THE DEVELOPMENT OF A SURGICAL SCHEDULER'S MANAGEMENT GAME WITH AN ADAPTIVE TRAINING DEVICE

by

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CHAPTER I
INTRODUCTION

In 1969, Americans spent 60.3 billion dollars on health care, which amounted to 6.7 percent of the gross national product. On a per person basis, the cost was 293 dollars, which was more than twice the amount spent in 1959. In the past several years, the health care costs have been rising at an average annual rate of 7 percent. Due to these rising costs, many people no longer can afford health care. The rise in hospital costs has also resulted in a rise in the cost of health insurance, which is now too expensive for many families to purchase. (Business Week, 1970)

Many proposals have been suggested to solve what has been described as a national health crisis. These proposals include national health insurance, rate regulations, franchise health care, educational programs, and management programs.

New emphasis has been focused on the educational levels of the hospital employees. As a result of this emphasis, the American Society for Hospital Education and Training of the American Hospital Association has been established. Its purpose is to improve the methods of training and educating hospital personnel. This emphasis
has occurred because hospitals have traditionally hired non-professional employees with marginal qualifications and paid them low wages. These non-professional employees have raised their pay levels through unionization and collective bargaining. This has contributed to the sudden rise in hospital costs.

In the past, hospitals have encountered problems in providing continuing education to their employees. These problems have related to the lack of supervisor training skills, unavailability of instructors and educational materials, and insufficient employee background for the material needed.

One method of training which has been used in industry is the management game, a training exercise which uses a model of a business situation to teach the participant a common terminology and procedure. To date management games have not been developed for the specific functions found in a hospital.

The objective of this research is to determine the major variables of the surgical scheduler's function and to develop a hospital management game which accurately reflects the relationships between these variables. The management game will be designed with an adaptive training unit, which will make the game more difficult as the proficiency of the player increases. The hypothesis that the adaptive training unit contributes to the effectiveness of a management game will be tested.
THE SURGICAL ENVIRONMENT

The operating room or surgical suite is one of the services provided by the hospital health care system. Patients brought to the surgical suite for major and minor operations undergo induction to anesthesia, a surgical operation, resuscitation from the anesthetic state, and recovery from the physiological consequences of surgery. The surgical environment must be designed to minimize the hazards to the patient from infection, error, and psychological distress. This is accomplished through the proper selection of equipment, facilities, staff, and procedures.

A Typical Operation

After the surgeon and the patient have decided that an operation needs to be performed, the surgeon calls the surgical scheduler. Arrangements are made for the patient to be admitted to the hospital and for the patient to be placed on the operating room schedule. The patient is admitted a few days prior to the scheduled operation, at which time all pre-operative tests are performed. Figures 1 and 2 illustrate the set of events that occur on the day of the operation for major and minor surgery cases, respectively.

Approximately 45 minutes before a major operation is scheduled to begin, a ward helper is sent to bring the patient to the operating suite. When the previous case is finished, the operating room personnel begin to clean the operating room. As soon as the clean-up is completed, the circulating nurse begins to lay out the supplies for
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**Figure 1.**

EVENTS VS. BOARDED (INCISION) TIME - MAJOR CASES
Figure 2.

EVENTS VS. BOARDED (INCISION) TIME - MINOR CASES
the next case; the scrub nurse or technician begins to set-up the instruments, and the anesthesiologist begins the preparation of the anesthetic.

When the patient arrives at the operating suite, he is checked in and then enters the operating room. About this time the surgeon's assistant arrives and starts to scrub. Five minutes later the surgeon starts his scrub. Ten minutes prior to the operation, the patient and the medical staff are in the operating room and all the equipment and supplies are set-up. The patient is now scrubbed and gowned by the staff, and the operation is ready to begin.

After the operation is completed, the patient is moved to the recovery room for one to two hours. If the recovery from the anesthetic is normal, the patient is then returned to his room for post-operative recovery.

Organization of the Surgical Service

A typical hospital organization chart is illustrated in Figure 3. The Nursing Service is one of several services provided by the hospital. One of the departments that the Nursing Service is responsible for is the Surgical Service. In this department the nursing personnel, technicians, and operating room scheduler are under the direction of the operating room supervisor, who is usually a registered nurse. She is responsible to the Chief of Surgery, as is the medical staff. The medical staff may be composed of the surgeons, the
Figure 3.
HOSPITAL ORGANIZATION CHART
residents, the interns, and the anesthesiologists. Below is a list of the various position titles and their functions.

1. Operating room supervisor: a registered nurse in charge of one of the three operating room complexes.

2. Head nurse: a registered nurse who is assigned as an assistant to the operating room supervisor.

3. Staff nurse: a registered nurse who performs general operating room duties.

4. Scrub nurse: a registered nurse, licensed practical nurse, or scrub technician, who, in gown and gloves, passes instruments to the surgeon.

5. Circulating nurse: a registered nurse, licensed practical nurse, or scrub technician, who moves about one or more operating rooms during an operation to provide supplies and other support to the scrubbed personnel.

6. Surgical nurse: a licensed practical nurse who is allowed to administer medications and perform general operating room duties under the supervision of a registered nurse.

7. Surgical technician: an employee, who, under nursing supervision, assists physicians while performing surgical procedures, but who has no fixed state requirements for training or licensure and is not allowed to administer medications.

8. Nurse aide: an unlicensed person who is not allowed to administer medications, but who performs nursing duties under
the supervision of a nurse in the operating room, and usually prepares supplies in the workroom.

9. **Orderly:** the lowest skill level of operating-room employees, who wheels patients and performs courier duties.

10. **Central supply technician:** a person who prepares supplies (not in the operating room), gives no nursing care, and receives a lower salary than a nurse aide.

11. **Anesthesiologist:** a physician who limits his practice to the administration of anesthetics.

12. **Anesthetist:** a nurse who administers anesthetics.

13. **Surgical scheduler:** a person who keeps a record of when the operating rooms are available and schedules surgeon's requests.

**Physical Facilities**

Operating suites are usually composed of seven types of rooms: the induction room, the operating rooms, the recovery room, the workroom, the storage rooms, the staff rooms, and the administrative rooms. (Fisher, 1968) (Ludwig, 1968) The definitions for these rooms are listed below.

1. **Induction room:** a room other than the operating room in which to administer anesthetics.

2. **Recovery room:** a special area for intensive nursing care to be given to patients who are recovering from an anesthetic.

3. **Workroom:** a room within the immediate operating room area
for the preparation and sterilization of instruments, linen, and supplies for use in surgery.

4. **Operating room:** a room in which surgery is performed.

5. **Central storage room:** a room for storage of surgical supplies.

6. **Staff room:** a series of rooms in which the surgeons and nurses can change and store street clothes, rest between operations, and record medical data in the medical records.

7. **Administrative rooms:** rooms where the surgical operation room supervisor and others work.

At some point in the growth of a hospital, specialized operating rooms develop, such as, the Urology Room, the Fracture Room, the Orthopedic Room, the Eye Room, the Neurosurgical Room, the Cystology Room, and the Proctology Room. (Arbuckle, 1970) (Ludwig, 1968) (Denbo, 1963)

**Patient Classification**

There are many methods for classifying patients. Resh (1967) developed three patient categories: emergency patients, house patients, and elective patients. He defined emergency patients as those who are admitted upon arrival and require immediate surgery, house patients as those who are admitted by the house staff physicians and require surgery within the next day or two, and elective patients as those who apply for an admission date from the hospital admission
office.

A more general patient classification scheme includes an emergency patient, an urgent patient, and an elective patient category. (Harris, 1965) The emergency patient requires an operation within one to six hours, the urgent patient requires an operation within one to six days, and the elective patient requires an operation within one week to six months. The surgeon or physician determines the patient classification.

THE SCHEDULING PROCESS

The surgical scheduler's objective is to minimize the idle time of the operating rooms, the lead time to schedule an operating room, and the waiting time of the users. To accomplish this there must be a smooth flow of the operations through the surgical facilities. The flow of the operations is established by some procedure or algorithm that the surgical scheduler learns and tries to implement.

The schedule which is developed has a drastic effect on whether a surgical service makes a profit or a loss. If the schedule allows too much time for operations, the operating facilities and staff will be idle. This might eventually result in needless expenses in order to meet the demand of the community, such as building additional operating rooms or hiring extra staff. If the scheduler does not allow enough time for the operations, the patients and surgeons will have to wait, and the operating room staff will have to work overtime.
This can result in a decrease in performance, a change in the quality of care, and an increased expense. Thus, it is very important that the surgical scheduler is well trained and aware that her schedule has an effect on the income and expenses of the surgical services, as well as on the staff.

When a doctor requests that a patient be scheduled for surgery, he is actually requesting that the patient be scheduled for a hospital bed and an operating room. The admission process can either require that the patient be scheduled for admission to the hospital and then scheduled for surgery, or that he be scheduled for surgery and then scheduled for admission to the hospital. Regardless of which admission procedure is followed, the patient must receive an affirmative reply from both the admitting and the surgical schedulers.

