A STUDY OF SUBOPTIMIZATION
WITH A MANAGEMENT GAME

DISSERTATION

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By

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INTRODUCTION

A great deal of work has been done by scientists with human behavior, either under laboratory conditions or descriptive field studies by sociologists under uncontrolled circumstances. A substantial body of theory has been developed, primarily by academicians interested in human behavior in the business environment. However, very few research studies have attempted to provide an integrating bridge between theory, research and field observations. The study reported below is an attempt by the author to provide an interdisciplinary building block to elicit information which may assist an organization theorist or operating managers in the analysis of existing organizations. The long range intent is to improve the overall efficiency of organizations by providing additional information for manager to draw inferences from the findings of this study.

In the first chapter, the problem of suboptimization from the businessman's point of view is examined. Selected parts of the relevant research literature are reviewed, and the general hypotheses with assumptions and limitations to the study are stated.

Chapter II reviews the general principles behind theory construction, describes several relevant theoretical positions, and discusses some preliminary and necessary assumptions for the development of a testable model.

Chapter III describes the instrument used in the investigation with the advantages and disadvantages of this particular tool (a management game) and examines the potential validity of the results.
In Chapter IV the research design and procedures are outlined with descriptions of the data. The methods of analysis are described, and the generic hypotheses are put into operational form.

These four chapters comprise the base upon which the remainder of the study rests. They are intended to provide a reasonably stable foundation for the collection of the data and the inferences drawn in later chapters.

In Chapter V the data are presented. The dependent variables are described and the results of the statistical analysis are discussed.

A survey of possible extensions of this research is made in Chapter VI. Several models which appear related are examined.
CHAPTER I

THE ORGANIZATIONAL PROBLEMS OF SUBOPTIMIZATION AND CONFLICT

This study is concerned with an investigation of some parameters related to the overall effectiveness of a firm as related to individual behavior. We are concerned with the component behavior of individuals taken singly and collectively and the possibility of the self-interest principle of the individual operating in conflict with the end goals of the firm.

General Statement of the Problem

The study is designed to examine inter-individual conflict (representing inter-departmental conflict) and will investigate the effects of a competition-cooperation variable coupled with a communications variable to determine the effects of these variables on the tendency of individuals to supoptimize.

The assumptions for many parameters of the area of administration seem to be that there is an inate tendency in the human organism toward an attitude of cooperation. Some of the recent studies done by behavioral scientists have indicated that humans behave in either irrational or non-rational patterns, and that they will often tend to compete rather than cooperate, even though cooperation can be shown to possess significant long range advantages. These results will be summarized in the section surveying the literature.

Where conflict does exist within a group or organization there may be some environmental constraints which mediate the tendency toward
conflict or suboptimization. The study is designed to examine two variables:

1. Ease of communications

2. Severity of external competitive conditions

The partitioning of these variables may be artificial as it can be argued that an increase in the severity of competitive conditions may force decentralization which will in turn affect the communication-coordination variable. However, for the purpose of experimentation, the variables have been partitioned within the study, and are assumed independent as structured.

Decentralized Control

The decentralization of American enterprise, at least to some degree, has apparently become a virtual necessity for an organization of any size. This has been given both theoretical (Morgenstern, 1951) and practical (Cordiner, 1956) support. These and other writers have discussed evolutionary decentralization, both in so far as physical facilities and management control are concerned.

Morgenstern (1951), in his preliminary work on organization theory, discussed the problem of decentralization from the viewpoint of information transmission, implying that while centralization is perhaps the preferable state of affairs (for maximum efficiency in an organization), it is rendered impossible by the communications systems which must be operative at any moment in time. He notes that centralized systems are not sufficiently flexible or fast enough for the controlling mechanism to react. He points to the example of the dinosaur which he says became extinct because of the length of time it took neural impulse to travel
from its tail to its brain and back to initiate action. An example from contemporary society would be the necessity of decentralized control on a hook and ladder truck. While the flexibility of the fire truck "system" is greatly increased by the decentralization of steering to the rear of the truck, it does substantially increase the need for coordination as two individuals have some (steering) control over the system.

It is this increased need for flexibility and rapid action within today's economic society, coupled with the inherent rigidities and speed constraints of modern communications systems, which require (at least to some degree) a decentralization of control and decision making. As the organization system moves toward increased decentralization of control, presumably in the search for increases in productivity, the centralized system no longer operates in an optimal manner. Increased size suggests a change toward decentralization. Decentralization can be viewed as the formal creation of semi-autonomous departments. It is within these subsystems that Hitch and McKean (1954) have suggested that problems of suboptimization will appear.

As more and more subsystems are created, it becomes increasingly likely that the optimal scale of operations for the firm as a whole will not be congruent with the optimal scale of the subunits. The subsystems will have "derived" goals assigned to them by the hierarchy of the organization. These goals, (unit production or unit sales costs,) have been derived both from the overall survival goals of the organization and from the need for an evaluation system for the subunits.

Unit cost has provided a convenient, if not completely valid, yardstick for the measurement of performance of subunits in the organization.
However, these types of goals may introduce an objective evaluation system which tends to reward subunits for operating at a scale different from the optimum for the total organization. If a production department, while being evaluated on a unit cost basis, is charged with inventory carrying costs for finished product, the tendency of the production department will be to minimize inventories of finished product. The coupled inventory system for an entire organization may have a substantial effect on the number of lost sales, when distributors are unable to meet the customer demands. These lost sales due to inventory stockouts are generally incurred after marketing expenditures have been made, and the overall tendency is to increase the unit cost for the marketing department. In this system, the production department will benefit from reduced inventories and the marketing department from increased inventories. This particular example could probably be alleviated by charging all inventory carrying costs for finished product to the marketing department as a transfer payment.

With any specific evaluation system for the subunits, there may be created circumstances in which the optimal scale for a particular department is not equal to the optimal scale for the firm as a whole. If the individuals within these departments pursue short run goals, the general tendency will be to move towards suboptimization. Maffei (1958) has suggested that suboptimization or the tendency towards suboptimization is a function of the insulation of the particular subsystems. In so far as there is no interdependence or interaction between subsystems, the tendency toward suboptimization will be reduced.
Communication and Coordination Between the Subsystem

Morgenstern (1951) and Rapoport (e.g., 1962a) have discussed (implicitly) the problems of suboptimization as inherently being those of communication and coordination between organization units. Morgenstern discusses the lack of complete information for the top executive (his term is "competence"). He points to the existence of organization for the express purpose of cooperation, and indicates that the central direction of the organization is necessary if the human individuals are expected to cooperate (Morgenstern, 1951, p. 16). Rapoport (1962b) feels that interpersonal or interunit coordination and cooperation can probably not be achieved without face-to-face communication.

Etzioni (1961) in his sociological analysis of complex organizations discusses conflict, using "compliance" as a comparative base, noting this as a universally existing variable, usually thought of as "power." This classification would be appropriate for a normal business organization with multi-level relationships. It may also apply when there are perceptions of dominant and submissive personalities or powerful departments or subunits. He suggests that these problems may be resolved with face-to-face communications, supporting Rapoport's view.

Seiler (1963a), discussing inter-departmental conflict, points to wasteful complicated ideas and the traditional explanation, illegitimate authority conflicts. He gives a four-fold category between "point of view" and "consistency of authority" as indicated by work flow. Seiler suggests that there are both functional and dysfunctional aspects of conflict. March and Simon (1958, p. 125) indicate that the differentiation of subunit goals is characteristic of organizational maturation.
These are representative views of current researchers working with organizational problems. A great deal of the current work centers around the problems of communication and coordination between departments or subunits in the structure of the organization.

Severity of Competition

Competitive conditions should, in general, increase the severity of the pressure upon the actors within any particular organization. The severity of this competition may be in terms of decision time or a variety of other forms. Some competition is natural within the business system operative in the United States today and is a necessary adjunct to a capitalistic society.

However, within any particular system, there may be practices which tend to promote severity of competition. Newman (1961) discusses some cost accounting procedures in manufacturing industries which will tend to depress prices in an industry below their normal level, perhaps pushing the industry to a survival stage rather than allowing it to operate as a healthy system. He differentiates between "volume-sensitive" and "price-sensitive" industries.

Many manufacturers have special cost accounting systems rather than using an industry wide system of cost accounting. (The latter practice is implicitly if not explicitly discouraged by the Justice Department, as it borders on collusion, at least in industries that could readily arrive at an agreement on cost accounting systems.) An industry which approximates the ideal of pure competition (with many individual units) would have much more difficulty in arriving at a uniform costing system. Newman
comments that in any particular industry, the price level is usually set by whomever offers the lowest price. A high price is difficult to maintain without some type of direct or indirect collusion. However, a low price, when set by any manufacturer will tend to be met by other manufacturers.¹

If any manufacturer feels that he is operating under volume-sensitive conditions and attempts to increase his total profit by price cutting, there should be a substantial effect upon the industry. If his firm controls any sizeable share of the market, and if in fact the industry is price-sensitive, there should be a significant shift in the market. This situation may be brought about by a manufacturer's being deluded by the mass production stereotype prevalent in the United States; that volume will necessarily make the unit cost of manufacture and distribution lower. This problem may exist even with a single manufacturing unit if there is a multi-product line in which the products may be divided into volumesensitive and price-sensitive categories.

Direct cost accounting problems will generally appear when different manufacturers use different methods of apportioning overhead to the costing of the product. If one firm uses a percentage of direct labor cost and the other a percentage of material cost, there will usually be variable total costs for the end product. Assuming homogeneity of finished product, this leads to the possibility that one of the manufacturers will be pricing his product below cost. If this is not compensated for, by overpricing at some other point in the firm, there will very probably be

¹This is suggested by the "kinked" demand curve from oligopoly theory.
increasing pressure throughout the firm to cut costs to maintain a satisfactory profit position. This then will put increasing pressures for performance upon individual subunits within the organization. If the criteria for the subunits is not congruent with profit maximization, there will be an increasing tendency to suboptimize.

We have given three major (but not exclusive) conditions which may cause suboptimization within the firm.

1. The tendency toward decentralization,
2. The tendency toward interpersonal conflict within the organization due to the increased necessity of communication and coordination, and
3. The severity of the external competitive conditions.

These are not the only major variables which tend to lead to suboptimization, but these variables will account for a substantial shift when present.

Specific Statement of the Problem

Individuals and subunits within the organization incline toward suboptimization. This tendency may be mediated by the degree of communication present, the amount of coordination necessary and the severity of the external environment. The specific problem of this study is to determine the main and interaction effects of two variables: (1) "communication - coordination," and (2) "severity of environment." These variables will be studied in a $2^2$ factorial design in a specified task environment. The abstraction from performance in a business firm to a similar task-oriented situation will provide an experimental environment for the investigation. The specific research design will be discussed in a later chapter.
Significance of the Problem

The costs to the organization associated with suboptimization and coordination can be depicted in a classical inventory model (see Fig. 1). This is an obvious oversimplification of the interrelationships of these variables and their isolation from other variables, and is simply done to graphically depict the problem. This graph represents a "time slice." If a third axis was added, it would be some measure of organization size. The vertical axis can be listed as a cost axis and the horizontal axis depicted as some "difference" measure in the organization. It is not clear what the horizontal axis should represent. However, the existence of an optimum mix of the two variables implies the existence of a variable on both ordinate and abscissa. These two cost lines can then be summed together to a total (subtotal for the entire firm) cost function and the manager's problem indicated as a minimization of the sum of the two costs. The minimum is defined by the first derivative of the equation of the total cost curve. It should be noted that many classical scholars would seriously question the linearity or regularity of any relationship of this kind. For instance, the primary basis for the Graicunas' discussion of span of control was based upon the theory that under certain conditions, coordination costs were not linear but were accelerating. It must again be emphasized that this is intended to represent conceptually the interrelationships, and the example should not be taken literally.

Cost of Suboptimization

We have defined suboptimization as the tendency for an individual or subunit to operate or perceive an optimum scale for himself or for his
Figure 1: An "Inventory Model" for Some Organization Costs
subunit different than the optimum scale for the organization as a whole. Any deviation from the optimal scale for the larger organization will add to the cost of that system. As an example, those costs incurred due to differences in goal direction will be discussed in this section.

This can be illustrated with a vector diagram (Keenan, 1964b) such as given in Figure 2, where $G_0$ is the direction of the goal orientation of the organization and $G_s$ is the direction and magnitude of the goal orientation of the subunit. If $G_s$ is resolved into its vertical and horizontal components, it may be clearly seen to what degree the activity of $G_s$ contributing to the organization's goal. In this sense the vertical component $G'_v$ is contributing directly to the goal of the organization whereas $G'_h$, if not directly dysfunctional and at least represents time, effort and resources used which will make no contribution to the organization goal. The $G_{s2}$ represents the goal directions for a second subunit in the organization and, as can be seen, $G'_{s2}$ partially neutralizes $G'_{s1}$.

Any action by the organization in the direction of any $G'$ is a dysfunctional expenditure, which might better be utilized for other activities.²

²It should be noted that Chris Argyris (1960) would disagree with this model, arguing that freedom of choice should indicate the direction of the organization goal, and that innovations and other expenditures of energy will be greater because the individuals are allowed to go in the direction that they choose. That is, they are not required to conform to $G_0$, but are rather pursuing individual goals.

At the risk of taking an illustrative model too seriously, an apparent difficulty with the Argyris model is that any collection of individuals, if allowed to select their own goal direction, will have different directions for their vectors and all Argyris is suggesting is that the summation vector for the components will be greater than the
Goals of the organization

Goals of individuals, 1 and 2

Components of individual goals which contribute to $G_{oi}$

Components of individual goals which contribute only to $G_{s1}, G_{s2}$

Figure 2: A vector model for differences in goals of subunits
Costs of Coordination

Some of the difficulties of coordination under decentralized systems have been discussed in the sections above. In general, the cost of coordination as discussed will be increasing in a linear manner as the absolute number of decentralized subunits within the organization is increased. The Graicunas model, for geometrically increasing segments of interaction, is assumed to be correct for the conditions present in this study. Suojanen's (1955) model appears extreme and the majority of studies relative to organization growth have not tended to corroborate his hypothesis.

For the most part, interdepartmental coordination will be a function of the number of direct contacts. That is, the particular segmented subunit which has been newly created will either coordinate with those immediately above or parallel within the same section; that is, a fifth department head may coordinate with four other departments and a section head but the coordination will probably be done by the section head in any event.

Service staff may have to work with the entire organization but do not coordinate in an active sense, that is, as an intra-organization coordination. There will be an inevitable increase in cost of coordination, as the organization decentralizes. Perhaps the problem could better be

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effort expended under a more classical system where the $G_0$ is pre-selected. The classical argument would simply be that this is a selection problem. Management must employ the individuals who will have some contributing features to the organization. Without a systematic selection system, vectors selected at random will tend to sum to zero regardless of magnitude.
considered, not as a cost of coordination, but as a cost of lack of coordination; losses in the transmission of information about the activities of other units.

From top management's viewpoint, it is necessary to minimize the sum of these two costs (as well as many others) and find an optimum balance between the increasing trend towards decentralized and the costs incurred by this decentralization. It will be a matter of weighing the advantages of decentralization against the advantages of centralized information processing.

Review of the Literature

The phenomena of interest in this study are the patterns of behavior under conditions of conflict and uncertainty within a group structure. The pertinent literature may be grouped in a variety of ways. A four-fold categorization has been selected; behavior under conflict, behavior under uncertainty, leadership theory, and game theory and related behavioral research.

This classification scheme is appropriate for this study as the concern is with the research literature of

1. behavior under the external conditions of conflict and uncertainty, and
2. the conflicting predictions of some of the work done with leadership, and
3. the behavioral research using the Prisoners' Dilemma Game as an instrument.
Behavior Under Conflict

The psychological literature categorized under conflict generally is concerned with conflict within the individual (internal), while the organization literature related to behavioral conflict is concerned with interpersonal conflict; that is, conflict in dyads, small group theory, or conflict within larger group structures. The literature on intrapersonal conflict is relevant to the study at hand as the goals and motivations of the individual subject within the dyad are internally determined.

Intrapersonal conflict

Berelson and Steiner (1964, p. 271) have schematized intrapersonal conflict as follows: (1) the choice between two or more mutually exclusive positive goals ("approach-approach" conflict); (2) ambivalence with respect to a goal that embodies both positive and negative characteristics ("approach-avoidance" conflict); (3) the dilemma between two or more threats ("avoidance-avoidance" conflict). This simple classification of the most elemental forms of intrapersonal conflict and its behavioral outcomes will be relevant in any decision situation.

Conflict of the approach-approach type, aptly depicted in the parable of Buridans' Ass (Richardson, 1939) does not present particular problems for the individual, because the model is essentially one of unstable equilibrium. The model, as predicted in the theoretical analysis, would be such that the perceived reinforcement of the goal would be increased as one approached the goal. For the parable of Buridans' Ass to hold, the power of perceived reinforcement must be inversely proportional to distance. This has not been demonstrated to be true with individual behavior.
The ambivalence inherent in an approach-avoidance conflict situation will link internal conflict and external conflict with other factors in the system. Any behavior within the task situation with which the subjects are confronted will inevitably have approach-avoidance characteristics. The tendency for the individual to suboptimize inherently contains an approach-avoidance conflict.

Festinger (1957) deals with the construct of "cognitive dissonance." Cognitive dissonance refers to the interrelationship between cognitions which exist simultaneously for an individual. Generically speaking, dissonance will be created if two or more cognitions in some manner do not agree or are not congruent with one another. An example given by Festinger is an individual who recognizes that he is highly intelligent and capable and yet meets repeated failure. The individual, within his need and motivation structure, must somehow reduce or eliminate this dissonance. An attempted reduction of cognitive dissonance should tend to increase movement toward suboptimization by the individual in the solution of an approach-avoidance conflict.

The studies reported by Festinger can be adapted to the work on achievement motivation. The resolution of inherent problems of cognitive dissonance will be dependent upon the relative strengths of the approach-avoidance conflict. Atkinson et al. (1960) integrate the concepts -- level of aspiration, achievement motive, and anxiety -- with performance, indicating basically that those individuals with high-approach and low-avoidance tendencies will perform better than other categories.
Interpersonal conflict

The literature on interpersonal conflict, generally in the realm of social psychology, is concerned with the interaction process of individuals with conflicting goals. Hare (1962) in his summarization of small group research lists Morton Deutsch's (1949a) study as the classic study of cooperation versus competition with the effects on group processes. Deutsch (1949b) found that cooperative groups had the following characteristics: stronger individual motivation, greater division of labor, more effective intermember communication, more friendliness and more group productivity.

Current behavioral research, particularly that research using the dyad, has not always supported these results. Representative examples and bibliographies on this research can be found in Criswell, Solomon and Suppes (1962), Bush and Estes (1959), and Rapoport and Orwant (1962). Some studies from these works will be reviewed in more detail below.

Behavior Under Uncertainty

A number of dimensions contribute to the uncertainty inherent in any situation, the real world or an experimental task. While a manager may define a task and the criteria for performance evaluation clearly, at least one aspect of uncertainty usually will remain inherent: the finite probability, and in some circumstances the overwhelming probability, that the real criteria for performance evaluation are not those stated.

Hoffman, Festinger, and Lawrence in their chapter on competitive bargaining (Thrall, Coombs, and Davis, 1960) note that individuals, in
order to evaluate their own ability, frequently tend to compare their performance with the performance of others they perceive as comparable to themselves. Consequently, the behavior of actors in a system may be determined more by their performance relative to others than by the absolute level of their own performance, as compared with the criteria used or given by the organization.

Haberstroh (Rubenstein and Haberstroh, 1960, p. 332) indicates that the number of independent goals should be fairly small and that reduction of conflict will be facilitated if these goals are formulated in terms of acceptable levels rather than optimal levels. As the number of independent goals pursued by the actors in the system grow smaller, the uncertainty should be reduced. In the model illustrated in Figure 2 (Keenan, 1964b), the number of independent goals would be represented by the number of independent vectors in the system. In the illustration given, the vectors are considered absolute; when representing individuals these vectors would be an expected value rather than an absolute value. Therefore, the particular vector is a "best estimate" of the probability distribution at a given point in time.

Rubenstein and Haberstroh (1960, p. 382) comment that even if the problem or task is concrete and easily understood, but clear criteria have not been given for performance evaluation, the differing viewpoints or goal directions (as represented in the vector model) may make it exceedingly difficult to arrive at any collective decision. This example emphasizes the possibility of conflict of interest and the frequent necessity of bargaining in small group situations. Much of the small group research has indicated this necessity (e.g., Costello and Zalkind,
1964, and Hare, 1962). Three examples of potential uncertainly are definition of task, clarity of goals, and criteria; they may be viewed as definitional problems and/or subordinate confidence.

Leadership Theory

The number of publications on leadership or related to leadership in recent years has been very large; for example, the bibliographies of Stogdill (1959), Likert (1961) and Bass (1960). These and other anthologies on organization behavior have reviewed a vast amount of literature in the attempt to systematize leadership theory.

It is beyond the scope of this study to extensively examine this literature, and we have selected a review article (Bennis, 1961) to summarize some of the contemporary positions of leadership theory. He has differentiated between three groupings of thought about human productivity and performance within an organizational contest. Bennis feels that these theories have developed sequentially in time and in some respects are dependent upon one another.

The first could be termed classical organization theory, as developed by Max Weber. This theory views organizations as independent entities differentiated from the individuals which operate within the organization structure. This system and body of theory views the organization as a formal model (when operating correctly). A given output is assumed deterministic upon a given input, and the individuals are manipulated by the organization for the achievement of organizational ends. Deficiencies in organization performance are analogous to friction or a lack of technology in a mechanical system.
Bennis then moves to a consideration of the "human relations" approach and summarizes this position in counterpoint to the classical position (Bennis, 1961, p. 28). The "human relations" model denies any essential conflict between man and the organization. Satisfaction of the worker is presumed congruent with the organization goals of effectiveness and productivity. Given this assumption, no authoritarian mediating force is necessary.

The leader is seen as facilitating, an agent who smooths the pathway to goal achievement. Individual satisfaction (morale, etc.) and organizational satisfaction are both achieved by the authority (leader) facilitating forces which will increase personal satisfaction. He associates Mayo, Roethlisberger, Moreno, and Rogers with this school.

The third group, the Revisionists, Bennis characterizes by a tendency to integrate behavioral science research and a recognition of the naive, unrealistic aspects of the human relations approach while maintaining its contributions to theory. This group draws from all prior positions regarding organization behavior. Two of the authors he reviews have been strongly influenced by the human relations movement and are of primary interest in this study. Chris Argyris and Douglas McGregor have focused on the positive qualities of man, and they argue that those aspects of man which are dysfunctional to organization performance have been created by the organization (the organization's assumption) rather than being inherent in the individual. Thus, Argyris (1957) feels that the organization forces the individual into a mold which inhibits growth on a number of significant personality dimensions which he postulates as relevant to performance. Argyris suggests that conflict is dysfunctional and created by the organization by improper organization design.
McGregor (1960) develops a "Theory X" and "Theory Y" which he describes as assumptions by which managers tend to operate (Theory X), and assumptions more closely characterizing the human organism (Theory Y). McGregor postulates a positively-oriented, creative, conflict resolving organism, that will tend to pursue these goals unless "forced" by the organization to do otherwise.

The point of concern in the work of these well-known theorists and researchers (as well as those associated with the human relations movement) is the assumption that the individual will tend to avoid interpersonal conflict. This is of particular interest when grouped with the findings of behavioral scientists directing research on interpersonal conflict, and particularly the work which has used the Prisoners' Dilemma Game as an investigating instrument.

Some Behavioral Research with Experimental Games

The literature pertaining to research studies using experimental games as an instrument has become quite extensive. There is one appropriate review article, (Rapoport and Orwant, 1962). This article categorizes and thoroughly reviews the research publications to September, 1961. In general, studies done since this articles have tended to corroborate the results that are suggested here.

They describe game theory as "a branch of decision theory specifically concerned with situations in which there are two or more decision-makers with (typically) conflicting interests" (Rapoport and Orwant, 1962, p. 1). This is a general description of the content material which may be handled with the game theory models, and adequately describes the
situation with which we are dealing in the present study. They list, among their categories for study, the Prisoners' Dilemma type of two-person game. This is the game most appropriate for consideration in the present paper.

The constraints for the Prisoners' Dilemma Game are given by Professor Lave (1962). He has added a condition from those commonly given (Scodel et al., 1959) which takes into consideration the possibility of improving the payoff by an optimal mixed strategy. In general, the matrices used in earlier experiments have met this condition, insuring strict dominance of strategy B over strategy A. The results of the studies can be categorized by the $2^2$ factorial design used in the present experiment. The two variables are communication between subjects and severity of external conditions imposed upon the game (analogous to differential payoff matrices).

Communication

Rapoport (1962a, 1962b) has pointed out that given a game of the Prisoners' Dilemma type, conflict from competing behavior cannot be reconciled (in nontrivial situations) without collective rationality. Communication relative to individual self-interest cannot be successful addressed individually to the participant but must be addressed in the presence of concerned parties. He suggests that a coordination system with feedback should be under a condition of mutual awareness (and probably face-to-face contact) to be successful.

The studies done by Deutsch (1949a, 1949b, 1958, 1960) have consistently suggested that communication will increase the tendency to
cooperate and vice versa. The Deutsch results have been consistent with other studies (Loomis, 1959, Scodel et al., 1959, and Minas et al., 1960).

**Differential pay-off matrices**

Both the Scodel and Minas articles suggest that the "motive of competition" may have a higher utility for the subject than that of cooperation in certain types of game situations. Rapoport (1962b) has suggested that there will be minimal tendency to compete if there is no temptation to defect; that is, the size of the differential reward between individuals is relevant. However, in the highly competitive game, cooperation may be indiscriminant. His findings support the position that, given differential rewards, there will be a tendency to compete.

Flood (1952, 1958) has indicated the possibility that players may be more concerned with maximizing differences between payoffs rather than the payoffs themselves. He suggests that their motives are directed in a competing manner rather than in a cooperating manner.

**Other relevant conditions**

Sakaguchi (1960) has suggested that there is a tendency towards more rational play as the game is repeated. Much of the work done by Rapoport has substantiated this conclusion; however, it may be better to use the word "consistent" rather than "rational" to describe this mode of behavior. The "learning curve" concept was recognized by these authors.

Loomis (1959) and the Deutsch studies have indicated that motivations or orientations as to cooperative, competitive or individualistic behavior can be induced to moderate degrees. However, these studies have
generally been for one or two experimental sessions rather than the relatively large number (23) used in this study.

Flood (1952, 1958) and Sakaguchi (1960) have tested the Nash (1953) solution to experimental games. The Nash solution suggests that people tend to make their first choices near an equilibrium point and then try to find a better equilibrium if it exists. The Nash equilibrium point, as examined by Flood (1952, 1958), corresponds roughly to the Bowley point used in the bilateral monopoly studies (Siegel and Fouraker, 1960, and Fouraker and Siegel, 1963).

The Bowley point is analogous to a price leadership situation in which the seller can maximize his personal payoff. In the bilateral monopoly studies, it was found that subjects tend to move toward a "split-the-difference" payoff and then to the Paretian optimal (the maximum equal joint payoff).

These studies also support the Schelling (1963) theory (equivalent to price leadership); that is, the ability to take a position from which your opponent knows you cannot retreat. The opponent then must select his best "residual" optimum. The achievement of a maximum joint payoff (the Paretian optimal) can only be achieved with some form of communication (explicit or implicit).

In the present experiment these conditions are met in the situation where the communications are separated and the decision-making is sequential. The production manager, placed in the second class, will have no bargaining power over the marketing manager from the first class.
Generic Hypotheses

The literature, both theoretical and experimental, suggests many hypotheses; however, this study will address itself to an examination of the effects of manipulation of two major variables: (1) communication and coordination internal to an organization environment and (2) the severity of the environment external to the organization. In this study, coordination is controlled by physically separating half the participants from their partners and severity of environment by manipulating loss of sales due to stockouts.

Some theoretical writing (e.g., McGregor, 1960) has suggested that individuals will tend to avoid interpersonal conflict when possible. Rapoport (1962a) and others (e.g., Scodel et al., 1959a) have obtained experimental results which seem to indicate that the motive of competition is stronger than that of cooperation, in some circumstances. In general, the work done with experimental games has suggested that the structural parameters of the environment will affect behavior. This conflict in the literature is the focal point of this study.

