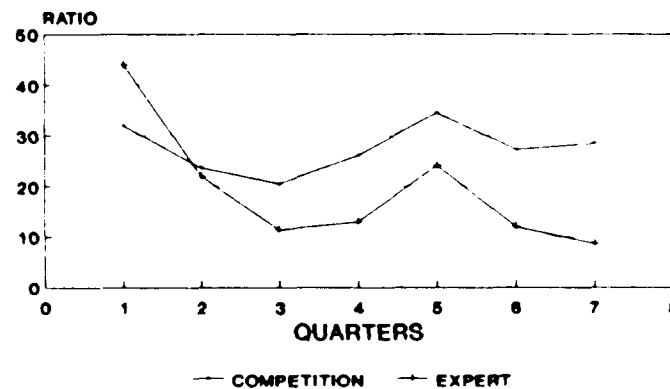


Figure A4.7b

### GAME 1 PROFIT ON SALES

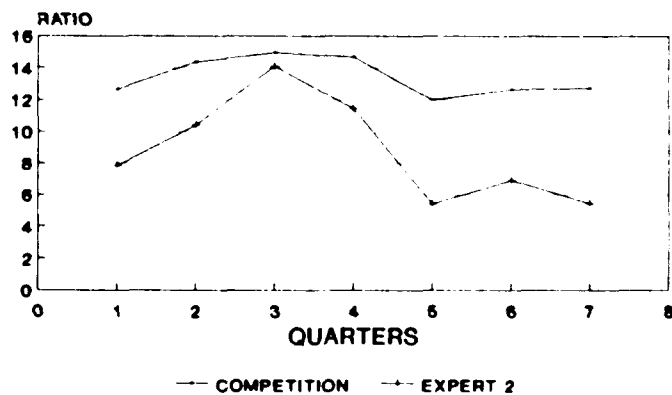


Figure A4.7d

### GAME 1 DIVIDENDS PAID

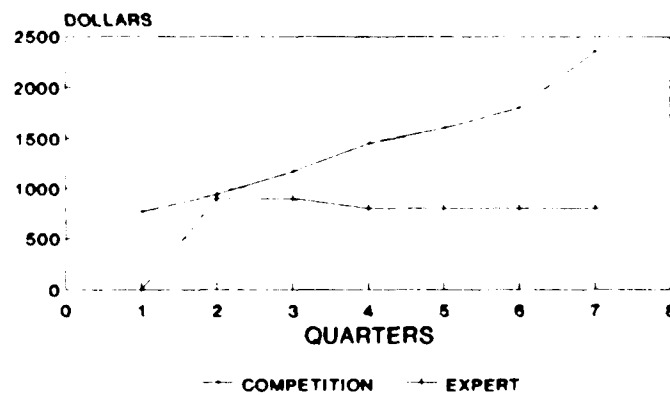


Figure A4.7c

### GAME 2 CONSUMER MARKET PRICE

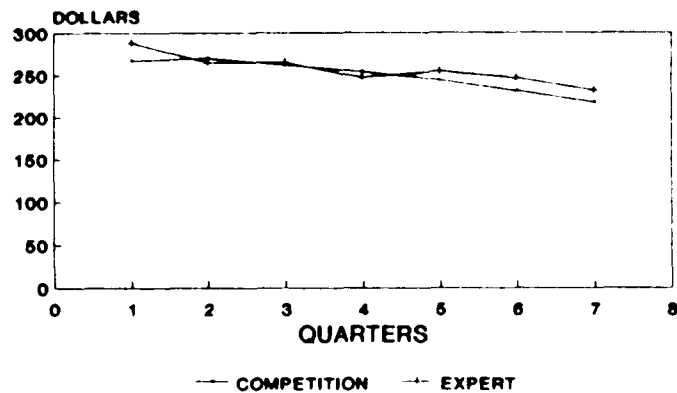


Figure A4.8a

### GAME 2 INDUSTRIAL MARKET PRICE

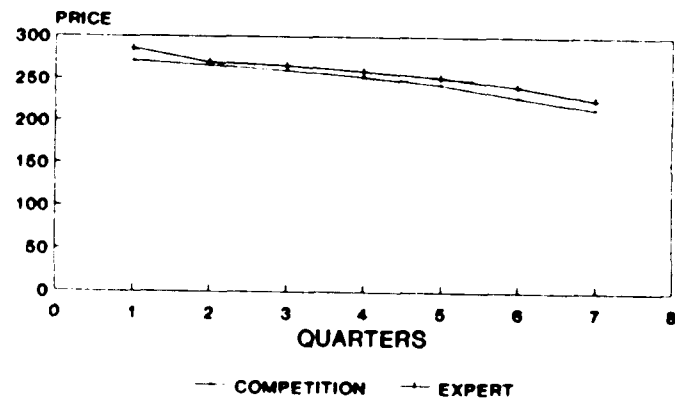


Figure A4.8b

### GAME 2 CONSUMER MARKET PERCENT SHARE

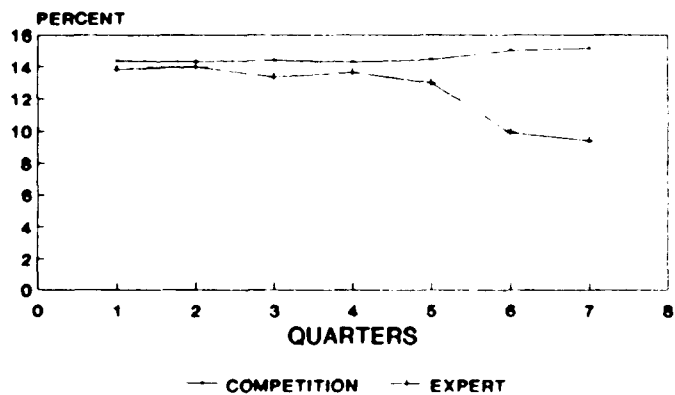


Figure A4.8c

### GAME 2 INDUSTRIAL MARKET PERCENT SHARE

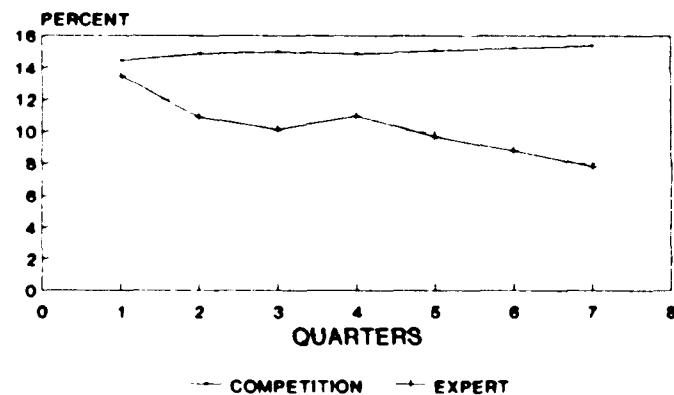


Figure A4.8d

### GAME 2 RAW MATERIALS INVENTORY/ TOTAL PRODUCTION

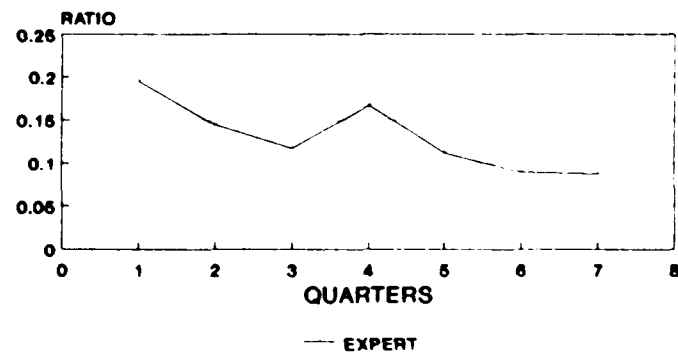


Figure A4.9a

### GAME 2 PRODUCTION WORKFORCE

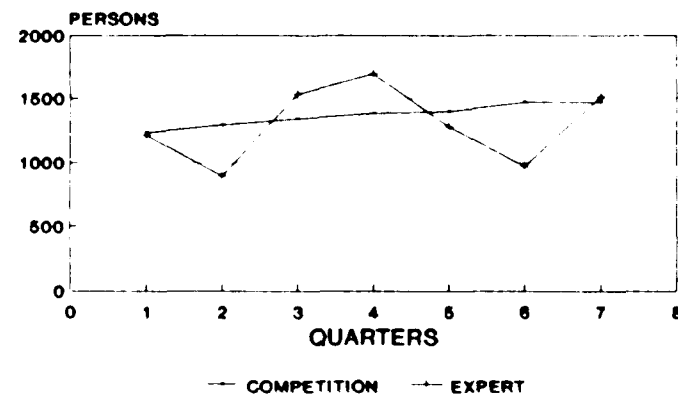


Figure A4.9b

### GAME 2 PLANT AND EQUIPMENT VALUE/ TOTAL SALES

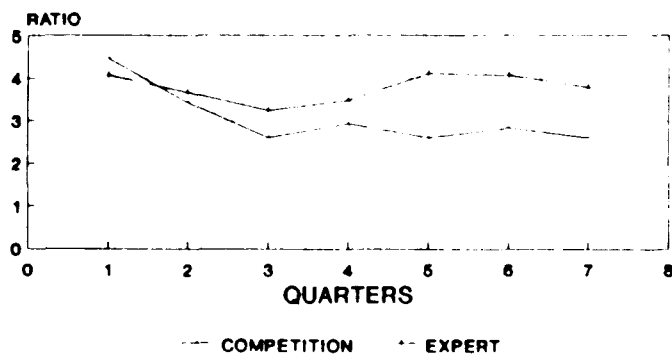


Figure A4.9c

### GAME 2 PRODUCTIVITY

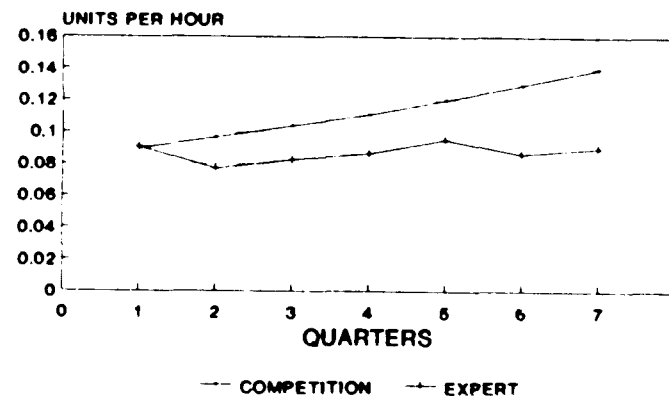


Figure A4.9d

## GAME 2 NET INCOME

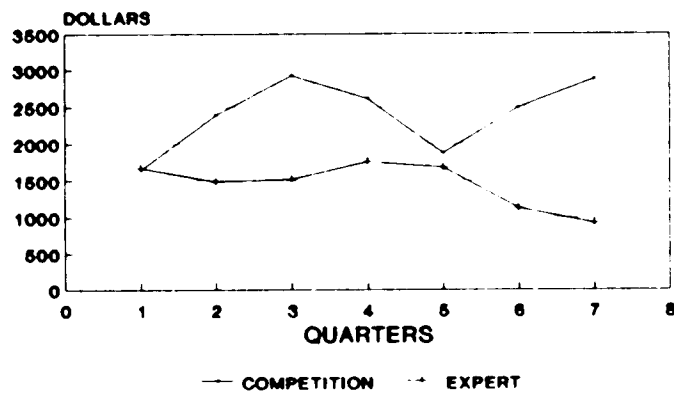


Figure A4.10a

## GAME 2 P/E RATIO

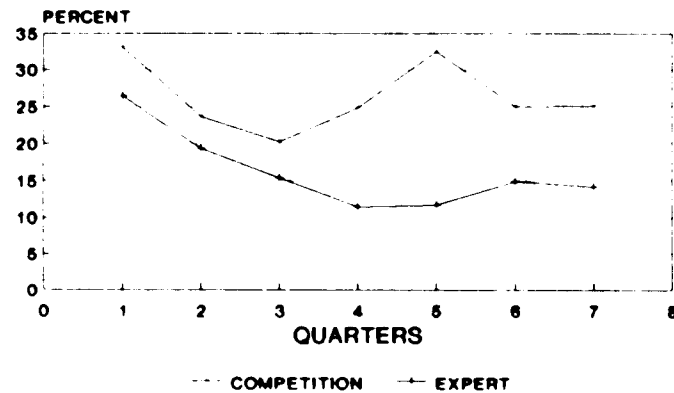


Figure A4.10b

## GAME 2 PROFIT ON SALES

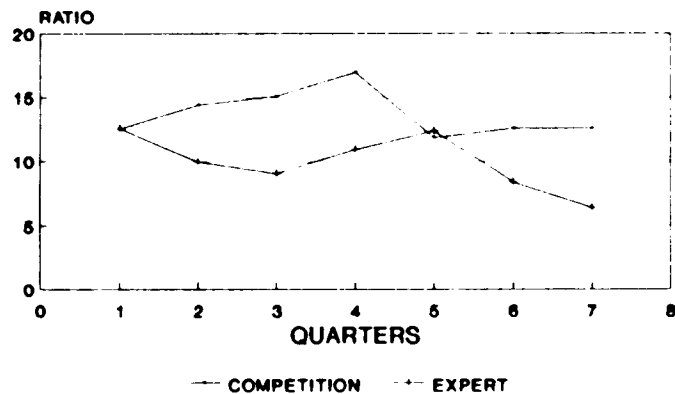


Figure A4.10c

## GAME 2 DIVIDENDS PAID

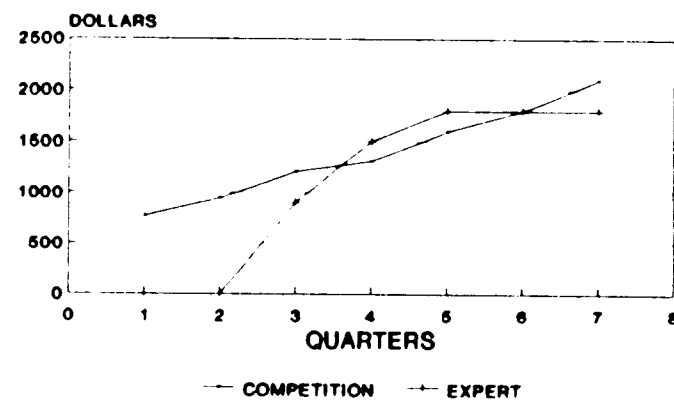


Figure A4.10d

### ORIGINAL GAME COMPARISON CONSUMER MARKET PRICE

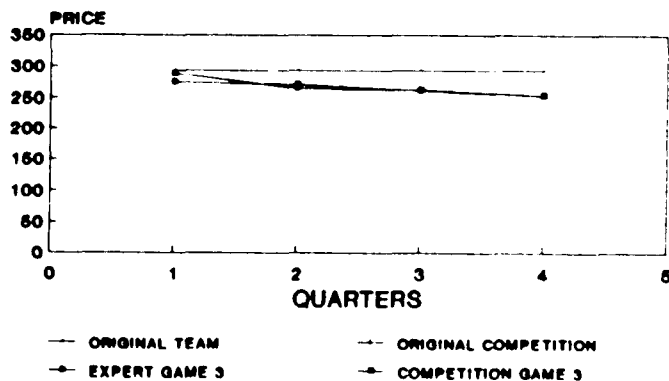


Figure A4.11a

### ORIGINAL GAME COMPARISON INDUSTRIAL MARKET PRICE

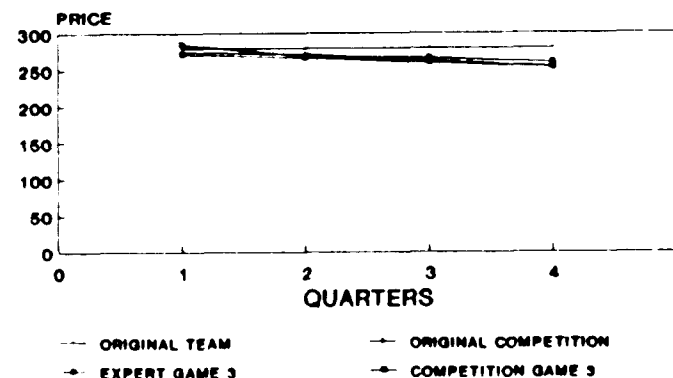


Figure A4.11b

### ORIGINAL GAME COMPARISONS INDUSTRIAL MARKET PERCENT SHARE

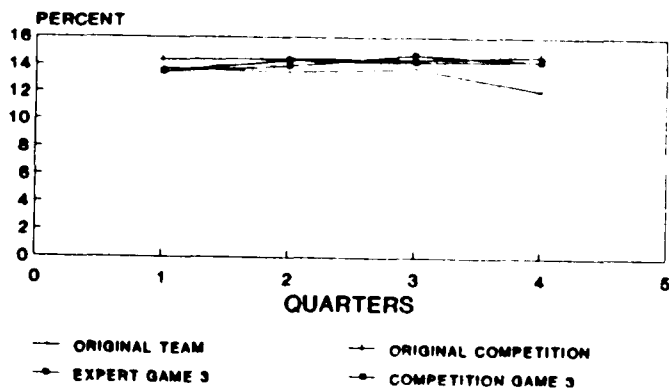


Figure A4.11d

### ORIGINAL GAME COMPARISONS CONSUMER MARKET PERCENT SHARE

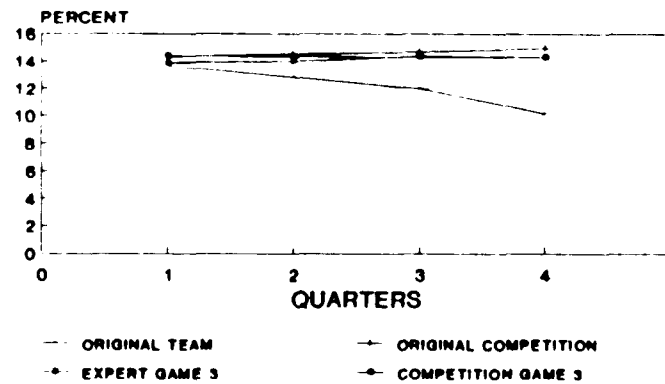


Figure A4.11c

## ORIGINAL GAME COMPARISON PRODUCTIVITY

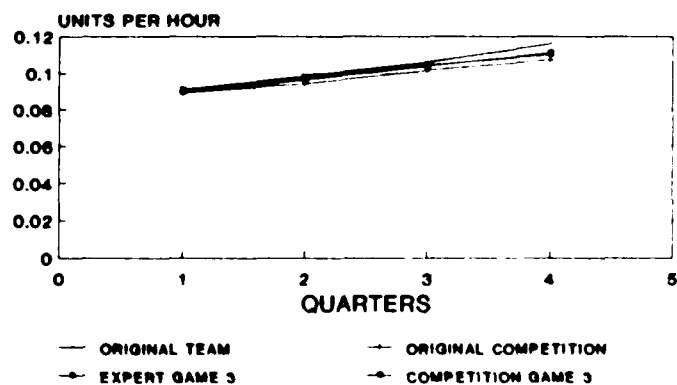


Figure A4.12a

## ORIGINAL GAME COMPARISON NET INCOME

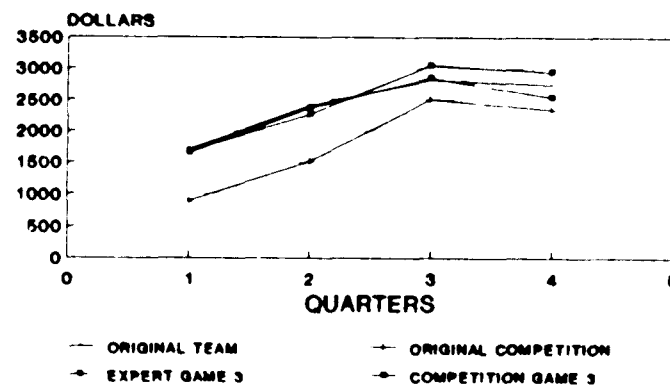


Figure A4.12b

## ORIGINAL GAME COMPARISONS PROFIT ON SALES

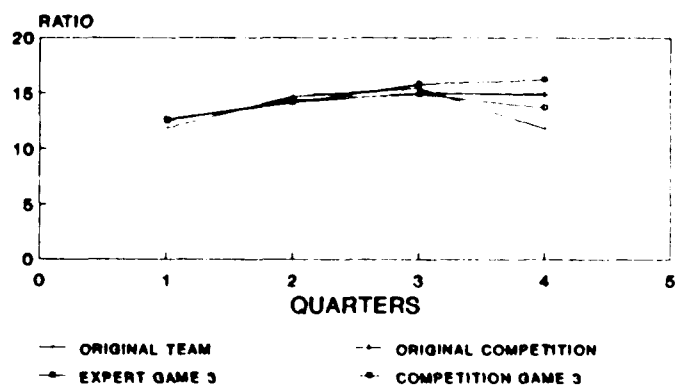


Figure A4.12c

## ORIGINAL GAME COMPARISONS P/E RATIO

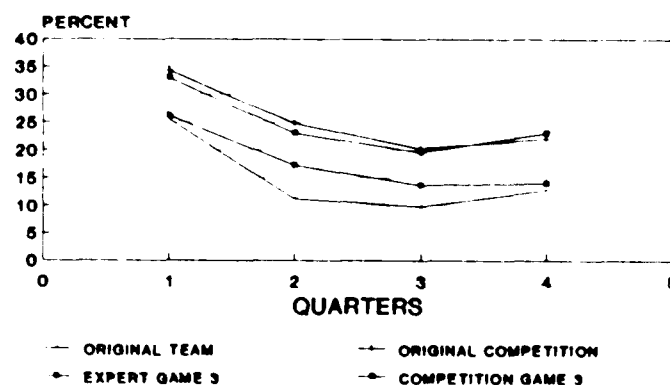


Figure A4.12d

Table A4.1 - Ranges of the Decision Choices by the Competing Teams  
(Game decisions before the expert system replaced  
one of the student teams)

| Decisions                      | Quarter 1 |       | Quarter 7 |       |
|--------------------------------|-----------|-------|-----------|-------|
|                                | Range     | Ratio | Range     | Ratio |
| Ave Product Price              | 19        | (.07) | 20        | (.10) |