The general procedure for scheduling an operation is straightforward. The surgeon calls the surgical scheduler and requests to schedule a particular operation, on a particular date, and possibly at a particular time. The surgical scheduler then attempts to meet this request. In order to schedule an operation, the scheduler must have a breadth of knowledge concerning hospital operating policies, medical requirements, and surgical staff characteristics. Specifically the scheduler usually requires five pieces of information: the date requested for surgery, the surgeon's name, the patient's name, the name of the operation, and the type of anesthesia. In addition, the scheduler may ask for the patient's age, weight, sex, the number
of assistants required, an estimate of the operation length, the operating room preferred, and the type of special preparations. With this information, the surgical scheduler makes an estimate of the length of time to allow for the operation. The scheduler then attempts to find an available operating room with the necessary equipment and with the correct time interval available.

Once a mutual date and time are agreed upon, the surgeon or the surgical scheduler calls the Admitting Department to schedule a hospital bed. If a hospital bed is available, the date and time of the operation is officially posted on the operating room schedule. If a hospital bed is not available, the scheduler and the surgeon contact each other and repeat the scheduling cycle.

A variation of the above process is to schedule a patient for a given day and at a later date schedule the time for the operation. Another variation of the surgical scheduling process is to assign a particular operating room to a surgeon for a given block of time, for example, all morning on Tuesday. The surgeon then schedules the operations he wishes in that block of time. If he is not going to use the time, then he notifies the surgical scheduler and releases this time for general use.

In summary, in order for the surgical scheduler to be able to perform her task properly she must know the following:

1. the names of the hospital surgeons,
2. the operating habits of the surgeons, such as whether they
take longer to do an operation than other surgeons,
3. the names and definitions for each operation type,
4. any special requirements associated with a particular type of operation,
5. the average duration time associated with each operation,
6. the limitations of each operating room,
7. any personnel limitations.

In the literature there does not appear to be any formal program for training the surgical scheduler. Most hospitals use an on-the-job training procedure. A person is hired and works with the present scheduler or some other person who has performed scheduling functions. The person hired for the position usually has no previous hospital training or medical terminology background. When the trainer feels the new scheduler is capable of handling the basic job, the formal training period ends. The formal training usually ends in three to four weeks, but some operating-room supervisors feel the scheduler requires up to two years before being completely trained.

A modification of the above procedure is to select a person from the Admitting Department, Medical Records Department, or the Nursing Department (not a nurse) for the surgical scheduler position. This selection decreased the training time because persons from these departments usually have a knowledge of medical terminology.

In this chapter it has been theorized that one method for slowing down the rise in hospital costs is through better education and
training of non-professional hospital personnel. One technique which would be of assistance is the management game designed for use in hospitals. It was shown that the surgical service is one of several services provided by the hospital. Since the surgical scheduler's function is the primary one in the surgical service that determines the efficiency of the surgical facilities, a management game was developed for the surgical scheduler's position.
CHAPTER II

SURVEY OF THE LITERATURE

The purpose of this chapter is to introduce the reader to the pertinent literature and studies related to management games, to the hospital surgical service, and to adaptive training. The first section of this chapter is devoted to defining a management game, distinguishing the difference between a management game and a simulation, defining the general features and types of management games, defining the guidelines for designing a management game, reviewing the history of management games, and outlining the purpose of management games.

The second section of this chapter reviews the studies conducted to determine whether management games accomplish their goals. These studies were conducted by McKenney (1961), Raia (1961), Babb (1966), Cook (1967), and Philippatois (1969).

The third section of this chapter reviews three management games designed specifically for use in hospitals. Two of these games are computer games and one is a paper and pencil game.

The fourth section of this chapter reviews some of the studies conducted in the surgical service. First, a typical study conducted for a specific surgical service is reviewed. Next, six general research projects are reviewed. Three of these are simulations and three are statistical studies.
The last section of this chapter is concerned with adaptive training. Adaptive training is defined and its principles are explained.

**MANAGEMENT GAMES**

What is a management game? Amos R. L. Deacon defines the management game in the following manner:

Simulation, as a general field of activity, has to do with the design, building, manipulation and study of models. A simulation or a simulation exercise is an experiment performed upon a model....A model is an artificial representation of a system, process, organism, or environment designed to incorporate certain features of that system, process, organism, or environment according to the purpose which it is intended to serve. Simulation models are of two distinct types:

1. **Analytical models** which are used for purposes of problem solving, mathematical analysis, design, and forecasting, and do not ordinarily include human decision makers.

2. **Training models**, which always include human decision makers and are used for purposes of teaching the participants or players and also of observing their behavior (Graham, 1961, p.61).

Many of the points that Deacon mentions are incorporated in the following definition:

A business game is a contrived situation which imbeds players in a simulated business environment, where they must make management-type decisions from time to time and their choices at one time generally affect the environmental conditions under which subsequent decisions must be made. Further, the interaction between decisions and environment is determined by a referencing process which is not open to argument from the players (Dill, 1961, p.7-8).
A shorter definition is: "A management game is a dynamic training exercise utilizing a model of a business situation." (Kibbee, 1961, p.3) These three definitions have one factor in common; each definition mentions that a game is a simulation exercise requiring human inter-action.

It has been pointed out that the distinction between a game and a simulation is a subtle one, since both are dynamic numerical models (Meir, 1969). The difference is in their purpose and mode of use. Simulation models are generally designed to generate a sequence of activities in a system and to record statistics regarding the operation of the system. The purpose of simulation models usually is to study the dynamic behavior of systems. Games are designed to incorporate the player in the decision-making phase of the simulation for the purpose of improving the decision-making skills of the players.

Games are played in teams composed of from one to twenty participants, usually with some competition between the teams. This competition can be part of the game, with each team competing against the other team and the decisions of each team directly affecting the decisions of the other teams. Sometimes the games are non-competitive and the decisions of one team do not affect the results of the other teams.

Most games contain some measure of effectiveness. To determine this, the participants usually make a set of decisions which are submitted either to clerks or to the computer for evaluation. Reports which contain the measures of effectiveness are generated for each
team. The number of decisions submitted will depend on the type of
game being played. In most games each decision represents a time
period of a day, a week, a month, or a quarter.

There appear to be three general guidelines that should be observed
when designing a management game. The game should be designed with a
stable environment, an observable response to the decisions of the
participants, and no opportunity for the participant to use an unrealis-
tic tactic to influence the outcome. The stability of the environment
requires that the game must react slowly and in a realistic fashion.
The second guideline requires each decision variable to produce some
observable effect. The third guideline requires the game to be designed
so that the participant conducts a conscientious analysis of the data
and makes rational decisions (McKenney, 1967).

In addition to the guidelines for designing a game, the type of
game must be determined. Games are usually classified as general
management games, functional management games, and industry management
games (Graham, 1969). General management games are usually designed
to focus on the decision making at the top management level. Functional
games focus on middle management decisions and emphasize particular
areas of the firm. The industry games focus on a particular industry
with the emphasis on introducing the participant to the type of
decisions made by that industry. The industrial game may be either a
general or a functional management game.
Most authors give Von Reisswitz credit for developing the first modern management game (Meir, 1969), (Graham, 1969), (Kibbee, 1961). Von Reisswitz introduced the Prussian army to the modern war games in the early eighteenth century. This game required opposing officers to issue orders to their troops, which were represented by wooden blocks placed on a map. The orders made by the officers were evaluated by an umpire.

The Von Reisswitz game developed into what is known today as the classic three-room war game. Thomas described one version of the game in the following manner:

The idealized version of the classic game may be pictured as the kind that is played largely for 'research' purposes, at several military and research organizations which maintain gaming facilities, on a more or less continuing basis. Typically, there may be from ten to fifty players organized into three teams, a room for each team, maps, counters, slide rules or desk computers, clocks keeping 'game time', and appropriate communication channels between rooms. The red team and the blue team represent opposing forces or nations or blocks of nations, with their players assuming pertinent military or political roles. Other nations, and the laws of nature generally, both deterministic and stochastic, are represented by the control team in accordance with a set of rules which it enforces. Play starts from the initial condition of a scenario, goes through a succession of red moves and blue countermoves, and finally is terminated at the discretion of the control team, usually after several days or weeks have elapsed. There may be one or more replays starting from the same basic situation. After the play has concluded, there may issue from it a succession of analyses, reports, and summaries (Thomas, 1961, p. 426).
Since World War I, the military has developed many types of games. Some have been war games, and others, such as the inventory management game called Monopologs, are similar to the modern business game. Monopologs was developed at RAND in 1955 to simulate the U.S. Air Force logistic system (Graham, 1969). In this game the players act as inventory managers of a supply depot and make monthly decisions on procurement of new parts, repair of parts, and distributions of parts among bases.

In the past fifteen years the most extensive use of games has been in businesses and educational institutions. The Top Management Decision Simulation developed by the American Management Association in 1956 appears to be the first business management game (Graham, 1969). This is a computerized general management game in which the decisions are similar to ones which would be made at the top management level. Participants are assigned to a team and become the managers of a hypothetical company and then compete with one another for the market of their single product. From this game, many similar games were developed for use in the classroom and for use in major corporations (Meier, 1969).