This section will present some generalized hypotheses which will be placed into operational form in Chapter IV. After the research design is presented, the hypotheses can be reworked and stated in a form amenable to statistical analysis.

Hypotheses Related to Group Measures

Hypothesis A: Profits should be greater for firms operating under less severe competitive conditions.

Hypothesis B: Profits should be greater for firms with higher order coordination systems.
Hypothesis C: Profits should be lower for firms subject to both severe competitive conditions and lower order coordination than firms subject to only one condition.

Hypotheses Related to Individual Performance Measures

Hypothesis D: Individual performance measures in firms subject to one or both experimental conditions should be extreme (good or bad).

Hypothesis E: Subjects will attend to measures of individual performance under more severe competitive conditions.

Hypothesis F: Subjects will attend to measures of individual performance with lower order coordination systems.

Hypotheses Related to Specific Decision

Hypothesis G: The decision behavior will be different for those individuals who have a comparatively poor historical performance than those with good historical performance.

Hypothesis H: The decision behavior will be different for those individuals (and firms) operating under one or both experimental conditions.

The assumptions and limitations relevant to the study will be discussed in Chapter IV after the operational statements of the hypotheses have been made.
CHAPTER II

THEORETICAL FRAMEWORK FOR THE STUDY

Theory and Experiment

"Experiments ought to be done for a purpose -- a purpose other than just to do another experiment" (Weiss, 1964). This statement was made by an eminent biologist to characterize much of current research. Weiss continues to suggest that much contemporary experimentation is "shot gunning" in the hopeful anticipation of hitting something. He suggests that research should have a well organized purpose, and it may be inferred from his remarks that a reasonably well developed and well structured or delimited theory will help the researcher to avoid the pitfalls of the "random approach" to data collection. This chapter will outline in brief the theoretical system by which the hypotheses were derived. The preliminary development of a systematic structure will provide a frame of reference within which this investigation can be imbedded.

The concept, "theory," has a range of meaning between the physical and social sciences. Campbell (1952, p. 89), while discussing the concept of theory from the point of view of the physical sciences (physics, specifically) describes a theory as follows:

1. Laws can be deduced from it
2. It explains laws
3. New laws which must then be correct can be predicted.

An acceptable social science definition will differ somewhat from the rigor of the above because of the lack of predictability inherent in
social science research. A current dictionary (English and English, 1958, p. 551) describes a theory (psychological) as "a general principle, supported by considerable data, proposed as an explanation of a group of phenomena; a statement of the relations believed to prevail in a comprehensive body of facts." The key word in this definition seem to be "proposed" and "believed." The apparent reason for this slack in the definition is the lack of reliability of prediction in the social sciences. For the purpose of this work we will use the latter definition.

Brody and Weinstock (1962) discuss one of the most common deficiencies of theories in social science; derived predictions based upon common sense or an appearance of reality or logic may be contradictory. Brody and Weinstock point out that a theory developed in this manner can generally be used to develop the polar opposites of existing predictions; ones so flexible as to provide a "rational" set of deductions which contradict. One advantage of a highly structured theory, for example a mathematical theory, is the prevention of contradictory deductions by operational rules.

If the theory is well developed and meets the test of internal consistency and the hypotheses derived are demonstrated by the results of the experiment, the conclusions reached are then considerably stronger than those which accompany a test without a prior prediction. This is to say that a "two-tailed" statistical test is less convincing than a "one-tailed" test, in the sense that the direction has been accurately predicted by the experimenter in the latter case.

The total structure of a deductive system will provide us with a basic frame of reference within which to view the small-scale system
involved in the present experiment. A deductive system has been described (Ackoff, 1962, p. 22) as follows:

1. a set of undefined and defined concepts,
2. a set of assumptions (axioms and postulates, or formation and transformation rules),
3. a set of deduced theorems,
4. instances of the theorems.

Within this structure the assumptions taken together as a unified and integrated body form the theory or the basis of the theory. From the basic set of assumptions, various postulates and hypotheses may be derived. The above outline is a generic description of the formal framework that this report will follow.

**Business Theories**

In general, theories and experiments which deal with human behavior in a business setting are difficult to keep within the rigorous bounds suggested by the above system because of the vast number of unknown variables. The ideal described, if not achieved, will at least be the target.

We are concerned with a behavioral system in a given context, the business firm. Within this context there will be a set of behavior patterns, on the individual level, on the group level and on the organization level, all interacting within a total environment provided by the larger society. This system is depicted by a set of fields (Figure 3) wherein members of each larger area provide, by their goals, behavior structures and instructions, the environment for the lower order systems (smaller fields). The group provides the environment for the individual.
Figure 3: "Field" Representation of Intergroup Environments
The theory within this particular framework will be structured as closely as feasible to a realistic set of assumptions. The theory will conform to scientific evidence and be built upon as few assumptions as feasible to allow for deduction and manipulation of a reasonable number of hypotheses covering a broad spectrum of behavior in the business environment. This logical system will provide the theoretical frame of reference for the experiment.

McGuire (1964) in his discussion of business theories uses a two-part breakdown, holistic theories of business behavior and behavioral theories. He describes the former as often computationally simple, but not realistic, whereas behavioral theories are often descriptive and detailed, but not readily manipulated.

We will attempt to build a deductive system based upon reasonable assumptions, rich in content but amenable to operational definition. These assumptions and deductions, insofar as possible, will be derived from or supported by the research literature. Constructs may be used which have been questioned but which are particularly appropriate for the model being developed here. This work is primarily aimed at developing an understanding of the parameters and variables which are involved in conflict behavior in an organizational setting. A conceptual model will be derived from the assumptions and the research literature.

A General Model for the Effectiveness of a System

Most studies investigate or discuss some phase of the efficiency or the performance in a system. In the operations research literature, these elements are grouped together under the concept of the "effectiveness" of
a system. When reducing any structured system to its simplest form, we are interested in the effectiveness, given a set of independent variables, and the environment in which they operate. Ackoff (1962) gives the following functional model:

\[ V = f(X_i, Y_i) \]

where,

\[ V = \text{effectiveness of the system} \]
\[ X_i = \text{those aspects we can control} \]
\[ Y_i = \text{those aspects we cannot control} \]

The controllable dimensions will usually be variables subject to manipulation in the \textit{short run}; such things as inputs to the systems, the reward system and goal determination. Often the \( Y_i \), those elements that we have designated as uncontrollable, will be subject to managerial control in the long run, but not in the short run. A business firm, operating under an autocratic leadership climate, might comprise for the purposes of a particular study a set of variables of the uncontrollable type. However, if the study concerned a particular style of leadership, the point of reference were from "above," and if the individual could be transferred or discharged, the variables would be controllable. In this sense, the degree of insulation of the subsystems from one another and from a two way feed-back to the higher ordered system must be described.

The simple model described above must be refined into a more specific and meaningful model which will be useful for predictive or descriptive purposes. The \( Y_i \)'s, the exogenous factors, must be delineated to describe the boundaries of the system under study. The \( X_i \)'s, the variables under study, should be sufficiently delineated to provide a basis for a concrete description of the interrelationships of the necessary conditions for the
development of operational hypotheses. We are interested in a description of the assumptions to the relevant theory so as to develop the "boundaries" (Krupp, 1961) of the theory used.

While it may not be possible to derive a mathematical model for behavior within the business system which we are discussing, it is nevertheless useful to develop a conceptual model in as quantitative a manner as reasonable. A developmental approach of this type will lessen the chances for internal inconsistencies and clarify the insulation of the particular subsystem under study from the larger order system in which it is imbedded (Maffei, 1958.)

**Generic Assumptions**

In this section assumptions relative to organizations and individuals will be discussed. Their relationship between behavior in operational units in research studies will be considered.

**Assumptions about the Organization**

The following set of assumptions will be those relevant to the organization, that is, the environment provided to the subsystem under study. In this section some of the major constraints placed upon the individual subsystem are listed. These assumptions comprise the exogenous variables, the $Y_i$ factors, and are as follows:

1. Organization behavior is goal-directed.
2. The primary organization goal is long run survival.
3. Organization behavior is some type of grouping of the subsystems of individual behavior.
This set of assumptions approximates an integrated description of organization behavior. They describe the environmental system as comprising an integration of the behavior of the subsystems (Seiler, 1963). Organization behavior must somehow be goal directed, as is individual behavior; this leads to the assumption of long run survival of the organization as a goal.

The use of the long run survival concept as a final goal of the business organization avoids the problem of choosing between lower order goals, as for example, the selection between the "profit motive" or "service motive." This controversy is a means — end debate and may be circumvented by conceptually moving a step into the higher order goal system (long run survival). The "survival" goal is common to both biological and social organisms and is evidenced in both moral and behavioral codes of conduct.

Assumptions about the Individual

The following assumptions regarding individual behavior are neither exhaustive nor mutually exclusive. They are intended, as described above, to provide a workable set of basic premises from which reasonable hypotheses may be derived. The specific assumptions, while not accepted by all researchers, seem to fall within reasonable bounds insofar as current and past research findings indicate. In some instances, they are a combination of the works of many writers. In others they can be identified fairly clearly with a specific theory of psychology or organization behavior. Four assumptions are made about the individual:

1. Human behavior is goal-directed.
2. Operant behavior is a function of
   a. Subjective value of the goal.
   b. Subjective probability of obtaining the goal.
   c. Motivation.
3. Human behavior is adaptive.
4. Human behavior is "satisficing."

These four assumptions will embrace a substantial portion of human behavior.

The above assumptions have a wide range in terms of generality; that is, the first assumption relative to goal-directed behavior is virtually a behavioral theory, while the latter three assumptions are subcategories of a holistic theory of behavior. In the system of the first assumption, the end point will be defined for a particular stream of activity by an actor. The second and third assumptions describe the search pattern of the actor, and the fourth assumption describes the selection of alternatives for need reduction when the actor arrives in a feasible solution area.

The two preceding sets of assumptions, those about the organization and those about the individual, will provide the foundation for the extensions and deductions regarding human behavior in a specific task oriented environment. These assumptions are neither mutually exclusive nor exhaustive; however, they will probably account for a major proportion of human behavior operating in a task situation. With a possible exception of the fourth assumption regarding individual behavior, that is, the satisficing assumption, they do not contradict the major theoretical positions regarding individual and organizational behavior.
Preliminary Deductions and Extensions of Assumptions

Assumptions about the Organization

Any discussion which regards an organization as different from the simple summation of the individuals comprising the organization must consider a definitional constraint as to what the organization actually is and to what degree it can be treated as a separate and distinct entity from the individuals which pass through it over time.

There seems to be, at this stage, sufficient evidence (see for example March and Simon, 1958) for the acceptance of a set of ongoing behavior patterns (operant behavior) which can be identified with the "organization" rather than the particular individuals within the organization. The assumptions about the organization have been made sufficiently general to embrace the more specific theories of organization behavior. Most theorists explicitly or implicitly recognize that an organization is moving through time towards a goal. There is some debate as to what the goal is, but little as to whether or not the behavior is goal directed. Thus, the first assumption about organizational behavior describes a hypothetical end point in time.

The second assumption, of long run survival, is made to provide a sufficiently general goal pattern to embrace some rather specific problems within administrative theory; the debate as to whether the primary objective of a business is service or profit. This assumption implies that service and/or profit seeking are means to the ultimate goal (that of long run survival) of the system. The apparent contradiction of unusual behavior of individuals in terms of immediate survival can be explained
under this system by noting that it is impossible to survive in the long run without surviving in the short run.

Lastly, we assume that organizational behavior is some type of "grouping" of the individual behavior systems which are operating within the organization. Various authors have discussed many ways in which the "grouping" does or should comprise organization behavior. Indeed, most organization theorists spend some time discussing this particular segment and have quite differing viewpoints ranging from whether the organization should serve the individuals or the individuals serve the organization. Krupp (1961) and Argyle (1957) have discussed at some length how the organization is at least a summation of the behavior of the individuals within it and how the assumptions about individual behavior ought to carry over to organizational behavior (Seiler, 1963b).

Thus, any system has an end or ultimate goal or reason for maintaining existence and that goal is, at a minimum, long run survival. Further, the behavioral system of the organization is composed of some type of grouping or summation of the behavior of the subsystems, ultimately individual behavior.

Assumptions about the Individual

The assumptions about the individual may be viewed as internal or "stored" programs by which the individual reviews and selects a course of behavior. Implicit within each assumption is a selection mechanism which will initiate a program of behavior given some form of a stimulus. In this sense, there is a large set of underlying assumptions behind the set listed. For example, the first assumption, "human behavior is goal
directed," contains a series of implicit assumptions about the nature of goals, needs, wants, drives, and other behavior initiators of this type. It is not within the scope of this work to build an elaborate description of human behavior. Rather, an intermediate generalization about some specifics of human behavior in situations of interest to the businessmen will be proposed and tested.

**Human behavior is goal directed**

There are as many forms of language structure related to human behavior as there are theorists. Most of these, however, explicitly or implicitly assume that human behavior is purposive; that is, any activity has some reason (or direction) for being performed. It should be noted, however, that the "reason for being performed" does not imply "reasoning" in the human sense. The behavior may be caused by instinct, as is the case with much of animal behavior. Nor is behavior necessarily assumed to be "reasonable," at least in the short run for a particular subsystem. There are many examples of the latter found in animal behavior, particularly in group actions such as stampedes or marching ants. While this behavior certainly appears dysfunctional insofar as this particular group is concerned, it may not be dysfunctional when a higher order system is considered; that is, it may not be dysfunctional when related to the total balance of nature.

"Reward" seems to be the major term used as a synonym for goal-directed behavior. A reward may be considered "a satisfaction-yielding stimulus or stimulus object that is obtained upon the successful performance of a task (which may be self-or other-imposed)," (English and English, 1958). The term "reinforcement" is often used as a synonym for
a reward or goal. Reinforcement is generally considered as something which "strengthens" behavior or increases the probability of the particular form of behavior being repeated. Reinforcement has come to have a variety of meanings; for the purposes of this work the concept of "strengthening behavior" will be used. Something that is reinforcing can be either a goal, per se, or something incidentally contributing toward directing behavior along a particular pathway. We will utilize the overlapping portion of these definitions and the general concept that a person will tend to move toward a preferable state from the existing state. The inefficient human organism will not necessarily move towards an objectively superior state, but rather to a state which is perceived as preferable. Hence, in latter definitions we will use subjective evaluations rather than objective evaluations.

Lewin (1935) has used a topological model as an expository device to discuss personality theory. In his work he describes "fields" in which a subject is located. As the subject views the surrounding "areas" or topological spaces, he will tend to move towards a favorable field, if the balance of the "force fields" allows a potential improvement in position by movement in a particular direction (goal or reward seeking behavior).

The classical economists, following the lead of Adam Smith, used as an assumption the existence of the motive of "self-interest." This assumption, as a base for the explanation of economic behavior, has been criticized by pointing to the existence of behavior which does not appear to follow this model. By differentiating response patterns into those directed towards immediate reward and those directed towards delayed
reward this problem should be circumvented. The possible behavior modes of the individual are defined as:

1. **Short run:** The selection of a set of responses oriented toward immediate reward through controllable variables.

2. **Long run:** The selection of a set of responses oriented toward indirect (or delayed) reward and through variables which may require extended cooperation from other actors in the system.

Short run rewards are those visualized within an organization structure that the individual has within his power to manipulate. An example is a situation where a supervisor takes credit for a suggestion made by one of his subordinates. He will probably receive some immediate reward (at least perceived reward) for this, and the "credit-taking" is controllable by the individual. A long run reward will generally require the cooperation of other actors within the organizational system. This cooperation may be implicit, for example, the cooperation necessary between a marketing and a production department is not always operationally defined. While there will be specific rules which must be followed by each, strict adherence to these rules would probably be chaotic to the total system. The behavior required in any operative system will usually contain implicit elements of cooperation.

**Conditions of operant behavior**

Much of the behavior in a business organization, or for that matter any organizational system, seems to come from a sufficiently complex environment to defy analysis by classical stimulus - response theory. For this reason we have chosen to discuss behavior under the category
"operant." English and English (1958) define operant as a "behavior identified by its consequences in its environment." They continue to discuss the typical lack of a specific (or identifiable) stimulus, even though the behavior may take place in a definable circumstance. The individual "behaves" in this manner in the organization situation. He is faced with a multitude of stimuli, apparently goes through some type of a search and selection procedure and acts.

We have subdivided this generalized description of behavior into three categories: the individual's subjective evaluation of the reward, the individual's subjective assessment of the probabilities of obtaining the goal, and the driving motivation pattern. An example illustrating these decision processes may be useful for clarification. A group of criminals who plan a robbery of a particular bank characterize this type of behavior. Their behavior can be identified readily by its consequences in the environment; by their selection of bank robbery as a career, and by their selection of a particular bank. They have exhibited subjective evaluations of the potential rewards and subjective probabilities of obtaining the rewards. They choose a bank rather than a vault of furs; they may choose a small bank which has fewer guards, rather than Fort Knox which has a great deal more money but considerably greater risk associated with it.

They have exhibited a set of decision criteria with unknown parameter values based upon the value of the reward and the probability of obtaining the particular goal. These are, of course, subjective assessments.
Subjective value of the goal

The concept of "utility" was developed by economists (or philosophers) to provide a neutral measurement device with which varying rewards could be compared in value. Money, of course, would be the obvious choice as a neutral measurement. However, it has been shown that money per se has a non-linear utility function (Edwards, 1954) and a variable function for differing individuals which prevents it from being utilized as a universal measure. There are some obvious things such as "Heaven" which cannot be described by a monetary measurement system. In this example, the belief generally is that obtaining this particular goal cannot be achieved with money at all.

For these reasons, the economists have developed the concept of a "utile" as a unit of measurement of utility. Edwards (1954) reviews briefly the economic literature before moving to the psychological literature in his discussion of decisions. He also comments that the concept of utility is very much like the "valence" of Kurt Lewin. Valence, in the Lewinian system, is the degree of attractiveness of an object or activity (Edwards, 1954, p. 389).

The work in utility theory has usually only assumed an ordinal scale of measurement for utility. That is, the utility of a certain series of outcomes could be ranked in a preference order and is subject to some weak mathematical restrictions. For example, if the utility of outcome A is greater than the utility of outcome B, and the utility of outcome B is greater than the utility of outcome C, then the utility of outcome A is greater than the utility of outcome C.

\[ U(A) > U(B) > U(C) \]

Therefore, \( U(A) > U(C) \)
Additional axioms have been derived (see for example Davidson, Suppes, and Seigel, 1957).

The individual presumably goes through some type of a search program, selects a set of possible outcomes, ranks them by utility, and selects the outcome with the greatest utility. This decision process or theory worked fairly well, assuming an economic man. An economic man is generally assumed to have three properties:

1. Perfect information
2. Perfect rationality
3. Perfect sensitivity

Given these assumptions, the maximizing of utility works fairly well.

The real man, however, did not fulfill these assumptions, nor did he appear to behave as if he were simply inefficient. This led to some modification of the classical utility concept. Reconsideration of the "likelihood" seemed to be necessary to account for behavior which did not select the goal with the apparent highest utility.

Subjective probability of obtaining the goal

The computation for "mathematical expectation" is the conventional way of dealing with likelihood and the resultant value. Mathematical expectation has come to be termed expected value (EV) by economists. This is the mathematical method of summing the value (v) of a possible goal, weighted by the probability (p) of the event happening. Thus:

$$EV = p_1 v_1 + p_2 v_2 + \ldots + p_n v_n$$

The formula should take into account all possible outcomes or events given a particular action, and therefore, the sum of the p's will be one. This model, as a modification of the classical utility model, begins
to explain why the individual does not always select the alternative with the greatest absolute outcome. In the bank robbery example, the robbers will investigate each term and select an activity. In the term for Fort Knox, the probability of success was sufficiently low as to dictate a greater expected value in the long run for selecting an activity with less absolute value. In this example, EV would represent the value of robbery as a career in the long run and a particular term in the equation, \( p_m v_m \), the value of one job.

In the use of the formula given above, it should be noted that the concept of utility for the value of the event may be reintroduced to account for many fairly common types of behavior. Examples are when the house takes a percentage, or insurance, in which the mathematical expectation or expected value of the event is negative, if only dollar payments are taken into consideration. Apparently the individual attaches some utility value, when purchasing insurance, to a series of small payments rather than to the possibility of a single large payment.

Edwards (1954), in his discussion of the "expected utility maximization theory," comments on several experiments which indicate problems with expected utility maximization. He describes a series of experiments that he has performed to demonstrate that subjects have preferences for particular probabilities as well as the value of the events.\(^3\) Savage (1954) is usually considered the leading exponent of the subjective

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\(^3\)Some of the difficulties of transformations with subjective probabilities are discussed by Edwards (1954). He raises such questions as: Is the scale of subjective probability bounded by zero and one, as is the scale for objective probability?
probability notion. Some utilization of subjective probabilities coupled with Bayes' theorem is discussed by Schlaifer (1959).

To go back to the example utilized, we would hypothesize that the behavior of the bank robbers could be explained by their subjective evaluation of the potential reward; that is, the utility of the reward weighted by subjectively determined probabilities of obtaining the reward. The above suggests that the individual in a decision-making process somehow subjectively estimates the utility of the reward and subjectively estimates the probability of obtaining that reward, multiplies these two things together and selects the largest perceived value.

Human behavior would also seem to indicate some type of a "discounting to present value" program which is applied either to the goal or to the weighted value of the goal. This behavior can be illustrated by "death-bed repentance" and other behavior of this type. From the above then we would suggest that the individual tends to maximize (or as is suggested, satisfice) some discounted value of a set of weighted rewards and selects among these potential rewards with the maximization program.

Motivation

Atkinson (1957) and Siegel (1957) have discussed utility theory with a frame of reference of the effect of personality variables. Atkinson constructs a behavioral equation with the following components:

\[ M_s = \text{Motive to achieve success (achievement motivation)} \]

\[ M_p = \text{Motive to avoid failure} \]

\[ P_s = \text{Subjective probability of achieving success} \]

\[ P_f = \text{Subjective probability of failure} \]
\[ I_s = \text{Incentive value of success} \]
\[ I_f = \text{Negative incentive value of failure} \]

He then develops two models: (1) the strength of motivation to approach success and (2) the motivation to avoid failure.

\[ (M_s \cdot P_s \cdot I_s) = \text{Motivation to approach success} \]
\[ (M_p \cdot P_f \cdot I_f) = \text{Motivation to avoid failure} \]

These models are not the direct inverse of one another. In standard psychological language the first equation is an "approach" model and the second an "avoidance" model. He postulates that every task may be viewed as an approach-avoidance problem. He defines the following relationships:

\[ I_s = (1-P_s) \]
\[ I_f = (-P_s) \implies P_f = (1-P_s), \]

and indicates that resultant motivation is the approach motive plus the avoidance motive; therefore,

\[ P_s(1-P_s) (M_s-M_f) = \text{resultant motivation}. \]

The major problem is, of course, a determination of values for these variables. This determination is beyond the scope of the present study, but various researchers have worked with the assessment of these variables. We have included as an adjunct to this work a personality assessment with a score which should correspond to \( M_s \). This is discussed in greater detail below.

Siegel (1957; Siegel and Fouraker, 1960; Fouraker and Siegel, 1963; Starbuck, 1963) has worked with "level of aspiration theory," as a major variable in decision making. He describes level of aspiration as the
particular goal for which the person strives. Thus, Siegel discusses the perceived goal and Atkinson the strength of motivation to get to the goal.

Siegel describes an extended model adopted from Edwards (1954) where:

$$\text{SEU} = \sum_i P_i U_i$$

$\text{SEU} =$ Subjectively expected utility

$P =$ Probability of events

$U =$ Utility and

$U = f(R, LA)$

$R =$ Reinforcement effects

$LA =$ Level of Aspiration

He relates this theory to the Lewinian concept of valence, using achievement as equivalent to ability (both positive and negative). Thus, Siegel's utility is similar to Atkinson's achievement, probabilities are subjective for both, while he will be "satisfied." The models should therefore be compatible, with Siegel adding a "satisficing" boundary and an acceleration for reinforcement effects. In the present study we should, according to the structure, expect subjects with high achievement motivation to either succeed or exhibit vigorous search behavior until the aspiration level has been attained and then stabilize behavior.

**Human behavior is adaptive**

Adaptation, as used in this work, is "any beneficial change to meet environmental demand" (English and English, 1958). The rigorous definition of adaptation introduces some problems when dealing with human behavior - problems similar to those when dealing with maximizing utility.
The rigorous definition requires perfect intelligence on the part of the actor for maximum consistence or reliability. A preferable definition of the term would be to suggest that humans attempt to be adaptive and are generally successful. The above is a conceptual description of a stochastic selection procedure in which the individual is right more often than wrong.

Adaptive behavior should occur in response to errors in the search and selection mechanism described. There are basically three types of errors possible - incorrect estimates of

1. Value of the goal,
2. Difficulty of the pathway to the goal,
3. The discounting process.

A rational individual probably should use Bayes' theorem to compute posterior probabilities to determine the existence and location of errors of this types (Savage, 1954; Schlaifer, 1959; Edwards, 1964). The latter work suggests that people tend to grossly underestimate the true probabilities which might be derived with a Bayesian model.

**Human behavior is satisficing**

We cannot improve upon the introduction to the second edition of *Administrative Behavior* by Herbert Simon (1957).

While economic man maximizes - selects the best alternative from among all those available to him; his cousin, whom we shall call administrative man, satisfices - looks for a course of action that is satisfactory or "good enough" (p. XXV)

...of the behavior of human beings who *satisfice* because they have not the wits to *maximize* (p. XXIV)

We are assuming that the human organism in the course of his search behavior
will tend to select a satisfactory course of action, that is, the particular action selected will rarely be maximal.

Individuals will probably tend to select different criteria and have different perceptions relative to these criteria and the potential satisfactions available to reduce needs and drives. This differential selection of criteria will lead to differing selections of behavior in the organizational setting. In this manner one man in the organization may select a criterion of maximizing his likelihood of being selected for the presidency of a firm. A second may select as a criterion the minimization of being discharged. Much of administrative theory would suggest that the first man, indeed, would be likely to become president than the second, and the second would be far more likely to have a secure position in middle management. In terms of the satisficing assumption, the first man well might diminish his drive upon being selected vice president, (or better, the president of a smaller company) and the second, upon being given a "dead end" in the organization.

**Extended Deductions**

In this brief summary we have suggested that the individual is embedded within an organization system and that his behavior will be in part determined by his environment. In an individualistic sense, it will also be determined by his subjective selection of goals, his subjective selection of pathways to goals, his motivation, and the discounting program he utilizes to determine present expected value. He is also subject to errors in terms of incorrect estimates of the above. Individuals will tend to take a satisficing program rather than a maxi-
mizing program. They will tend to select different criteria and have different perceptions in reference to these criteria.

We would suggest that due to this set of behavior modes, the selection of different criteria, errors in the behavior choice system, and the satisficing program, that there will be a tendency on the part of the individual toward what Charles Hitch (McCloskey and Trefethen, 1954, pp. 168-186) has called suboptimization. Suboptimization is basically the selection of goals which are optimal for a subunit in the total organization as a whole. That is, the optimal scale of operations for a particular subsystem may not be the optimal scale for the organization as a whole. The organization goals and corresponding discounting programs are not congruent with individual goals and discounting; the individual's behavior will tend to be dysfunctional for the organization.

From the earlier frame of reference, (short run and long run rewards), the inference is drawn that the individual would tend to suboptimize because his perceptions are such that the short run rewards are greater than discounted future rewards. Suboptimization will probably be mediated by some exogenous variables. The research literature as summarized in the preceding chapter has suggested that some of these mediating variables are facility of communications between individuals of subunits, and the "severity of pathway." The latter refers to the severity of competitive conditions under which the individual may be operating; both in the market place for the organization as a whole and within and between the particular subunits as structured by higher management.

In this chapter an apology for the development of a theory of behavior in the business organization is given. In the development of
this theory, a set of organization and individual assumptions were listed. The organization assumptions being these:

1. Organization behavior is goal directed.
2. The primary organization goal is long run survival.
3. Organization behavior is some type of grouping of the subsystems of individual behavior.

And under the category of individual behavior, we have assumed that:

1. Human behavior is goal directed.
2. Operant behavior is a function of
   a. Subjective value of the goal.
   b. Subjective probability of obtaining the goal.
   c. Motivation.
3. Human behavior is adaptive.
4. Human behavior is satisficing.