| Ave Advertising Budget         | 21        | (.10) | 12        | (.04) |
| Product R&D                    | 42        | (.44) | 100       | (.37) |
| Sales commission               | 11        | (.44) | 10        | (.03) |
| Prod work week                 | 0         | (.00) | 0         | (.00) |
| Workforce Size                 | 262       | (.26) | 322       | (.27) |
| Process R&D                    | 58        | (.25) | 155       | (.42) |
| Sales Salary                   | 20        | (.01) | 35        | (.03) |
| Sales Training                 | 12        | (.40) | 48        | (.45) |
| Salesforce size                | 1         | (.08) | 1         | (.08) |
| Prod Wage Rate                 | .05       | (.01) | .12       | (.06) |
| Prod Training                  | 10        | (.31) | 33        | (.44) |
| Profit Sharing                 | .26       | (.13) | .30       | (.10) |
| Dividends Paid                 | 766       | (.39) | 650       | (.38) |
| Plant and Equipment Investment | 433       | (.25) | 66        | (.04) |

The remaining decisions either remained constant or were zero during the game playing.  
The product price, advertising budget, and salesmen size are aggregate values of all the markets

Table A4.2 Decision Comparisons at the end of the Testing  
Iterations Between the Best Team and the Expert System

| DECISIONS                          | BEST TEAM<br>Test Number |      |      | EXPERT SYSTEM<br>Test Number |      |      |
|------------------------------------|--------------------------|------|------|------------------------------|------|------|
|                                    | 1                        | 2    | 3    | 1                            | 2    | 3    |
| Average Product Price              | 258                      | 258  | 258  | 256                          | 251  | 256  |
| Ave Advertising Budget             | 316                      | 316  | 316  | 266                          | 181  | 316  |
| Product R&D                        | 600                      | 600  | 600  | 225                          | 225  | 280  |
| Sales Commission                   | 3.8                      | 3.8  | 3.8  | 3.8                          | 3.8  | 3.8  |
| Process R&D                        | 1300                     | 1300 | 1300 | 295                          | 290  | 300  |
| Sales Salary                       | 1054                     | 1054 | 1054 | 1038                         | 1038 | 1038 |
| Sales Training Budget              | 50                       | 50   | 50   | 50                           | 50   | 30   |