In the 1960's the number of games available increased rapidly. Kibbee (1961) describes eighty-five games and Greenlaw (1962) lists eighty-nine games. A selective description of one hundred and eighty-two games was compiled by Graham.
Management games have a variety of purposes and goals. Graham lists the following four uses of games:

1. Teaching specific items - the importance of planned and critically timed decisions, PERT, or specific routine items such as Civil Service regulations, or particular decision-assisting tools.

2. Teaching general behavioral factors such as the importance of flexible, organized efforts, the need for inclusion of appropriate persons and factors in decision making, the importance of a balance among managerial functions, the matching of task-person-group, and so on.

3. Teaching the power of the modeling, mathematical, or scientific approaches to business problems.

4. Generating a high degree of involvement as either an introduction or a conclusion to a training program (Graham, 1969, p. 28).

Kibbee (1961) points out that management games are used primarily for training purposes. He mentions that they have two unique characteristics which enable them to contribute powerfully to management education: the time dimension and the objectivity of the feedback.

Torgersen (1969) points out that:

The business or management game is essentially a pedagogical device. It facilitates an element of involvement through overt individual participation. Learning can then occur in three successive phases:

1. the common language and the facts expressed in the game may be acquired,

2. the processes simulated within the game model, including the parameters and constraints may be learned, and

3. the relative trade-offs - the costs, the advantages and disadvantages - required of different strategies and alternatives may come to be understood.
In a more general sense, the student of management also learns the importance of the systematic approach to establishing objectives, evaluating alternatives and making decisions. He also learns of the necessity to make decisions under conditions of uncertainty (Torgersen, 1969, Phase I-A, p. 3)

**THE EVALUATION OF MANAGEMENT GAMES**

The question has been raised as to whether management games accomplish their goals. Very little experimentation has been conducted in the evaluation of management games. Dill (1961) reached the following conclusion after the Tulane University Conference on Business Games:

...the conferees were generally dissatisfied with the existing evidence supporting the educational virtues of business gaming. Although a few relatively formal evaluation attempts are reported upon in the individual discussion papers, most of the present support for gaming consists of intuitive judgements with little or no basis in scientifically objective evidence (Dill, 1961, p. 13).

Since the Tulane Conference, only five attempts have been made to quantitatively evaluate management games. These studies were conducted by McKenney (1961) at the Harvard Business School, by Raia (1961) at the University of Maryland, by Babb (1966) at Purdue University, by Cook (1967) at the University of Arkansas, and by Philippatois (1969) at Pennsylvania State University. In this section, these studies will be summarized under four topics; the management game, the subjects, the experimental design, and the conclusions.
The Management Games

The five researchers cited used management games which were business oriented. McKenney and Cook used the UCLA Executive Management Game. In this management game, each firm produces the same three products and the participant sets the selling price, marketing expenditures, design and styling expenditures, and production volume. Philippatois used a management game very similar to the UCLA Executive Management Game. Raia used a complex management game similar to the UCLA Executive Management Game, which required eighteen decisions related to sales, production, and finance for one group. For the other group, he used a management game in which the hypothetical industry produced a single product with a single raw material. This management game required only eight decisions per period. Babb used a competitive dairy industry management game and a farm supply industry management game.

SUBJECTS USED

In the experiments conducted by McKenney, Raia, Babb, Cook, and Philippatois, students were the primary participants in the management game. McKenney used ninety first-year graduate students enrolled in a program leading to a Master of Business Administration. Raia obtained his one hundred and thirty-nine participants from a business policy course composed of graduating seniors. Cook used one hundred and twenty sophomore and junior business administration students who were
enrolled in an accounting course. Philippatois used thirty-two undergraduate and thirty-six graduate students with no background in marketing and seventy-two graduate students taking a marketing course. Babb used an unknown number of undergraduate students, twenty-four experienced dairy managers, and twenty-three experienced farm supply managers.

Experimental Design Used

Each researcher divided his participants into either two or three groups. One group was a control group. Each team then played the management game for a set number of periods. The number of periods played varied from five to twelve periods. The participants were given various tests, both prior to and after playing the management game. Using the appropriate statistical methods, each researcher tested his hypothesis and reached certain conclusions.

Each researcher used a variety of measures of effectiveness. McKenney used the scores on a written examination. Raia used the scores on written examinations, questionnaires, and student ratings. Babb measured real-life success by profit as a percentage of sales, managerial ability by rankings made by the participants and by consultants familiar with the participants, and game success by the net profit made in the game. Cook measured the psychological effect of the feedback frequency with a questionnaire after each period, the game performance by the rate of return, and the aspiration level by the expected operating budgets for the next period. Philippatois used the price/quantity ratio as the measure of effectiveness.
Conclusions Reached

McKenney concluded from his study that management games can teach planning to decision-makers and that it was worthwhile to trade time spent on case studies for time spent playing a management game.

From his data Raia concluded the following:

(1) that, when used as a supplementary teaching aid, the games enhanced learning and heightened student interest and motivation and (2) that the relatively simple game provided essentially the same benefits as the more complex one. Contrary to what was hypothesized, however, the games did not develop more favorable attitudes toward the course (Raia, 1966, p. 351).

Babb examined the problems and potentials of business games as a research method and summarizes the findings of several studies conducted at Purdue University. In one of his experiments Babb found that for success in a management game, the participant had to rank high in the traits of reasoning ability, cautiousness, and emotional stability. To be successful in the farm supply business, the participant needed to rank high in the traits of personal relations, cautiousness, vigor, and membership in organizations. In order to be a successful manager, the participant needed to have spent several years in his position and be very sociable. From the results of this study and others, Babb concluded that there was little correlation between game success, real-life success, and managerial ability of the participants. He also concluded that management games must be played individually when the results are to be related to individual characteristics, and that there were striking differences in behavior and game results, between students
and experienced managers.

Cook found that the frequency of the performance reports that the participant received was directly related to the interest and satisfaction of the participant in the management game and the degree of success in the management game. She also found that the interest and satisfaction of the participants was related to the degree of success. The experiment also indicated that the level of aspiration of the participants raised or lowered as a result of the success or failure in the preceding report.

Philippatois concluded from his research at Pennsylvania State University that:

The authors could not find evidence that specialization in a given discipline produced superior results to those achieved by non-specialists. Furthermore, we could not find any evidence that knowledge of the nature and rules of the game aided in making decisions that were significantly different from those made by the 'blind' control group. Neither did we find the eliminations of briefing and debriefing sessions, the reduction of decision-making time, and the increase in the frequency of decisions in any way increasing the variability in decisions (Philippatois, 1969, p. 12).

**HOSPITAL MANAGEMENT GAMES**

There are only three management games oriented toward hospital management and training. These are the IBM Hospital Administration Decision Laboratory Game (Lucas, 1967), A Computer Game On Hospital Planning (Feldstein, 1968), and You Are Barbara Jordan (Doolan, 1969). The first two games require the use of computers, are competitive in nature, and are designed for use by the upper level hospital management.
The third game is a paper and pencil game and is designed for use by the nursing personnel.

In the medical area several games are being developed. One game is being played by the students at the University of Illinois Medical Center campus in Chicago. They are diagnosing and treating computer "patients". Using an on-line computer system, the students interview, diagnose, and treat "patients" who have varying personalities and different ailments.

**IBM Hospital Administration Decision Making Laboratory Game**

The IBM Hospital Administration Decision Making Laboratory Game (Lucas, 1967) is a computerized management game designed to be used by hospital administration. The game is set in an environment in which the player makes a set of decisions which affect admissions, discharges, emergencies, medical and non-medical staff losses, and medical and non-medical staff absences. These variables are affected when the player makes decisions on bedsize addition, emergency reservations, prices (room and board, treatment, and supplies), supplies purchases, staff additions and discharges, and staff payroll.

This game has two variables which make it dynamic. The first variable is a metropolitan population growth factor which changes the need for facilities and staff. The second variable is a seasonal index which affects the admissions and discharges for each week during a period.
After making a set of decisions, the player receives three sets of reports. The Decision Report lists the decisions made for this period. The Metropolitan Hospital Report is a summary of information from each of the hospitals, such as the hospital bedsize and census, staff assignment levels, assets account balances, and price decisions. The Confidential Report consists of four summary reports: census report, staff report, operating income and expense report, and balance sheet. Each one of these reports contains from seven to twenty-five items of information.

A Computer Game On Hospital Planning

Another hospital-oriented management game is "A Computer Game On Hospital Planning" (Feldstein, 1968). This game attempts to incorporate the basic hospital planning problems of:

1. How is the future utilization of services for an area predicted?
2. Which services are to be provided by which hospitals?
3. Are these services consistent with the goals of the organizations providing them?
4. Are these services consistent with the programs and plans of other hospitals in the area?
5. How are anticipated services and facilities to be financed?
6. What is the role of the consultant in planning?
7. What are the goals, procedures, and problems of area-wide planning for health care facilities?
In addition to answering these questions, the players' decisions will affect their insight into some non-quantified aspects of hospital planning, especially into their recognition of the need for cooperation among the individual hospitals (Feldstein, 1968, p. 1).

There are two features unique to this game. First, the concept of "demand" rather than "need" is used as a basis for predicting the number of future facilities. For example, an area may need more hospital beds, but the demand may not reflect this "need." The second feature is the introduction of an additional person into the game who has the role of a voluntary hospital planning agency. This person attempts to get the hospitals to work together.