These assumptions will embrace a substantial portion of behavior in the business organization, and deductions from them will be consistent and can be operationally tested. This chapter has been devoted primarily to a discussion of theory and theoretical aspects of behavior; the succeeding chapter will describe the experimental instrument used in the study.
CHAPTER III

THE INVESTIGATION MEDIUM

The range of experimental methodology has been discussed at length by Cohen and Nagel (1934). In current research on business and economic problems the controversy which has continued in psychology for many years regarding the "purity" or "control" associated with a particular experimental method is becoming an issue of some significance. It has only been in the last few years that applications of the laboratory experiment have been directly related to performance in economic enterprises. The results of research done in the psychological sciences have been adapted for business usage, particularly those of the small group or group interaction research, and they are appropriate for abstraction to the business enterprise. However, there is an overriding task environment operating in the normal economic organization which has not been inherent in most of the small group experiments. This work has certainly been useful; however, it needs to be strengthened with research into task performance under varying conditions in economic organizations.

Methods of Testing

The dimension of ultimate interest is the development of results to impute behavior modes to executives or middle managers, and therefore some method of controlling the variables and testing the effects of manipulating these variables must be devised. Fouraker and Siegel (1963) have, in this second book in their sequence of experiments on bargaining
behavior, discussed the problems associated with discriminating among economic theories by means of experimentation. Their interest is primarily focused on conflict as might appear in bilateral monopoly and oligopoly. This study is focused on inter-personal conflict within the firm, but under oligopolistic conditions. Thus the work that Fouraker and Siegel have done is related to the present study, insofar as both are experimental tests of economic and/or behavioral theories operating under analogous circumstance to the real world. They note that unique "laws" or "principles" have not evolved due to a lack of empirical uniformity. It is this lack that has led them to a group of research studies which are empirical, but related to behavior in the real world. The extremes of the empirical method for testing the variables range from manipulation in the real world to some form of laboratory research study.

Manipulation in the Real World

The ideal in experimentation would be to create an experimental circumstance within the environment of an existing and ongoing organization. However, one of the constraints of this particular method of research is the necessity of developing an experimental design which is amenable to repetition so that the results of a particular study can be cross-checked against variable experimental conditions and by other researchers. This constraint virtually precludes elaborate experimentation in the real world by the very nature of the environment. Repeatability of external conditions is, by definition, virtually impossible if for no other reason than that the participants would have been through the experiment and, therefore, would not be suitable subjects for repeti-
tion. This problem is handled by using large numbers of subjects in experimental situations, washing out deviations statistically and imputing the inferred behavior of the mean subject to actors in the real world.

At this end of the experimentation range we have the advantages of "reality" and of operating the experiment under the environmental conditions under which day-to-day behavior occurs. The disadvantage is the lack of control and repeatability. While ongoing research of this type is unquestionably useful, it is beyond the scope and interest of the present study.

Laboratory Research

Research within a laboratory situation has a substantial advantage in that the environmental conditions (presumably the relevant conditions) are amenable to experimental control. Rapoport (Haire, 1959) has listed some desired features or circumstances under which an organization system can be approached experimentally.

1. There should be a task whose performance can be evaluated in objective or quantitative terms.

2. Preferably there should be more than one criterion of evaluation.

3. Attempts to optimize performance on some criterion should conflict with attempts to optimize it on others.

4. There should be a division of labor among the members of the team confronted with the task.

5. The performance of the various sub-teams should depend on the performance of other sub-teams.

6. Communications should go on among the members of the sub-teams.

7. There should be criteria for evaluating the communication.
Virtually all of the above are present in the task utilized for the present experiment, and in general those which are not present are manipulated experimentally. Rapoport points out that the laboratory approach to the study of organization has much to offer, noting that laboratory behavior will cause or enable the researcher to begin to ask the right questions on a more conceptual level. This attitude toward laboratory research as "preliminary" reflects the viewpoint of the present study. This is to suggest that the present research is not intended to have a self-sustaining autonomy insofar as "meaning" is concerned. The research is aimed at understanding organization behavior and the development of predictive criteria.

Golembiewski (1962, p. 46) comments,

...given the assumption that it is possible to create laboratory replicas of group processes which are relevant in the empirical world, the usefulness of such experimentation is considerable.

He indicates in several places in his book on the small group the value of laboratory research in the understanding of interpersonal behavior.

For these reasons this study is what might be termed a semi-laboratory approach to the study of interpersonal behavior. The present experiment does not have the "richness" of experimentation or "action" research in the real world, nor does it have the "tune" controls which are available in a pure laboratory situation. However, some of the advantages of both approaches have been included.

Management Games as Research Tools

Spencer (1963), Cohen and Rhenman (1961) and Shubik (1960), among others, have discussed at length the use of management games as research
tools. Their conclusions are generally favorable insofar as the utility of this instrument is concerned. However, there are very few published reports of actual experiments which have been done with management games. The most notable to date is Hoggatt (1959). Some other work has been done, notably at Carnegie Institute of Technology, and the University of Pittsburg (see for example: Bass, (1964); Bass and Leavitt, (1963); Heskett, (1961); and Symonds, (1963). These works are, in general, small scale experiments bordering on the small group experiments. Cohen and Rhenman, (1961) provide a particularly good classification of the variables inherent in the use of the management game as a research instrument. Their orientation is toward a game which can be utilized for educational purposes as well as research purposes, and thus their classification suffers somewhat from an orientation towards teaching value.

Advantages and Disadvantages of Management Games as Research Instruments

Advantages

The primary advantages of the use of the management game as a research instrument lie with its intermediate position on the scale of research rigor. A game can be constructed so as to provide a very "rich" experimental environment. It can be designed to reflect economic and interpersonal relationships which have been abstracted from the real world. This lends a certain amount of validity (at least face validity) to the results of experimental runs with the simulation. On the other hand, while a simulation "looks like" the real world, it also "looks
like" many of the more rigorous experimental instruments which have been used in small group research.

"Games" of a wide variety of types and classifications are becoming more and more widely used. Rapoport and Orwant (1962) have reviewed much of the research done with "experimental" games, abstracted from the Theory of Games. Siegel and Fouraker (1960) have reported a series of experiments in bilateral monopoly. They have used a bidding situation which would fall into the "gaming" category, but is substantially different from the experiments reported by Rapoport and Orwant. Management games or decision simulations provide the opportunity to bridge the gap between the latter rigorous experimental work and behavior in the real world.

Disadvantages

In general the disadvantages in the use of games as research tools are reflections of the advantages. That is, there are certain advantages to abstracting a problem from the real world. The disadvantage is that you have abstracted from the real world and that the conclusions reached are only valid for your model and not necessarily for the real world. Thus for the advantage of manipulation and an increase in rigor the confidence in imputing the results of the experiment into behavior in the real world is decreased. There is also a disadvantage to "rich" environments. While we have moved away from the narrow research done with experimental games toward a position which reflects more "reality" we have also moved toward the reduction of purity or control inherent in the experimental design of these rigorous experiments.
Verisimilitude

A unique difficulty when dealing with a management game has been the problem associated with "reality" versus "appearance of reality." This problem appeared with the present instrument during a trial run. The parameters of the game had been set to represent "reasonable" costs and economic relationships. This approach was not successful, apparently due to the participants' inexperience with actual costs in an industrial situation. They tended to focus on large differences in absolute amounts rather than on controllable components of total cost. For example, the subjects were quite concerned with raw material and scheduled assembly costs (per unit), which were outside of their control while inventory carrying charges, setup charges, order costs, expediting cost, and stock-outs were individually such small percentages of total cost that while the students could control them, they treated them as insignificant.

In later runs the "controllable" component costs were amplified out of proportion to what one would expect to find in industry. This caused a problem with some of the more sophisticated participants; however, the relationships were usually accepted without question. To those students who did recognize the deviation from reality, it was indicated that relationships were amplified for instructional purposes. We emphasized to all students that they were practicing a method of analysis and that the particular relationships were not significant.

Validity of the Study

Some rationale for the validity of any research effort must be presented before the results can be imputed to prediction of behavior in
the real world. To briefly summarize we will argue that there are certain underlying behavior traits which are common to all problem solving or conflict situations. While these may not be surface variables they will certainly be relevant to behavior in a problem solving or conflict situation. If we can put the individual into a situation which he perceives as (a) problem solving and (b) conflict generating, we can observe his behavior and predict that his behavior mode if not actual behavior, will be similar in other problem solving and conflict situations.

The Consistency of Motive and Behavior Patterns in the General Population

If behavior patterns have any consistency across different types of tasks, the individual must have some "heuristics" or a general set of rules or guidelines for action implicit within his own behavioral system. As discussed above, it is difficult to obtain repetitive conditions in the real world. This can be done in a laboratory situation. We must, therefore, ask the individual questions or ask him to perform tasks in which he will use these heuristics.

The problem of simulation and behavioral research is to pose a set of questions which will force the subject to reach back and utilize a general purpose set of rules for performance or behavior (Figure 4). If we can elicit a response from the subject, based upon his set of heuristics, we may generalize that the individual will use these same rules in other task situations which may be of greater interest. The research task may be to determine at what depth to elicit a response. If the research task is too unfamiliar, the subject does not respond at the level desired; the rules he uses will be sufficiently general
Unknown response determinants
\( R_i \) where \( i = 1 \ldots m < n \)

Heuristics
\( H_j \) where \( j = 1 \ldots n < p \)

Developed Rules
\( R_k \) where \( k = 1 \ldots p < q \)

Behavior
\( B_L \) where \( L = 1 \ldots q \)

Number of rule categories at a given decision level

Figure 4: Extension Diagram of Underlying Heuristics in Behavior Patterns
that it will not be possible to impute behavior patterns. On the other hand, if the task is too familiar, generalizations are made from behavior patterns that are responses to a specific stimulus and not responses to a generic category of problems. Any generalizations made about the real world based upon such a model will be fallacious, (this would correspond to a Type II error). The scheme we have outlined below is a rationale for the "depth" we are attempting to probe in the present study.

**Goal directed behavior**

Reward, reinforcement seeking, or goal directed behavior is evident in virtually all types of organisms. Therefore, our preliminary deduction is that the individuals participating in the management game will somehow be behaving in a goal directed manner. The study of goal directed behavior per se has differentiated the quality of the goal and the value of the goal to the participant. This establishes the examination as directed toward a "neutral" mode of behavior. It is a study of generic behavior traits, without consideration of the "loadings" which may influence the dependent variables.

Insofar as a performance task is mediated by differing constraints, there should be differential behavior patterns. Task complexity as related to the real world should create performance differences. In general, performance will be motivated by the underlying force of the goal directed behavior, coupled with the additional constraints to provide direction. In this manner, we are building a structure to impute similar behavior patterns (from the research task) to task situations in the real world. We have assumed that the underlying force field which motivates activity will be universal across most types of rewarded or reinforced behavior.
Discounting and estimating

Estimation was discussed at some length in the preceding chapter. The distinctions were made between objective and subjective probabilities and objective and subjective values (utility). These traits should be universal in all situations; the solutions selected will be different dependent upon the absolute size of the reward. However, people will utilize some type of an estimating program to evaluate the goal and to evaluate the probabilities of obtaining the goal. These will be coupled to determine a course of action. The notion was examined that the individual will probably have some type of a discounting program which he uses as a heuristic system for computing the present value of future rewards. Variance is readily observable in the real world; that is, there are different discounting programs between differing people. A program of a particular individual is assumed to be at least internally consistent. The assumption includes as given the same perceived utility of a future event, when the future utility is discounted to present value and compared against the utility of an immediate event. The program will be consistent in that if \( U(A) = U(B) \), the discounted value of \( U(A) \) equals the discounted value of \( U(B) \).

Discount and estimation errors

Since our subjects and actors in the real world do not operate with the rigorous assumptions of "economic man" they will make both discounting and estimation errors. These errors will be of two types - systematic and random. The variance of a random error will undoubtedly vary from individual to individual; however, this is not the concern of this study, because the expected value of random error will sum to zero. However, the
direction of systematic error will be of interest when comparing behavioral patterns in a laboratory task situation and the real world. We do not feel that present theory or the state of the art is of sufficient sophistication to measure with adequate reliability the magnitude of systematic errors. However, we are assuming in the present study for validity purposes, that the direction of the error will be consistent across a variety of task situations. A particular subject's systematic error should be similar in the simulation and in task situations in real life.

Deductions relevant to the validity of the study

The first three conditions, that is, goal directed behavior, discounting and estimating, and the error conditions, lead to the extension that certain generic behavior patterns will be consistent over time. If there is a tendency toward suboptimization, away from group collaboration, in certain types of task situations, this tendency will probably be present in task situations in the real world. This suggests that an attitudinal approach to behavior should lead to the conclusion that behavior in reinforcement seeking task performance will be reasonably consistent insofar as direction, if not magnitude, is concerned. Behavior patterns will be similar in research environments and in the real world. If the individual tends to suboptimize in a simulation he will tend to suboptimize in the real world.

Isolation of Behavior Types

We have, for the purpose of this study, classified behavior patterns in this task situation as falling into two groups - those that do
suboptimize and those who do not. Some distinction should be made relative to these behavior patterns insofar as potential results are concerned. The simple dichotomous classification is inadequate to embrace all possible behavior modes. It is necessary to differentiate between intended and accidental success or failure. Some verifying measure across the subjects is needed so that there is some indication that if they suboptimized they were in fact trying to suboptimize. This type of behavior may be difficult to identify, as individuals may not admit to conscious suboptimization. The construct, "Stability," may offer a possibility for the identification of a behavioral tendency toward the value of long run rewards. The variance of the participants' decisions, when coupled with their success, may offer a measurement methodology for the identification of intentional suboptimizing behavior. The interest in describing the personality types via the personality variables is to develop a "cluster" which can be described as suboptimizing behavior. In the real world, this would lead an executive, when faced with this behavior syndrome, to spend additional funds or energy on coordination to reduce the tendency toward suboptimization.

Relevant Dimensions of the Particular Game Used as a Research Instrument

The Interaction Simulation, a management game, developed by the author and briefly described elsewhere (Keenan, 1964a); is presented in some detail in Appendix I.

There are some specific features of the instrument that are particularly relevant to this study that will be outlined here.
Dependent variables

There is in theory only one dependent variable in the simulation ultimately - accumulated profit within a particular firm. However, so that interdependence could be studied with the instrument, variables were included to measure individual performance as well.

They are represented in the output format received by the subjects as average unit cost of marketing (over time) and average unit cost of production (over time). These variables are an "efficiency" measure for the individual. To the degree that subjects are able to control these variables there is a rough measure of a combination of ability and a tendency to focus upon individual reward measures rather than a joint measure of performance such as accumulated profit. These unit cost variables are subject to direct control by the individual. Present is only a minor amount of "punishment" that one actor can inflict upon a second if the second chooses not to cooperate. Thus the individuals have direct control over their own performance measures (unit cost) and have only indirect influence over the dependent variable of accumulated profit. They must cooperate with one another in order to maximize the group dependent variable. There are, therefore, some of the conditions for suboptimization discussed above.

Interdependence Effects

As Maffei (1958) has suggested, the cost of suboptimization to the firm will be inversely proportional to the independence of the subunits. If the subunits are well insulated from one another there should be no problems of cost of suboptimization.
To demonstrate or study the effects of suboptimization there must be some "linkage" or interdependence measure built into the simulation. This has been done through the mechanism of stockouts. These are described to the marketing manager as sales lost due to inefficiencies in the system. Hypothetically speaking, a potential customer has come into a store, placed an order, has not been serviced adequately, and has cancelled the order. Stockouts are significant to the marketing manager's individual performance, in that his costs are "sunk costs" at the time they are computed, and his efficiency measure (unit cost) will increase as sales are lost.

The parameters affecting stockouts within the game are focused on the finished product inventory. Stockouts do not cost the production manager anything but are "charged" to the marketing manager. On the other hand, increases in finished product inventory are not charged to the marketing manager, only the production manager. From an individual viewpoint, the production manager would prefer to lower finished product inventories (lowering his unit production cost) and the marketing manager would like to lower stockouts, thereby lowering his unit marketing cost. The marketing manager would like to have the production manager carry large finished product inventories. From the point of view of the firm there must be a balance between these two positions. There is again an inventory model (Figure 5) with one dimension an increasing cost of stockouts and the other an increasing inventory holding cost. The firm would like to minimize the sum of these two costs. A production and a marketing manager may in some way "control" their own efficiency measures. However, they must cooperate to maximize on the dimension which is
Figure 5: An "Inventory Model" for Minimization of Stockout and Inventory Holding Costs
<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperate (Hold Marketing Effort)</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>-</td>
</tr>
<tr>
<td>Compete (Jump Marketing Effort)</td>
<td>-</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td>j</td>
<td>k</td>
<td>l</td>
</tr>
</tbody>
</table>

Subject to:

\[
\begin{align*}
& a > b > c > d > e > f \\
& g > h > i > j > k > l \\
& g > a \\
& h > b \\
& i > c \\
& j > d \\
& k > e \\
& i > f
\end{align*}
\]

Figure 6: Payoff Table for the 6 x 2 Prisoners' Dilemma Game in the Interaction Simulation
relevant to the firm as a whole. This provides necessary but not sufficient conditions for suboptimization in the simulation.

Relation to the Prisoner's Dilemma game

The simulation was constructed to model the Prisoner's Dilemma Game from formal game theory. However, a great deal more complexity is built into the simulation, and the analogue is of sufficient complexity to warrant careful examination when extending the results of the more rigorous research studies. There are actually two "games" built into the simulation - the game external to the firm and the game internal to the firm.

The game external to the firm, the industry game, could be represented as a six-person, two-strategy, cooperative, non-zero sum game. The precise definitions of a game of this type are not clear from the literature; however, the representation maintains those relationships necessary to define a two-person, two-strategy, Prisoner's Dilemma Game and are probably sufficient to describe a six-person game.

The industry game is represented in Figure 6, as a payoff table. The table indicates the relative payoff to those firms cooperating and those firms competing. For instance, if four firms cooperated (maintained a stable marketing effort) and two firms competed (increased their marketing effort one way or the other), those four firms that cooperated would get payoff c and those two firms that competed would get payoff h. As may be seen from the restrictions, h must be larger than c, \( h > b > c \), thus the payoff will always be favorable to the player who defects, in the short run. This will not be true in the long run, due to punishment effects available to the other players.
Subject to:

1. \( c > a > d > b \)
   \( c' > a' > d' > b' \)

2. \( a > \frac{nc + mb}{n + m} \)
   \( a' > \frac{nc' + mb'}{n + m} \)

\( n, m = 1, 2, \ldots \) (Lave, 1962)

Figure 7: Prisoners' Dilemma Game Between Subjects
The second Prisoner's Dilemma Game (Figure 7) built into the simulation appears as the connecting device between the partners, as described above. Thus we have built the simulation around a 6 x 2 game (industry) which has imbedded within its structure, (in each series of payoff cells) a 2 x 2 game (firm) to determine the ultimate allocation of the market.

\footnote{The second constraint given in Figure 7 needs some explanation. This is to assure that the joint payoff of any mixed strategy employed at random by the partners in the long run will not average to greater than the collaborating strategy.}
CHAPTER IV

RESEARCH DESIGN AND PROCEDURES

Design of Study

This experiment was designed to determine if the variables discussed above create conditions under which individuals suboptimize or adopt individual goals rather than group goals. The study utilizes a specifically devised management game which allows for the simultaneous manipulation of two experimental controls. The simulation was designed to provide performance measures both for a dyad (partners) and for the individuals as they might act in their own belief.

Information as to aggregate performance over time was automatically collected while the game was conducted so that accumulated performance measures would be available at the end of the experiment. As the interest centers around the simultaneous investigation of two different factors, and the inclusion of potential interaction effects may be of relevance, a simple $2^2$ factorial design was selected.

Factorial Experiments

One of the major advantages of factorial experimentation is the ability to determine statistically the independence of the variables manipulated. In the present experiment there would seem to be "face validity" to the conjecture that the variables would in fact be dependent or interrelated. The design should, in the statistical analysis, indicate the degree of potential interrelation.
The condition selected, a $2^2$ factorial design, will permit an estimation of the simple effects, the main effects, and the interaction effects of two variables. The main effect of the manipulation of a variable is the average of the simple effects where the simple effect is the result of holding one variable constant and manipulating the second. The main effect then is the mean of the simple effects, an estimate whose variance provides, in a sense, a combined estimate of experimental error and the independence of the factors (Cochran and Cox, 1957, p. 148-153).

The $2^2$ Factorial Design

The two main variables manipulated within this experiment were: competitive sensitivity (severity of exogenous conditions), and ease of communication and coordination. Based upon prior theoretical and experimental work, the design was intended to demonstrate that subjects operating within the verisimilitude provided by a management game would tend to suboptimize when conditions were favorable.

Variable I - Competitive Sensitivity

If the management game was to be analogous to the two-person Prisoner's Dilemma Game (internal to a firm), it was necessary to provide an interaction feature between the partners. The individual performance of one should be inversely proportional to the performance of the other, insofar as some minor effect was concerned.

Accordingly, a feature of sales losses due to inventory stockouts was introduced. The number of stockouts in a period was computed as a function of the average inventory level for the period. As the individual
performance measure for the production manager included a carrying charge for inventory, it was to his advantage, as an individual, to maintain a relatively low average inventory. On the other hand, as the production manager reduced his inventory, he simultaneously increased losses to the firm due to the inability of the marketing manager to supply demand at specific points of time during the period.

The stockout variable was, in this sense, an index of the interaction between partners. It also controlled for the effectiveness of the marketing manager; the parameter value selected for "brand loyalty" was 60 percent. Given a set of customers whose requirements were not fulfilled, 60 percent of them would return in the subsequent period to the same firm. The other 40 percent was divided among the other five firms, based upon share of the market.

The manipulation of this variable for the experimental design consisted in the modification of another parameter which might be termed "product loyalty" as contrasted with "firm loyalty." If the demand was not supplied, this parameter set the degree to which customers would shift away from the entire industry (in economic terms, product substitution.)

The industries were broken into two groups, those with sensitivity and those without sensitivity to substitution. In the latter group there was no loss to the industry based upon stockouts; that is, demand was completely inelastic to supply (over time). Once the demand for a given quantity had been created, it remained until fulfilled.

The second condition, sensitivity, was created by setting a parameter so that 16 percent of the customers whose demand has not been met...
would shift their requirements to another industry. That is, 16 percent of the stockouts were lost to the industry forever. While this method is not the most realistic way of handling stockouts, it appeared to be satisfactory insofar as the subjects' understanding of the concept, producing the desired effect and retaining computational simplicity.

In the design of the game marketing costs were "sunk" insofar as stockouts are concerned. Therefore, the loss to a firm, per unit of stockout appeared to be the price for the period minus the unit cost for production. This averaged around $60. With a fairly continuous stockout level of around 500 units, the "opportunity loss" averaged about $30,000, and the loss due to sensitivity—that is, the manipulation of the sensitivity parameter—was about $5,000, a small proportion of expected profit or loss for the period. The attempt was to create an image of substantial losses while keeping actual losses low.

The danger associated with this minor difference between the two experimental conditions was that the intra-group variance would mask any inter-group variance. However, it was desired to manipulate one of the two experimental variables without the knowledge of the participants. For this reason, the difference was kept slight so that there would not be readily apparent differences between industries on this dimension.

**Variable II - Communication-Coordination**

Many of the experiments with the Prisoner's Dilemma Game have indicated that different results are obtained if the subjects are allowed to communicate and that some of the variance may be attributed to the structure of the communications allowed. In many industrial firms it
would appear that ease of coordination is substantially different; that is, in some firms there are deliberate, coordinating meetings between marketing and production while others do not have regular meetings. Physical location is another coordination dimension; managers may be separated by hundreds of miles, and the majority of coordinating and communicating efforts are formal in nature. These conditions were simulated by physically separating the marketing and production managers for half the industries.

Subjects

The students participating in the experiment (sophomores and juniors in a Principles of Management course at Western Michigan University) were assigned to two classes, meeting twice weekly on Tuesdays and Thursdays. Class One met from 8:15 to 9:30 a.m. and Class Two, from 10:15 to 11:30 a.m.

The people assigned to the two classes were randomized as nearly as possible within scheduling constraints, and any students who were not selected at random were excluded from consideration in the results. Half the students, in both the early and the late class, were sitting beside their partners during the decision-making time. (The forms from the preceding period were returned to them; they made their decision for the next period.) The other half of the students were separated from their partners by virtue of the fact that they were in the other class.

For those firms which operated under the difficult coordination system, the marketing managers were all selected from the 8:15 class and the production managers were from the 10:15 class. This deviation from random selection was done as a marketing-production sequence (produce to
a generated demand) is not equivalent to a production-marketing sequence (generate demand for products already assembled) in real life. If appeared necessary, therefore, to have the marketing decision made first.

Other than the constraint of time, every effort was made to facilitate coordination between marketing and production. The 45 minutes between the end of the first class and the start of the second class were free for all students and the two managers were told that they were free to communicate; inconvenience, not deprivation, was intended.

Within the classroom the marketing manager for a given firm would be sitting in the same relative position as the production manager in the next class. That is, for Firm 1, Industry 10, the marketing manager might be sitting in chair 25; the production manager for the same firm would be sitting in chair 25 at the later time.

The observable communications between the marketing manager and the production manager tended to be notes left on the chair. There were some notable deviations from this, and some partners met almost daily throughout the experimental run. The subjects were given the addresses and telephone numbers for their partners. All partners could be reached via telephone fairly conveniently. An outline of the design can be seen in Figure 8.

Reward Structure

A reasonable reward system which would allow for both perceived group goals and perceived individual goals was difficult to devise. The system finally utilized (it had been tested in a pilot run) was to rank the performance measures within an industry and give "grade points" on the basis of position in the industry.
Notes: Subscript "2" basically indicates a replication. The A and B blocks are independent 6-firm industries. The C and D blocks are stratified at random into two groups. Performance measures are in ranks across all 48 firms.

All marketing managers for blocks C and D will be from 8 a.m. class. All production managers for blocks C and D will be from 10 a.m. class. This deviation from random selection is done because the decision process for a marketing-production sequence is not equivalent to the process of a production-marketing sequence.

The period from 9:30 to approximately 10:05 will be free time for all subjects and the two managers may communicate. That is, complete deprivation is not intended; simply inconvenience.

Figure 8. The $2^2$ Factorial Design
The subjects were given points either for their firm's profit position or for their individual performance measure. This device allowed the individuals to select group-oriented or self-oriented behavior.

The "points" assigned were sufficient to change a marginal grade to the next higher grade. Sixteen students (total of 105) raised their grade with points from the game. Points were awarded on end-point values (actually after 23 periods of play).

**Description of the Data**

The input and output variables for the subjects, the decisions and the dependent variables based upon those decisions are shown in Figure 9, a replication of an output form. The decisions made by the marketing manager were advertising, sales promotion expenses, price, and whether or not to order a market report; the decisions by the production manager were quantity of finished product and raw material and the number of setups and orders.

The set of decisions for an industry were submitted to the computer for evaluation under the model presented in Appendix I. This form was the computer output.

The composite dependent variable was the "income or loss," stated in two forms both for the period and accumulated to date. The dependent variables for individual performance were "average unit cost for marketing" and "average unit cost for production" as aggregates. Cost per unit sold or produced were for a particular period. The remaining variables were components and printed out as commonly given accounting information for decision making.
INDUSTRY+10 COMPANY+6 PERIOD+18.

PROFIT

LAST PERIOD INCOME OR LOSS -70941.
INDUSTRY RANK, LAST PERIOD +4
ACCUMULATED INCOME OR LOSS -300569.
INDUSTRY RANK, PROFIT TO DATE +2

MARKETING REPORT

NET SALES, LAST PERIOD +1594979.
NUMBER OF UNITS SOLD +13403.
SHARE OF THE MARKET +.16
COST OF MARKETING, LAST PERIOD +975000.
MARKETING COST PER UNIT SOLD +72.74
MARKETING-AVERAGE UNIT COST +60.51
RANK, MARKETING EFFICIENCY +3
STOCKOUT, LAST PERIOD +656.

PRODUCTION REPORT

PRODUCTION COST LAST PERIOD +690921.

COMPONENT COSTS
INVENTORY HOLDING +33516.
SET UP AND ORDER +16500.
RAW MATERIALS +259648.
EXPEDITE RAW MATERIALS +83553.
ASSEMBLY-FINISHED PRODUCT +220000.
OVERTIME-FINISHED PRODUCT +77702.