| Salespersons                       | 15                       | 15   | 15   | 16                           | 16   | 17   |
| Production Wage                    | 4.20                     | 4.20 | 4.20 | 4.20                         | 4.15 | 4.20 |
| Production Workweek                | 40                       | 40   | 40   | 40                           | 40   | 40   |
| Prod training Budget               | 60                       | 60   | 60   | 140                          | 140  | 105  |
| Labor Force Size                   | 1384                     | 1384 | 1384 | 1547                         | 1696 | 1266 |
| Profit Sharing                     | 3.1                      | 3.1  | 3.1  | 2.5                          | 3.2  | 2.0  |
| Plant & Equip Investment           | 3000                     | 3000 | 3000 | 1700                         | 1700 | 2200 |
| Bonds Sold or Redeemed             | 0                        | 0    | 0    | 0                            | 0    | 0    |
| Bank Loan Requested                | 0                        | 0    | 0    | 0                            | 0    | 0    |
| New Stock Issued                   | 0                        | 0    | 0    | 0                            | 0    | 0    |
| Long term Investment or Withdrawal | 500                      | 500  | 500  | 0                            | 0    | 450  |
| Dividends paid                     | 800                      | 800  | 800  | 800                          | 1500 | 900  |

Table A4.3 Performance Measure Comparisons

| PERFORMANCE              | TEAM 3 (BEST) |           |       | EXPERT SYSTEM |           |           |
|--------------------------|---------------|-----------|-------|---------------|-----------|-----------|
|                          | 1             | Test<br>2 | 3     | 1             | Test<br>2 | 3         |
| Market Share             | 15.91         | 16.21     | 15.91 | 12.39(28)     | 12.75(27) | 14.25(11) |
| Productivity             | .1234         | .1215     | .1191 | .0918(34)     | .0864(40) | .1101(08) |
| Stock Price              | 7.85          | 8.12      | 7.79  | 3.74(1.1)     | 3.43(1.1) | 6.89(13)  |
| P/E Ratio                | 14.53         | 14.76     | 14.70 | 12.89(42)     | 11.83(24) | 13.66(07) |
| Earnings per Share       | .54           | .55       | .53   | .29(86)       | .29(86)   | .49(08)   |
| Quick Ratio              | 20.9          | 21.16     | 21.02 | 19.87(05)     | 21.81(02) | 9.74(06)  |
| Profit on Sales Ratio    | 16.03         | 15.81     | 15.45 | 11.46(40)     | 10.98(43) | 16.22(04) |
| Bonds/Loan Interest Rate | 6.0           | 6.0       | 6.0   | 9.2(35)       | 8.0(25)   | 9.2(35)   |