Each decision sheet requires two types of decisions: necessary decisions and optional decisions. The only necessary decision is an estimate of the expected number of patient days for the next period. The optional decisions can be made in any period. These decisions include constructing new beds; adding new facilities or services, such as a radiology department; changing the room rate; starting a community fund drive; conducting a community survey; transferring funds from the operating revenue fund to other accounts; and transferring funds to other hospitals with which facilities are shared.

After a period of play (one year), the teams receive three types of reports: Income and Expense Statement, Balance Sheet, and Memos to the Players. The first two reports contain the usual information associated with that type of report. The Memos to the Players contains additional information, such as informing the team that they have
incurred a deficit in excess of forty percent of their total revenue.

You Are Barbara Jordan

The last management game oriented toward hospitals is the "You Are Barbara Jordan" game (Doolan, 1969). This game is a paper and pencil game in which the player assumes the role of Barbara Jordan, director of the nursing service department in a two hundred and five bed, short-term, general hospital. The player responds to memos, letters, telephone messages, and other items which accumulate on her desk. The purpose of the exercise is to help nursing personnel to recognize the need to establish priorities, evaluate their ability to delegate authority, practice skills in reading and writing communications, perceive relationships between problem situations, develop sensitivity to the attitudes and feelings of co-workers, and analyze the factors that affect the decision-making process.

The three games described above appear to be the only ones readily available to the public. Other games do exist, but they have been developed by various consulting agencies and are not generally distributed.

SURGICAL SERVICE STUDIES

The surgical service studies can be classified into two groups: those studies conducted for specific hospitals and those studies applicable to hospitals in general. The first group of studies is usually conducted by consultant groups, hospital engineering management
programs, and university hospital administration intern programs. Studies of the latter type are usually M.S. theses and Ph.D. dissertations or federally sponsored research projects. In this section a typical study conducted by engineering management groups is presented. In the second category, three surgical simulation models and three statistical studies of the surgical service are reviewed.

Organizations, such as the Hospital Management Engineering Program, Western New York Hospital Association, Industrial Extension Service, North Carolina State University, and Community Systems Foundation, Ann Arbor, Michigan, have conducted numerous surgical service studies. These studies deal with a variety of topics or problems, such as an excessive length of time between surgical cases (Denbo, 1963), (Friedland, 1965), (Williams, 1968), scheduling of the operating room facilities (Harris, 1965), (Nagy, 1968), cost analysis of surgery (Yamamoto, 1963), staffing requirements of the surgical service (MacLeod, 1966), organization of surgical service (Ludwig, 1965), and utilization of the surgical rooms (Grant, 1969).

A typical surgical service study was performed by Harris, in which he states:

The primary goal of the study was to document existing conditions relative to the scheduling of surgery, performance of surgery relative to the schedule, and the utilization of facilities and personnel. Included in the goal was a concern with whether or not delays occur in meeting the surgical schedule and if so, what effect these delays have on utilization (Harris, 1965, p. 1).
After conducting the study and analyzing the data, Harris makes the following recommendations:

1. Inform all case personnel of the time they are to be ready to perform their tasks prior to the scheduled time of the first incision.

2. Remove from the operating room supervisor the task of scheduling urgent cases.

3. Eliminate the unnecessary restriction of booking most cases by periods of one and one-half hours duration.

4. Develop a history of past performance by doctor and by procedure so that cases can be scheduled on the basis of experience rather than on the basis of subjective judgment.

5. ...unless delays can be eliminated no case should be scheduled for the first incision after 1:30 P.M.

6. ...the task of booking urgent cases should be assumed by the booking clerk.

7. ...either the dayshift personnel be rescheduled to work from 7:15 A.M. to 3:45 P.M. or that the first cases be boarded at 7:45 A.M. (Harris, 1965, pp. v-vii).

This set of recommendations is an example of the type found in the management engineering surgical service reports. They are concerned with solving a particular problem and solving it quickly and economically. Usually tools such as time study, work sampling, flow chart analysis, frequency and charting analysis, and elementary statistical analysis are used for collecting and evaluating data.

The problem of the surgical service has also received the attention of the academic community. At Yale University, Kavet (1962) developed a simulation model of the surgical service. The model was used to
investigate the operational consequences of utilizing separate sets of beds for pre-operative and post-operative care instead of having the same beds serve as both pre-operative and post-operative beds. Due to the cost of running the model, only one experimental run was made. The run indicated that the use of pre-operative and post-operative beds resulted in a marked loss in efficiency in terms of the number of beds needed and the occupancy rate of those beds. The simulation program was written in the SIMSCRIPT language.

Barnoon (1968) investigated various combinations of the number of operating rooms, nurses, and anesthetists for a specific hospital situation. After developing a SIMSCRIPT simulation program, a simulation was run for four possible combinations in order to determine the lowest cost combination.

The simulator determined the number of operating rooms, anesthetists, and nurses for each case. The data for the program was developed from actual hospital data or generated by probability distributions. At appropriate times a performance report was generated which included the idle time and the waiting time for facilities and personnel. The simulation was designed for elective surgery and not a general system of operating rooms. In this simulation the limiting factor was not the operating room time available, but the number of beds available.

R. N. Davis (1968) developed a simulation model of an operating service. His basic model was designed for a specific facility. After using various scheduling algorithms, the work load in the surgical
Lister (1964) attempted to develop a mathematical model to assist the scheduler in predicting the length of the operation. He developed the following model:

\[ Y = X + D + W + A + S + E \]

where:
- \( Y \) = expected length of surgical procedure
- \( X \) = average length of surgical procedure
- \( D \) = the \( i \)th doctor in attendance factor
- \( W \) = the \( j \)th patient weight factor
- \( A \) = the \( k \)th patient age factor
- \( S \) = the \( l \)th patient sex factor
- \( E \) = experimental error

Due to the lack of data, Lister was able to test only the effects of the above factors on the gall bladder operation, the appendectomy operation, and the tonsillectomy. He found that sex and weight affected the gall bladder operation length, only age affected the appendectomy, and none of the factors affected tonsillectomy. He was not able to test the significance of the doctor on the operating time.

The purpose of a statistical study conducted by J. G. Davis (1961) was to develop a prediction model for estimating the total weekly
operating time. The prediction models tested were: the least-square line based on various amounts of prior weekly data, weighted moving averages with varying weighting factors and covering various periods of prior data, correlation between clinic admissions and operating suite load conditions, and application of seasonal fluctuations as displayed by data from previous years. He found that the average of the four preceding weeks predicted any given week as accurately as any of the other methods.

One approach for trying to obtain improved time estimates for the scheduler has been through the development of an adaptive Bayesian prediction model. Esogbue (1970) studied 467 various surgical operations for which he had both the time estimate and the actual times. For his first mathematical model he used a simple linear regression model:

\[ t_{or} = a + bt_{es} + \epsilon \]  \hspace{1cm} (1)

where:  

- \( t_{or} \) = the operating time  
- \( t_{es} \) = the estimated time  
- \( a \) = the fixed operating time  
- \( b \) = the regression coefficient  
- \( \epsilon \) = error
He found a correlation coefficient of 0.67 existed between the
time estimates and the actual operation times. From this he concluded
that the scheduling nurses' estimates could be used as an acceptable
predictor of the lengths of surgical procedures. After further analysis
of the data, it was found that on the average, the time estimates were
longer than the average time actually taken, and that the times esti-
mated showed much less variation than that of the actual operating
times. He concluded that this indicated that the nurses tended to be
consistent in their estimates. It was also found that the scheduling
nurse appears to overestimate short-lasting operations and to under-
estimate the long ones.

For predicting the length of operations Esogbue recommends the
following model:

\[
\hat{t}_{or} = \bar{t}_{or} + b(\bar{t}_{es} - \bar{t}_{es}) \tag{2}
\]

where: \( \hat{t}_{or} \) = predicted time for an operation

\( \bar{t}_{or} \) = the average value taken for operations as
calculated in this analysis

\( \bar{t}_{es} \) = time estimated by surgeon

\( \bar{t}_{es} \) = the average of such surgeon estimates as
calculated in the foregoing

\( b \) = the regression coefficient between \( \bar{t}_{or} \) and \( \bar{t}_{es} \)
The second mathematical model Esogbue developed used the following Bayesian prediction model where:

\[
P_N(\text{t}_{or}/\text{t}_{es}) = \frac{p(\text{t}_{or}) \ast p(\text{t}_{es}/\text{t}_{or})}{\sum_{\text{t}_{or}} \ast p(\text{t}_{or}) \ast p(\text{t}_{es}/\text{t}_{or})}
\]

where: \( \text{t}_{es} \) = time normally estimated by nurse for an operation

\( \text{t}_{or} \) = time taken for the operation estimated in equation (1)

\( p(\text{t}_{or}) \) = the prior distribution of operating times

\( p(\text{t}_{es}/\text{t}_{or}) \) = the conditional probability that the time estimate, \( \text{t}_{es} \), will be given for an operation intrinsically due to take \( \text{t}_{or} \)

With this probability, Esogbue believes that the scheduling nurse can prepare a more representative schedule.