RAW MATERIAL PRICE +3.37
PRODUCTION COST PER UNIT +50.84
PRODUCTION-AVERAGE UNIT COST +49.45
RANK, COST PER UNIT +5

ENDING INVENTORY
FINISHED PRODUCT +656.
RAW MATERIAL +.

COMPANY +1 +4 PRICE +120. +125.
+2 +5 +140. +115.
+3 +6 +115. +119.

LAST PERIOD DECISIONS
ADVERTISING EXPENDITURES +350000.
SALES PROMOTION EXPENSES +350000.
MARKET REPORT +.
FINISHED PRODUCT +11000.
NUMBER OF SETUPS +3.
RAW MATERIAL +77000.
NUMBER OF ORDERS +3.

Figure 9. Output Form for Management Game
Thus, we have indices of efficiency for marketing and production in terms of cost per unit (conventionally used measures by industry) and an index for the firm in terms of accumulated profits. There are "intermediate" indices such as net sales in dollars and units, share of market, and so forth. These data, presented in Figure 9, represent either dollars, numbers of units, or their relative ranks within the industry for the individual firms. A more complete description of the instrument is given in Appendix I.

Measurement Considerations

These data have been collected and reported to the subjects on an interval measurement scale with the exception of the feedback of rank within the industry on some of the variables. The consideration of these data as measured on an interval scale and the corresponding use of the more powerful statistics available may lead to unwarranted conclusions about the significance of the results.

The sample size varies substantially depending upon the particular analysis on the data; it may range from 6 to 960. Especially with the larger sample size, it will be very difficult to differentiate significant correlation from spurious correlation, and the expectation would be that the within group variance would be so high as to mask the between group variance. Any analysis of the data as a whole—that is, with a sample size of 960 (48 firms over 20 periods)—should lead to highly significant, although relatively low, correlations. However, the variance of the variables will probably be so high as to make accurate prediction unrealistic.
In general, nonparametric statistics will be used in the analysis of the data as related to the operational hypotheses. These distribution-free statistics approximate 90 to 95 percent power efficiency and allow the researcher to avoid making unrealistic assumptions. Insofar as continuation of the research and generation of new hypotheses, the experimenter may utilize more powerful measures without sharply impairing his extension. In this manner, some additional analysis with parametric statistics will be performed on these data.

Methods of Analysis

As discussed in the preceding section, the majority of the statistics used will be nonparametric. Siegel (1956) provides a satisfactory presentation of the tools available in this area. His book will be used as the major reference for purposes of analysis.

The structure of the management game would allow these data to be viewed as related samples. We could view subjects within firms as matched with a corresponding subject in another firm and/or industry. However, the samples will be viewed as independent as there did not seem to be any way, a priori, to determine if there were unknown variables relevant to performance. This problem may be resolved for future research with this instrument.

Perhaps matched pairs could be generated by the use of Discriminant Analysis (Hoel, 1962). Some use of Discriminant Analysis will be made in this study, especially in generating hypotheses for future research.
Nonparametric Measures Utilized

**Main effects**

With the large number of variables inherent in the design of a management game, it is desirable to examine the differences between the groups due to specific main effects rather than use only analysis of variance to determine the total differences. If differences exist between subgroups on any of the relevant variables, it will be useful to recognize the degree of significance shown by the differences.

The main tests to be used for these effects are the Mann-Whitney U Test and the Kolmogorov-Smirnov 2-Sample Test (Siegel, 1956). The Mann-Whitney U Test allows measurement on an ordinal scale and is analogous to the parametric t test. The power efficiency approaches 95.5 percent as N increases and is close to 95 percent even for moderate size samples. Siegel points out that the test is an excellent alternative to the t test since it does not require the same assumptions about the universe and parameters (Siegel, 1956, p. 127).

He indicates (p. 157) that both of these tests are sensitive to differences in location (central tendency) and suggests the use of the Mann-Whitney U with larger samples, pointing out that the Kolmogorov-Smirnov Test is preferable when the samples are small. The Kolmogorov-Smirnov Test, which is slightly more efficient than the U Test on small samples, will be used to determine significant differences between either small groups or particular industries. Siegel indicates (p. 157) that this test is the most powerful of all nonparametric tests for any kind of difference.
**Interaction effects**

To determine the significance of the interaction effects, the Kruskal-Wallis One-way Analysis of Variance (by ranks) will be utilized (Siegel, 1956, p. 184). The major difference between this test and the standard F test is the use of the rank order of the observations rather than the raw scores. Compared with the F test, the Kruskal-Wallis test has a power efficiency of approximately 95 percent (Siegel, 1956, p. 193). For the above tests there are other alternatives; for example, the Median test. However, those selected use more information by ranking the data rather than dichotomizing it at the mean or median. Kruskal and Wallis (1952) have discussed their test at some length.

**Suboptimization effects**

It is desirable to determine the degree to which managers tended to focus on individual scores in the different experimental blocks and across the major experimental variables. This may be done with the nonparametric test, the Spearman Rank Correlation Coefficient. With the use of this test, a negative correlation between the ranks of production and marketing managers on their individual indices of efficiency should be an indication of tendencies to suboptimize.

This expectation is in contrast with a similar correlation to the profit of the firm in which the expectation would be a negative correlation for production cost and a positive correlation for marketing cost (under the design of the model with the parameter values used.)

**Confidence Level**

The same confidence level will probably not be appropriate for all the measures taken on these data as the large sample size in some cases
will almost inevitably lead to a significant value with the variance remaining so high as to mask any useful differences or predictions. Therefore, in the case of large samples—for example, difference between mean effects when the entire run is utilized—the 1 percent level will be required. With the smaller groups the 5 percent level will be used.

The major test utilized, Kruskal-Wallis Analysis of Variance, has a power efficiency of 95 percent without the limiting assumption of the parametric test. It may be used with \( n \) at least 5; \( (n = 12 \) for this experiment in the small sample cases). The 5 percent level of confidence appears to be adequate insofar as a conservative position is concerned, while retaining the feasibility of identification of significant results.

**Sampling Distribution**

The sampling distribution used for most of the test statistics will be the \( \chi^2 \) distribution. The normal distribution and the \( t \) distribution will be utilized for the parametric measures used. Other distributions will be specified as appropriate.

**Operational Statement of Hypotheses**

The hypotheses presented in this section will be related item by item to the generic hypotheses stated in Chapter I. The first operational statement related to Hypothesis A will be designated Hypothesis A1, the second Hypothesis A2, and so forth. The notation of the \( 2^2 \) factorial design (Figure 8, p. 80) will be utilized. The block of subjects, together, which have no sensitivity to competitive pressures will be designated as Group A. The complete designation is given in Figure 10. The variable numbers will be numbered as referenced in Appendix II.
<table>
<thead>
<tr>
<th>Block Number</th>
<th>Experimental Condition</th>
<th>Industry Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity</td>
<td>Communication</td>
</tr>
<tr>
<td>A</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>B</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>C</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>D</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Figure 10. Designation of Experimental Blocks by Industry

The generic hypotheses may be grouped into three logical sections; (1) those related to measures of performance for the dyad together, i.e. accumulated profit, (2) those related to performance of an individual, i.e. unit cost figures and (3) those related to all the decisions grouped together for purposes of a discriminant analysis. This technique will be used to determine if the subjects in the experimental groups can be differentiated. The first group of hypotheses, those related to profit are outlined below.

Generic Hypothesis A

Profits should be greater for firms operating under less severe competitive conditions.

Operational Hypothesis A1:

"Accumulated Income" at Period 20 is significantly greater for Industries 10, 20, 30, 40 than Industries 60, 70, 80, 90.

Null Hypothesis:

\( H_0: \) Group 1 (A + C) and Group 2 (B + D) have the same distribution on variable X9 after Period 20.

\( H_1: \) After Period 20: \( X_{91} > X_{92} \)
**Statistical test:**

Mann-Whitney U Test

**Sampling distribution:**

Normal for \( n_2 > .20 \); \( z \) scores are determined (Siegel, 1956, p. 121)

**Significance level:**

\( \alpha = .05, n_1 = n_2 = 24 \)

**Rejection region:**

\( H_1 \) predicts the direction of difference and the region of rejection is one-tailed.

\( z \leq 1.65 \) for \( p \leq .05 \)

**Comment:**

The Mann-Whitney U is utilized as it is desired to test for a difference in location with a large sample. Figure 8, p. 80 outlines the design; A, B, C, and D are the block designators. Appendix II includes the variable names from the output form. See Appendix III for formula.

**Generic Hypothesis B**

Profits should be greater for firms with higher order coordination systems.

**Operational Hypothesis B1:**

"Accumulated Income" at Period 20 is significantly greater for Industries 10, 30, 60, 80 than Industries 20, 40, 70, 90.

**Null Hypothesis:**

\( H_0: \) Group 1 (A + B) and Group 2 (C + D) have the same distribution on variable X9 after Period 20.

\( H_1: \) After period 20: \( X_{91} > X_{92} \)

**Statistical test:**

Mann-Whitney U Test

**Sampling distribution**

Normal for \( n_2 > 20 \)
Significance level:

\[ \alpha = .05, n_1 = n_2 = 24 \]

Rejection region:

\[ H_1 \text{ predicts the direction of difference and the region of rejection is one-tailed.} \]
\[ z \geq 1.65 \text{ for } p \leq .05 \]

Generic Hypothesis C

Profits should be lower for firms subject to both severe competitive conditions and lower order coordination than firms subject to only one condition.

Operational Hypotheses C1-C5:

"Accumulated Income" at Period 20 is significantly greater for Industries 10, 30 than 20, 40 or 60, 80 which should be greater than 70, 90.

Null Hypothesis:

\[ H_0: \text{ Blocks A, B, C, D have the same distribution on variable X9 after Period 20.} \]
\[ H_1: \text{ After Period 20: C1: } X_{9A} > X_{9B} \]
\[ C2: X_{9A} > X_{9C} \]
\[ C3: X_{9B} > X_{9D} \]
\[ C4: X_{9C} > X_{9D} \]
\[ C5: X_{9A} > X_{9D} \]

Statistical test:

Kolmogorov-Smirnov Two Sample Test

Sampling distribution:

Distribution of maximum deviation between two cumulative step functions; Table L (Siegel, 1956, p. 278).

Significance level:

\[ \alpha = .05, n_1 = n_2 = N = 12 \]
Rejection region:
\[ K_D \geq 6, \text{ one-tailed test} \]

Comment:
Selected rather than Mann-Whitney U as \( n_1 = n_2 < 20 \); see Appendix III for formula.

**Operational Hypothesis C6:**
Accumulated income is significantly different for the four experi-
groups.

Null Hypothesis:
\[ H_0: \text{ Blocks A, B, C, D have the same distribution on variable } X9 \text{ after Period 20.} \]
\[ H_1: \text{ After Period 20 the 4 groups are not the same on variable } X9 \]
\[ X9_A \neq X9_B \neq X9_C \neq X9_D \]

Statistical test:
Kruskal-Wallis One-way Analysis of Variance, (Siegel, 1956, p. 185).

Sampling distribution:
\[ H \text{ approximately distributed as } \chi^2 \text{ where } df = k-1 \]

Significance level:
\[ \alpha = .05, df = 3 \]

Rejection region:
\[ H \geq 7.82 \]

The hypotheses related to measures of individual performance are out-
lined in the following three sections.

**Generic Hypothesis D**
Individual performance measures in firms subject to one or both experi-
mental conditions should be extreme.
Operational Hypotheses D1-D3:

Average unit cost for marketing is negatively correlated with average unit cost for production for Groups B, C, D.

Null Hypothesis:

$H_0$: The variables X26 and X29 are unrelated in the populations of Groups B, C, D.

$H_1$: After Period 20:

D1: $r_s (X_{26}, X_{29})$ Group B is significant and negative

D2: $r_s (X_{26}, X_{29})$ Group C is significant and negative

D3: $r_s (X_{26}, X_{29})$ Group D is significant and negative

Statistical test:

Spearman Rank Correlation Coefficient ($r_s$)

Sampling distribution:

For $N \geq 10$ use Student's with $t$, $df = N-2$

Significance level:

$\alpha = .05$, $N = 12$

Rejection region:

$t \geq 1.812$, one-tailed test

Comment:

See Appendix III for formulae.

Operational Hypothesis D4:

Average unit cost for marketing is positively correlated with average unit cost for production for Group A.

Null Hypothesis:

$H_0$: The variables X26 and X29 are unrelated in the population of Group A.

$H_1$: After Period 20: $r_s (X_{26}, X_{29})$ for Group A is significant and positive.
Statistical test:

Spearman Rank Correlation Coefficient

Sampling distribution:

For $N > 10$ use Student's $t$, $df = N - 2$

Significance level:

$\alpha = .05$, $N = 12$

Rejection region:

$t \geq 1.812$, one-tailed test

Operational Hypotheses D5-D6:

For firms above the median in profit the correlation between average unit cost for marketing and average unit cost for production should be positive; for those below the median in profit the correlation should be negative.

Null Hypothesis:

$H_0$: The variables $X_{26}$ and $X_{29}$ are unrelated in the populations divided by median profit.

$H_1$: After period 20:  

D5: $r_s (X_{26}, X_{29})$ Group above median profit is significant and positive  

D6: $r_s (X_{26}, X_{29})$ Group below median profit is significant and negative

Statistical test:

Spearman Rank Correlation Coefficient ($r_s$)

Sampling distribution:

For $N \geq 10$ use Student's $t$, $df = N - 2$

Significance level:

$\alpha = .05$, $N = 24$

Rejection region:

$t \geq 1.717$, one-tailed test
Operational Hypotheses D7-D8:

Individual performance is significantly different for the 4 experimental groups.

Null Hypothesis:

\[ H_0: \text{Blocks A, B, C, D have the same distribution on variables X26, X29 after Period 20} \]
\[ H_1: \text{After Period 20: D7: } X26_A \neq X26_B \neq X26_C \neq X26_D \]
\[ \text{D8: } X29_A \neq X29_B \neq X29_C \neq X29_D \]

Statistical test:

Kruskal-Wallis One-way Analysis of Variance (Siegel, 1956, p. 185-193)

Sampling distribution:

\[ H \text{ approximately distributed as } \chi^2 \text{ where } df = k-1 \]

Significance level:

\[ \alpha = .05, df = 3 \]

Rejection region:

\[ H \geq 7.82 \]

Generic Hypothesis E

Subjects will attend to measures of individual performance under more severe competitive conditions.

Operational Hypotheses E1-E2:

Measures of individual performance at Period 20 should be significantly lower for Industries 10, 20, 30, 40 than 60, 70, 80, 90.

Null Hypothesis:

\[ H_0: \text{Group 1 (A + C) and Group 2 (B + D) have the same distribution on variable X26 and X29 after Period 20} \]
\[ H_1: \text{After Period 20: E1: } X26_1 < X26_2 \]
\[ \text{E2: } X29_1 < X29_2 \]
Statistical test:

Mann-Whitney U Test

Sampling distribution:

Normal

Significance level:

\( \alpha = .05, N = 24 \)

Rejection region:

\( z \geq 1.65 \)

Generic Hypothesis F

Subjects will attend to measures of individual performance with lower order coordination systems.

Operational Hypotheses F1-F2:

Measures of individual performance at Period 20 should be significantly lower for Industries 10, 30, 60, 80 than 20, 40, 70, 90.

Null Hypothesis:

\( H_0: \) Group 1 \((A + B)\) and Group 2 \((C + D)\) have the same distribution on variables \(X_{26}\) and \(X_{29}\) after Period 20.

\( H_1: \) After Period 20: F1: \(X_{26_1} < X_{26_2}\)

\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ F2: \ X_{29_1} < X_{29_2}\)

Statistical test:

Mann-Whitney U Test

Sampling distribution:

Normal

Significance level:

\( \alpha = .05, N = 24 \)

Rejection region:

\( z \geq 1.65 \)
Operational Hypotheses F3-F12:

Measures of individual performance at Period 20 should be lower for Industries 10, 30, than 20, 40, 60, 80 which should be less than 70, 90.

Null Hypothesis:

H₀: Blocks A, B, C, D have the same distribution on variables X26, X29 after Period 20

H₁: After Period 20:  
F3: X₂₆ₐ < X₂₆₃ₐ
F4: X₂₆ₐ < X₂₆₃₉
F5: X₂₆₃₈ < X₂₆₃₉
F6: X₂₆₃₈ < X₂₆₃₉
F7: X₂₆₃₈ < X₂₆₃₉
F8: X₂₉ₐ < X₂₉₃ₐ
F9: X₂₉ₐ < X₂₉₃₉
F10: X₂₉₃₈ < X₂₉₃₉
F11: X₂₉₃₈ < X₂₉₃₉
F12: X₂₉₃₈ < X₂₉₃₉

Statistical test:

Kolmogorov-Smirnov Two-sample Test

Sampling distribution:

Table L (Siegel, 1956, p. 278)

Significance level:

α = .05, N = 12

Rejection region:

Kₖ ≥ 6, one-tailed test

The hypotheses related to discrimination into groups are outlined in the following two sections.
Generic Hypothesis G

The decision behavior will be different for those individuals who have a comparatively poor historical performance than those with good historical performance.

Operational Hypothesis G1:

The decision variables should discriminate between two groups divided at the median on profit on the basis of variance.

Null Hypothesis:

\[ H_0: \text{Values of decision variables (variables X1-X7, X21-X22) are from the same distribution for Group 1 (profit above the median) and Group 2 (profit below the median)} \]

\[ H_1: \text{The two groups can be discriminated on the basis of these 8 (see comment) decision variables} \]

Statistical test:

Discriminant Analysis, Mahalanobis \( D^2 \) converted to \( F \) ratio or \( \chi^2 \)

Sampling distribution:

\( F \) or \( \chi^2 \)

Significance level:

\( \alpha = .01 \)

Rejection region:

\( F(8,478) \geq 2.54 \)

\( \chi^2 \geq 20.09, \text{df} = 8 \)

Comment:

Variables X21-X22 can be utilized together to account for the variance due to price or can be used to transgenerate a new variable equal to price for a period by \( \frac{X21}{X22} \).

There does not seem to be a convenient non-parametric equivalent for Discriminant Analysis; however, Mahalanobis' \( D^2 \) is generalized (BIMED, 04, 1961) to \( \chi^2 \).

The 1 percent level is used due to the more powerful statistic and the increased sample size.
Generic Hypothesis H

The decision behavior will be different for those individuals (and firms) operating under one or both experimental conditions.

Operational Hypothesis H₁:

The decision variables should discriminate between the 4 experimental groups.

Null Hypothesis:

- \( H_0 \): Values of decision variables (variables X₁-X₇, X₂₁-X₂₂) are from the same population for the 4 experimental groups.
- \( H_1 \): The 4 groups can be discriminated on the basis of the 8 decision variables

Statistical test:

Discriminant Analysis, Mahalanobis D² converted to \( \chi^2 \)

Sampling distribution:

\( \chi^2 \)

Significance level:

\( \alpha = .01 \)

Rejection region:

\( \chi^2 \geq 20.09, \text{ df } = 8 \)

Assumptions and Limitations of the Experimental Design

The assumptions relevant to the behavior of individuals and organizations were discussed in Chapter II. This section will include some structural assumptions and limitations related to the specific research design.
Management Games

The use of a business game in behavioral research raises most of the issues of laboratory research in additional to the unknown effects of a set of complex interaction phenomena which cannot be replicated in a rigorous manner.

The game used was devised to present subjects with a set of complex stimuli, which would appear to possess parameters similar to those in real world activities. It is assumed that these stimuli, as input parameters to a problem-solving situation, were perceived as similar (in the mathematical sense) to the problems faced in the real world.

Any simulation or laboratory device suffers from the inherent difficulty some subjects have in understanding how to respond. This problem may be particularly troublesome in games of the competitive type. Subjects seem to react, intellectually, to a perceived, deterministic model, e.g., "I lowered my price----why didn't sales go up?" The explanation, "The average price went down a larger percentage," seemed too abstract for some to comprehend fully. Conceptual problems with the instrument should be uniform across the experimental blocks and therefore appear as a constant in the statistical manipulation. If there is any substantive effect, the significance of particular result will be lowered; however, the direction will remain the same.

As the game provides a "rich" experimental environment, the results will be difficult to replicate. An inherent limitation is the bridge from results derived in the playing of a game to the real world. In a rigorous sense, results are valid only for the model.
Subjects

College students, like rats, are comparatively inexpensive experimental animals. Parsimony dictates the necessity of reducing the set of all feasible areas of research to a manageable subset of projects which show promise. The use of students helps to accomplish this result. The general assumption (previously discussed) is that there are needs, drives, etc., that motivate people to respond in particular ways to reinforcement or reward. If these needs can be aroused, and/or reinforced, some conclusions about human behavior can be tentatively projected. In this study, it is assumed that modes of problem analysis and solution are similar in both adults and college students and that any particular method of attack, as a reaction to an environment, is relatively stable over time. That is, even with different problems, reaction to frustration and/or stress will be reasonably uniform, person by person. This postulate rests upon a thesis of personality stability. While some personality traits modify over time, it is assumed that the dominating characteristics relevant to problem-solving remain stable.

The heterogeneity of individuals remains a limitation which can only be partially alleviated by random selection. There was no effective way to match pairs within or between industries, and the effects due to experimental manipulation may be dominated by personality, intelligence, education or other factors.

Statistical Manipulation

The experimental ideal, a design which requires no statistical analysis, is virtually impossible to realize with human subjects. This
study suffers (as well as gains) from a rich environmental setting. Any predictions from derived results are only as strong as the typical assumptions underlying all statistical inference. Insofar as possible, distribution-free measures have been utilized.

If the assumptions of an interval scale of measurement have been met (an event which would seem to have a very low probability), it is possible that a significant effect will be discarded. However, the cost of this error is probably much lower than rejecting a null hypothesis which is in fact true. We have tried to design the study so to err on the conservation side wherever possible.

The data matrix from the game output will be discussed in the succeeding chapter. Specific results will then be considered.
CHAPTER V

PRESENTATION AND ANALYSIS OF THE DATA

In this Chapter, the data gathered in the first experimental run (fall semester of 1963) of the management game devised by the author will be presented in summarized form preparatory to the subsequent analysis. The participant in the management game had a set of independent variables (decisions) which he controlled in a state-to-state sequence over a "collapsed" time period representing some longer time period in the real world.

A single set of decisions was recorded and fed into the computer to interact with the competitors' decisions and the mathematical model. The dependent variables (calculated results of the interaction within the computer) were then returned to the individual participant. Some of the dependent variables were accumulated across the experimental run to provide a summarization of each subject's activity. These accumulated figures were relatively insensitive to point-in-time errors in clerical recording or "bad" decisions.

The Independent Variables

The marketing manager made decisions as to amounts of money to allocate for advertising and sales promotion. He set a price for the succeeding period and decided whether to purchase marketing information.

The production manager made two categories of decisions, (1) those related to production level and (2) "balancing" factors in the production process. The quantity of finished product to assemble and the quantity of raw materials to order determined the production level. The number of
setups for production of finished product and the number of orders of raw materials over the next decision period were the balancing decisions. The means and standard deviations of the decisions for all 20 periods are given by industry in Table 1.

Marketing Decisions

Of the decisions made by the marketing manager, only the request for information did not interact with the decisions of the other firms to determine share of the market. There was a constant charge for the purchase of the market report which was then delivered to the subject one period earlier than normal return (at no charge.) The information contained on the market report gave generally available figures as to estimates of marketing expenditures by competitors. These figures probably can be found in trade magazines or estimated. The charge for the market report was for time; that is, the information was received at an earlier period.

Of the remaining three decisions, all contributed to the determination of the share of the market controlled by the firm. Only one, price, had any effect on the total demand for the industry (industry equations are shown in Appendix I.

An expected demand was computed for a particular period. This equation had a long run linear rise, a sine function representing yearly sales cycle, and an additional sine function to generate "noise."

Expected industry sales for the decision period were then modified by the division of the average industry price into a parameter. The results were multiplied by expected sales. If the average industry price
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<table>
<thead>
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<th>Units finished product</th>
<th>Units raw materials</th>
<th>Number setups</th>
<th>Number orders</th>
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<td>μ σ</td>
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Table I. Summary of Marketing and Production Decisions by Industry
was above the "standard," expected sales for that period were reduced. This introduced an effect of point elasticity.

Share of the market for a firm was computed by comparing the decisions made by the marketing managers in the entire industry. In general, this was done by comparing the $i$-th firm with the industry total or average. For example, the percentage (for a single firm) of the industry total for sales promotion expenses was computed and adjusted by a sensitivity parameter. This factor was multiplied by similar factors computed for advertising effect (this included a "lag" brought forward from the preceding decision period) and price. A composite figure was derived for each firm, totaled and a percentage was computed firm by firm to determine share of the market.

One of the basic tasks of the marketing manager was to determine if the information returned by the market report was of sufficient value to warrant the cost. This information could have been used to estimate the parametric equations in the game model and the parameter values. In addition, he should predict future actions of his competitors. As discussed above, the effect within an industry was similar to that of a six-person Prisoner's Dilemma Game.

Production Decisions

The decisions required by the production manager were a good deal more amenable to calculation than those made by the marketing manager. These decisions fell into two categories, level of production (aggregate) and balancing of production and purchasing.

In the determination of level of production for the succeeding period, he accepted an estimate of future sales from the sales manager
(or made a private adjustment), coupled this with existing inventories to balance overtime cost versus inventory carrying costs.

The number of units of raw material in the production of the product was constant and the decision as to quantity of raw material was similar to the production decision, with differing cost factors and a cycling raw material price. Ideally, the decisions should have been influenced slightly by the expected movement of the price of raw materials.

The determination of the number of setups and orders was standard economic lot size problem under demand uncertainty. The students did not possess the sophistication to use EOQ formulas; however, most adopted some simple heuristic scheme which approximated an EOQ theory. The use of an appropriate model would have decreased unit cost for production substantially. If this usage was not a function of the experimental conditions, the results would be unchanged.

**The Dependent Variables**

The variables on the output form, with the exception of the recorded decisions, were "dependent." However, some were composites or accumulations, either within the period or across the entire experimental run. Production cost for the period was the sum of the component production costs. The average unit cost figures were accumulated over all prior decision periods.

**Accumulated Profit**

This variable (X9) was a cumulative distribution of period-by-period profit. Values from the preceding period were carried over into the computer model with a set of output cards. This provided continuity for
an industry by carrying forward inventory balances, cumulated profit figures, and average unit costs.

In classical economic theory, accumulated profit is the variable an entrepreneur is attempting to maximize. The accumulated profit figures (Table 2) are largely negative; only five firms out of the forty-eight remained "in the black" over the twenty decision periods. This is surprising considering that the parameters were set to provide substantial "slack."

This unusually poor performance seems to be attributable to the effect of the Prisoner's Dilemma Game built into the design. A defecting strategy by any competitor in the six-firm industry seems to have initiated an oscillation and escalation of marketing expenditures which were dysfunctional for the oligopoly market. A perfect collusive strategy on the part of the six firms would have been to eliminate advertising and sales promotion expenses. There were no indications that attempts at collusion were successful for more than a period or two.

Two different industries reported overt attempts at collusion which could not be held. The industries may have stabilized more effectively if mergers had been allowed. Unfortunately, it was necessary to keep all the people in the game for the entire period. If bankruptcies or withdrawal from the market had been allowed, movements toward industry stability might have been facilitated.

Average Unit Cost

Average cost figures were computed for both marketing and production to provide a measure of individual performance.
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Table 2. Accumulated Data on the Dependent Variables
Marketing

The average unit cost figures for marketing (and production) are given in Table 2. This statistic was computed by dividing all units sold over the 20 periods into the total cost of marketing for 20 periods. Period by period this figure gave the participant a smoothed average to estimate his costs for pricing purposes.

Production

The average unit cost for production was computed by dividing the summation of all units produced (both scheduled and overtime) into the total production cost across the 20 periods. This provided a measure of efficiency for the production manager and a cost figure for pricing decisions by the marketing manager.

Discrimination on Decisions

Hoel (1962) discusses the problem of discriminating between two groups of individuals on the bases of more than a single variable. If scores overlap between two groups, it may not be feasible to discriminate on the basis of a single variable; however, it may be possible to derive a linear combination of a set of variables from which scores may be computed with little overlap between two groups. This equation (a linear discriminant function) will develop a type of index number for which the researcher can determine a critical value to separate members into two groups.