### LIVE GAME CONSUMER MARKET PRICE

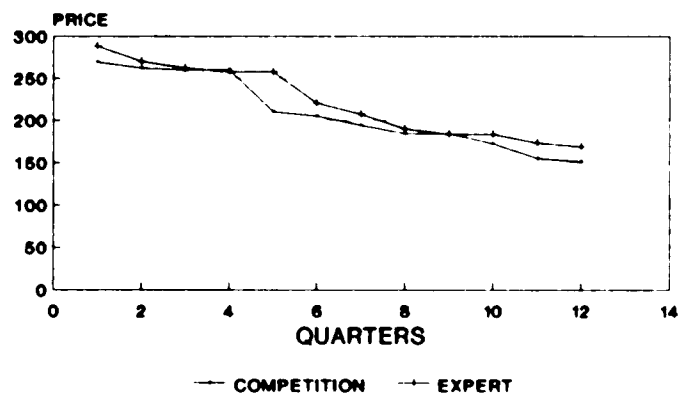


Figure A5.1a

### LIVE GAME INDUSTRIAL MARKET PRICE

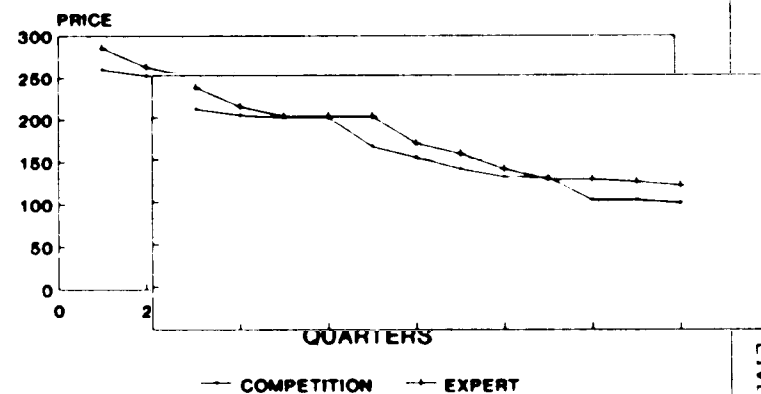


Figure A5.1b

### LIVE GAME CONSUMER MARKET PERCENT SHARE

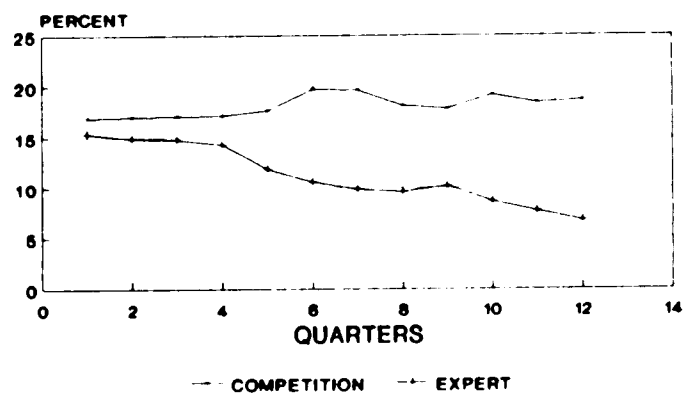


Figure A5.1c

### LIVE GAME INDUSTRIAL MARKET PERCENT SHARE

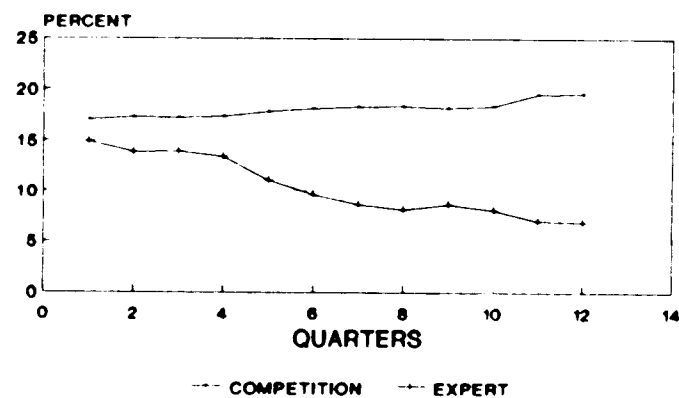


Figure A5.1d

## LIVE GAME NET INCOME

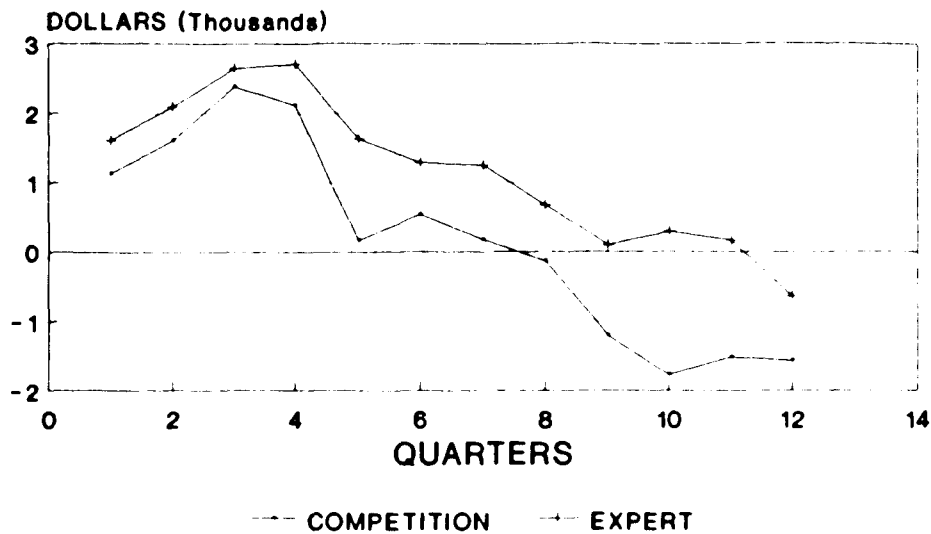


Figure A5.2a

## LIVE GAME PROFIT ON SALES

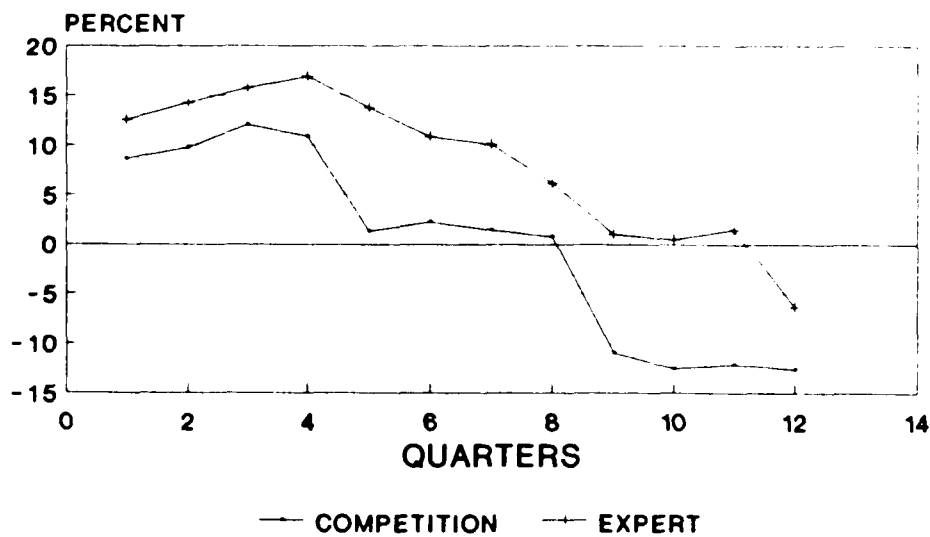


Figure A5.2b

### LIVE GAME RAW MATERIAL REQUIREMENTS

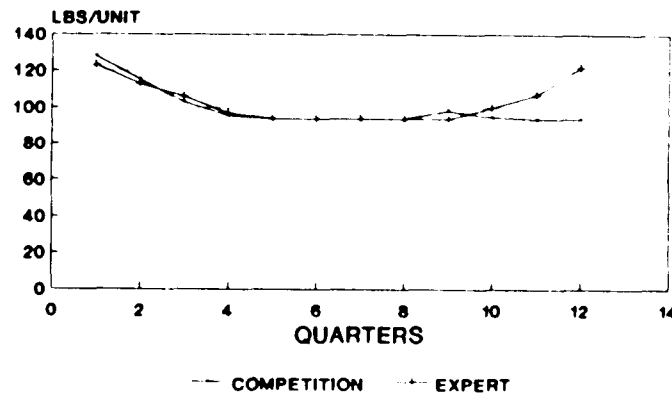


Figure A5.3a

### LIVE GAME PRODUCTIVITY

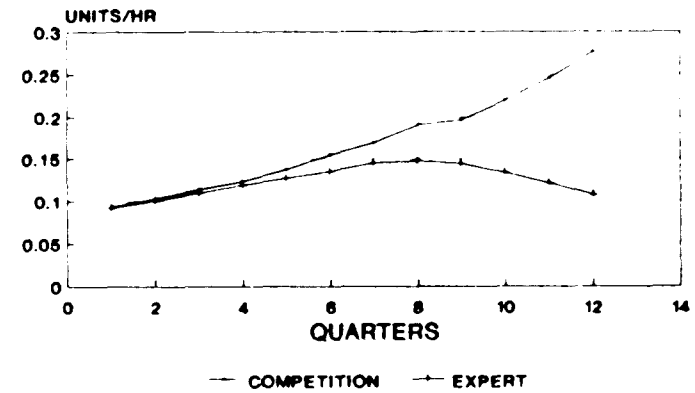


Figure A5.3b

### LIVE GAME RAW MATERIALS INVENTORY/ TOTAL PRODUCTION

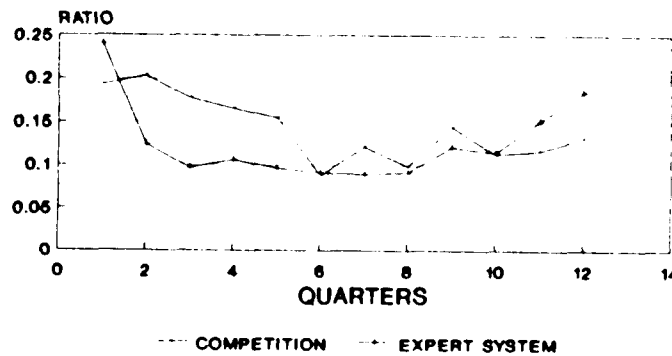


Figure A5.3c

### LIVE GAME TOTAL PRODUCTION COSTS

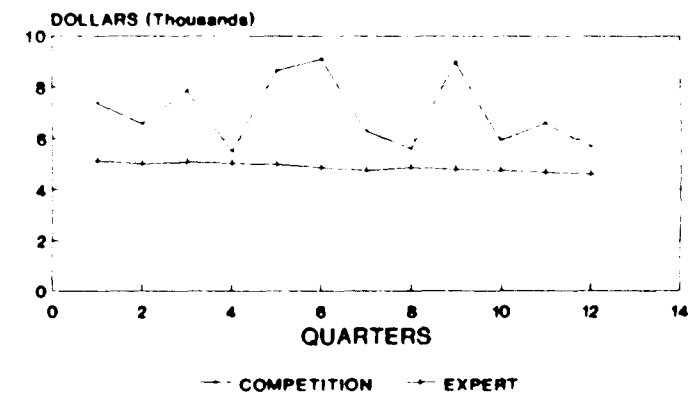


Figure A5.3d

# COMPANY COMPARISONS RAW MATERIAL INVENTORY / TOTAL PRODUCED

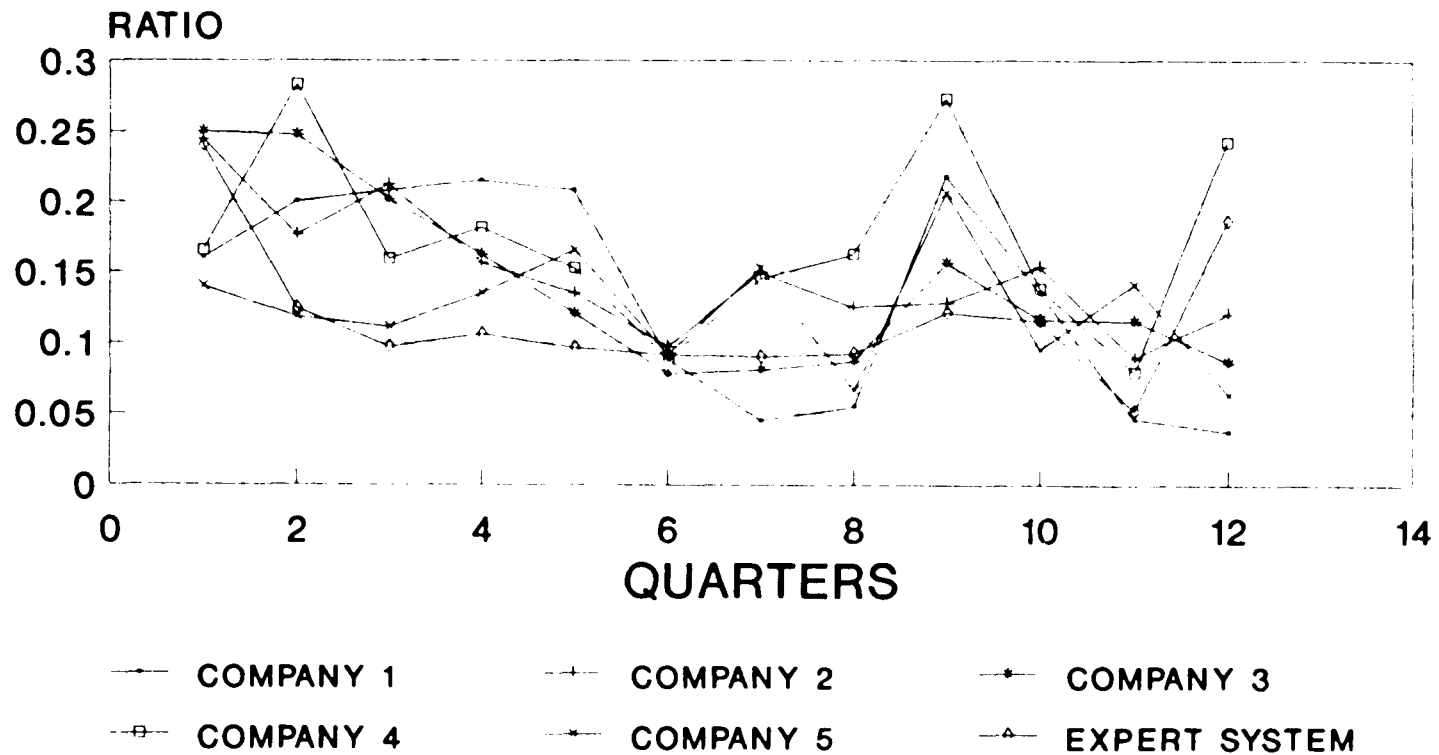


Figure A5.4a

# COMPANY COMPARISONS TOTAL PRODUCTION COSTS

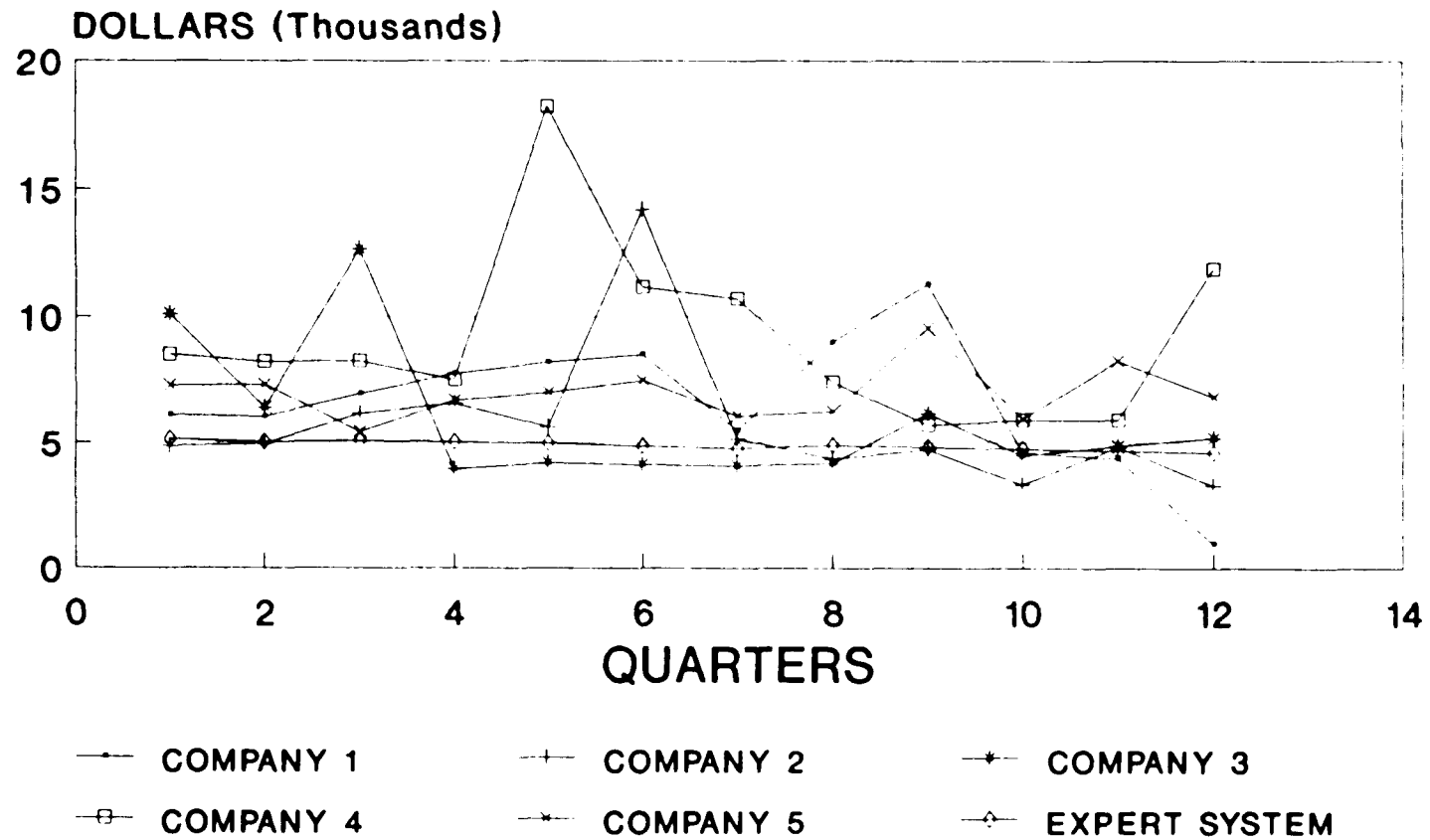


Figure A5.4b

### LIVE GAME PRODUCTIVITY

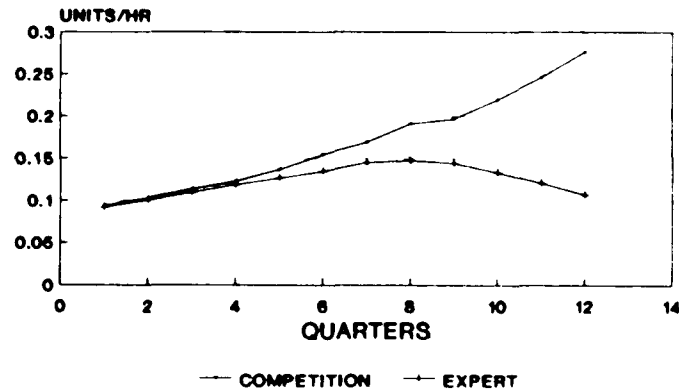


Figure A5.5a

### LIVE GAME EMPLOYEE PROFIT SHARING

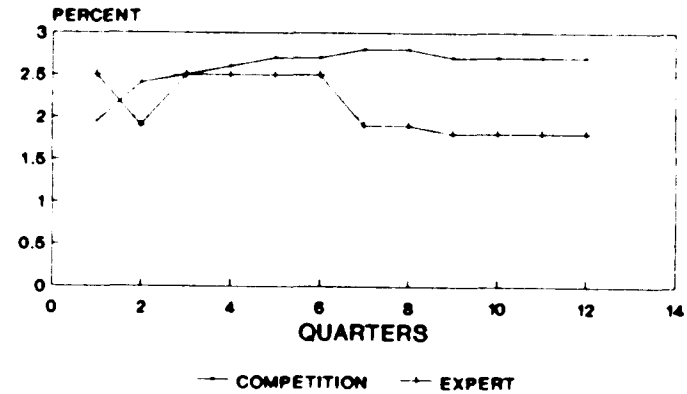