From the above studies, it appears that the development of a good procedure for scheduling operating rooms has not been developed. Also, very little attention has been given to the surgical scheduler, who must develop the surgical schedule.
ADAPTIVE TRAINING

Most of the adaptive training research has been conducted for the military, in particular the U.S. Navy. This author was not able to find any research which applied the adaptive training concept to management games.

Adaptive training is defined as "training in which the problem, the stimulus, or the task is varied as a function of how well the trainee performs" (Kelley, 1969, p.547). Not all adaptive man-machine systems are designed for training, but training is the area in which most of the current research has been directed. Before discussing the research related to adaptive learning, an introduction to some of the concepts might be appropriate.

There have been two requirements established for adaptive training (Kelley, 1969). First, the performance should be continuously or repetitively measured in some manner; and second, the measurement should be employed to make appropriate changes in the stimulus, problem, or task.

Figure 4 compares a fixed training model and an adaptive training model. The primary difference between the models is the feedback loop. This requires that a machine-controlled, adaptive training model have three elements:

(1) a means for measuring performance, (2) an adjustable feature of the task or problem which changes its difficulty (the adaptive variable), and the adaptive logic which automatically changes the adaptive variable as a function of the performance measurement (Kelley, 1969, pp. 547-48).
a. Fixed Training Model

b. Adaptive Training Model

Figure 4
FIXED AND ADAPTIVE TRAINING MODELS
This simply means that as the subject becomes more skilled, the task gets harder.

It appears that the first work conducted in the machine-controlled adaptive device in the continuous field was done by Henry Birmingham at the U.S. Naval Research Laboratory in 1959. Prior to 1959, there was related research conducted by various researchers. A good review of this work is presented by Kelley. The next group to do major research was Dunlap and Associates in California. This group conducted numerous studies for the U.S. Naval Research Laboratory on the use of adaptive training for various activities, such as measuring piloting skills. This group developed the Dunlap adaptation technique. Previous researchers varied the system by making the adaptive variable a direct function of a time-averaged measurement; however, the Dunlap adaptation technique makes the rate of change of the adaptive variable a function of the error. The results of this concept are shown in Figure 5, where the abscissa refers to the level of skill and the ordinate refers to the adaptive variable. In the fixed difficulty system, as the skill increases the adaptive variable remains constant. In the adaptive system, the adaptive variable changes as the skill level increases; in the Dunlap adaptive system, the change in the adaptive variable is linear.

When the abscissa is the level of skill and the ordinate is the performance measurement, a fixed difficulty system will theoretically result in an increase in performance. If an adaptive system is used,
a. Fixed difficulty system

b. An adaptive system

c. Dunlap adaptive system

LEVEL OF SKILL

Figure 5

ADAPTIVE VARIABLE AS A FUNCTION OF SYSTEM DIFFICULTY IN FIXED AND ADAPTIVE SYSTEMS
the increase in performance should have a linear relationship. If the Dunlap adaptive system is used, the performance should remain constant. These situations are illustrated in Figure 6.

**SUMMARY**

In this chapter it has been shown that a management game is a simulation with human interaction. Although management games have been used extensively in business administration curricula and in industry, very little research has been conducted on the effectiveness of the games. The limited research that has been conducted indicates that management games have advantages over case studies and outside readings.

Only three management games, which are generally available, have been developed for hospitals. Two of these games were designed to be played by the hospital administrator. The third one was designed to be played by head nurses.

Adaptive training techniques essentially make the task harder as the proficiency of the participant increases. The primary research on adaptive learning has been conducted by Kelley at Dunlap and Associates, Inc. There has not been any application of the adaptive learning concept to management games. In summary, it appears that the development of management games for use in hospitals has been very limited and the application of adaptive training concepts to management games has not occurred.
Figure 6

PERFORMANCE MEASUREMENT AS A FUNCTION OF SYSTEM DIFFICULTY IN FIXED AND ADAPTIVE SYSTEMS
CHAPTER III

THE SURGICAL SCHEDULER'S GAME

The Surgical Scheduler's Game focuses on the scheduling function of the surgical service in a four hundred bed, short-term, non-profit, medical-surgical, teaching hospital with three operating rooms. The participant is asked to assume the surgical scheduler's position, which is to determine if a surgical room is available at the surgeon's requested time and, if not, to reach a mutually agreeable date and time with the surgeon when the operation can be performed. To assist him, he receives five data sets: Data Set 1 contains the player's instructions; Data Set 2 contains a list of the operations and the average time associated with each operation; Data Set 3 is the list of the surgeons who compose the surgical staff; Data Set 4 contains the work sheets for each working day for the month of January; and Data Set 5 contains the events to be scheduled for the first period and the Confirmation Sheet. This sheet serves as the communication device between the participant and the Surgical Scheduler's Game. Data Set 1 is contained in Appendix B, and examples of the last four data sets are found in the back of Appendix C.

To begin to play the Surgical Scheduler's Game, the participant turns to Data Set 4, which contains a scheduling page for each working
day of the month of January. The previous surgical scheduler scheduled some operations for the days in January, so the participant should look over the schedule he inherited and make sure that he agrees with it. If he wishes to make changes, he records them on the Confirmation Sheet at the end of Data Set 5. The exact details of how to do this are found in Appendix B.

After making the desired changes, the participant turns to Data Set 5. The first event should be a scheduling request. Each scheduling request is composed of the name of the surgeon making the request, the name of the operation to be performed, the patient number, the age of the patient, the date and time the surgeon would like to perform the operation, and the surgeon's estimate of how long the operation will last. The participant decides how much time he will allow for the operation and the date and time it can be performed. He records the necessary information on the appropriate Scheduling Work Sheet and on the Confirmation Sheet. After he has completed this procedure for each scheduling request in Data Set 5, the participant submits his Confirmation Sheet to the game administrator. The scheduling requests are key punched and submitted to the Surgical Scheduler's Game computer program for evaluation.

After the schedule has been processed the participant receives four reports, which are to assist him in evaluating the schedule he developed. The first report is the Schedule Feedback Sheet, which lists the information the participant placed on the Confirmation Sheet. The
second report is the Operating Room Results Report. This report provides the scheduler with the operating schedule he developed for this period and the schedule that actually resulted. The Surgical Service Performance Report, the third report, indicates in summary form how well the participant utilized the surgical facilities, how well he estimated the length of the operations, and how well he met the surgeon's scheduling requests. The Financial Report is the final report the participant receives after each period. This report indicates the financial status of the surgical service. With these reports the participant receives a new Data Set 5 and the scheduling procedure starts again.

It was pointed out that Data Set 5 consists of a set of requests which the player of the game must schedule. Each request is composed of the name of the surgeon making the request, the name of the operation to be performed, the patient number, the age of the patient, the date and time the surgeon would like to perform the operation, and the surgeon's estimate of how long the operation will last. Associated with each one of the above items there is a data file, a probability distribution, or parameters. In this chapter the data files, the probability distribution, and the parameters selected and the reasons for the selection will be discussed.

The data files and probability distributions needed for the surgical scheduler's game can be associated with the surgical operations, the surgeons, or the patient. The following discussion will be
organized under these three groups.

**PROCEDURE AND OPERATION RELATED DATA FILES AND DISTRIBUTIONS**

Procedure and operation related data include the operation's name file, the procedure frequency distribution, the procedure parameter file, the length of operation distribution, the age distribution, the scheduling request distribution, and the cancellation request distribution.

**The Operation Name File**

The name of an operation or procedure refers to the type of action a surgeon is going to take on a patient. There are many sources of name lists for procedures and operations. One of the best known sources is the Commission of Professional and Hospital Activities (CPHA, 1969) located in Ann Arbor, Michigan, which collects information from hospitals throughout the United States. One of its publications lists the fifty operations most frequently performed. A list of all the operations performed by CPHA member hospitals is available.

The difficulty with the CPHA data is that it is coded in accordance with the hospital adaptation of International Classification of Diseases System. As pointed out by Arbuckle:

Surgical procedures are classified in this index according to the anatomical classification with no regard to the time required to perform the operation. Therefore, procedures requiring significantly different times are coded together. There is no provision in this index for assigning a single code to frequently occurring multiple operations. (Arbuckle, 1970, p. 16)
Gordon (1970) has developed a dictionary of terms and codes for the naming and designation of diagnostic and therapeutic procedures in surgery, medicine, and specialties, which groups the procedures by a code system and associates each procedure with a five digit code. If this author had known this code book existed, it probably would have been used to code the surgical data.

The next primary source of a list of names of procedures and operations is from a particular hospital. The list this author used was developed by Arbuckle in conjunction with Community Hospital of Roanoke Valley (CHRVA Roanoke, Virginia. This list contains over three hundred and twenty-two operations and procedures. Although it is not exhaustive, it does represent all the types of operations performed during a seven month period in a particular 400 bed general hospital with nine operating rooms. The surgical staff at CHRV was composed of approximately fifty surgeons. For the Surgical Scheduler's Game the list of procedures was reduced to one hundred operations by eliminating procedures which occurred less than eight times during the seven month period. The remaining two hundred and twenty-two are available if desired.