If the groups are different, it is possible to make this discrimination with a high percentage of success. This function can be used to classify future observation into proper groups, or for testing the hypothesis that two groups differ on the basis of a set of variables.
Kendall (1957) discusses the extension of this analysis to more than two groups. One additional difficulty is added; it is necessary to divide the sample space into more than two mutually exclusive regions. With more than two groups, the boundaries must be determined either with several functions or with a single function at the risk of reducing the power of the statistic. Kendall discusses (pp. 158-159) the significance of the function, pointing out that there are three possibilities:

1. There is a real difference between groups but they are so close that the discriminant function is not effective,

2. There is a real difference between populations but sample sizes not large enough, or

3. The function is incorrect.

Discriminant analysis has been used in this study to estimate the probability that groups are different.

The Data Pertinent to the Hypotheses

Other than Hypotheses G and H, the data utilized are given in Table 2, the accumulated profit and cost figures. The Industry, Company, Accumulated Profit and Unit Costs, are shown with their respective rank order. The statistics utilized for Hypotheses A through F used rank order to determine differences either in location or dispersion.

Analysis of the Data

In Appendix III, the formulae used for the statistical tests are listed. The hypotheses will be discussed in order and the results of the statistical test on each hypotheses given. The critical figures for statistical significance may be found in Table 3, and the statistical
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Table 3. Critical Figures for Statistical Significance
results are summarized in Table 4. The hypotheses may be grouped as in
the previous chapter for clarity of exposition. The next three sections
are those hypotheses related to group performance.

Hypothesis A1

Profit should be greater for firms operating under less severe
competitive conditions.

Statistical test:

Mann-Whitney U Test.

Computational result:

The sum of the ranks (R1) for the experimental groups (B + D) is
equal to 501. By the computational formula given in Appendix III, z = 1.79.

Significance:

The critical figure for the 5 percent level of confidence for a
z score in the Mann-Whitney U with these degrees of freedom is 1.65. This
figure is significant at the 5 percent level; however, the hypothesis is
one-tailed in the other direction.

Discussion:

This result is one of the most interesting of the study. The dif-
ference between the two experimental conditions was not great; the first
group was absorbing an expected loss of approximately $4,000 a period or
$80,000 over the twenty decision periods. (Price less production cost
times units sold times expected stockout loss to industry). This result
was computed without adjusting for this loss; if the statistic had been
significant in the other direction, it would have been necessary to
modify the raw scores before reaching any conclusions relative to per-
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\textsuperscript{a} Mann-Whitney  
\textsuperscript{b} Kolomogorov-Smirnov  
\textsuperscript{c} Spearman Rank Correlation Coefficent  
\textsuperscript{d} Discriminant Analysis  
\textsuperscript{e} Significant in wrong direction  
\textsuperscript{f} Significant at 1 percent level of confidence  
\textsuperscript{g} Significant at 5 percent level of confidence

Table 4. Compilation of all Significant Values by Hypothesis
formance. However, the group operating under more severe competitive conditions performed significantly better than the group under the "loose" conditions, even without the adjustment.

While it is difficult to infer specific behavior patterns from this result, the conditions are certainly sufficient to suggest an hypothesis for future studies relative to optimal competitive conditions as related to individual performance.

Perhaps performance under competitive conditions is analogous to human performance under frustration or anxiety. With these variables both too little and too much are dysfunctional, leading to a parabolic type of function which can be optimized.

Hypothesis B

Profit should be greater for firms with higher order coordination systems.

Statistical test:

Mann-Whitney U Test.

Computational result:

The sum of the ranks for the experimental groups \( (A + B) \) was equal to 562. By the formula in Appendix III, \( z = 0.54 \).

Significance:

As the critical score is 1.65 for the 5 percent level of confidence with the given degrees of freedom, the null hypothesis (the groups have the same distribution on the profit variable) must be accepted.

Discussion:

There is no reason to reject the null hypothesis on this dimension. Apparently, one of two conditions can prevail; either the coordination-
communication variables are not relevant to performance under these experimental conditions or there are variables, not included in the experimental design, which "mask" the effect of the given experimental condition.

Hypotheses C1 - C5

"Accumulated Income" at period 20 is significantly greater for industries 10, 30 than 20, 40 or 60, 80 which should be greater than 70, 90.

Statistical test:

Kolmogorov-Smirnov Two Sample Test.

Computational result:

By the formula in Appendix III, $\chi^2$ is a function of the maximum difference in the cumulative distributions between the two groups.

Hypothesis C1: $D = \frac{3}{12}$, and $\chi^2 = 1.5$
Hypothesis C2: $D = \frac{5}{12}$, and $\chi^2 = 4.166$
Hypothesis C3: $D = \frac{2}{12}$, and $\chi^2 = 0.667$
Hypothesis C4: $D = \frac{6}{12}$, and $\chi^2 = 6.0$
Hypothesis C5: $D = \frac{3}{12}$, and $\chi^2 = 1.5$

Significance:

This test has a sampling distribution approximated by the $\chi^2$ distribution with df = 2. Where df = 2, the $\chi^2$ value of 4.60 is significant at the 10 percent level and a value of 5.99 is significant to the 5 percent level.

In this series of tests, only Hypothesis C4 is significant at the 5 percent level with a $\chi^2$ value equal to 6. From the frame of reference
of the analysis of variance model, apparently the communications-coordination dimension is only relevant when the firms are operating under severe competitive conditions.

The null hypothesis may be rejected (with some qualification) for the experimental conditions under severe competitive operations with the addition of a coordination difficulty. Apparently the severity of competition variable was sufficiently strong to mask the main and interaction effects of the communication variable.

Hypothesis C6

Accumulated income is significantly different for the four experimental groups.

Statistical test:

Kruskal-Wallis One-Way Analysis of Variance.

Computational result:

By the formula in Appendix III, we are interested in \( R_j \), the sum of the ranks in the \( j \)-th sample divided by the sample size. The sum of the ranks for each of the experimental groups are given in Table 5.

<table>
<thead>
<tr>
<th>Block</th>
<th>Profit</th>
<th>Production</th>
<th>Marketing</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(10,30)</td>
<td>312</td>
<td>282</td>
<td>306</td>
</tr>
<tr>
<td>B(60,80)</td>
<td>250</td>
<td>343</td>
<td>296</td>
</tr>
<tr>
<td>C(20,40)</td>
<td>363</td>
<td>326</td>
<td>343</td>
</tr>
<tr>
<td>D(70,90)</td>
<td>251</td>
<td>215</td>
<td>234</td>
</tr>
</tbody>
</table>

Table 5. Sum of the Ranks of all Groups

For Hypothesis C6, \( H = 3.77 \) with df = 3. This is not sufficient to reject the null hypothesis.
**Discussion:**

The experimental groups, while significant in some cases on a one-to-one comparison, are not sufficiently divergent to reject the null hypothesis when the analysis includes all groups. This lends evidence to the conjecture that the experimental variables were not of sufficient strength or influence to adequately differentiate sub-groups.

The following three sections are discussions of those hypotheses related to individual performance.

**Hypotheses D1 - D3**

Average unit cost for marketing is negatively correlated with average unit cost for production for groups B, C, D.

**Statistical test:**

Spearman Rank Correlation Coefficient.

**Computational result:**

The results of the computations from the simplified formula in Appendix III, are given below.

Hypothesis D1: \( r_s = 0.3146 \) and \( t = 1.0476 \).

Hypothesis D2: \( r_s = 0.1679 \) and \( t = 0.5390 \).

Hypothesis D3: \( r_s = 0.1119 \) and \( t = 0.3560 \).

**Significance:**

The critical value for \( t \) at the 5 percent level of confidence is 1.812 with \( df = 10 \). None of the results approach this level of significance and we accept the null hypothesis that these variables are unrelated in the populations of groups B, C, and D.
Discussion:

Based upon this statistical test, there is no evidence to indicate that extreme performance or decisions based upon self-interest were sufficient to dominate the decisions or results of the subject's partner. There appear to be at least two alternatives. The first is the null hypothesis, individuals do not interact at a level to force poor performance on the part of another person involved in the same task environment. The second alternative is that the interaction sensitivity built into the game is inadequate to differentiate the hypothesized performance.

During the administration of the game, there were several discussions between the instructor and the participants who indicated that they were attempting to suboptimize, but without sufficient sophistication to do so effectively. Before further conclusions could be drawn on this dimension, it would be necessary to repeat the experiment with increased sensitivity to interdependence between partners. It was shown in some of game theory experiments discussed above that differences in payoff matrices did in fact affect performance of the participants.

Hypothesis D4

Average cost per unit for marketing is positively correlated with the average unit cost for production for Group A.

Statistical test:

Spearman Rank Correlation Coefficient.

Computational result:

\[ r_s = 0.7308 \text{ and } t = 3.391. \]
Significance:

The critical value for t at the 1 percent level of confidence is equal to 2.764. The result on this test is significant to the one-half of 1 percent level.

Discussion:

Group A, not operating under any of the disadvantageous experimental conditions, was expected to perform with a minimum of disharmony between partners. The lack of internal pressure between the two participants within a particular firm was expected to create conditions under which the individual performance measures would be approximately in balance in the industry. The result was anticipated to be independent of the profit position of the firm or industry (considered across all industries). The null hypothesis can be rejected, and the alternative hypothesis accepted based upon the results of the statistical test.

In looking at the composition of the industries in this experimental block, it may be seen that the expected effect took place in marketing and production unit costs for both industries while they were substantially different on the profit figures. The "best" firm in industry 30 was only slightly better than the worst firm in industry 10 and a substantial distance behind the next-to-last firm in industry 10. The internal composition within an experimental block, the differences between industries 10 and 30 in this case, will be discussed in the following chapter. The within group variance seems to have been very large, perhaps sufficient to mask the between-group variance.
Hypotheses D5 - D6

For firms above the median in profit the correlation between average unit cost for marketing and average unit cost for production should be positive; for those below the median in profit the correlation should be negative.

**Statistical test:**

Spearman Rank Correlation Coefficient.

**Computational result:**

Hypothesis D5: \( r_s = 0.5687 \) and \( t = 3.242 \) with \( df = 22 \).

Hypothesis D6: \( r_s = 0.0548 \) and \( t = 0.2570 \) with \( df = 22 \).

**Significance:**

With 22 degrees of freedom, the critical value of \( t \) at the 1 percent level of confidence is 2.508. The value obtained for Hypothesis D5 is significant at the .005 level. The result on Hypothesis D6 is not significant and we cannot reject the null hypothesis.

**Discussion:**

Upon examination of the data pertinent to Hypothesis D5; it would appear that there are other conclusions which might be drawn from the results obtained. Caution should be exercised to avoid the possibility of a "Type III error" (asking the wrong question). The alternative hypothesis may be accepted but at least one other interpretation seems to be reasonable.

For those firms above the median in profit, marketing costs are substantially higher than for firms below the median in profit. For firms that are high in marketing costs, the absolute level of sales should increase and the standard deviations of the decision variables for pro-
duction managers should be correspondingly higher. The increase in the variation of units sold will make production scheduling more difficult, leading to increased inventory carrying costs or increased overtime. These are the "controllable" costs and therefore average unit cost is sensitive to fluctuations in these variables. This conjecture would suggest that the management game, as devised, may be sensitive to the decisions of the marketing manager and relatively insensitive to the decisions of the production manager. For this reason, it seems appropriate to maintain some reservations relative to accepting the alternative hypothesis as stated.

This question could be resolved with a computer simulation of the decisions of the participants, designed to determine sensitivity parameters in the model.

Hypotheses D7 - D8

Individual performance is significantly different for the four experimental groups.

**Statistical test:**

Kruskal-Wallis One-Way Analysis of Variance.

**Computational result:**

Hypothesis D7: $H = 2.6$ with df = 3.

Hypothesis D8: $H = 1.67$ with df = 3.

**Significance:**

As the critical value for $H = 7.82$, we accept the null hypothesis that these blocks have the same distribution on the two variables after period 20.
Discussion:

The interesting implications of the results on these two hypotheses are the relatively low values of $H$. The tests used above were nonparametric equivalents of testing the significance between means of two groups, whereas this test is examining the variance between groups for four experimental blocks.

The significant results on some hypotheses previously tested between individual groups would seem to imply that there should be a significant difference in this test for all the experimental blocks. This apparently inconsistent result could happen when a single block is in fact different from all other experimental blocks which were drawn from the same population. A second possibility is that the individual experimental blocks tested were from the extremes of the population universe and would appear different when in fact both came from the same universe. The results obtained above would seem to indicate that the within group variance was very large in this experiment; that individual blocks may be different from the group as a whole, and that the analysis of variance design was not sensitive to the between-group variance.

Hypotheses E1 - E2

Measures of individual performance at Period 20 should be significantly lower for industries 10, 20, 30, 40 than 60, 70, 80, 90.

Statistical test:

Mann-Whitney U Test.

Computational result:

Hypothesis E1: $R_1 (B + D) = 527$ and $z = 1.257$ (Marketing)

Hypothesis E2: $R_1 (B + D) = 558$ and $z = 0.619$ (Production)
Significance:

The critical value for \( z \) at the 5 percent level is equal to 1.65. Neither value is sufficient for rejection and we cannot reject the null hypothesis that the distribution are the same on these two variables.

Discussion:

See this section following Hypotheses F1 and F2.

Hypotheses F1 - F2

Measures of individual performance in Period 20 should be significantly lower for industries 10, 30, 60, 80 than 20, 40, 70, 90.

Statistical test:

Mann-Whitney U Test.

Computational result:

Hypothesis F1: \( R_1 \ (C + D) = 577 \) and \( z = 0.227 \) (Marketing)

Hypothesis F2: \( R_1 \ (C + D) = 541 \) and \( z = 0.969 \) (Production)

Significance:

As the critical score for \( z = 1.65 \) to reject at the 5 percent level, we cannot reject the null hypothesis that these groups have the same distribution on these variables.

Discussion:

Hypotheses E1, E2, F1, and F2 were designed to indicate the extent to which individual managers tend to suboptimize, based upon the main effects of the experimental blocks. These tests indicate that the main effects, if existent, are not of sufficient strength to differentiate between groups, and we conclude that there is no difference, or that the instrument is insensitive to the discrimination of this difference.
Hypotheses F3 - F12

Measures of individual performance at Period 20 should be lower for industries 10, 30 than 20, 40, 60, 80 which should be less than 70, 90.

**Statistical test:**

Kolmogorov-Smirnov Two Sample Test.

**Computational result:**

Hypotheses F3 - F7 are on Variable X26, Marketing Average Unit Cost and Hypotheses F8 - F12 are on Variable X29, Production Average Unit Cost.

Hypothesis F3: \[ K_D = 5, D = 5/12, \chi^2 = 4.166. \]

Hypothesis F4: \[ K_D = 3, D = 3/12, \chi^2 = 1.50. \]

Hypothesis F5: \[ K_D = 5, D = 5/12, \chi^2 = 4.166. \]

Hypothesis F6: \[ K_D = 6, D = 6/12, \chi^2 = 6.00. \]

Hypothesis F7: \[ K_D = 4, D = 4/12, \chi^2 = 2.667. \]

Hypothesis F8: \[ K_D = 3, D = 3/12, \chi^2 = 1.5. \]

Hypothesis F9: \[ K_D = 3, D = 3/12, \chi^2 = 1.50. \]

Hypothesis F10: \[ K_D = 6, D = 6/12, \chi^2 = 6.0 \]

Hypothesis F11: \[ K_D = 6, D = 6/12, \chi^2 = 6.0. \]

Hypothesis F12: \[ K_D = 3, D = 3/12, \chi^2 = 1.50. \]

**Significance:**

The critical value for these hypotheses with df = 2 are \( K_D = 6 \) and \( \chi^2 = 5.99 \). These values are met by Hypotheses F6, F10, and F11. On the remaining hypotheses in this section we cannot reject the null hypotheses that the distributions are the same on the variables.

**Discussion:**

Hypothesis F6: This hypothesis is concerned with the marketing variable between Block C and Block D. Both groups are operating under
severe competitive conditions, with the participants in Block C in
communication and those in Block D separated. Apparently the communica-
tion variable operated with sufficient strength when the industries were
subjected to the increased competitive pressures; average marketing costs
were held down in Block C, and under the "sensitive-autonomous" conditions
they were not.

The original hypothesis suggested that actions of the production
manager would force the marketing costs up; however, as discussed above,
the possibility remains that it is the autonomy of an aggressive profit
seeking marketing manager. Hypothesis F10 and F11: The alternative
hypotheses may both be accepted at the 5 percent level. When compared
with Hypothesis F6, the question arises as to whether these hypotheses are
mutually exclusive. Marketing costs (under F6) may have been sufficiently
high to allow greater variance in production quantities demanded, increas-
ing the average unit cost of production to a sufficient degree to dif-
ferentiate from Blocks B and C. The alternative hypotheses should be
accepted only with reservation.

The following two sections contain the discussion related to the
hypotheses on the discrimination between groups.

Hypothesis G1

The decision variable should discriminate between two groups divided
at the median on profit on the basis of location and dispersion (variance).

**Statistical test:**

Discriminant analysis.
Computational result:

The discriminant function coefficients may be seen in Table 6 for both hypotheses G1 and H1. The statistical result was: \( F = 20.607 \) with \( df = (9,950.) \)

Significance:

The critical value assigned was 2.54 for rejection at the 1 percent level of confidence. The result is highly significant. We reject the null hypothesis and accept the alternative hypothesis that the two groups can be discriminated on the basis of decision variables.

Discussion:

The linear discriminant function derived gives a considerably better than chance method of allocating individuals to proper groups. An analysis of the overlap, about one-third between the two groups, may indicate relevant variables to improve the discrimination.

Hypothesis H

The decision variable should discriminate between the four experimental groups.

Statistical test:

Discriminant analysis (four groups).

Computational result:

The computer listed the degrees of freedom as the number of variables times the number of groups minus one (27). The more conservative position of seven degrees of freedom has been listed for the rejection region. The \( \chi^2 \) value for this test equals 157.32. The discriminant functions can be seen in Appendix IV.
Coefficients for X1 - X7, X21 - X22

Hypothesis G1: Coefficient Variable

40235069. X1
64273887. X2
901.78358 X3
1903700.8 X4
73625.831 X5
24915479. X6
1118.1704 X7
61372738. X21
383767.12 X22

Hypothesis H1:

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Table 6. Discriminant Functions for Hypotheses G1 and H1
Significance:

The critical value for the rejection region at the significance level of .01 was \( \chi^2 = 20.09 \). The result is highly significant; we reject the null hypothesis and accept the alternative hypothesis that the four groups can be discriminated on the basis of the decision variables.

Discussion:

The linear discriminant functions will select more than 50 percent of the members in each group, rather than the expected 25 percent under a rectangular distribution. Random selection for the remainder will increase the correct selection by about 17 percent. The correct predictions, group by group, ought to approximate 67 percent as contrasted with an expected 25 percent. The item by item analysis for composition of errors should improve this result.

Significant Results

The discussion of results will be divided into two segments; where nonparametric statistics were utilized and where discriminant analysis was utilized.

Results with Nonparametric Statistics

When those results with statistical significance are abstracted a significant pattern begins to emerge. On two of the hypotheses, Hypothesis A1 and Hypothesis C4, the results were significant on a one-tailed test but in the wrong direction. On Hypothesis A, profit was expected to be greater for groups (A + C) than for groups (B + D), and on C4, profit was expected to be greater for group C than for group D. Groups C and D appear in both of these results.
On Hypotheses F6, F10, and F11, the results are significant on a one-tailed test. The direction is consistent with that designated in the original hypotheses. Group D appears in all three of these hypotheses and Group C in two of them. The inference which remains is that the performance in experimental groups C and D dominated the remaining groups.

Groups C and D were operating under the severe competitive conditions with Group C being in communication and Group D not being in communication. These statistics support the hypothesis that communication and coordination are sensitive under conditions of competitive severity while performance is not sensitive when the severity of competitive conditions is low.

The remaining two hypotheses which are significant are D4 and D5. The former is relevant to the production and marketing costs in Group A. This is the only place among the significant results where Group A appears (assuming its presence in Hypothesis A to be incidental). Apparently conditions were sufficiently loose to permit behavior differences but not force them.

Under Hypothesis D5, those firms above the median in profit apparently coordinated their activities sufficiently to be sensitive to the correct balance needed between production and marketing costs.

Results with discriminant analysis

Hypotheses G and H were included as parametric controls to the analysis of variance and to determine if the experimental groups could be discriminated on the basis of their period to period behavior. Both were highly significant and between the two discriminant functions derived it would be relatively easy to separate these subjects into their power groups.
Limitation of Results

After the completion of the experiment, some additional limitations to the significance of the results can be seen. In the experimental design a number of things were done which seem to have raised within-group variance. One of the dominating factors appears to have been the division of the subjects into smaller subsets due to the design of the game.

In the four experimental groups there were a total of 96 subjects. These subjects were divided, half marketing managers and half production managers. They were then divided into eight industries, leaving subsets of six.

Two industries were put into each experimental block, with the assumption that this effectively increased the sample size to 12 (marketing and production separately). In retrospect, this does not appear to be a valid assumption. In experimental Block A the performance of Industries 10 and 30 were very different from one another (by the parametric t test, highly significant). While this block is the extreme, the within-group variance was very high and in effect the sample size in a particular block may have been only two (the number of separate industries).

The effective unit that should have been studies may have been the industry rather than the firm or the individual. This probable deficiency in design could be corrected with a larger computer by expanding the number of firms per industry to 12. All firms within an experimental block would have been operating within the same industry and subjected to the same environmental conditions.

With this design two deviant marketing managers, one "high" and one "low," could increase the within-group variance sufficiently to mask any
potential effect of the experimental variables. After the fact, this appears to be the greatest limitation to the study as performed.

As cross check against the common assumption that the experimental groups are equivalent, a discriminant analysis based upon personality variables obtained with the Edwards Personal Preference Scale was performed. When a two-group analysis was performed, groups (A + C) against groups (B + D) and groups (A + B) against groups (C + D) the significance level was at about the 7 percent level that the groups were in face different. When a four-group analysis was done on the 16 variables a $\chi^2$ value of 55.27, was obtained. This should happen by chance is less than 1/10th of 1 percent of the time. Thus a very specific assumption, generally made in studies with behavioral variables, is probably incorrect. With these considerations, caution should be used in extending the results. The analysis suggests the possibility of placement of subjects in the experimental design rather than by random draw.

Interpretation of Results

The predominant result in this experiment seems to be either that performance was better under the more severe competitive conditions or a function of some unknown variable. Those industries which suffered an ongoing stockout loss consistently performed in a superior manner to those operating with more slack in the competitive conditions.

The manipulation of the communication variable seemed to produce a significant effect only when the competitive conditions were severe. Apparently the environmental constraint was the controlling variable. The additional constraint of communication difficulty appeared to act
under a multiplier effect and was significant only when coupled with the severe competitive conditions. This more or less fits the concept of "organizational slack" under standard industrial conditions, and suggests that the sophistication of management control necessary for operations is inversely proportional to the severity of current market conditions. That is, a monopolist operates with more "organizational slack" than an ologopolist or a competitor and the latter conditions require greater management control than the former.

The performance of those industries in experimental Block C is unusual considering the severe hazards under which they operated. Their accumulated profit is significantly above that of the other industries. In both marketing and production the experimental conditions seemed to "sharpen" the acuity of analysis by these subjects.

As discussed above, the within-group variance appears to have been sufficiently high that any interpretation of the results must be with qualifications. On the other hand, for some of the experimental hypotheses to be substantiated suggests that these variables must strongly effect performance to survive the tendency of the within-group variance to mask the effects of between group variance.

Discriminant Analysis

The discriminant analysis was added to the preliminary design as a cross check against the nonparametric statistical results and to examine the potential this technique seemed to have for behavioral research. The results of this analysis indicate that the groups are substantially different. The highly significant results obtained with discriminant
analysis (on the decision variables) seems to indicate that the dependent variables are insufficiently sensitive to adequately discriminate between experimental groups or individuals. This conjecture led to additional analyses which are discussed in the succeeding chapter as extensions to the experimental results.

The linear discriminant functions derived by this analysis suggest potential weightings by composition of the decision variables. As may be seen by the discriminant function coefficients derived by the two-group test, the values of the decision variables are divided by fairly large numbers (from 1,000 to 100 million). This difference is the weighting on Variables X3 and X1. As Variable X3 is two-state (0 and 1), this weighting will adjust the term in the discriminant function approximately .0005, whereas 100 million divided into the average values on Variable X1 will adjust the values into the range of .003. The weighting will be approximately 10 to 1 in favor of Variable 1. This considers only the powers of 10; incorporating the absolute value of the coefficient would reduce the weighting down to about 5 to 1 for Variable 1 against Variable 3.
CHAPTER VI

EXTENSIONS AND MODELS FOR FUTURE RESEARCH

A number of additional statistical tests were performed on the data gathered in this study with standard computer programs out of the BIMD series. The analysis reported in this chapter was done to suggest extensions and for the generation of hypotheses for future studies.

Extended Analysis of the Data

In this section the additional analyses which have been performed will be presented and discussed. For this portion of the report the additional variables, "manifest needs," as measured by the Edwards Personal Preferences Schedule are included.

This test, an economical objective examination, provides a quick measure of fifteen relatively independent normal personality variables and a profile stability index. There are well-established norms for college students as the test was developed primarily for use as a research instrument to differentiate subjects. Validity is not a relevant consideration as the test is designed to be used primarily for sorting purposes.

The scales appear to measure cultural responses rather than actual personality dimensions. For example, the heterosexuality scale probably measures a response to imputed group values rather than any glandular need.

Standard Statistical Measures

The descriptive statistics discussed in this section were obtained by the use of the BIMD program BMD X13. This program computes sums, means,
cross product deviations, standard deviations, variance-covariance matrix, and the correlation matrix. In Table 7, the means and standard deviations for 40 variables (see Appendix II) are given.

These figures result from grouping all subjects without consideration of the experimental conditions. The mean of a variable is computed in the three dimensional data matrix by a double summation on the variable across all individuals and across the 20 decision periods (sample size of 960). With any sample this large there inevitably is a large number of significant correlations; therefore, no specific conclusions can be drawn from these data. The statistics computed on the subsets appear in Table 1.

**Firms split at median profit**

The concern here is specifically with the decision variables. (The personality scores are discussed under the section on discriminant analysis). The major differences of significance are in the marketing area; the similarities in the production area are quite striking. The marketing managers, above the median in profit, spend almost $40,000 a period more on advertising and $35,000 a period more on sales promotion, with corresponding differences in average price of 112.3 for those above the median to 104.6 for those below the median.

The marketing managers above the median ordered the market report approximately 51 percent of the time compared to 29 percent for those below the median. When this variable was added to the game and the parameter set at $5,000, it was assumed that almost everyone would order the market report as the charge was such a small percentage of total costs. It is surprising that few people sought this information. The difference in
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Table 7. Means and Standard Deviations for Personality and Decision Variables
orientation between the two groups toward the game may be reflected on this variable.

The difference in sales between the two groups was about 730 units per period. This would account for about $37,000 a period in opportunity losses as marketing costs are "sunk." The average loss, period by period, was above $78,000 for all firms together, so the opportunity losses were a significant amount.

The production decisions reflect the approximate difference in sales level between the two groups. The number of setups is very slightly different on the average (.11) and the mean number of orders is identical between the two groups; the difference between setups and orders is negligible (.32). Apparently the production managers did not develop much sophistication in the determination of economic lot sizes. They seem to be focusing on controllable numbers (order quantities) rather than controllable costs.

Firms split on sensitivity

The average loss for Industries 10, 20, 30, and 40 was approximately $94,000 in contrast to $63,000 for the remaining four industries. The means on almost all variables are very close between these two groups. Rarely do they exceed 2 percent and never more than 10 percent.

The major difference appears to be in production costs, with a difference of approximately $20,000 per period. Apparently the production managers in the latter group were able to contain their costs.

The standard deviations indicate that the variation was considerably higher for the first four industries than the last four, with approximately
80,000 difference. Standard deviations are considerably higher (approximately 50 percent) than with the group not subject to sensitivity. Apparently the production managers engaged in more successful search activity in the latter group; over time they were able to find areas where marginal revenue exceeded marginal costs.

**Firms split on communication**

Those industries where the partners were in communication were 10, 30, 60, and 80; they were separated in 20, 40, 70, and 90. The means were very close with those in communication at approximately $11,000 lower loss per period. Sales were greater in the group without communication and average price higher where there was communication.