Figure A5.5b

### LIVE GAME PROCESS RESEARCH AND DEVELOPMENT BUDGET

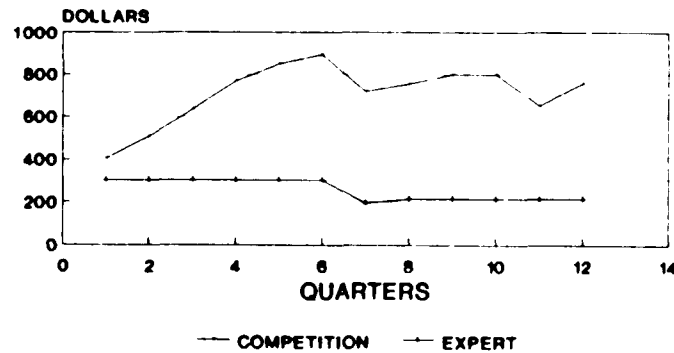


Figure A5.5c

### LIVE GAME PRODUCTION TRAINING BUDGET

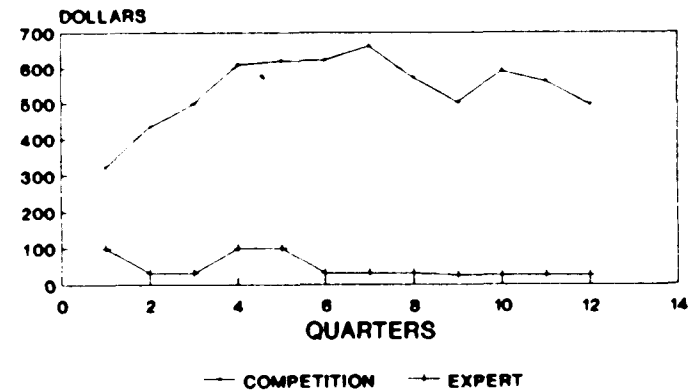


Figure A5.5d

## LIVE GAME PROFIT ON SALES

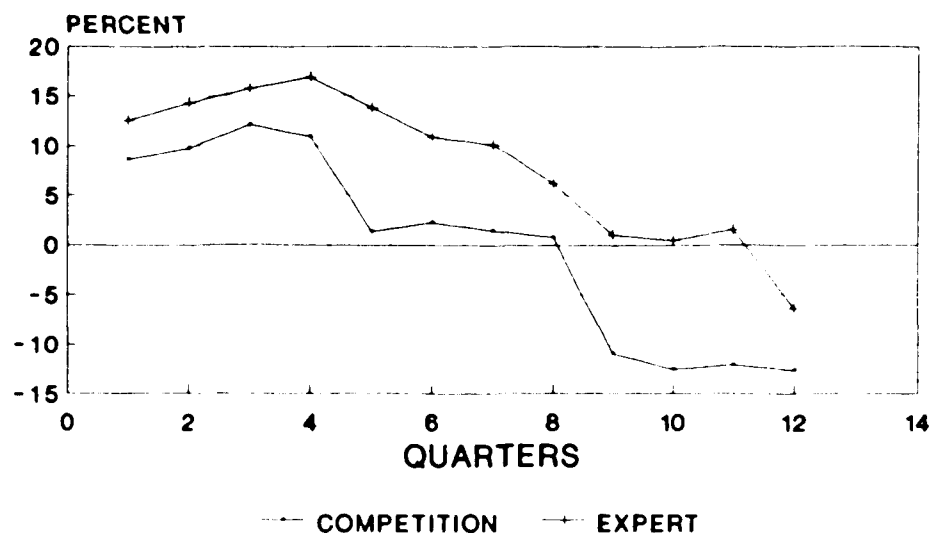


Figure A5.6a

## LIVE GAME PROFIT ON STOCKHOLDERS EQUITY

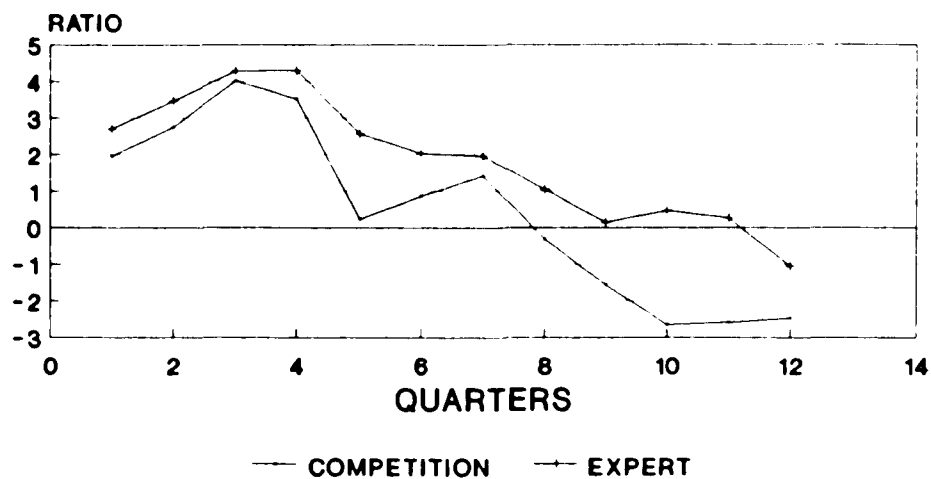


Figure A5.6c

# COMPANY COMPARISONS PROFIT ON SALES

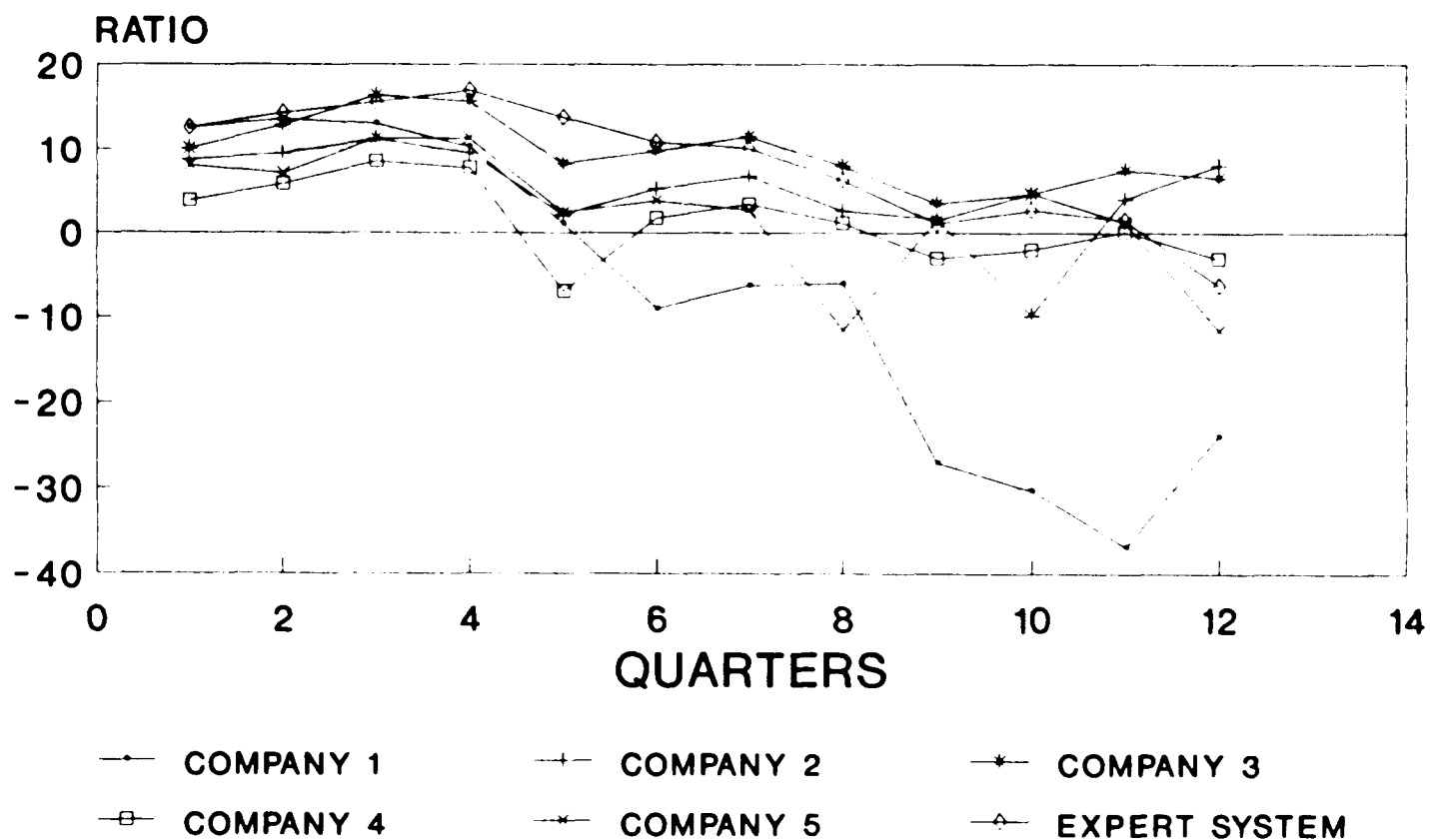


Figure A5.6b

# COMPANY COMPARISONS PROFIT ON STOCKHOLDER EQUITY

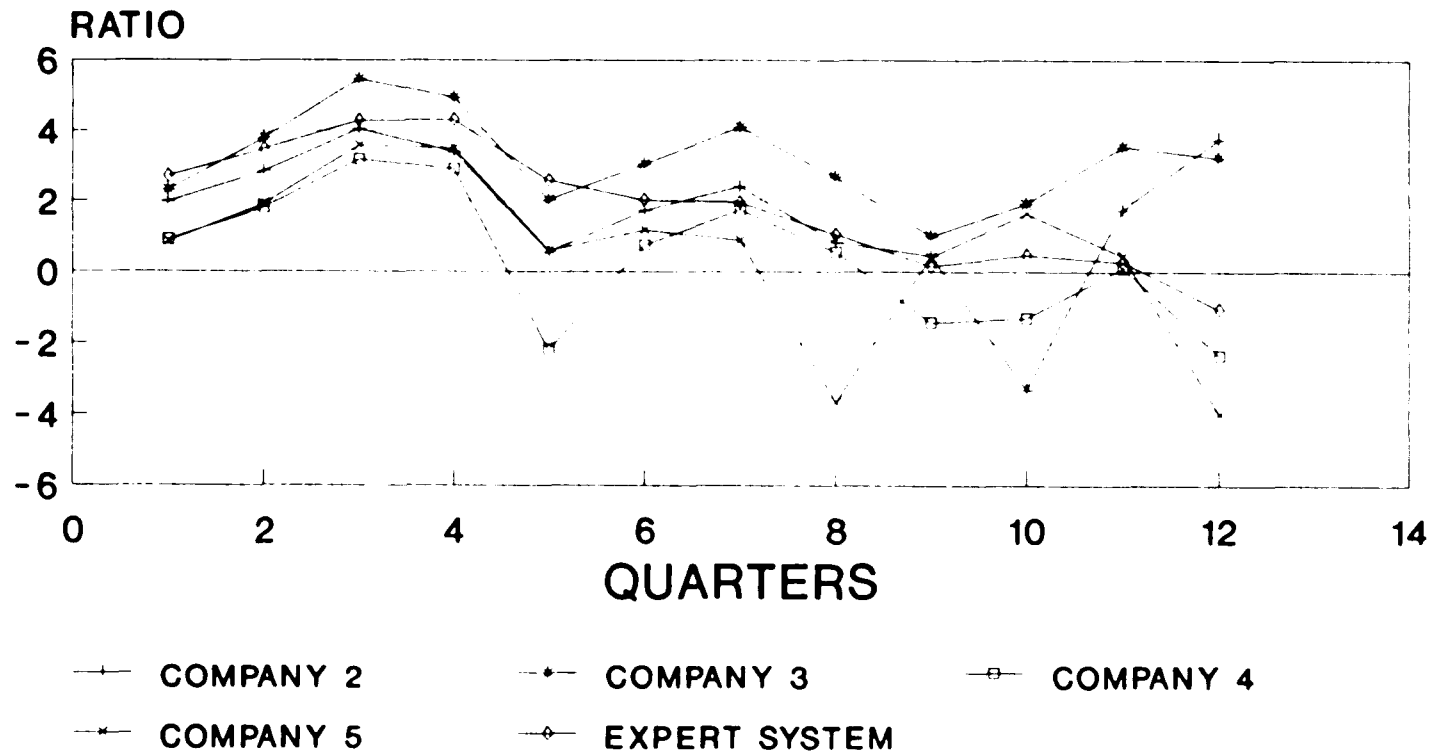


Figure A5.6d

### LIVE GAME QUICK RATIO

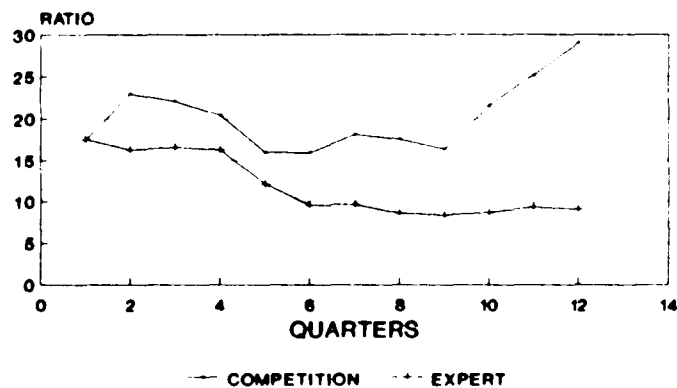


Figure A5.7a

### LIVE GAME RETURN ON TOTAL ASSETS

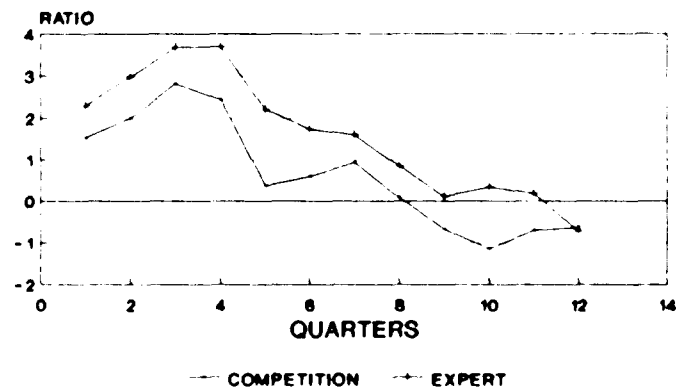


Figure A5.7b

### LIVE GAME INTEREST RATES

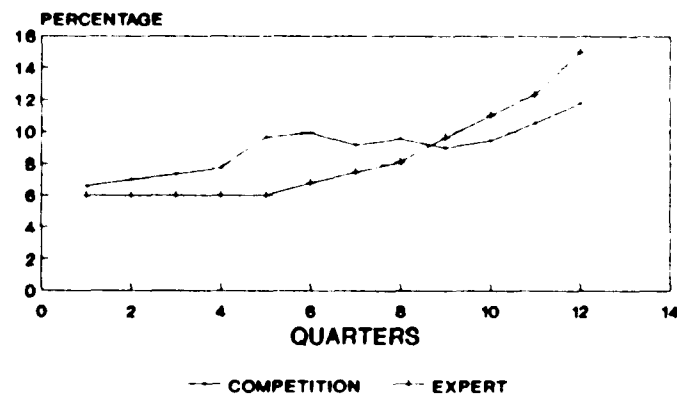


Figure A5.7c

### LIVE GAME CASH FLOW

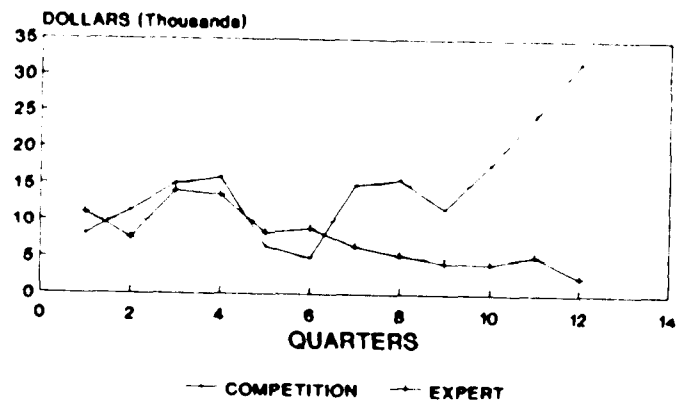


Figure A5.7d

# LIVE GAME P/E RATIO

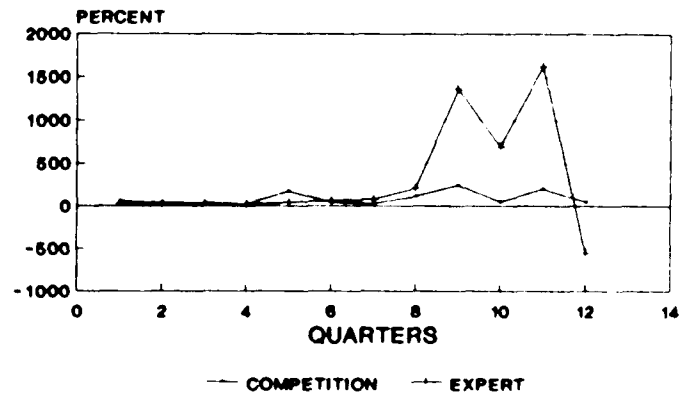


Figure A5.8a

# LIVE GAME EARNINGS PER SHARE

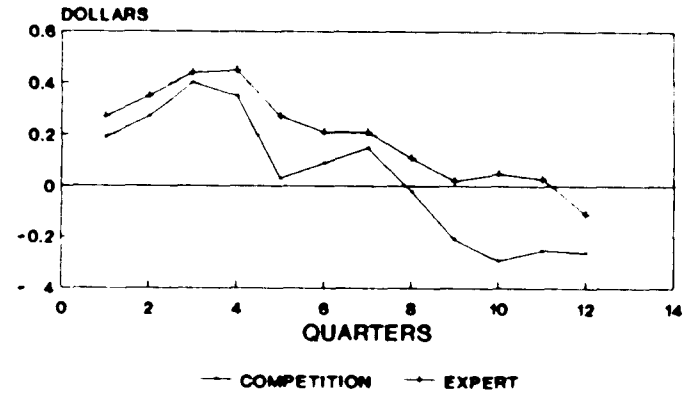


Figure A5.8b

# LIVE GAME STOCK PRICE

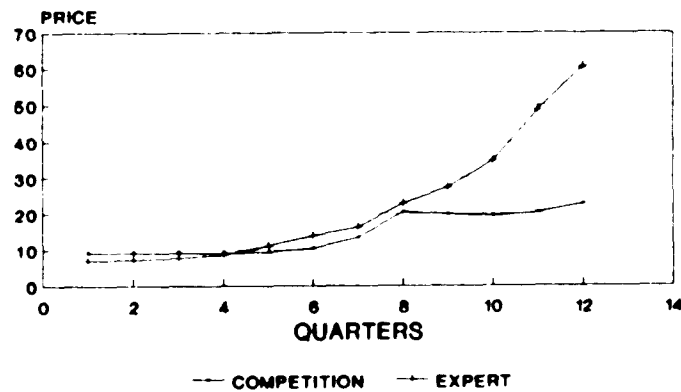


Figure A5.8c

## STUDENT QUESTIONNAIRE RESPONSES

## WHAT WAS YOUR INITIAL PRICING STRATEGY?

|             |                                                                                           |