Procedure Frequency Distribution

As might be expected, certain operations are performed more often than others. A file was developed containing the number of times an operation was performed at CHRV during the study period. From this data an empirical probability distribution and a cumulative distribution was developed. The empirical probability distribution and
cumulative distribution will automatically change for a different set of operations.

Procedure Parameter File

One of the main functions of the surgical scheduler is to estimate the time to be allocated for each procedure. The scheduler may obtain assistance in estimating the scheduling time from the surgeon, from a table, from her own past experience, or from an educated guess. Regardless of the source of assistance, she must make the final estimate. If it is too high, surgical facility utilization decreases and surgeons will find it necessary to schedule procedures further in advance. If the estimate is too low, surgeons must rush, cases must be postponed or operating schedules must be extended.

One of the main objectives of the Surgical Scheduler's Game is to assist the surgical scheduler in learning a reasonable scheduling time estimate for each procedure. Therefore, it was necessary to develop or obtain data on each procedure.

Data was collected by Arbuckle for 4,037 procedures and operations and classified into the 322 different pre-operative procedures which were mentioned earlier. These operations and procedures were processed by Arbuckle and the author, and the mean, the standard deviation, and the minimum and the maximum operating times were calculated for each procedure. This data is stored in the procedure parameter file.
Length of Operation Distribution

One section of the game simulates the length of an operation. Since the length of an operation is probabilistic in nature, it was necessary to select a probability density or mass function for the procedures or develop an empirical probability density or mass function for each operation. Arbuckle tested ten procedures with a Kolgorov-Smirow Goodness-of-Fit Test to determine the distribution of the actual operation times. He concluded that the probability distributions were normally distributed when classed according to pre-operative procedure. Thus, in the Surgical Scheduler Game a truncated normal distribution was selected to be used to generate the length of time it takes to perform the procedure. Barnoon (1968) also found the length of an operation to be normally distributed.

Age Distribution

With each procedure there is an associated age distribution. For example, very few persons over the age of eleven have a tonsillectomy. The mean age, the standard deviation, the minimum age, the maximum age, and the number of cases were determined from the same source of data as the procedures mentioned earlier. It was decided to use a uniform distribution for the age, with the limits being the minimum and maximum age associated with each procedure.
Scheduling Request Distributions

In the Surgical Scheduler's Game, the probabilistic average time for the operations in the Operation Name File is calculated. This value is the mean time between calls per operating room. To generate the number of scheduling requests per period it is assumed that the time between scheduling requests is exponentially distributed. Thus, an exponential process generator is used. Due to the lack of data, the assumption that the time between requests is exponentially distributed could not be documented. Young (1962) showed that for his study the above was true.

Cancellation Distribution

A study by Harris (1965) indicated a 6.4 percent cancellation rate per day. An analysis of Community Hospital of Roanoke Valley indicated a 5.1 percent cancellation rate per day. Arbuckle conducted a one-way analysis of variance test on the cancellation rate per day and concluded that the number of cancellations is independent of the day of the week. For the game a 5.0 percent cancellation rate was used. The time between cancellations is assumed to be exponentially distributed with a mean rate of ANUM*0.05 operations per day where ANUM is the average number of operations scheduled per day.
SURGEON RELATED DATA

Surgeon related data includes the Surgeon Name File and Surgeon Frequency Distribution.

Surgeon Name File

A data file containing a list of the fifty hypothetical surgeons who were to perform the operations was developed. The game is designed with the idea that when it is played at a different hospital, the names of the hospital's surgical staff would replace those names supplied. The procedure to accomplish the change in names is explained in the Game Administrator's Manual. This document is in Appendix C.

Surgeon Frequency Distribution

Each surgeon has a different frequency or number of surgery cases he performs each year. This frequency is arbitrarily assigned to the hypothetical surgical staff. This frequency distribution is converted into an empirical probability density function and a cumulative distribution.

PATIENT AND TIME RELATED DATA AND DISTRIBUTIONS

The patient and time related data and distributions are composed of the patient number, the data request distribution and the time request distribution.
A patient number is assigned to each request, starting in sequence with 101.

Requested Date Distribution

The future date on which the surgeon would like to perform the operation is assumed to have a Poisson distribution with a mean of five days and a maximum of thirty days. This author discussed with several surgical schedulers the lead time given by the surgeons. From their description, it appeared that an assumption of a Poisson distribution seemed reasonable. Usually the request lead time is much longer than the five days, but it was necessary to use a shorter time in order that the game may be completed in seven periods.

Requested Time Distribution

From the CHRV data it appears that the time of day that the surgeons request to perform an operation is uniformly distributed. There are limits on the distribution. Most surgeons prefer to start after seven o'clock in the morning and not stop before three o'clock in the afternoon. For the Surgical Scheduler's Game, the limits are a variable, but are initially set at eight o'clock and two o'clock.

Using the above distributions, data files, and parameters, it was possible to generate scheduling requests and cancellation events. From these events and other parameters, the simulation model of the surgical service was developed.
CHAPTER IV
THE GAME MODEL

The routines in the computer program for the Surgical Scheduler's Game can be classified into two categories: the accounting routines and the mathematical model routines. The accounting routines include the portions of the game which control the input of data, the conversion of data into usable form, the storage of data, the transfer of data, and the output of data. The Game Administrator's Manual deals primarily with the accounting routines of the game. The mathematical routines of the game are concerned with the generation of events and the evaluation of the player's performance. In Chapter III, distributions and data files used to generate the events were discussed. The purpose of this chapter is to discuss the mathematical model used to evaluate the player's performance.

The results of this period's schedule are presented in four reports: the Schedule Feedback Sheet, the Operating Room Results, the Surgical Service Performance Report, and the Financial Report. The first two reports are basically feedback of data the participant submitted and will not be discussed. The second two reports will be discussed in detail in this chapter.
The Surgical Service Performance Report is composed of two reports: the Utilization Report and the Estimation Report. In this section the purposes and indexes of each report will be discussed and the mathematical models will be presented.

The Utilization Report

The purpose of the Utilization Report is to give the player a measure of how well he is using the available operating time. The Utilization Report contains five indexes, each having associated with it a value for today's performance and the accumulative value for the performance through today. The Utilization Report contains the following five indexes: the number of regularly scheduled surgical hours available, the number of regularly scheduled surgical hours used today, the percentage of usage, the number of overtime hours used, and the total number of surgical hours used. Its main purpose is to give the player an idea of the demand level for the surgical facilities and the utilization level of the surgical time available.

**Number of Regularly Scheduled Surgical Hours Available:** The Today statistic equals the product of the number of hours a surgical room is regularly available and the number of surgical rooms. The Through Today statistic equals the sum of the Today statistic for this period and all previous periods.
\[ d = r \times h \]

\[ t = \Sigma d_i \]

where:  
- \( d \) = the number of regularly scheduled surgical hours available today
- \( t \) = the number of regularly scheduled surgical hours available through today
- \( r \) = the number of operating rooms
- \( h \) = the number of hours per day the operating rooms are regularly available
- \( p \) = the number of periods played
- \(* = \) times or multiply by
- \( \Sigma d_i = \) sum of \( p \) values of a

**Number of Regularly Scheduled Surgical Hours Used:** The Today statistic is the sum of the actual length of each operation performed before a specified clock time for this period. The Through Today statistic is the sum of the actual length of each operation performed prior to a specified clock time, for this period and all previous periods. If the operation extended beyond the specified clock time, that portion of the operation is considered to be performed on overtime.
\[
d = \sum_{k} a_k + \sum_{j} x_j
\]
\[
t = \sum_{i} d_i
\]

where: 
- \(d\) = the number of regularly scheduled surgical hours used today
- \(t\) = the number of regularly scheduled surgical hours used through today
- \(a\) = the actual time duration of an operation
- \(m\) = the number of today's operations completed before \(c\) o'clock
- \(c\) = the time when the operating room is scheduled to close
- \(x\) = the time between when an operation starts and \(c\) o'clock
- \(n\) = the number of today's operations completed after, but started before \(c\) o'clock
- \(p\) = the number of periods played

Percent Usage: This Today statistic equals the quotient of the Number Regularly Scheduled Hours Used Today times one hundred divided by the Number Regularly Scheduled Hours Available Today. The Through Today statistic is the sum of the number of regularly scheduled hours used each day multiplied by 100 and divided by the sum of the daily
number of regularly scheduled hours.

\[ d = s * \frac{100}{r} \]

\[ t = 100 * \frac{\sum p_i}{\sum r_i} \]

where:  
\( d = \) percent usage today  
\( t = \) percent usage through today  
\( s = \) the number of regularly scheduled hours used today  
\( r = \) the number of regularly scheduled hours available today  
\( p = \) the number of periods played.