Those in communication seemed to be able to take advantage of the marginal return offered by increasing price.

The standard deviations were generally about 50 percent higher for the group that was better on the profit measure. This again seems to indicate that those people engaged in search behavior as a problem solving technique were rewarded.

**Firms split by experimental block**

The average losses incurred ranged from $62,000 for Block C to $104,000 for Block B, with Blocks A and D falling between. The means on most variables were close in percentages with the amount effect apparently being price.

The standard deviations were substantially different, ranging from $173,000 to $377,000 on the profit figure with a corresponding percentage difference on most of the decision variables. Two exceptions were
information in which the range was 0.02 and number of setups in which the range was 0.25. While these figures are essentially "double counting," they indicate that within this particular experiment one should be able to discriminate better using measures of variance than measures of central tendency, (an analysis of variance on the variances (or SD) might elicit the information desired.) The rewards were apparently high for search behavior. (See Bonini, 1963, pp. 135-140 for a discussion of results which corroborate this conclusion.)

**Firms split by industry**

When the results are reduced to this level the problems in this experiment associated with the within-group variance become very evident. The discussion at the end of the prior chapter relative to the necessity of placing all firms in one experimental block into the same industry become quite evident.

**Comparison of Block A**

Within Block A, Industry 10 did very well over all, finishing second over all eight groups in accumulated profit. Industry 30 finished last; the differences in means between these two groups is substantial in production decisions and pricing. They are considerably lower for Industry 10 with the exception of accumulated profit. This suggests the presence of "disastrous" decisions made at some point in time. This type of error was usually made by a production manager who forgot to schedule production or order raw materials, causing his firm to go onto overtime or expedite purchasing for a period.
Overproduction, by a clerical error, caused substantial inventory costs. The difference in variance in the production decisions between the two industries would suggest that this may have happened. For example, in the quantity of production scheduled, the standard deviation for Industry 10 is approximately 3,900 and about 10,400 for Industry 30.

These figures strongly suggest that the within-group variance is so high as to make conclusions based upon the experimental design subject to suspicion. On the other hand, it may suggest that the effect was so strong that it overcame the within-group variance.

Comparison of Block B

This block consists of Industries 20 and 40. The average loss for Industry 20 was about $113,000 and for 40 about $95,000. The average units sold was about 600 per period greater for Industry 40. Most of the figures are very close although there is about a $25,000 a period difference on sales promotion expense. There does not seem to be sufficient reason on the basis of arithmetic means to conclude that these industries were substantially different. The standard deviations were similar on all decision variables.

Comparison of Block C

This group consisted of Industries 60 and 80; as with Block A there was substantial within-group variance. The average loss for Industry 80 was about $7,000 a period while the same figure for Industry 60 was $116,000. Industry 80 was the only group close to a net profit for the 20 decision periods.
The means are quite different for the two industries; $40,000 per period on advertising, $30,000 on sales promotion, 12 percent less requests for the market report, and (inversely) 3,000 units in sales. The average industry price was about $144 for Industry 80 and $102 for Industry 60. The standard deviations on the significant marketing decisions were about 2-1/2 times as large for Industry 80, further indicating the functionality of search behavior.

Comparison of Block D

Block D consisted of Industries 70 and 90; 70 showed an average loss of about $36,000 and 90 of about $93,000. The difference on requests of market reports was very high; Industry 70 requested market reports twice as often as 90. Industry 70 was reasonably stable with prices staying around $108 or $109 and advertising and sales promotion expenses not spiraling. This industry appears to have had the best opportunity to stabilize, had they been able to avoid price-cutting while lowering promotion costs.

Industry 90 was stable in price, with the average ranging from $107 to $170. The standard deviations on marketing decisions are similar, but low for both industries. There is a marked difference on the production decision on quantity, with the standard deviations being twice as large for Industry 70.

There is one unusual difference in the standard deviation for the number of orders of raw materials; 1.8 for Industry 70 and 7.1 for Industry 90. This is the most extreme difference on deviations for all groups. These differences seem to lend additional support to the conclusion that within-group variance masked between-group variance.
Discriminant Analysis

In this section, the analysis reported was done with computer programs 04 and 05 from the BIMD series; the two discriminant analysis programs utilized to test Hypotheses G and H.

The discriminant analysis technique was useful in extensions of this research and in the derivation of quantifiable hypotheses where variables may be coupled to discriminate between groups. It should be useful for a posteriori analysis to differentiate performance between individuals. This analysis, if applied to behavioral differences between industry executives, may assist in the identification of predictive traits. As an extension to the results reported here, a discriminant analysis based upon a partitioning of the data would give additional information about subjects that performed well on the tasks assigned other than as differentiated by the experimental design.

In additional to the results reported, an analysis was run on the personality variables obtained from the Edwards Personal Preference Schedule. This was done to verify the assumption that subjects drawn at random into experimental groups will not be sufficiently different to disrupt the experimental conditions. Discriminant analysis offers a way to specifically examine this assumption.

The subjects were broken into two groups in several ways for inputs to BIMD 05. They were split into marketing and production, and the production and marketing managers were compared across the major experimental conditions. Mahalanobis $D^2$ was converted to the F statistic to compare significance. In general, the significance approximated the 6 percent level.
A cross check was run with BIMD 04, which can handle five groups. The two groups were split and $\chi^2$ was determined. The significance was at approximately the 6 percent level. Then the actual scores (without substitutes for missing scores) were broken into four groups (the experimental blocks) and the analysis performed on the personality variables. The $\chi^2$ value was 55.486, with 48 degrees of freedom. This is a highly significant value and substantial evidence that the assumption was incorrect.

In the following section, a step-wise multiple regression was performed on decisions against profit. The results of this section coupled with the regression analysis should indicate methods of a priori placement into experimental groups for future research.

The discriminant analysis technique would seem to hold a great deal of promise for behavioral research. A method which will differentiate between groups on the basis of more than a single variable can be very valuable. This analysis was run on subsets of the output variables for the 20th decision period and discriminated between industries in experimental groups at highly significant levels. The placement of subjects as a result of the linear discriminant function should introduce a control variable into future experiments, and in some types of research offer significant improvements in design.

**Step-Wise Multiple Regression**

The program used for the results presented in this section was BIMD 34. This program computes a multiple linear regression, printing out the intermediate results at each step. As the program sequences, the variable
which makes the greatest improvement in "goodness of fit" is selected to enter the regression equation which is then recomputed. The selection is made of the residual variable which has the greatest partial correlation with the dependent variable after the previous step. When n variables are selected by the program, the multiple regression equation at the nth step is identical to that which would have been computed by forcing all n variables into the analysis.

This technique seems to offer the same general type of result as a factor analysis while allowing the researcher to identify single variables into the prediction equation. In a standard multiple regression the researcher computes a multiple $r$ for all variables; with the step-wise regression he is given the option of minimizing the standard error.

As variables enter the regression equation, the multiple $r$ will continually increase. However, the standard errors will form a parabolic function. Ultimately, a variable enters the equation which has a greater dispersion than the previous estimating equation, increasing the multiple $r$ but also increasing the standard error.

The step-wise regression was on profit, average unit production cost and average unit marketing cost for period 20. Personality against the decision variables was computed for the entire run (sample size of 960).

Some of the relevant regression equations are shown in Appendix IV. They have been arbitrarily truncated, either where the standard error of the estimate increased or where the marginal increase of the multiple $r$ seemed to be too low to warrant inclusion (no reason to attribute change to anything but "noise"). In Appendix II, the variables on the Edwards Personal Preference Schedule are listed.
Regression against accumulated measures

In this section, the regression equations computed upon the ending measures of average unit cost and accumulated profit are discussed.

Profit versus personality scores

The standard error on the equation decreased until 15 variables had entered; the regression and the multiple r was equal to 0.74830. The multiple regression equations in Appendix IV are written in the order that the variable entered.

The first four variables to enter were Aggression for the marketing manager, Aggression for the production manager, Affiliation for the production manager and Change for the marketing manager. This balance, an equal split on personality traits, continued through the steps. Aggression for the marketing manager is positive and significant to 1 percent level; Aggression and Affiliation for the production manager are significant to the 5 percent level. The direction for Aggression of the production manager is negative and Affiliation is positive. This tends to support the conclusion that the game is dominated by the marketing manager. The firm seems to do well as the production manager cooperates with the marketing manager.

Marketing against personality

The multiple r is high, 0.819, after 14 variables enter the equation; the standard error is 0.05. Passive personality traits of the production manager enter early and seem to play a significant part in the marketing position at the end point.
Production against personality

This result is unusual because the "wrong" variables entered the regression equation. The multiple r is high, 0.83, and the standard error low, 0.02. If these results are to have predictive value, the variables on the Edwards' test must be examined to determine the degree to which they are measuring cultural values. The descriptions may be only conceptually useful.

In summary, it should be noted that the aggressive tendencies of the marketing manager and the passive tendencies of the production manager had a positive influence on most decisions. Affiliation of the production manager appears very early in the three sets—positive, when entering the profit and marketing equations, and negative when entering the production equation.

The high multiple r derived, would seem to indicate that personality was a major determinant in the overall results. If this conjecture is true, the experimental variables manipulated were probably masked by the effect of personality differences between the subgroups.

Regression Against Decisions

As may be seen in Appendix IV the multiple correlation coefficients are substantially lower on the period by period decisions. The notable exception is against Variable X3, the decision to purchase a market report. The multiple r is equal to 0.64; the first variable entering, Endurance for the production manager had an r of 0.32.

The prediction equations were substantially better for the accumulated figures than for the state-to-state decisions. The tentative conclusion
drawn is that the variance in the decisions, period by period, was sufficiently high to mask significant trends. However, where functional search and effective problem solving behavior had time to operate and sensitivity to competitors' reactions could be used, personality differences seemed to play a fairly dominant role.

The regression equations based upon personality could be used to form a discriminant function for a future study in which complementary and conflicting personality types were put into dyads for a task of this type.

An analysis could be performed on the data from this study to determine the matching characteristics of the extreme performers as measured by aggregate figures.

This type of analysis seems to offer the researcher an excellent way to segregate variables as they contribute to explaining the variance in a particular study.

**Behavioral Models**

The psychological constructs—level of aspiration and achievement motive—offer possibilities for inducing behavioral sets coupled with motive strength to produce differential results with man-machine simulations of real world behavior. Personality traits may be used for selective placement of subjects in dyads or experimental groups to determine the interaction effects of pairs working together on a task of this type.

With an increase of participants within a firm, there are possibilities of manipulating group structure. However, based upon the complexity of the results obtained in this study, it would seem that the
introduction of variations in group structure would unduly complicate the environment.

The Carnegie Tech Management Game appeared to have great possibilities for behavioral research as it was being written. However, the potential has not been realized due to the complexity of the operations within a firm. The group structure problem apparently has been sufficiently complex to eliminate possibilities of comparison based on personality variables.

**Learning Models**

One of the limitations of this study was the lack of an intelligence measure on the participants. At least at extreme ranges, intelligence must be relevant to performance in a task of this type. If an intelligent response is viewed as ability to adapt, these data should be amenable to some type of analysis by partitioning the data matrix, and comparing the changes in performance of successful and unsuccessful participants.

New variables could be generated to indicate response to a competitor's performance. The values entering the regression equation could be lagged across periods and the decisions of a given subject could be compared with the decisions of some or all of his competitors. This analysis would require considerable modification of presently developed computer programs and an exceedingly large core storage. This manipulation would, in effect, multiply the size of the data matrix several times. These data presently use more core than available on the CDC 1604 or IBM 7090.

The theory that adaption to competitors' responses or to the particular industry is attractive because it redefines the success criteria
to success within the environment established by a particular set of subjects. The analysis in this study focused on the individual's success in a wider environment. He could not control or know the values in the theoretical payoff matrix. These subjects were competing only within their industry, and the analysis was done across the corresponding "economy."

Information Theory

The measures utilized in communication theory are concerned with the amount of information transmitted in a sequence of events or signals. These data could be viewed as an information transmission. The variance in the behavior of the participants varied widely. As the individual stabilizes his decisions, he transmits less information (in the mathematical sense). His future decisions are, therefore, more predictable to his competitors. As decisions stabilize and become more predictable, it is easier for a competitor to maximize.

A certain amount of statistical randomness may be beneficial, insofar as a game theory model is an appropriate way to view marketing behavior. These data could be analyzed by examining the uncertainty and redundancy of events across a sequence of decisions. A Markovian analysis would indicate the probability that an individual will repeat the same decisions. Negative entropy as a measure of the predictability of competitor's decisions would facilitate future actions.

This model may be too complex to provide more than conceptual assistance to a subject. However, a dummy participant simulated by the computer could analyze his competitor's decisions and maximize based on this type
of analysis. To the degree that there was certainty in the market place, an individual firm could maximize at an equilibrium point substantially greater than the other firm. This would be particularly true if stable marketing decisions were maintained and profit figures increased by manipulation of the production function.

Other Methods of Analysis

In this section, some current studies will be discussed as they relate to the results.

Marketing Strategies

Kotler (1964) is currently developing a game to examine strategies for new product marketing. He discusses a variety of alternative strategies for marketing new products. The data reported in this study could be used to provide empirical support for the types of strategy that he considers.

Basically he categorizes his strategies by the degree of built-in adaptability to various changes in the environment. These ranges in extremes from a completely non-adaptive strategy (corresponding to a fixed marketing strategy over the twenty decision periods), to a completely adaptive strategy where the company would alter its marketing mix, period by period in response to its environment.

These extremes are unlikely to be found in the game utilized here. However he discusses intermediate strategies which he calls partially adaptive; it is these choices which appear feasible for analysis on the data gathered for this study. He lists four types of partially adaptive strategies (Kotler, 1964, p. 19).
1. time-dependent strategies,
2. competitively adaptive strategies,
3. sales-responsive strategies,
4. profit-responsive strategies.

It would be feasible to examine these data using the categories listed to compare results with human subjects to Kotler's computer simulation. These strategies are briefly described as follows:

1. Time-dependent provides for automatic adjustments over time, e.g., responses to cycles,
2. Competitively adaptive strategies are those adjustments in response to marketing mix changes made by other firms (responses made after receipt of the market report),
3. Sales-responsive strategies are those which lead a company to change because of its last period's sales, profit, or market share, and,
4. Profit strategies are those changes in response to "significant" inter-period changes in company profit.

The examination of these data from this frame of reference might yield much information about the subject's behavior. Coupled with a discriminant analysis based upon strategy types, it should be feasible to identify the type of market environment within which the participants perceived themselves operating.

Growth Models

As a very simplified model, the following statements abstract some relevant dimensions from the real world and include virtually all items from the task environment.
Growth = f (firm decisions, competitors decisions, environment).

Firm decisions = f (environment, perception of potential events).

Perception of potential events = f (personality of managers).

The data collected in this study could be used to examine the relationship between the subject's score on the personality test and his firm's performance on three specified measures of growth: cumulative profit, cumulative sales in dollars, and cumulative sales in units.

Computer Simulation

Oliver (1964) in his study developed a computer program which would hold constant the decisions of five firms and then optimize the decisions which could have been made by the sixth firm. This program could be modified to simulate the decisions made by the competitors in this experimental run to examine the "expected effect" of different subjects' being matched in an industry. This type of simulation would yield information regarding the sensitivity of the model to various combinational effects of decisions as made at various levels of operations.

Other Designs with the Game as Devised

The Interaction Simulation (Keenan 1963) was designed as a research instrument and the mathematical model was constructed with several modules (e.g., production decisions on subassemblies) and most equations were parameterized. A wide variety of industry conditions can be set to provide differential environments for the subjects. The number of firms in an industry can be modified from two to six (IBM 1620). An increase of this number would tend to decrease the effect on the market of a particular
competitor's decisions. A system effectiveness model for evaluation on an ongoing basis could provide additional research information for the experimenter as the possible modifications within the game are almost infinite.

In this chapter, a number of possible extensions to the study were discussed. A summary of the work and the author's conclusions are presented in the next chapter.
CHAPTER VII

SUMMARY AND CONCLUSIONS

The first part of this chapter is a brief summarization of the topics discussed in the earlier chapters; the second contains the conclusions reached by the author upon completion of the study.

Summary

The primary considerations of each of the chapters will be reviewed for the convenience of the reader.

The Organizational Problems of Suboptimization and Conflict

This study was an investigation of some dimensions relating to the overall effectiveness of an organization. Some relevant aspects of individual behavior were of specific concern. An examination was made of interpersonal conflict under varying environmental conditions.

When conflict exists in an organization there will be factors inherent to the system, encouraging the individual toward suboptimization. The two variables, hypothesized to create conditions facilitating suboptimization, manipulated in this study were (1) ease of communication and (2) severity of external competitive conditions.

The decentralization of American industry is a response to the necessity of flexibility and rapid action in the contemporary business environment. These requirements, coupled with the inherent rigidities and speed constraints of communications systems, tend to cause a system
to operate at less than optimal performance. As increasingly large numbers of subsystems evolve, the probability that the optimal scale of operations for the firm will not be congruent with the optimal scale for the subunit increases.

Performance measures for both subunits and the total organization are necessary for evaluation. Unit cost has been used as a yardstick for the measurement of subunits. Goals of this type (unit cost) tend to force an evaluation system which rewards suboptimal operations.

If the problems of suboptimization are functions of communication and coordination between organizational units, the lack of complete information at the executive level will tend to increase organization costs by fostering inter-departmental conflict, illegitimate authority conflict, and suboptimal behavior.

Competitive conditions and their relation to pressure upon actors within a system was discussed. Competitive severity may be in the form of decision time, costs, limited resources, substitute products or many other dimensions. There are objective reasons, e.g., differential cost accounting procedures by competing firms, which may cause increased pressures on the firm.

The specific problem of the study was to determine the main and interaction effects of two variables; (1) "Communication-Coordination" and (2) "Severity of Environment."

The costs relative to suboptimization and the balancing cost of coordination were depicted in an inventory model. The problem was presented as a minimization of two interacting variables.
The major aspects of the research literature were examined under three primary categories: (1) behavior under external conditions of conflict and uncertainty, (2) conflicting predictions of leadership theory, and (3) the behavioral research using the Prisoners' Dilemma Game as an instrument. A set of generic hypotheses was derived from the research reviewed.

The Theoretical Framework for the Study

Research should have a well-organized purpose, and a well-developed or delimited theory will help the researcher collect data relevant to his hypotheses. The advantages, disadvantages, and limitations of a well-designed theoretical structure and its relationship to deductive systems was discussed.

Business theories of two categories, holistic theories of business behavior and descriptive behavioral theories, have been developed in recent years in attempts to predict behavior within the business environment. This work has been subject to many constraints in the development of diagnostic and predictive parameters.

A general model for the effectiveness of a system, as given by Ackoff (1962), includes as dependent, the effectiveness of the system and as independent, those which are controllable and those aspects which are not controllable. This model is discussed as a frame of reference for the study. A deductive approach to a theoretical structure was used to minimize internal inconsistencies in the study.

Some general theoretical assumptions about organizations and individuals were abstracted from the current work of behavioral science.
Organization behavior was assumed to contain the following elements; it is goal directed, the ultimate goal is long run survival, and system behavior is some collation of the subsystems of individual behavior.

Individuals were assumed to behave as goal directed organisms. Operant behavior was assumed to be a function of the subjective value of the goal, the subjective probability of obtaining the goal, and motivation. Human behavior was assumed to be adaptive and "satisficing."

These assumptions were selected as they seemed to embrace a substantial range of human behavior while being sufficiently delineated to allow for the development of a deductive system. The assumptions about the individual were discussed and related to some models current researchers and theoreticians relate to human behavior in an organizational setting.

The individual was described as imbedded within an organizational system, a system which would in part determine his behavior. His behavior would be modified by his subjective selection of goals, subjective selection of pathways to those goals, motivation, and the discounting program he utilized to determine present expected values.

The individual was described as subject to errors in estimating the above values and tending to select a "satisficing" program rather than a maximizing program.

These tendencies were expected to cause the individual to suboptimize and select goals which are optimal for a subsystem in the total organization.

The Investigation Medium

This chapter was concerned with a discussion of the possible task environments which might be given to subjects to induce an analogue of
their future performance in the real world organization. The placement of experimental subjects into an environment that will illicit behavior from which behavior modes of executives or middle managers may be imputed is highly desirable. The focus of interest in the development of the research medium was on interpersonal conflict under varying conditions of competitive severity.

The ideal in experimentation would be to create conditions within the environment of an existing organization which would be amenable to repetition. The results of studies could be examined against differential experimental conditions. However, it is virtually impossible to reach this ideal in the real world, due to variability in the environment.

At the other extreme, laboratory research has the advantage that the environmental conditions are subject to control by the experimenter. This facilitates replication by other researchers and the manipulation of experimental variables in a systematic manner.

The recent development of management games appeared to offer a possibility of spanning the gap between controlled experimentation in a laboratory environment and descriptive case studies. Management games seem to provide an environment which appears similar to business decisions made by middle managers and executives, and simultaneously is subject to some experimental controls.

This rich experimental environment may be designed to reflect economic and interpersonal relationships drawn from the real world. Inherent in the use of an instrument of this type are the disadvantages of abstraction and that the conclusions reached are therefore valid only for the model. For the advantages of manipulation and the increase in rigor,
there is a corresponding decrease in the amount of confidence with which we may impute the results into real world behavior.

With management games there is an unusual problem relative to the "appearance" of the research instrument to the subject. In a standard experimental design a certain amount of "noise" is generated by the subject trying to outguess the experimenter. With this instrument the problem arises as to perceptions of the subjects as to types of decisions executives make, and how business cycles perform in the real world. The subject-experimenter relationship remains with the addition of perceptions of the business world. Participants seem to demand that returns to investments be greatly accelerated over what would normally happen in the business environment. Thus it is necessary to create a circumstance which looks as though it behaves as the real world; that is, responds to perceptions instead of replicating reality.

This problem was attacked by assuming certain underlying behavior traits common to problem solving or conflict situations in human performance. If the researcher can place an individual into a situation which he perceives as problem-solving or conflict-generating and observe his behavior, predictions of future behavior should evolve if his behavior mode remains constant in other problem solving and conflict situations.

The inference drawn is that there is a consistency of motive and behavior patterns within the individual across the general population. An individual is assumed to have a set of heuristics or principles which are implicit to his behavioral or homeostatic system. If a set of questions or tasks for the individual, identical to real world tasks,
cannot be presented, the researcher must attempt to reach an implicit or underlying set of heuristics by which the individual solves general problems with unknown constraints.

If his behavioral structure contains a consistent set of heuristics he may be presented with a set of analogous problems, his responses examined, and future behavior to similar types of questions posed by the real world inferred.

The three major considerations were that an individual behaves in a reinforcement-seeking or goal-directed manner, that he tends to estimate the value of a goal and that he discounts to present value. In the discounting estimation process the individual can make errors. This can be adjusted by direction, if systematic. These three assumptions linked behavior in the experimental environment with the theoretical models presented and results of the pertinent research reported.

The relevant dimensions of the particular research instrument used were discussed as they related to this specific study. The internal design of the mathematical model and its analogue to the Prisoners' Dilemma Game was outlined. An industry operates in an analogous fashion to a 6 x 2 Prisoners' Dilemma Game and the two subjects with a firm operate in an analogue to a 2 x 2 Prisoners' Dilemma Game.

The game for the firm is imbedded within the industry game. This mechanism facilitates conflict behavior between participants, both within the firm and within the industry. The analogue design relates the results of behavioral experiments using the Prisoners' Dilemma Game to the data from this study.
Research Design and Procedures

The experiment was designed to determine if the variables of communication and competitive severity would create conditions under which individuals would suboptimize or tend to adopt individual goals rather than group goals. A \(2^2\) factorial design was utilized to generate an estimation of interaction effects as well as the main and simple effects of two variables.

Competitive sensitivity was utilized to develop forced interaction between partners. Inventory stockouts and implicit product substitution were used to manipulate these conditions. Stockouts were computed as a function of average inventory for the period. In the computation of the individual performance measures (unit cost), it was punishing for the marketing manager to lose the sales and beneficial to the production manager to maintain low inventory levels. Thus, there was a direct link between the individual performance measures of two partners within the firm.

The second variable was the ease of coordination between the partners within a firm. In one group the partners were sitting side by side in a classroom and in the second group they were separated but not prevented from communicating outside of the classroom.

The subjects were sophomores and juniors in a core course in the business school at Western Michigan University. They were randomized (as nearly as possible) between the marketing and production positions. They operated under a reward structure giving them points towards their final grade, dependent upon their finishing position within their industry.

The dependent variables used for the statistical analysis were Aggregate Profit, Average Unit Cost for Marketing and Average Unit Cost
for Production over 20 decision periods. The major portion of the statistical analysis utilized nonparametric statistics. They were used as these measures are distribution free and approached 90 to 95 percent efficiency. This appeared to be a very small loss of efficiency in contrast to corresponding gains in the advantage of avoiding assumptions about the distribution of the variables.

Presentation and Analysis of the Data

For the analysis of the data, the independent variables were the decisions made by the participants. The marketing manager made decisions as to expenditures for advertising and sales promotion. He set prices and decided whether to purchase a market report.

Other than ordering the market report, the decisions made by the marketing manager interacted with the other firms in an industry to determine relative share of the market. Only price caused a change in the size of the market. Quantity for the industry was perfectly inelastic to sales promotion and advertising expenses.

The characteristics of the market were a long-term linear increase, a yearly cycle and a function which created "noise." There was a lag in the effect of advertising.

The production manager decided on the amount of finished product to assemble and the quantity of raw materials to order. He determined the number of setups for assembly and the number of orders of raw materials.

The production decisions were a function of expected demand for the product, safety stocks and a balancing of relevant costs that would normally go into an economic order quantity formula. The students were not familiar with EOQ formulae and did not appear to utilize them directly.
However, most participants developed an heuristic scheme which approximated EOQ theory.

The dependent variables utilized in the analysis were accumulated measures of individual and firm performance. The success criterion for a firm was measured by accumulated profit; individual performance was measured by average unit costs of marketing and production.

An additional analysis was performed on the decisions to determine if the experimental groups could be discriminated on the basis of a "pooling" of the means and variances of more than a single variable. A linear discriminant function was computed for this analysis.

Other than with the discriminant analysis, for which the raw data were utilized, the data were transformed into rank order, based upon the accumulated figures. The ranks were then utilized as inputs to the nonparametric statistical formulae used.

When the alternative hypotheses which had been accepted were grouped, (Table 4) a significant picture began to emerge. Two of the experimental groups appeared in most of the original hypotheses. On two of the tests the statistics were significant to the .001 level in the opposite direction than hypothesized. These two groups, which appeared to dominate the results, were operating under the severe competitive conditions.

Apparently, the increased severity of the environment did cause significant differences in subject performance, but not always in the direction predicted. The communications variable was relevant only when the firms were operating under the severe competitive conditions and apparently not relevant under the other constraints.

The results obtained with the discriminate analysis were highly significant. Apparently, the subject groups could be identified and segregated with a linear discriminant function.
A number of limitations appeared after the experimental run. The intra-block variance was exceedingly high and can apparently be accounted for by the replication in the design. Within any one experimental block, there are two industries operating. In at least one case, (Block A), the variance between these two industries was so great as to mask any apparent effect of the experimental conditions. Apparently, it is necessary to treat an entire industry as the subject case or to group the individuals in a block into only one industry.

The predominant result appeared to be that performance was better under the more severe competitive conditions and that the manipulation of the communication variable had a significant effect only when coupled with severity of competition. Communication appeared to have some type of a multiplier effect, suggesting that the necessary sophistication of management control is inversely proportional to the severity of current marketing conditions.

Extensions and Models for Future Research

Some additional tests, other than those directly related to the hypotheses, were performed. These data were examined with the descriptive measures of means, standard deviations, and inter-correlations. The data were examined by grouping all figures into a single data matrix, computing the standard statistics on the entire matrix, and then partitioning the data in a variety of ways. The matrix was first divided on median profit for the 20 decision periods. The major differences were in the marketing decisions; the production decisions tended to be remarkably similar between the two groups.

The marketing managers for the group above the median in profit tended to spend considerably more for sales promotion and advertising and
to charge a substantially higher price. Sales were greater for the group above the median profit, indicating that these firms had more accurately assessed marginal revenue than those firms below the margin.

The production decisions tended to reflect the difference in sales between the two groups. The production managers did not seem to develop much sophistication in usage of the concepts of economic order quantities. They appeared to focus on absolute costs (assembly and material cost) which were not amenable to control and not attend to those costs which made significant differences in average unit cost.