|-------------|-------------------------------------------------------------------------------------------|
| Company 4   | Initial price high to differentiate the product                                           |
| Company 5   | Choose price lower than industry average price to gain market share, then raise the price |
| Company 2,3 | Low price aimed at a large market share                                                   |
| Company 1   | Choose price as a constant amount over costs                                              |

## DID YOUR TEAM CONSIDER THE COMPETITION WHEN MAKING YOUR OPERATING DECISIONS?

All teams responded YES

## IF YOUR TEAM HAD AN INITIAL STRATEGY, DID YOU STAY WITH THE STRATEGY OR CHANGE TO ANOTHER?

|             |                                                                                    |
|-------------|------------------------------------------------------------------------------------|
| Company 4   | Initial high price lowered to gain market share                                    |
| Company 5   | The initial low price, then high price changed to a low price to gain market share |
| Company 2,3 | Low price aimed at a large market share did not change                             |
| Company 1   | The price as a constant over costs changed to a flexible price-cost strategy       |

## DID YOU ATTEMPT TO UNDERSTAND OR CONSIDER THE STRATEGY OF THE COMPETING COMPANIES?

|           |                                                                                            |
|-----------|--------------------------------------------------------------------------------------------|
|           | All the companies observed the behavior of the other companies through the company reports |
| Company 2 | Attempted to interpret the strategy of the competition                                     |

## DID YOU THINK THERE WAS ANYTHING UNUSUAL ABOUT THE PERFORMANCE OF THE COMPETING COMPANIES? IF SO, IDENTIFY THE COMPANIES BY NAME(S).

|               |                                                                                                               |
|---------------|---------------------------------------------------------------------------------------------------------------|
| Company 1,2,4 | Company suspicion and amazement concerning the most successful company (They considered this to be Company 3) |
| Company 3     | Nothing unusual                                                                                               |
| Company 5     | Expertcorp (Expert System) always had the lowest sales in the industry                                        |