**Overtime Hours Used:** The Today statistic equals the sum of the time the operating rooms were in use after a specified clock time for this period. The Through Today statistic equals the sum of all overtime hours for all periods.

\[ d = \sum y_i + \sum a_i \]

\[ t = \sum d_i \]

where:  
\( d = \) the overtime hours used today  
\( t = \) the overtime hours used through today  
\( a = \) the time duration of an operation  
\( c = \) the time when the operating room is scheduled to close
\[ y = \text{the actual time duration between } c \text{ o'clock and the end of the operation} \]
\[ p = \text{the number of periods} \]
\[ r = \text{the number of today's operations which were started before, but completed after } c \text{ o'clock} \]
\[ s = \text{the number of today's operations which were started after } c \text{ o'clock} \]

**Total Number of Surgical Hours Used:** The Today statistic is the sum of the actual length of all the operations performed this period. The Through Today statistic is the sum of the actual length of all the operations performed through this period.

\[ d = r + v \]
\[ t = \sum_{i=1}^{p} d_i \]

where: \[ d = \text{the total number of surgical hours used today} \]
\[ t = \text{the total number of surgical hours used through today} \]
\[ r = \text{the number of regularly scheduled surgical hours used today} \]
\[ v = \text{the number of overtime hours used today} \]
\[ p = \text{the number of periods} \]
Estimation Report

The second part of the Surgical Service Performance Report is the Estimation Report. The purpose of the Estimation Report is to inform the player how well he is estimating the length of the operations, how well he is meeting the surgeons' requests and how close he is coming to meeting the best operating policy. This is accomplished through the development of the average operating time index, today's gain (loss), today's best normal gain (loss) possible, the community benefit index, and the average request time difference in hours.

**Average Operating Time Index:** The Today statistic provides the player with a measure of how closely he is estimating the length of the operations when compared to the actual length of the operations. The Operating Time Ratio is equal to the player's estimate of the operation's length divided by the actual operation's length. The Average Operating Time Index Today is the average of the individual Operating Time Ratio. The Average Operating Time Index Through Today is the average of each period's Average Operating Time Index Today.

\[
d = 100 \times \frac{\sum S_i / a_i}{m}
\]

\[
t = \frac{\sum d_i}{p}
\]

where: 
- \(d\) = the average operating time index today
- \(t\) = the average operating time index through today
\[ s = \text{the scheduled duration of the operation} \]
\[ a = \text{the actual time duration of the operation} \]
\[ m = \text{the number of operations performed this period} \]
\[ p = \text{the number of periods} \]

**Today's Gain (Loss):** This statistic is obtained from the Financial Report. It represents the net dollar gain (loss) that was incurred by the surgical service for today's activity. This statistic takes into consideration the real dollar income and expenses a hospital would incur and the social benefits and costs expressed in dollars that a community possibly would incur. Only the main factors are shown in the equation below. These factors will be defined in greater detail in the next section of this chapter.

\[ g = a + b + c + d \]

where: 
\[ g = \text{today's net financial gain or loss} \]
\[ a = \text{today's income from the operations} \]
\[ b = \text{today's hospital expenses associated with the operations} \]
\[ c = \text{the net social benefit (loss) for meeting (for not meeting) the request demand for surgical facilities} \]
\[ d = \text{the net social benefits (loss) for not requiring (for requiring) the surgeon and patient to wait for the facility they scheduled.} \]
Today's Best Normal Gain (Loss) Possible: This statistic indicates the net gain (loss) that would have been obtained if the scheduler met the surgeons' requests for today and developed a schedule which best utilizes the facilities for the demand. This index is composed of four parts: the best income for the surgical service, the minimum expenses for the surgical service for today's request demand, the best social benefit, and the minimum social costs.

\[
z = a - b + c + d
\]

\[
a = h \sum_{i=1}^{m} k_i
\]

if \( \sum_{i=1}^{m} k_i \leq q \)

\[
b = e \cdot q + f \sum_{i=1}^{m} k_i
\]

if \( \sum_{i=1}^{m} k_i > q \)

\[
b = q \cdot (f + e) + q \cdot (\sum_{i=1}^{m} k_i - q)
\]

\[
c = x \sum_{i=1}^{m} k_i
\]

\[
d = m \cdot s \cdot t
\]
where:  
z = the best normal gain (loss) for today  
a = the income from the operations requested to be performed today  
b = the fixed and variable cost for the operations requested to be performed today  
c = the social benefit for scheduling the operations requested today  
d = the social cost for performing the operations requested for today  
e = the fixed hospital costs per operating room hour available  
f = the variable hospital cost per operating hour  
g = the overtime cost per overtime operating hour  
h = the income per operating hour  
k = the actual time duration of an operation  
m = the number of operations requested for today  
q = the total number of operating hours available today  
s = the time credit allowed for performing an operation  
t = the cost per hour of the patient and surgeon  
x = the basic social benefit for scheduling an operation
Community Benefit Index: The Today statistic is the main overall measure of the player's performance. It is a ratio between the net gain for today and the best net gain for today. The Through Today statistic is the average of the Community Benefit Index for each day.

\[d = \frac{(a + b)}{(c + e + b)}\]

\[t = \frac{\sum d_i}{p}\]

where:  
\(d\) = the community benefit index today  
\(t\) = the community benefit index through today  
\(a\) = the best non-total gain (loss) for today  
\(b\) = today's hospital fixed expenses  
\(c\) = the hospital's net gain (loss) for today  
\(e\) = the community's net gain (loss) for today  
\(p\) = the number of periods

Average Request Time Difference Hours: This statistic gives the player an indication of how well he is meeting the surgeon's request dates. The Today statistic gives the average hours that the request times were changed. The Through Today gives the average of the Today statistics.

\[d = \frac{\sum_{j=1}^{q} \text{ABS}(r_j - s_j)}{q}\]

\[t = \frac{\sum d_i}{p}\]
where: \( d \) = the average request time difference in hours for today
\( t \) = the average request time difference in hours through today
\( ABS \) = the absolute value
\( p \) = the number of periods
\( q \) = the number of operations scheduled for today
\( r \) = the date-time the operation was requested to be performed
\( s \) = the date-time the operation was scheduled for

**FINANCIAL REPORT**

The Hospital Report and the Community Report compose the Financial Report. The purpose of this report is to express in more detail and in terms of dollars the performance of the player.

**Hospital Report**

The Hospital Report presents the income from today's operations, the expenses incurred today, and the net gain or loss through today. In this section each entry in the Hospital Report will be discussed.

**Hospital Net Gain (Loss) To Date:** This statistic equals the sum of the profits or losses of the past periods.
\[ b = \sum_{i=1}^{p-1} h_i \]

where:  
- \( b \) = the hospital net gain (loss) to date  
- \( h \) = the hospital net gain or loss for each period  
- \( p \) = this period number

**Today's Income:** This statistic represents the dollars which the hospital bills the patient for the use of the surgical facilities. It equals the product of the hourly operating room charge and the sum of the operating time for all patients.

\[ c = w \times v \]

where:  
- \( c \) = today's income  
- \( v \) = the patient charge per operating hour  
- \( w \) = the total number of surgical hours performed today

**Today's Expenses:** The hospital expenses for today are given in three parts: the fixed expenses, the variable expenses, and the overtime expenses. The fixed expenses are those expenses which occur just because the operating rooms are available. The variable expenses are those additional expenses which are incurred because an operation is performed. The overtime expense is the expense incurred because part or all of the operation is performed after the normal available operating time. The overtime rate includes the fixed rate and the variable rate and an additional rate. The Today's Expenses equal the
sum of the fixed expenses, the variable expenses, and the overtime expenses.

\[
d = q \cdot t \cdot u \\
e = r \cdot n \\
f = (q + r + s) \cdot w \\
g = d + e + f
\]

where:  
\(d\) = today's fixed hospital expenses  
\(e\) = today's variable hospital expenses  
\(f\) = today's overtime hospital expenses  
\(g\) = today's total expenses  
\(m\) = the number of operating hours performed after the normal closing time  
\(n\) = the number of surgical hours performed today  
\(q\) = the fixed hourly rate  
\(p\) = the variable hourly rate  
\(s\) = the overtime hourly rate  
\(t\) = the number of hours the operating rooms are regularly available  
\(u\) = the number of operating rooms

**Today's Hospital Net Gain (Loss):** This statistic equals the difference between the income and the expenses for today. This difference when added to the Hospital Net Gain (Loss) To Date equals the Hospital Net Gain (Loss) Through Today.
\( h = r - s \)
\( p \)
\( k = \sum h_i \)

where:
- \( h \) = the hospital's net gain for today
- \( k \) = the hospital's net gain through today
- \( r \) = the hospital's income for today
- \( s \) = the hospital's expenses for today
- \( p \) = the number of periods

**Community Report**

The purpose of the Community Report is to express in dollar terms the non-cost items, such as not meeting the demand for service and making the doctor and patient wait for an operating room. The Community Report is composed of two primary sections: Today's Request Benefits and Today's Time Benefits.