The firms were then split on the two major experimental variables, communication and sensitivity. They were divided by experimental block and then by specific industry. The results were substantially the same as those derived with the nonparametric statistics.

Certain differences became apparent upon examination of the standard measures. The major distinction between firms appears to have been in the variation of decisions. Systematically, those firms with high profit had a substantially greater variance of decisions than those firms with lower profit figures. If this may be taken as an indication of functional problem-solving behavior, apparently those individuals willing to engage in search behavior did in fact determine the parameters on which the game was sensitive.

A discriminant analysis was run on a personality test (Edwards Personal Preference Schedule) given to the students which were utilized for this experiment. The results of the test were incidental to the experiment. The analysis on the personality variables indicated that the experimental groups contained individuals who were significantly different insofar as personality is measured by this test. Personality
appeared to be highly related with accumulated performance by the individuals.

A step-wise multiple regression was performed on the aggregate figures at the 20th decision period and each of the decision variables. The multiple correlations on the aggregate variables after 20 periods were very high, ranging from 0.75 to 0.83 with fairly low standard errors.

On the individual measures of performance, in both cases the second variable to enter was a dimension of the partner's personality. This seems to indicate that interacting personality types are relevant for the performance of dyads.

In the regression against the decisions made by the participants, the multiple r was considerably lower. Apparently, not all the relevant variables are measured by personality in a decision-by-decision model, suggesting that some information is contained in the decisions but not entered into the regression equation.

The possibility of using some behavioral and learning models was discussed with the view that these data could be treated as a learning task and that adaption of an individual to the competitor's responses could be utilized as a measure of performance.

The possibility of introducing an information theory measure was examined, assuming that there was an optimal level for entropy in the decisions of a particular individual. This model may be too complex for convenient analysis; however, a dummy participant simulated by a computer could be utilized to analyze the market decisions and maximize at an equilibrium above the other firms.

The possibility of examining these data relevant to marketing
strategies and the relevance to particular types of marketing activities was discussed.

A computer simulation, maximizing with potential decisions or using the decision modes of the participants in this game, could be devised to play the different combinations of personalities against one another.

**Conclusions**

In this section, the author's overall impressions of the statistical results, the experimental environment and the constraint on experimentation of this type are discussed.

"Rich" Experimental Conditions

The experimental environment used for the study was what Ashby (1961) would call an "exceedingly complex probabilistic system." This categorization, used by cyberneticians, classifies small systems rather well by describing them as simple or complex, probabilistic or deterministic. This ordering is not sufficient for the environments used in rich experimental conditions, or for that matter, in the real world. The experimental conditions used in this study fall in this category.

As the researcher moves down the scale toward greater control (more elementary systems), he sacrifices either reality or the appearance of reality as an analogue to real world behavior. He exchanges control for validity.

Given a moderately complex design, he can compensate for loss of control by increasing sample size. This study was an attempt to provide a complex environment analogous to real world behavior, by providing a task for the experimental subjects which appeared similar to decisions made by operating managers. The results indicate that this was at least
partially successful. There were deficiencies in the environment provided for the subjects. Many limitations of the experimental conditions were apparent after the experimental run and are of a correctable nature.

There should be no basic conflict between these two positions; that is, rich versus controllable designs. They should be complementary, not conflicting. A preferable design might have the same set of subjects (or homogeneous subjects) operate both under laboratory conditions and in the task environment of the management game. They could be examined in the laboratory using the Prisoners' Dilemma Game and then systematically placed by firm and industry (for the game) based upon the laboratory results.

The type of experimentation used in this study is designed to reduce the number of possible studies which might be performed on executives. The cost of experimental subjects is very high when drawing from operating managers; less expensive subjects may be utilized to eliminate unfruitful experimental conditions. Further reduction of the possible studies can be careful use of computer simulations based upon the results obtained from the experiments done with the less expensive subjects.

It appears that research with experimental environments of the type utilized in this study holds promise for the derivation of operational results in the selection and performance of managers. A "rich" experimental environment seems to offer a bridge between the more abstract results obtained under laboratory controls and behavior in the real world environment.

Validity

This study was designed to elicit a general problem solving type of behavior under conditions of uncertainty. The experimental subject
was placed in an unfamiliar task situation. He became familiar with the requirements as the study progressed. His responses to a specific mathematical model, coupled with his interaction with a partner and a set of competitors, were examined so that inferences could be drawn about future behavior.

The study assumed that every individual has an operational set of heuristics for unknown or uncertain environments. This set of principles or heuristics, varying person by person, would be employed to determine behavior in any task situation associated with a potential reward. Similar behavior, based on the heuristics, should appear at a later date in a business environment. The implicit assumption was that this underlying set of heuristics is relatively constant for an individual. Education and experience tend to shift parameter values in the individual's decision model, but the structure of the model would stay approximately the same over substantial periods of time.

When the personality scores were coupled with the results of the management game, this assumption appeared to be supported by the evidence. Particular personality dimensions (manifest needs) were correlated with particular modes of behavior. When the individuals were operating in pairs, some personality types operating together performed better than other mixes.

This result supports the "complementary needs" hypothesis and indicates that there probably is an optimal pairing of individuals. Given certain matches, we can predict highly aggressive behavior of a functional nature; given other mixes, we can predict highly aggressive behavior between partners (dysfunctional).
The results obtained seem to indicate that the task environment provided for the subjects did approximate a circumstance in which consistent measurable personality dimensions (or heuristics) were tapped. If this is true, then experimental studies relative to the stability of personality dimensions over time are relevant. Then these individuals, given a task to perform with a partner, should behave towards their partner and the environment with similar patterns in the future. The results derived from this research and researches of this type may be useful in predicting real world behavior.

Behavior Under Experimental Conditions

One of the difficulties of experimentation with human subjects is that it is reasonably obvious that the researcher is conducting an experiment. This will elicit a response to the experimenter as well as the manipulated variables. The same phenomenon will appear in animal research; for example, the experimenter may assume that his reinforcement object is food, when in fact, the animal may be responding to some other mode of reinforcement (e.g., rough handling.)

Biases of this type appear in a college classroom where the students have adopted grades as a goal and the instructor imputes a "quality of education" goal. Ideally, of course, grades and education are congruent but due to measurement constraints, they probably seldom are. There will almost inevitably, be some experimenter bias unless a "double-blind" can be arranged. For this study, the subjects were not told of the second experimental condition (the separation of partners was obvious.) The individuals may be responding to what they perceive the instructor wants rather than to the experimental conditions. There was no specific reason
to assume that an unusual amount of bias was introduced; however it has been amply shown that experimenter bias does lead to differential results. There must have been some bias inherent in this study.

Rosenthal and Fode (1963) discuss at some length the effect of experimenter bias on albino rats. If there is substantial bias in studies with organisms of this type, one would expect more bias with a more sophisticated subject who can interact with the researcher on a higher level.

Statistical Decisions

Unfortunately, the social sciences usually cannot select the option of determining results with a specified experimental design, but must utilize derived, probabilistic conclusions. The hard sciences can develop a specific model and test it with exceedingly high degrees of reliability. If a certain chemical reaction is predicted and obtained, the result can be repeated with a high degree of reliability. It should be possible, with this study as a pilot, to develop a predictive mathematical model by computer simulation. A second set of subjects placed under the conditions thus determined should yield fairly reliable results. If the subjects behave as predicted, then the probability that the conclusions are correct is very high (with a Bayesian model).

The highly specified model, based on underlying personality dimensions or heuristics, presumably will be stable over time. If personality dimensions are consistent, experimental decisions rather than statistical decisions can be approximated. This study should provide sufficient information for a simulation model to derive a mathematical formulation of behavior based on matching personality types.
APPENDIX I

INTERACTION SIMULATION

General Description

The structure of the game permits from two to six "firms" per industry, with two persons (or two groups) per firm, each representing a functional area; marketing or production. Each participant makes four decisions per period; the marketing managers' decisions are on price, advertising expenditures, other sales promotion expenditures for the coming period, and whether to purchase market information relative to the competitors' decisions.

The production manager makes decisions as to the quantity of raw material and finished product, the number of orders or raw material, and the number of setups of finished product. Each "firm" is described to the participants as a "profit center" within a large organization producing a new product.

The firms operate in an environment structured for competition with two to five other firms for the allocation of limited resources. The degree of interdependence and the conditions favorable to conflict between partners can be varied by the experimenter with a parameter adjustment. A parameter is included to adjust the quality of performance as an individual versus performance as a contributor to group goals (the above are exogenous conditions).
Group performance measures cannot be directly controlled by the individual, whereas individual performance measures may be manipulated within established ranges. The environment is structured so that individual performance within the firm is an inverse relationship between the two participants (endogenous conditions), with sensitivity adjusted by parameter.

The degree of uncertainty present can be modified in a variety of ways. For example, the participant may purchase additional information (relative to competitor's decisions) or the experimenter can control the range in variation of competitors' decisions.

The "controllable" component costs are amplified out of proportion to what one would expect to find in industry. This causes a problem with some of the more sophisticated participants; however, the relationships are usually accepted without question. To those students who do recognize the deviation from reality, it was indicated that they are amplified for instructional purposes. All students were instructed that they were practicing a method of analysis, a method for the reduction of uncertainty, and that the particular relationships were not significant. The focal point was a flexible problem-solving approach which could be adopted by the particular student at a later date.

Feed-back to the subjects comes on two reports; cash flow and a "market report." The former primarily uses accounting charges internal to the firm. This eliminates a finance segment within the game and circumvents the problem of dealing with bankruptcies and sale of assets, which complicate classroom usage. The participants attempt to stabilize the market, reduce uncertainty, and to reach a break-even point or make
a profit. Performance within many industries has been such that a good deal of money was lost early in the run, and gradually as the market stabilized the behavior became less random and firms began to show a positive return.

The participants' decisions represent a quarter of the fiscal year; however, this period can be modified to monthly decisions by some minor programming changes. The game is programmed in FORTRAN I for the IBM 1620, and uses approximately 39 k for six firms per industry. Computation time is six seconds; five minutes are required to punch out the results for each industry and about 450 cards per industry per period are used. The relevant data to the research model is reduced to three cards with an additional program.

The supplies were purchased by the participants. They were charged $2.80, which included the cost of three-ply paper, decision cards and computer output. Decisions were recorded on IBM Port-A-Punch cards, which were transformed and corrected on the computer. Marked sense cards could have been utilized but would have had to be reproduced.

Fifty parameters in the model control sensitivity to price, advertising, sales promotion, standard costs, slippage in the system (stockouts and expediting), customer behavior, lag in advertising effect, and other dimensions of the economic environment.

The teaching orientation within which the game was presented to the students emphasizes the reduction of uncertainty. It was not intended to give them practice in marketing or production decisions, but with a general problem-solving approach. The participants were
instructed to formulate a policy based upon a yearly cycle, to test and revise the policy as necessary, and to move towards the routinization of decisions and improvement of subsequent behavior.

The research orientation is aimed towards the investigation of performance under varying degrees of potential conflict. As the game is designed, parameters can be changed to determine which firms or industries will fall under given conditions. As presently programmed, conditions can be modified in a 2 x 2 factorial design. The two digit industry identification number is selected and compared to ± 50 for one condition and ± 5 in the second digit for the second condition. That is, Industry 46 would be condition 1 from the first digit, and condition 2 from the second digit. If some other design based upon control of different parameters is desired, a slight modification in the program can be made.

The game is designed as an economical, small-scale tool for teaching and research. There are modules in the program to include or exclude the carryover of advertising effect, intermediate production (e.g., in-process inventory) and other conditions as desired.

There is a program to precorrect decisions for clerical errors, and to set limits on percent or absolute changes in decisions from the prior period and correct to a specified range. This is one of the obvious ways for reducing uncertainty. Unit costs for marketing and production are averaged and income is accumulated on the successive reports. There is a ranking subroutine for unit costs and income within an industry.
The market report includes information about market share and the advertising and sales promotion expenses for the preceding period for each firm. As structured, the reports were returned to the participants free at the second subsequent decision period; they were charged for receiving them at the first period forward.

The remainder of Appendix I contains reproductions of the materials given to the subjects before participating in the game and detailed information about the model.
GENERAL INFORMATION

The simulation (game) in which you will be participating has been designed to give you practice in manufacturing (including purchasing) and marketing decisions. For each company there will be a Production Manager and a Marketing Manager.

An industry will consist of several competing companies; however, there will be no competition among the various industries. For example, the managers of Company X in Industry I will compete with the managers of Companies Y and Z in Industry I but not with the managers in Industry II. The limitation on the number of competing firms will tend to emphasize the impact of your decisions.

As a participant in this game, you will be assigned the position of either Production Manager or Marketing Manager for a particular company within a particular industry. From the data which will be distributed at each decision period, you will determine the course of action for your department. The two managers from each firm will be free to communicate with one another to plan the strategy for the company. Each decision period will represent the position taken by the company for one quarter of a year.

The company that you represent produces several products; however, this game is concerned with only one of these. Its description, due to the design of the simulation, is relatively unimportant.

Prior to your first decision, a list of figures (descriptive materials) will be distributed representing the situation of the company for the preceding four quarters. All firms will begin on an equal basis and the quality of your decisions will determine your standing during the game.

DECISIONS TO BE MADE BY THE MARKETING MANAGER:

I. Allocation For Sales Force.
   This figure will include wages, expense accounts and other items associated with costs of maintaining a sales force. By increasing this expenditure it is possible to capture sales from competitors but not to increase total industry sales. You cannot eliminate this expense since the salesmen are the sole means by which orders are accepted for the product.

II. Advertising Budget
   By increasing this expenditure you may capture sales from your competitors, but not increase total industry sales. It may be assumed that the advertising dollars will be utilized effectively and your decisions will not be affected by the techniques or media
used. The data you receive will help in determining the amount you will spend. Note that sales will not always be in the same period as the advertising expenditure. Advertising effect and advertising expenditure are not the same.

III. Price of the Product
Normally one would expect that a decrease in the price of a particular product would increase total sales of that product. The game has been designed utilizing this type of market behavior. Price reductions will tend to generate new industry sales as well as capture sales from competitors within the industry. Note, however, that total revenue may not be increased as a result of the sale of a greater number of units. For example, if 10 units are sold at $5.00 each and 11 units are sold at $4.50 each, one discovers that gross revenue is greater for the sale of 10 units than 11 units. Price adjustments must be made in dollar units.

IV. Marketing Reports
There is a time lag (one intervening period) on the feedback of information concerning the decisions made by your competitors. It is possible to obtain this data earlier by purchasing market reports. The report will include figures for advertising and sales promotion expenditures, share of the market, average cost of marketing, and average cost of production. If you believe that this information will be worth the cost, you may purchase it prior to making your decision for the following period. This information will be available two periods later at no cost; if you wish to receive the information the next period it may be purchased.

General Note for the Marketing Manager

Even though there are specific techniques to utilize in arriving at the various required decisions, it is important to note that they are not mutually exclusive. It may be necessary to increase advertising to promote your product if the price is higher than the similar products of your competitors. It may be necessary to increase appropriation for the sales force to compensate for a reduction in advertising expenditures. Visualize your over-all program as well as the individual factors which comprise it.

DECISIONS TO BE MADE BY THE PRODUCTION MANAGER

I. Total Production for the Quarter
As the title indicates, this decision refers to the number of units which will be scheduled for the quarter's production. All production problems or difficulties which would lead to reduction of output are eliminated so the figure that you decide upon will be manufactured. There are penalties for producing too many units as well as for producing too few. If too many are manufactured, there will be a cost for storage of these items until the next quarter. When this occurs it is necessary to take the surplus
figure into account before making the decision for the following period. If too few are produced, the customer's orders must be produced on overtime. A certain percentage of these customers will buy from your competitors instead of waiting for your product. Note that decisions must be made in number of units (no fractions).

II. Quantity of Raw Material
Based upon your production quota for the quarter, you will have to determine the total quantity of raw material which will be purchased. The ending inventory for the preceding period should be taken into consideration. The cost of raw material will tend to increase in the fall and decrease in the spring. In addition to this fluctuating cost, there will be a storage expense. If raw material cost is expected to increase, it is conceivable that you may decide to order more than you need for a particular period and store the surplus.

III. Number of Set-ups.
As you produce the finished product, it will be necessary to manipulate the manufacturing equipment for this particular product (one of several which you produce) with a standard charge for each set-up. As you decrease the number of set-ups you will increase the average inventory to be stored. That is, if demand is 1 unit per day and you have 1 set-up per day, there will be 10 set-ups for 10 days and an average inventory of less than 1. On the other hand, if you have only 1 set-up the first day and manufacture 10 units, the average inventory will be 5 units. The latter situation will increase inventory cost (storage) and decrease set-up cost. The number of set-ups must be in units (it is not possible to have a fractional number of set-ups). It is not necessary to have the number divisible into the total quantity of finished product.

IV. Raw Material Orders
After determining the total requirements of raw materials it is necessary to decide how often they should be purchased. If the needs are taken care of by one large order for the entire quarter, the cost for storage will be relatively high. On the other hand, if many small orders are placed, one runs the risk of not having the necessary material on hand when it is needed and incurs additional order costs.

General Note for the Production Manager
Your decisions will not be mutually exclusive. If, for example, you decide that production for the quarter will be 10,000 units, you would normally not plan to order raw materials for only 5,000 units unless you have a high enough closing inventory from the preceding period to eliminate the deficiency.
**CARD FORMAT**

<table>
<thead>
<tr>
<th>Column #</th>
<th>Identification</th>
<th>Marketing</th>
<th>Production</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>Industry</td>
<td>Price</td>
<td>Raw Material</td>
</tr>
<tr>
<td>6</td>
<td>Firm</td>
<td>Advertising</td>
<td>Number orders RM</td>
</tr>
<tr>
<td>10</td>
<td>Job</td>
<td>Sales Expense</td>
<td>Finished Product</td>
</tr>
<tr>
<td>12, 14</td>
<td>Period</td>
<td>Information</td>
<td>Number of Setups</td>
</tr>
<tr>
<td>16, 18, 20</td>
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<td>32, 34, 36, 38, 40, 42</td>
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<td></td>
</tr>
<tr>
<td>Description</td>
<td>Value</td>
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<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>--------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Report</td>
<td>$5,000</td>
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<td></td>
</tr>
<tr>
<td>Sales force and Advertising as a percentage of</td>
<td>80%</td>
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<tr>
<td>total Marketing Cost</td>
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</tr>
<tr>
<td>Fixed Charge to Marketing</td>
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</tr>
<tr>
<td>Number of units of Raw Material to 1 unit of</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>finished Product</td>
<td></td>
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<tr>
<td>Price of Raw Material</td>
<td>$3.10 minimum</td>
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<tr>
<td></td>
<td>slowly rising</td>
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<tr>
<td>Assembly cost of finished product</td>
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<td>Assembly cost on overtime</td>
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<td>Inventory Carrying Cost Raw Material</td>
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<tr>
<td>Finished Product</td>
<td>$10</td>
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<tr>
<td>Setup: Finished Product/setup</td>
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<td>Order Cost: Raw Material/unit</td>
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<tr>
<td>Stockout Cost Raw Material/unit (to expedite)</td>
<td>+ $1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cost</td>
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**HISTORICAL DATA**

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<tr>
<th>Sales for Last Year</th>
<th>336,000 units</th>
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<td>Your Sales</td>
<td>56,000</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>14,000</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>15,000</td>
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<td>3rd Quarter</td>
<td>14,000</td>
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<td>4th Quarter</td>
<td>13,000</td>
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</table>

<table>
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<tr>
<th>Estimated Sales for you this year</th>
<th>60,000</th>
</tr>
</thead>
</table>

| Average Industry price for last year | 100    |
STARTING CONDITIONS

INDUSTRY COMPANY PERIOD

PROFIT

LAST PERIOD PROFIT +60367.
INDUSTRY RANK, LAST PERIOD +6.
ACCUMULATED PROFIT +60367.
INDUSTRY RANK, PROFIT TO DATE +6.

MARKETING REPORT

NET SALES, LAST PERIOD +1352745.
NUMBERS OF UNITS SOLD +13527.
SHARE OF THE MARKET +.16
COST OF MARKETING, LAST PERIOD +662500.
MARKETING COST PER UNIT SOLD +48.97
MARKETING-AVERAGE UNIT COST +48.97
RANK, MARKETING EFFICIENCY +1
STOCKOUT, LAST PERIOD +705.

PRODUCTION REPORT

PRODUCTION COST LAST PERIOD +629877.

COMPONENT COSTS

INVENTORY HOLDING +32583.
SET UP AND ORDER +27500.
RAW MATERIALS +294500.
EXPEDITE RAW MATERIALS +5294.
ASSEMBLY-FINISHED PRODUCT +270000.
OVERTIME-FINISHED PRODUCT +.

RAW MATERIAL PRICE +3.10
PRODUCTION COST PER UNIT +46.65
PRODUCTION-AVERAGE UNIT COST +46.65
RANK, COST PER UNIT +1

ENDING INVENTORY

FINISHED PRODUCT +972.
RAW MATERIAL +3500.

COMPANY PRICE

+1 +100.
+2 +100.
+3 +100.
+4 +100.
+5 +100.
+6 +100.

LAST PERIOD DECISIONS

ADVERTISING EXPENDITURES +250000.
SALES PROMOTION EXPENSES +200000.
MARKET REPORT +.
FINISHED PRODUCT +13500.
NUMBER OF SETUPS +5.
RAW MATERIAL +95000.
NUMBER OF ORDERS +5.
FUNCTIONAL EQUATIONS

I. Industry
1. \( \text{PIS} = f (\text{PIC}, \text{PSI}) \)
2. \( \text{PIC} = f (\text{J}, \text{D}) \)
3. \( \text{PSI} = f (\text{AIP}) \)
4. \( \text{AIP} = f (\text{PS}, \text{J}) \)
5. \( \text{PRM} = f (\text{D}) \)
6. \( \text{PTT} = f (\text{PT}) \)
7. \( \text{SUMS} = f (\text{S}) \)
8. \( \text{SEA} = f (\text{EA}) \)
9. \( \text{SUMSC} = f (\text{C10}) \)

II. Income
1. \( \text{TNP} = f (\text{PNP}) \)
2. \( \text{PNP} = f (\text{R}, \text{CA}, \text{CP}, \text{DSOC}) \)
3. \( \text{R} = f (\text{P}, \text{UQ}, \text{SC}, \text{IDI}, \text{SM}, \text{SUMC}) \)
4. \( \text{UQ} = f (\text{SM}, \text{PIS}) \)
5. \( \text{SM} = f (\text{PT}, \text{PTT}) \)
6. \( \text{EA} = f (\text{SAE}, \text{D}) \)
7. \( \text{SAE} = f (\text{AE}_j, \text{AE}_{j-1}) \)
8. \( \text{USL} = f (\text{R}, \text{P}, \text{C10}) \)

III. Cost
1. \( \text{CP} = f (\text{CCI}, \text{SUC}, \text{RMATL}, \text{ASFP}, \text{SOCRM}, \text{EIRM}, \text{PRM}, \text{EIFF}) \)
2. \( \text{CCI} = f (\text{AIRM}, \text{AIFP}) \)
3. \( \text{SUC} = f (\text{SF}, \text{RN}) \)
4. \( \text{RMATL} = f (\text{PRM}, \text{RM}) \)
5. \( \text{ASFP} = f (\text{FP}) \)
6. \( \text{SOCRM} = f(\text{FP}, \text{AIRM}, \text{EIRM}, \text{PRM}) \)

7. \( \text{AIFP} = f(\text{EIFP}_j, \text{EIFP}_{j-1}, \text{FP}, \text{SP}) \)

8. \( \text{AIRM} = f(\text{EIRM}_j, \text{EIRM}_{j-1}, \text{RM}, \text{RN}) \)

9. \( \text{OT} = f(\text{EIFP}) \)

10. \( \text{CA} = f(\text{S}, \text{AE}, \text{AI}) \)

11.* \( \text{DSOC} = f(\text{CIO}, \text{P}) \)

12.* \( \text{CIO} = f(\text{AIFP}, \text{UQ}) \)

*In the real world, these would be opportunity costs.

III. Inventory

1. \( \text{EIFP}_j = f(\text{EIFP}_{j-1}, \text{FP}, \text{R}, \text{P}, \text{CIO}) \)

2. \( \text{EIRM}_j = f(\text{EIRM}_{j-1}, \text{RM}, \text{FP}, \text{OT}) \)

**INDUSTRY EQUATIONS (ith firm, jth period)**

1. \( \text{PIS}_j = \text{PIC}_j \cdot \text{PSI}_j \)

2. \( \text{PIC}_j = \text{TN}(\text{E}_{28} + \text{D}_j \cdot \text{E}_3) + \text{E}_2 \left( \sin \chi_j + \text{E}_4 \sin (\text{E}_5 \cdot \chi_j) \right) \)

3. \( \text{PSI}_j = \text{E} / \text{AIP}_j \)

4. \( \text{AIP}_j = \text{PS}_j / \text{TN} \)

5. \( \text{PS}_j = \sum_{i=1}^{\text{TN}} \text{P}_{ij} \)

6. \( \chi_j = 1.570796 \cdot \text{D}_j \)

7. \( \text{PRM}_j = \text{E}_{19} + \text{D}_j \text{E}_{44} + A_5 \cdot \text{E}_{20} \cdot \sin (\text{E}_{21} \cdot \chi_j) + \text{E}_4 \cdot \sin (\text{E}_5 \cdot \chi_j / 19.) \)

8. \( \text{PTT}_j = \sum_{i=1}^{\text{TN}} \text{PT}_{ij} \)

9. \( \text{SUMS}_j = \sum_{i=1}^{\text{TN}} (\text{S}_{ij} + \text{E}_{29}) \)
10. \( SEA_j = \sum_{i=1}^{TN} (EA_{ij} + E_{10}) \)

11. \( \text{SUMSC}_j = \sum_{i=1}^{TN} C_{10_{ij}} \)

12. \( Y_1 = E_{39}, \text{IDI}_j \leq 50 \)
   \( = E_{41}, \text{IDI}_j > 50 \)

13. \( Y_2 = E_{40}, \text{IDI}_j \leq 50 \)
   \( = E_{42}, \text{IDI}_j > 50 \)

**INCOME EQUATIONS**

1. \( TNP_{ij} = PNP_{ij} \)

2. \( PNP_{ij} = R_{ij} - C_{A_{ij}} - C_{P_{ij}} - DSOC_{ij} \)

3. \( R_{ij} = P_{ij} (UQ_{ij} + Y_1 \cdot C_{10_{ij}} + Y_2 \cdot SM_{ij} (\text{SUMSC}_j - C_{10_{ij}})) \)

4. \( UQ_{ij} = P_{ISj} \cdot SM_{ij} \)

5. \( SM_{ij} = PT_{ij}/PT_{ij} \)

6. \( PT_{ij} = ((P_{Sj} - P_{ij}E_8)/P_{ij}) (EA_{ij}/SEA_j + E_{10}) (S_{ij}/SUM_j + E_{29}) \)

7. \( EA_{ij} = (SAE_{ij} + D_{ij}E_{18})/(E_{43} + D_{ij}E_3) \)

8. \( SAE_{ij} = AE_{ij} \cdot E_{32} + AE_{i,j-1} \cdot E_{32}^2 + A_{10} \cdot AE_{i,j-1} \cdot E_{32}^3 \)

9. \( USL_{ij} = R_{ij}/P_{ij} - C_{10_{ij}} \)

**COST EQUATIONS**

1. \( CP_{ij} = CCI_{ij} + SUC_{ij} + RMATL_{ij} + ASFP_{ij} + SOC{RM}_{ij}, \text{ and} \)
   if \( EIRM_{ij} < 0, + EIRM_{ij} \cdot E_{48} \cdot (PRM_{i} + E_{46}) \)
   if \( EIFP_{ij} < 0, + EIFP_{ij} \cdot E_{47} \)

2. \( CCI_{ij} = AIRM_{ij} \cdot E_{30} + AIFP_{ij} \cdot E_{25} \)