Figure 5.9 Student Questionnaire

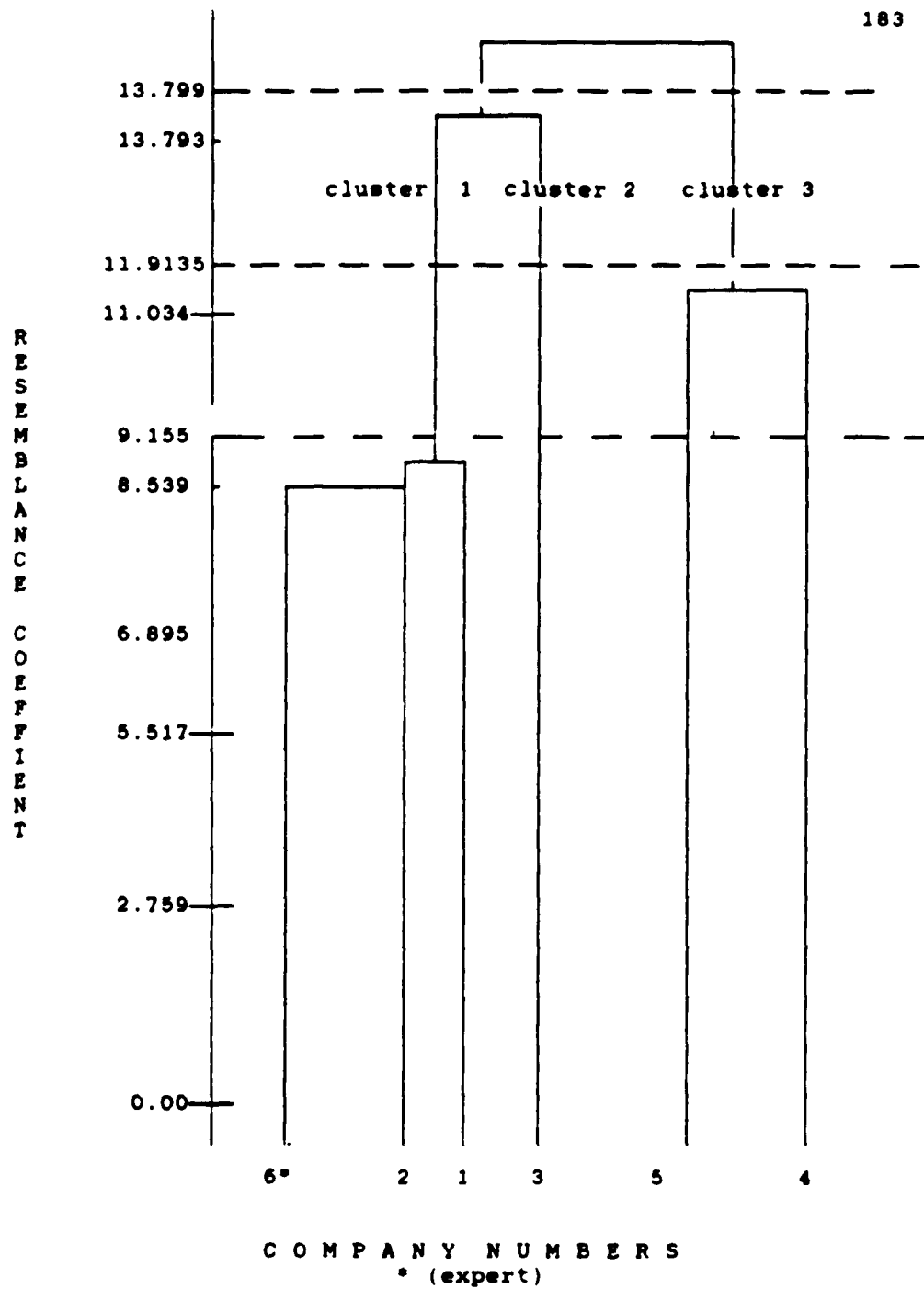


Figure A5.10 Dendrogram for Quarter 1 - Decision Variables

## DISTANCE OF COMPETING TEAMS FROM EXPERT SYSTEM BASELINE (Decision Variables)

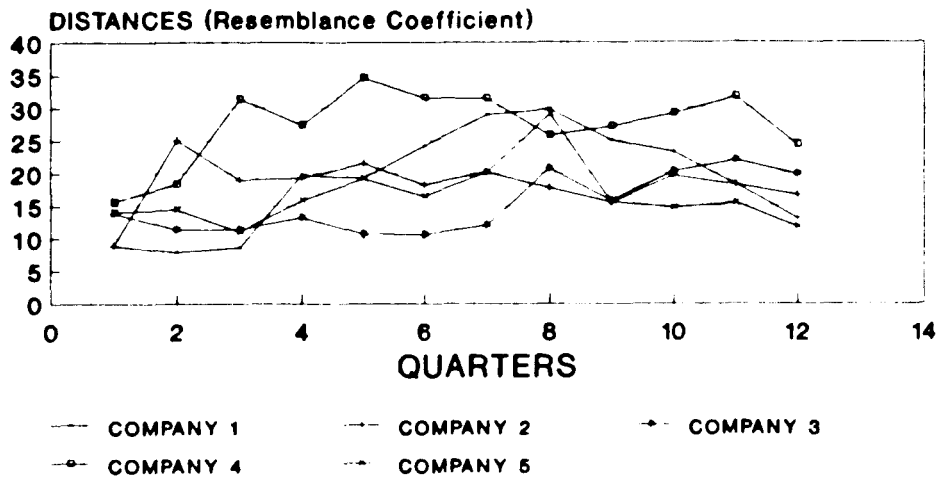


Figure A5.11a

## DISTANCE OF COMPETING TEAMS FROM EXPERT SYSTEM BASELINE (Performance Measures)

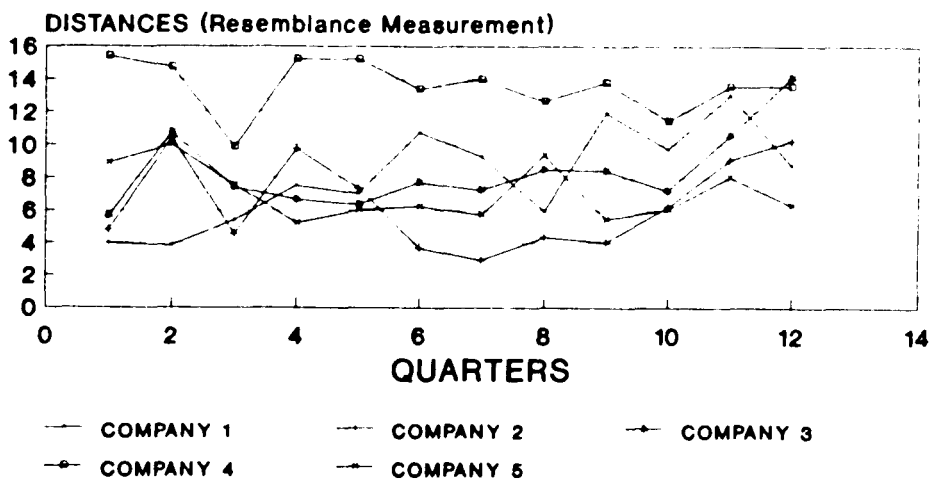


Figure A5.11b

## DISTANCE OF COMPETING TEAMS FROM EXPERT SYSTEM BASELINE (Combined Data)

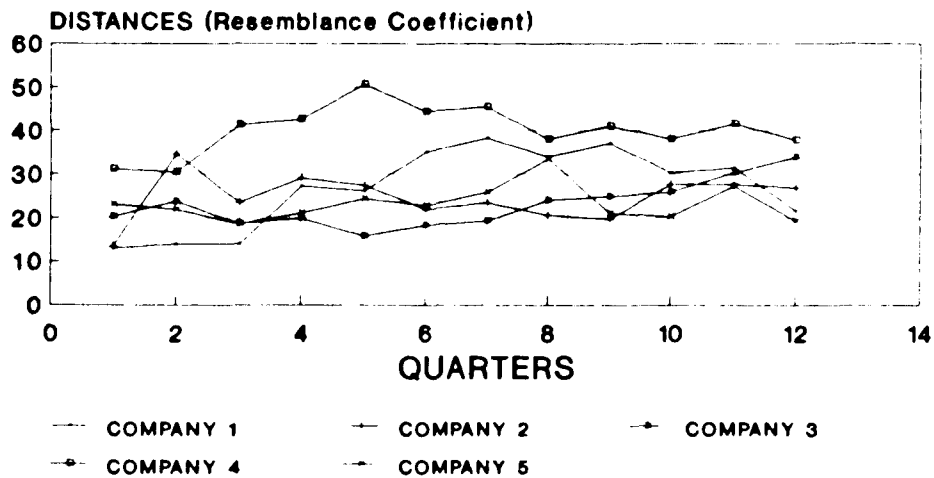


Figure A5.11c

## DISTANCE OF BEST AND WORST COMPETING TEAMS FROM EXPERT SYSTEM BASELINE (Combined Data)

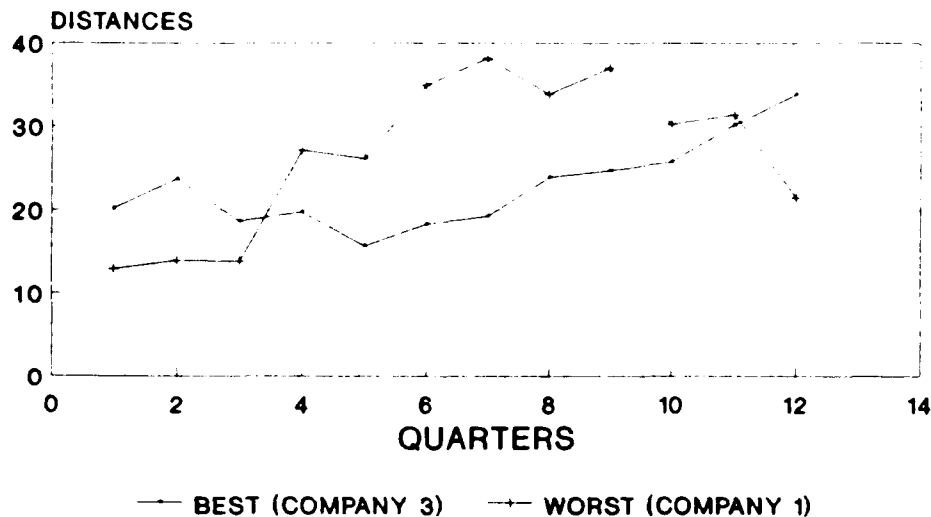


Figure A5.11d

Table A5.12 Cophenetic Correlation Coefficient  
(Dendrogram of Companies for the Operating Decisions  
in Quarter 1)

| Cell  | Resemblance<br>Matrix<br>X | Cophenetic<br>Matrix<br>Y |
|-------|----------------------------|---------------------------|
| (1,6) | 5.836                      | 5.836                     |
| (2,6) | 9.358                      | 8.275                     |
| (3,6) | 15.895                     | 14.456                    |
| (5,6) | 16.130                     | 16.474                    |
| (4,6) | 17.716                     | 16.474                    |
| (2,1) | 7.192                      | 8.275                     |
| (3,1) | 12.956                     | 14.456                    |
| (5,1) | 15.511                     | 16.474                    |
| (4,1) | 18.159                     | 16.474                    |
| (3,2) | 14.511                     | 14.456                    |
| (5,2) | 15.656                     | 16.474                    |
| (4,2) | 13.270                     | 16.474                    |
| (5,3) | 18.044                     | 16.474                    |
| (4,3) | 17.311                     | 16.474                    |
| (4,5) | 12.432                     | 12.432                    |

$$r = \frac{\sum XY - (1/n)(\sum X)(\sum Y)}{\{[\sum X^2 - (1/n)(\sum X)^2][\sum Y^2 - (1/n)(\sum Y)^2]\}^{1/2}}$$

$$r = 0.8810$$

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