3. \( SUC_{ij} = SF_{ij} \cdot E_{35} + RN_{ij} \cdot E_{37} \)
4. \( RM_{ij} = PRM_j \cdot RM_{ij} \)
5. \( ASFP_{ij} = FP_{ij} \cdot E_{31} \)
6. \( SOCRM_{ij} = FP_{ij} \cdot E_{16}/AIRM_{ij} \)
   subject to \( AIRM_{ij} > 0 \), if \( AIRM_{ij} < 0 \), \( SOCRM_{ij} = 0 \).
7. \( AIFP_{ij} = (EIFP_{ij} + EIFP_{i,j-1})/2 + FP_{ij}/2SF_{ij} \)
8. \( AIRM_{ij} = (EIRM_{ij} + EIRM_{i,j-1})/2 + RM_{ij}/2RN_{ij} \)
9. \( OT_{ij} = 0 \), \( 0 \leq EIFP_{ij} < 0 \), \( EIFP_{ij} E_{48} \)
10. \( CA_{ij} = E_{34} + (S_{ij}E_{33} + AE_{ij})/E_{15} + AI_{ij} \cdot E_{17} \cdot A_{8} \)
11. \( DSOC_{ij} = C10_{ij} \cdot P_{ij} \) (Equations 11 and 12 would be implicit costs in
    the real world.
12. \( C10_{ij} = 4000.0 \), \( 0 \geq (AIFP_{ij} - E_{49}) > 0 \), \( E_{1} \cdot UQ_{ij} / AIFP_{ij} \)

INVENTORY BALANCE

1. \( EIFP_{ij} = EIFP_{i,j-1} + FP_{i,j} - R_{ij}/P_{ij} + C10_{ij} \geq 0 \)
2. \( EIRM_{ij} = EIRM_{i,j-1} + RM_{i,j} - A6 \cdot E_{11} \cdot FP_{ij} - OT_{ij} E_{11} \geq 0 \).
### PARAMETERS

<table>
<thead>
<tr>
<th>Code</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Identify decision period</td>
</tr>
<tr>
<td>TN</td>
<td>Number firms per industry</td>
</tr>
<tr>
<td>E(1)</td>
<td>Adjust stockouts relative to sales and inventory</td>
</tr>
<tr>
<td>E(2)</td>
<td>Fluctuation magnitude for industry sales</td>
</tr>
<tr>
<td>E(3)</td>
<td>Long run increase in sales/firm/period</td>
</tr>
<tr>
<td>E(4)</td>
<td>Adjust price fluctuation of raw material</td>
</tr>
<tr>
<td>E(5)</td>
<td>Adjust price fluctuation of raw material</td>
</tr>
<tr>
<td>E(6)</td>
<td>Spare</td>
</tr>
<tr>
<td>E(7)</td>
<td>(Parts)</td>
</tr>
<tr>
<td>E(8)</td>
<td>Sensitivity constant - Price</td>
</tr>
<tr>
<td>E(9)</td>
<td>Constant to control effect of price on total industry sales</td>
</tr>
<tr>
<td>E(10)</td>
<td>Sensitivity constant - Advertising effect</td>
</tr>
<tr>
<td>E(11)</td>
<td>Number units of raw material per finished product</td>
</tr>
<tr>
<td>E(12)</td>
<td>Spare</td>
</tr>
<tr>
<td>E(13)</td>
<td>Spare</td>
</tr>
<tr>
<td>E(14)</td>
<td>Spare</td>
</tr>
<tr>
<td>E(15)</td>
<td>Percent burden charged to marketing</td>
</tr>
<tr>
<td>E(16)</td>
<td>Adjust inventory &quot;slippage&quot; in raw material</td>
</tr>
<tr>
<td>E(17)</td>
<td>Cost of Market Report</td>
</tr>
<tr>
<td>E(18)</td>
<td>Adjust effect of advertising</td>
</tr>
<tr>
<td>E(19)</td>
<td>Base price of raw material</td>
</tr>
<tr>
<td>E(20)</td>
<td>Adjust magnitude of price fluctuation of raw material</td>
</tr>
<tr>
<td>E(21)</td>
<td>Adjust period of price fluctuation of raw material</td>
</tr>
</tbody>
</table>
E(22) Parts
E(23) Spare
E(24) (Parts)
E(25) Holding cost per average unit for finished product
E(26) (Parts)
E(27) Spare
E(28) Base sales per firm
E(29) Sensitivity constant - sales promotion
E(30) Holding cost per average unit for raw material
E(31) Unit assembly cost - finished product
E(32) Adjust advertising effect (time cage)
E(33) Adjust relative percentage of overhead between advertising and sales promotion
E(34) Fixed cost of marketing
E(35) Setup cost - finished product
E(36) (Parts)
E(37) Order cost - raw material
E(38) Spare
E(39) Percentage stockouts retained (Variation = loss to industry)
E(40) Percentage others stockouts captured (Variation = loss to industry)
E(41) Percentage our stockouts retained (Variation = loss to industry)
E(42) Percentage others stockouts captured (Variation = loss to industry)
E(43) Adjust effect of advertising
E(44) Long run price increase per period for raw materials
E(45) Spare
E(46) Pure cost of expediting one unit raw material
E(47) Cost to produce one unit finished product on overtime
E(48) (-1.) Change numbers to positive values
E(49) Control (average inventory to limit stockouts to 4000 maximum)
E(50) Spare

MODULE CONTROLS (If 1. include equation, if 0. do not include equation)
A(1) Not used
A(2) Overtime production (with parts module)
A(3) Purchase parts outside
A(4) Parts module
A(5) Fluctuation in price of raw material
A(6) Withdraw raw material for regular production
A(7) Industry report for production
A(8) Marketing Report
A(9) Not used
A(10) Advertising lag from j-2
## GLOSSARY

<table>
<thead>
<tr>
<th>Code</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE(I)</td>
<td>Advertising expenditure</td>
</tr>
<tr>
<td>AI(I)</td>
<td>Purchase Market Report</td>
</tr>
<tr>
<td>AIFP(IK)</td>
<td>Average Inventory - Finished Product</td>
</tr>
<tr>
<td>AIP</td>
<td>Average Industry Price</td>
</tr>
<tr>
<td>AIRM(IK)</td>
<td>Average Inventory - Raw Material</td>
</tr>
<tr>
<td>AMKTC(IK)</td>
<td>Average cost/unit (Marketing)</td>
</tr>
<tr>
<td>APDRC(IK)</td>
<td>Average cost/unit (Production)</td>
</tr>
<tr>
<td>C(IK)</td>
<td>Sum of all units sold to date</td>
</tr>
<tr>
<td>CA(IK)</td>
<td>Cost of Marketing</td>
</tr>
<tr>
<td>CCI(IK)</td>
<td>Inventory carrying cost</td>
</tr>
<tr>
<td>CMKT(IK)</td>
<td>Marketing cost/unit</td>
</tr>
<tr>
<td>CP(IK)</td>
<td>Production cost last period</td>
</tr>
<tr>
<td>CP2(IK)</td>
<td>Research Report (Raw Materials) plus stockout costs for parts and Raw Materials</td>
</tr>
<tr>
<td>CI(I)</td>
<td>Not used</td>
</tr>
<tr>
<td>C2(I)</td>
<td>Average cost of production</td>
</tr>
<tr>
<td>C3(I)</td>
<td>Accumulated Profit</td>
</tr>
<tr>
<td>C4(I)</td>
<td>Advertising expenditure (D)</td>
</tr>
<tr>
<td>C5(I)</td>
<td>Advertising expenditure (D-1)</td>
</tr>
<tr>
<td>C6(I)</td>
<td>Finished Product Ending Inventory</td>
</tr>
<tr>
<td>C7(I)</td>
<td>Parts Ending Inventory (if used)</td>
</tr>
<tr>
<td>C8(I)</td>
<td>Raw Material Ending Inventory</td>
</tr>
<tr>
<td>C9(I)</td>
<td>Average Marketing Cost/Unit</td>
</tr>
<tr>
<td>C10(I)</td>
<td>Stockouts</td>
</tr>
</tbody>
</table>
C11(I) Not used
D Decision Period
DSOC(IK) Explicit Cost of Stockout (i.e. dollars lost)
EA(IK) Change of industry sales due to advertising (%)
EIPF(IK) Ending inventory finished product
BIPTS(IK) Ending inventory parts
EIRM(IK) Ending inventory raw material
EP(I) Amount of Finished Product Produced
ID(I) Firm Number
IDI Industry Number
IDJ Job (Marketing or Production)
KEND Constant used for alignment of form on printer
KR(1, IK) Rank - Income
KR(2, IK) Rank - Accumulated Income
KR(3, IK) Rank cost per unit for Marketing
KR(4, IK) Rank cost per unit for Production
N Marketing carryover card
N1 Production carryover card
OP(IK) Cost of units produced on overtime
OT(IK) Number units produced on overtime
P(I) Price
PDRC(IK) Cost per unit produced (average)
PIC Expected Sales for period D
PIS Expected Sales adjusted for advertising, price, promotion
PNP(IK) Gross Income for current period
PRM  Unit Price of raw materials
PS   Sum of unit price for all firms
PSI  Change in sales due to average industry price (%)
R(IK) Revenue
RM(I) Amount of Raw Material Purchased
RN(I) Number of orders of Raw Material
S(I)  Promotion Expense
SAE(IK) Sum of advertising effect for $D_i$ where $i = 1, 2, 3$.
SEA  Sum of EA(IK)
SF(I) Number of Setups for Finished Product
SM(IK) Share of Market
SOCPT(IK) Stockout cost for Parts (Automatically expedited)
SOCRM(IK) Stockout Cost for Raw Material (Automatically expedited)
SUC(IK) Set up and order charges
SUMS Sum of Promotion expense
SUMSC Sum of industry stockouts
T(IK) Sum of all units produced to date
TIFP(IK) Ending inventory finished product (computational variable)
TIRM(IK) Ending inventory Raw Material (computational)
TN   Number of firms/industry
TNP(IK) Accumulated Income to date
TP   Average finished product on hand based on amount scheduled and number of setups
TPP  Average Inventory purchased i.e. Total RM/# orders
UQ(IK) Expected Sales (units)
USL(IK)  Actual units sold this period
X  Sine function for seasonal variations in sales
Y1  Used to differ parameters for firms ≥ #50
Y2  Used to differ parameters for firms < #50
COMPUTER PROGRAM

DIMENSION RK1(4,6), RK(4,6), KR(4,6), OP(6), PT(6), ID(6)
DIMENSION E(50), A(10), P(6), AE(6), S(6), AI(6), RM(6), RN(6)
DIMENSION E1FP(6), EIRM(6), AIRM(6), CMKT(6), IDPRC(6), RMATL(6).
DIMENSION SF(6), SAE(6), EA(6), SM(6), USL(6), FP(6), C9(6)
DIMENSION SCRM(6), CP(6)
DIMENSION EIFP(6), EIRM(6), AIRM(6), CMKT(6), IDPRC(6), RMATL(6).
DIMENSION APDFC(6), TNP(6), PNP(6), CCI(6), SUC(6), DSOC(6).
DIMENSION OT(6), TIFP(6), TIRM(6), AMKTC(6), C(6), T(6).
DIMENSION C10(6), AIFP(6), R(6), SCI(6), CA(6), UQ(6)

3000 KEND=9
M=3
READ 1, D, J
1 FORMAT (F2.0,12)
DO 7000 I=1, 50
7000 READ2, E(I)
2 FORMAT (F15.5)
DO 7001 I=1, 10
7001 READ3, A(I)
3 FORMAT (F1.0)
2000 SUMS=0.
PS=0.
SEA=0.
SUMSC=0.
PTT=0.
SAM=0.
DO12 I=1, J
READ9, IDI, ID(ID(I), IDJ, P(I), AE(I), S(I), AI(I)).
9 FORMAT (14, I4, I3, 2X, F5.0, F8.0, F8.0, F3.0, 33X, 12)
10 READ8, IDI, IDF, IDJ, RM(ID(I), RN(I), FP(I), SF(I))
8 FORMAT (14, I4, I3, 32X, F8.0, F4.0, F7.0, F4.0, 4X, 12)
7 FORMAT (14, I4, I3, F9.5, F14.0, F9.0, F8.0, F8.0, 12, 12)
15 READ7, IDI, ID(I), IDJ, C2(I), C3(I), C4(I), C5(I), C6(I), CT
12 READ 6, IDI, ID(I), IDJ, C5(I), C6(I), CT
6 FORMAT (14, I4, 14, I3, 32X, F8.0, F10.5, F10.0, F10.0, F8.0, F8.0, 2X, 12, 12)
IF (101-50)16, 16, 17
16 Y1=E(39)
Y2=E(40)
GO TO 14
17 Y1=E(41)
Y2=E(42)
14 TN=J
I=J
X=D*1.570796
PIC=E(3)*TN*D+E(2)*(SIN(X)+E(4)*SIN(E(5)*X))*E(28)*TN
DO4 IK=1, I
3000 SUMS=SUMS+S(IK)+E(29)
EA(IK)=(SAE(IK)+D*E(18))/(E(43)+D*E(3))
SEA=SEA+EA(IK)+E(10)
SCI(IK)=C10(IK)
SUMSC=SUMSC+SCI(IK)
40 PS=PS+P(IK)
AIP=PS/TN
DO 42 IK=1, I
PRST=(PS-(P(IK)*E(8)))/P(IK)

195
PT(IK) = PRST*(EA(IK)/SEA+E(10))*(S(IK)/SUMS+E(29))
PTT = PTT + PT(IK)
PSI = E(9)/AIP
PIS = PIC*PSI
DO 44 IK = 1, I
SM(IK) = PT(IK)/PTT
UQ(IK) = SM(IK)*PIS
R(IK) = P(IK)*(U0(IK)+SC(IK)*Y1 + Y2)*SM(IK)*(SUM^SC-SC(IK))
CA(IK) = (S(IK)*E(33)+AE(IK))/E(15) + AI(IK)*E(17)*A(8)+E(34)
EIFP(IK) = C6(IK)+FP(IK)-R(IK)/P(IK)
TIFP(IK) = EIFP(IK)
IF (EIFP(IK) = 19, 20, 20
  TIFP(IK) = 0.
20 IF (FP(IK)*SF(IK)) = 22, 21, 22
  TP = .
GO TO 23
23 IF (EIFP(IK)) = 231, 233, 233
231 OT(IK) = EIFP(IK)*E(48)
233 TIRM(IK) = C8(IK)+RM(IK)-A(6)*E(11)*FP(IK)-OT(IK)*E(11)
24 TIRM(IK) = 0.
25 IF (RM(IK))*RN(IK)) = 24, 25, 25
24 TIRM(IK) = 0.
25 IF (RM(IK)*RN(IK)) = 26, 27, 26
27 TPP = 0.
GO TO 28
26 TPP = RM(IK)/(2.*RN(IK))
28 AIRM(IK) = (C8(IK)+TIRM(IK))/2.+TPP
IF (AIRM(IK)) = 282, 282, 281
282 SOC(RM(IK)) = E(16)*FP(IK)/AIRM(IK)
GO TO 283
282 SOC(RM(IK)) = 0.
283 ASFP(IK) = E(31)*FP(IK)
RimatL(IK) = RM(IK)*PRM
CCI(IK) = E(30)+AIRM(IK)+E(25)*AIFP(IK)
SUC(IK) = SF(IK)*E(35)+RN(IK)*E(37)
CP(IK) = CCI(IK)+SUC(IK)+RimatL(IK)+ASFP(IK)+SOC(RM(IK))
OP(IK) = 0.
IF (EIRM(IK)) = 29, 30, 30
29 CP(IK) = CP(IK)+EIRM(IK)*(PRM+E(46))*E(48)
SOC(RM(IK)) = SOC(RM(IK))+EIRM(IK)*(E(46)+PRM)*E(48)
30 IF (EIFP(IK)) = 31, 32, 32
31 CP(IK) = CP(IK)+E(47)*EIFP(IK)
OP(IK) = OT(IK)*E(47)*E(48)
32 IF (AIFP(IK)-E(49)) = 321, 321, 322
321 C10(IK) = 4000.
GO TO 323
322 C10(IK) = E(1)*UQ(IK)/AIFP(IK)
IF (FP(IK)+OT(IK)) = 3221, 3221, 323
3221 PDRC(IK) = 0.
GO TO 3231
323 PDRC(IK) = CP(IK)/(FP(IK)+OT(IK))
3231 APDRC(IK) = (C2(IK)*T(IK)+CP(IK))/(T(IK)+FP(IK)+OT(IK))
DSOC(IK) = C10(IK)*P(IK)
PNP(IK) = R(IK) - CA(IK) - DSOC(IK)
TNP(IK) = C3(IK) + PNP(IK)
USL(IK) = R(IK) / P(IK) - C10(IK)
CMKT(IK) = CA(IK) / USL(IK)
AMKTC(IK) = (C9(IK) + C(IK) + CA(IK)) / (C(IK) + USL(IK))
R(IK) = R(IK) - DSOC(IK)
C(IK) = C(IK) + USL(IK)
C2(IK) = APDRC(IK)
C3(IK) = TNP(IK)
C5(IK) = C4(IK)
C4(IK) = AE(IK)
C6(IK) = TIFP(IK) + C10(IK)
C8(IK) = TIRM(IK)
C9(IK) = AMKTC(IK)
T(IK) = T(IP) + FP(IK) + DT(IK)
PUNCH7, ID, ID(IK), IDJ, C2(IK), C3(IK), C4(IK), C5(IK), C6(IK), C7, N, M
PUNCH6, ID, ID(IK), IDJ, C8(IK), C9(IK), C10(IK), C11, C(IK), T(IP), N1, M
RK1(1) = PNP(IK)
RK1(2) = TNP(IK)
RK1(3) = C9(IK)
RK1(4) = C2(IK)
DO 45 L = 1, 4
DO 45 IK = 1, I
RK(L, IK) = RK1(L, IK)
J1 = I - 1
DO 46 L = 1, 4
J2 = 0
DO 47 IK = 1, J1
J2 = IK + 1
DO 47 K = J2, I
IF (RK1(L, IK) - RK1(L, K)) 33, 33, 47.
TEMP = RK1(L, IK)
RK1(L, IK) = RK1(L, K)
RK1(L, K) = TEMP
CONTINUE
DO 48 L = 1, 4
DO 48 IK = 1, I
DO 48 K = 1, I
IF (RK(L, IK) - RK1(L, K)) 48, 34, 48
IF (L-3) 35, 36, 36
KR(L, IK) = K
GO TO 48
36 KR(L, IK) = J + 1 - K
48 CONTINUE
DO 49 IK = 1, I
PUNCH 80, ID, ID(IK), D
FORMAT(2X, 8H INDUSTRY I3, 8H COMPANY I3, 7H PERIOD F4.0, /)
PUNCH82, PNP(IK), ID, ID(IK), D
82 FORMAT(32H 1LAST PERIOD INCOME OR LOSS, F10.0, I3, I3, F4.0)
PUNCH83, KR1(IK), ID, ID(IK), D
83 FORMAT(32H 2INDUSTRY RANK, LAST PERIOD, 7X, I3, I3, I3, F4.0)
PUNCH84, TNP(IK), ID, ID(IK), D
84 FORMAT(32H 3ACCUMULATED INCOME OR LOSS, F10.0, I3, I3, F4.0)
PUNCH85, KR2(IK), ID, ID(IK), D
85 FORMAT(32H 4INDUSTRY RANK, INCOME TO DATE, 7X, I3, I3, I3, F4.0)
PUNCH86
FORMAT(2X,16HMARKETING REPORT,/) 
PUNCH87,R(IK),IDI,ID(IK),D 
87 FORMAT(32H 5 NET SALES, LAST PERIOD 
PUNCH88,USL(IK),IDI,ID(IK),D 
88 FORMAT(32H 6 NUMBER OF UNITS SOLD 
PUNCH89,SM(IK),IDI,ID(IK),D 
39 FORMAT(32H 7 SHARE OF THE MARKET 
PUNCH90,CA(IK),IDI,ID(IK),D 
90 FORMAT(32H 8 COST OF MARKETING, LAST PERIOD 
PUNCH91,CMKT(IK),IDI,ID(IK),D 
91 FORMAT(32H 9 MARKETING COST PER UNIT SOLD 
PUNCH92,C9(IK),IDI,ID(IK),D 
92 FORMAT(32H 10 MARKETING-AVERAGE UNIT COST 
PUNCH93,XR(IK),IDI,ID(IK),D 
93 FORMAT(32H 11 RANK, MARKETING EFFICIENCY 
PUNCH94,C10(IK),IDI,ID(IK),D 
94 FORMAT(32H 12 STOCKOUT, LAST PERIOD 
PUNCH95 
95 FORMAT(19H PRODUCTION REPORT,/) 
PUNCH103,CP(IK),IDI,ID(IK),D 
103 FORMAT(32H 13 PRODUCTION COST LAST PERIOD 
PUNCH104 
104 FORMAT(17H COMPONENT COSTS,/) 
PUNCH105,CCI(IK),IDI,ID(IK),D 
105 FORMAT(32H 14 INVENTORY HOLDING 
PUNCH106,SUC(IK),IDI,ID(IK),D 
106 FORMAT(32H 15 SET UP AND ORDER 
PUNCH107,RNATL(IK),IDI,ID(IK),D 
107 FORMAT(32H 16 RAW MATERIALS 
PUNCH108,SOCRM(IK),IDI,ID(IK),D 
108 FORMAT(32H 17 EXPEDITE RAW MATERIALS 
PUNCH109,ASFP(IK),IDI,ID(IK),D 
109 FORMAT(32H 18 ASSEMBLY-FINISHED PRODUCT 
PUNCH110,GP(IK),IDI,ID(IK),D 
110 FORMAT(32H 19 OVERTIME-FINISHED PRODUCT 
PUNCH111,PRM(IK),IDI,ID(IK),D 
111 FORMAT(32H 20 RAW MATERIAL PRICE 
PUNCH112,PRC(IK),IDI,ID(IK),D 
112 FORMAT(32H 21 PRODUCTION COST PER UNIT 
PUNCH113,C2(IK),IDI,ID(IK),D 
113 FORMAT(32H 22 PRODUCTION-AVERAGE UNIT COST 
PUNCH114,KR(4,IK),IDI,ID(IK),D 
114 FORMAT(32H 23 RANK, COST PER UNIT 
PUNCH115 
115 FORMAT(18H ENDING INVENTORY,/) 
PUNCH116,C6(IK),IDI,ID(IK),D 
116 FORMAT(32H 24 FINISHED PRODUCT (UNITS) 
PUNCH117,C8(IK),IDI,ID(IK),D 
117 FORMAT(32H 25 RAW MATERIAL (UNITS) 
PUNCH118 
118 FORMAT(21H COMPANY PRICE) 
DO 50 L=1,1 
50 PUNCH119,ID(L),P(L),IDI,ID(IK),D 
119 FORMAT(2H25,5X,13,11X,F5.0,16X,13,13,F4.0) 
PUNCH 95
95 FORMAT( /23H LAST PERIOD DECISIONS) PUNCH 96,AE(IK),IDI,ID(IK),D
96 FORMAT(32H26ADVERTISING EXPENDITURES ,F10.0,13,13,F4.0)
97 FORMAT(32H27SALES PROMOTION EXPENSES ,F10.0,13,13,F4.0)
971 FORMAT(32H28MARKET REPORT ,F10.0,13,13,F4.0)
97 FORMA T(32H29FINISHED PRODUCT ,F10.0,13,13,F4.0)
100 FORMAT(32H30NUMBER OF SETUPS ,F10.0,13,13,F4.0)
101 FORMAT(32H31RAW MATERIAL ,F10.0,13,13,F4.0)
102 FORMAT(32H32NUMBER OF ORDERS ,F10.0,13,13,F4.0/)
49 PUNCH 120,KEND
121 FORMAT(10H INDUSTRY,13,7H PERIOD,F4.0/)
122 FORMAT(9H COMPANY,13,2X,F3.0)
123 FORMAT(28H ADVERTISING EXPENDITURES ,F10.0)
124 FORMAT(28H SALES PROMOTION EXPENSES ,F10.0)
125 FORMAT(28H SHARE OF THE MARKET ,F10.2)
51 PUNCH 126,AMKTC(IK)
126 FORMAT(28H AVERAGE COST OF MARKETING ,F10.2/)
37 SAM=SAM+1.
38 GO TO 49
38 PUNCH 120,KEND
123 FORMAT(48X,20X,12)
### APPENDIX II

#### VARIABLE NUMBERS AND NAMES

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APPENDIX III

STATISTICAL FORMULAE

Mann-Whitney U Test (Siegel, 1956, pp. 116-127)

\[ U = n_1 n_2 + \frac{n_1(n_2+1)}{2} - R_1 \]
\[ \mu_u = \frac{n_1 n_2}{2} \]
\[ \sigma_u = \sqrt{\frac{(n_1)(n_2)(n_1+n_2+1)}{12}} \]
\[ z = \frac{U-\mu_u}{\sigma_u} \]

For this study, \( R_1 = \) Sum of the ranks for Group 1;

\( n_1 = n_2 = 24 \).

\[ U = 876 - R_1 \]
\[ \mu_u = 288 \]
\[ \sigma_u = 48.5 \]
\[ z = \frac{588-R_1}{48.5} \]

Kolomogorov-Smirnov Two Sample Test (Siegel, 1956, pp. 127-136)

\[ D = \text{Maximum} \left[ S_{n_1} (x) - S_{n_2} (x) \right] \]
\[ K_D = D_{n_1} \]
\[ \chi^2 = 4D^2 \frac{n_1 n_2}{n_1+n_2} \]
For this study, the $S_{n_1}$ are the observed cumulative step functions for the Respective Groups; $n_1 = n_2 = 12$.

$K_D = 12D$

$\chi^2 = 24D^2$

Spearman Rank Correlation Coefficient (Siegel, 1956, pp. 202-213)

$$r_s = 1 - \frac{6 \sum_{i=1}^{N} d_i^2}{N^3 - N}$$

$$t = r_s \frac{\sqrt{N-2}}{\sqrt{1-r_s^2}}$$

For this study, $N = 12$ for Hypotheses D1 - D4 and $N = 24$ for Hypotheses D5 - D6.

For $N = 12$

$$r_s = 1 - \frac{\sum_{i=1}^{12} d_i^2}{286}$$

$$t = r_s \frac{\sqrt{10}}{\sqrt{1-r_s^2}}$$

For $N = 24$

$$r_s = 1 - \frac{\sum_{i=1}^{24} d_i^2}{2300}$$

$$t = \frac{\sqrt{22}}{\sqrt{1-r_s^2}}$$

Kruskal Wallis One-Way Analysis of Variance (Siegel, 1956, pp. 184-193)

$$H = \frac{12}{N(N+1)} \sum_{j=1}^{K} \frac{R_j^2}{n_j} - 3(N+1)$$

$H \geq \chi^2$, df = $K-1$ if $n_j \geq 10$

For this study, $R_j = $ Sum of the ranks for jth Group, $K$

$n_j = $ Sample size of jth Group = 12, $N = \sum_{j=1}^{K} n_j$, $K = $ Number of Groups.

$$H = \frac{1}{(2352)} \sum_{j=1}^{4} R_j^2 - 147$$

$\chi^2 = H$, df = 3
APPENDIX IV

MULTIPLE REGRESSION EQUATIONS

Selected Multiple Regression Equations
with Variables Listed in Order of Entry

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|       |          | X52      | MAGG          | 93.6507     | X62            | .58          |
|       |          | X56      | PORD          | -24.6627    | X60            | .62          |
|       |          | X59      | PAFF          | 53.4494     | X42            | .67          |
|       |          | X60      | PINT          | 47.5281     | X46            | .70          |
|       |          | X61      | PSUC          | -28.7898    | X56            | .72          |
|       |          | X62      | PDOM          | -51.9818    | X61            | .74          |
|       |          | X63      | PABA          | 31.4653     | X67            | .75          |
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BIBLIOGRAPHY


Helmer, O. The Game-Theoretical Approach to Organizational Theory. Santa Monica, California: The RAND Corp. P-1026, 1957.


I, John Michael Keenan, was born in Pendleton, Oregon, April 10, 1932. I received my secondary-school education in the public schools of Yakima, Washington, and Central Catholic High School in Portland, Oregon. My undergraduate training was first at the University of Portland and then at the University of Colorado, which granted me the Bachelor of Arts degree in 1957. I received the Master of Science degree from the University of Colorado in 1958. I was employed as an Instructor of Management at the University of Colorado from 1958 until 1960. In September, 1960, I enrolled at The Ohio State University to begin fulfillment of the requirements for the Doctor of Philosophy degree.

In September, 1962, I accepted a position as Assistant Professor of Management at Western Michigan University. In August, 1964, I was appointed Associate Professor of Business Administration and Economics at the U. S. Naval Postgraduate School in Monterey, California.