**Today's Request Benefits:** The purpose of the Today's Request Benefits is to give credit to the scheduler who is able to meet the surgeon's request, then a request cost is incurred.

\[ a = (f + d) \times s \]
\[ b = m \times r \times x + e \times s \]
\[ c = a - b \]
\[ d = \sum (t - u)_j \]
\[ e = q \times \sum (v - t)_k \]
where:  

- \( a \) = the request credit for scheduling the operation
- \( b \) = the request cost for not scheduling the operation on the requested date
- \( c \) = the net request gain or loss
- \( d \) = the number of credit units for scheduling an operation early
- \( e \) = the number of cost units for delaying an operation
- \( f \) = the number of operations scheduled this period
- \( m \) = the number of patients who had their request dates changed
- \( n \) = the number of operations scheduled for this period in which \( t > u \)
- \( q \) = the number of operations scheduled for future dates in which \( t \leq u \) and \( t \leq v \)
- \( r \) = the time needed to reschedule an operation
- \( s \) = the social benefit or cost per day for scheduling early or delaying an operation
- \( t \) = the date the surgeon wishes to perform the operation
- \( u \) = the date the operation is scheduled for
- \( v \) = the calendar date code for this period
- \( x \) = the rate per hour for the surgeon's and patient's time
Today's Time Benefits: This statistic is designed to determine credits and costs for developing a schedule which does not require the surgeon to wait for the operating room which he has scheduled.

\[ a = b - c \]

\[ b = d \times e \times g \]

\[ c = \sum [(k - h) \times g]_i \]

where:  
\( a \) = today's time benefit  
\( b \) = the social credit for starting the operations within 15 minutes of the scheduled time  
\( c \) = the social cost for delaying the operation after its scheduled time  
\( d \) = the number of operations performed today  
\( e \) = the rate per hour for the surgeon and patient  
\( g \) = the surgeon and patient time credit hours  
\( h \) = the time the operation was scheduled for  
\( k \) = the time the operation actually started  

The last three calculations determine the net community benefit for today, the net community benefit through today, and the net financial position through today. The equations for the above terms are given on the following page:
\[ a = d - e \]

\[ b = \sum a_i \]

\[ c = \sum f_i + \sum a_i \]

where:
- \(a\) = today's community net benefits (costs)
- \(b\) = the community net benefits (costs) through today
- \(c\) = the total net financial position through today
- \(d\) = the net request benefits (costs)
- \(e\) = the net benefits (costs)
- \(f\) = the hospital net gain (loss) for today
- \(p\) = the number of periods
SUMMARY

In this chapter it was shown that the Community Benefit Index is the primary measure of effectiveness. This index is a ratio between how well the schedule developed compares with the best schedule possible for today. The Financial Report is composed of the Hospital Report and the Community Report. The Hospital Report summarizes the income and the expenses a hospital might incur for providing a surgical service. The values of the income and the costs are known to the player. The Community Report summarizes the credit and the expenses that a community might incur if the hospital can or cannot provide adequate surgical service. The values of these credits and costs are not known to the player, since these are subjective values. From the Financial Report and the Community Benefit Index, the player should have a good idea of how well he is performing.
CHAPTER V

ANALYSIS OF THE RESULTS

The purpose of this chapter is to describe the adaptive training feature of the Surgical Scheduler's Game, to describe the experiment designed to test the usefulness or value of this feature, and to discuss the results of the experiment.

THE ADAPTIVE SYSTEM

Adaptive training is training in which the stimuli presented to the subject varies as a function of the subject's immediate past performance. In Figure 4 it was shown that the adaptive system is composed of a stimulus or problem generator, a subject, a response or performance measurement unit, and an adaptive unit.

The Surgical Scheduler's Game is designed with such an adaptive training device. The problem generator is the development of a schedule for the surgical unit, the subject is the player who assumes the position of a surgical scheduler, the performance measurement unit is the Community Benefit Index, and the adaptive unit causes the demand for the surgical facilities to increase.
The Performance Measurement Unit

The Community Benefit Index is the measure of effectiveness or the performance measurement unit. It is a ratio between the Today's Best Normal Gain and Today's Net Gain. These statistics were defined in detail in Chapter IV. Briefly, Today's Best Normal Gain is the maximum profit or minimum loss which the player could obtain if he scheduled them so that no conflicts developed. The profit or cost associated with providing the surgical services for that day is represented by Today's Net Gain. Both of the above statistics contain the fixed cost of providing surgical facilities. This fixed cost is subtracted from the two statistics. The equations for these two new statistics are given below:

\[ a = c + d + e \]
\[ b = c + f \]

where:  
\( a \) = the modified Today's Net Gain  
\( b \) = the modified Today's Best Normal Gain  
\( c \) = the hospital's fixed cost for today  
\( d \) = the hospital's net gain for today  
\( e \) = the community net gain for today  
\( f \) = the best normal gain for today
Since the value of CINA and CINB can be a negative value, positive value, or zero, it is necessary to have several equations for the Community Benefit Index. Under normal scheduling situations, both CINA and CINB should be positive, in which case the Community Benefit Index (CINDX) would equal CINA/CINB. However, if CINB were to be equal to zero, a problem develops concerning the value of the Community Benefit Index. To alleviate this problem, it was decided that if CINB were equal to zero and if CINA were negative, CINDX would equal zero. If CINA were positive, then CINDX would be set equal to one. Table I in Appendix A shows the equations used for each situation.

The Adaptive Unit

In the Surgical Scheduler's Game the adaptive unit is composed of the adaptive component and the maximum component. When the Community Benefit Index for a particular period reaches a certain level, called the adaptive level, the demand for the next period for the surgical facilities increases by a set increment. If the Community Benefit Index does not reach this adaptive level, the demand for the surgical facilities for the next period remains the same. This increase in the demand level results in an increase in the difficulty of developing a good surgical schedule.

The maximum component refers to the equation which sets the upper limit on the demand level. It is possible to continually increase the demand until it is impossible to develop an acceptable schedule. Thus, after each increment of the demand level, a check is conducted to
determine if the maximum level has been exceeded. The equations for the adaptive component and maximum component are given below:

if:  \( a > d \) and 
    \( b < e \) then 
    \( b = b + c \) 

otherwise: 
    \( b = b \)

where:  
\( a = \) the community benefit index 
\( b = \) the level of the community benefit index 
\( c = \) the level of incrementation 
\( d = \) the level that the CINDX must reach in order to be incremented, adaptive level 
\( e = \) the maximum demand level

THE EXPERIMENTAL DESIGN

In order to determine if the adaptive features in the Surgical Scheduler's Game were of some value, an experiment was designed. The design of the experiment required setting the parameters for the Surgical Scheduler's Game, setting the parameters for the adaptive unit, selecting the subjects, and determining the manner of the plays.

The Subjects

The forty-two subjects who participated were engineering sophomores and juniors who were taking an engineering economy course
in the Industrial Engineering Department. The final thirty-seven subjects used were divided into two groups on a random basis. Each group started the game with a demand level of sixty percent. After the first period, the twenty-one subjects which composed Group 60 continued with a demand level set by the adaptive unit. The sixteen subjects who composed Group 90 had their demand level raised to ninety percent. After each period a histogram of the Community Benefit Index was posted so that the players would know how their performance compared with that of the other players. A total of seven surgical schedules were developed by each player.

The Surgical Scheduler's Game Parameters

The Surgical Scheduler's Game used in the experiment was set up so that three operating rooms were available to the participant. Each operating room was regularly available from 8:00 to 14:00 o'clock.

There were twenty-five surgeons on the surgical staff who performed one hundred different operations. On the average, the surgeons requested an operating date five days in advance of the date on which the operation was to be performed. Group 90 received scheduling requests which required 16.2 hours of operating room time for each day. There were eighteen hours available. The participant in Group 60 set the demand level by his previous period's performance. He started with scheduling requests requiring 10.2 operating room hours and could reach the 16.2 level in seven periods. Each period the participant in Group
would receive an increase of 0.9 hours in scheduling requests if his previous period's CBI was above ninety.

For the experiment, the cost parameters were selected carefully, in order that good scheduling would result in a total net profit after a few periods and poor scheduling would result in a total net loss. The cost parameters were divided into those associated with the hospital and those associated with the community. The hospital income rate per surgical hour was set at $125.00. The hospital expenses were set at $1440.00 per day for fixed expenses, $20.00 per surgical hour for variable expenses, and $30.00 per surgical hour for overtime charges.

The community cost parameters were set so that the participant received a credit of $6.00 for each operation scheduled for that period. For each operation the participant postponed one day, he received a fixed charge of $6.00 for that period. The next period he would receive a charge of $12.00, the following period a charge of $18.00, etc., until the operation was performed. If the participant scheduled an operation earlier than requested, he would receive a charge of $6.00 and then a credit of $6.00 on the day the operation was performed, a credit of $12.00 for the next period, etc., until the day the surgeon originally requested to have the operation performed was reached.

The participant receives a credit of $6.00 for each operation performed that period. He incurs an expense of $1.00 per minute for each minute he requires the surgeon and the patient to wait to enter the operating room they were scheduled for. The above cost parameters
resulted in a demand level of seventy-one percent before a participant could show a net accumulative profit.

**THE RESULTS**

The first item to be investigated is whether the two groups were equivalent. An F-test and a t-test were conducted on the data after the first period of play. The null hypothesis is that the variance of the CBI for Group 60 was equal to the variance of the CBI for Group 90 for the first period. This hypothesis was tested with an F-test. The hypothesis was accepted at the 95 percent confidence level. This indicates that there is no reason to believe that the variance of the two groups was different. The calculations for this test are shown in Table IV, Appendix A.

Next, the null hypothesis that the mean CBI for Group 60 equals the mean CBI of Group 90 for Period One was tested with a t-test. The results of this test indicated that the null hypothesis should be accepted at the 95 percent confidence level. From these two tests it appears that the two groups were equivalent after one period of play. The calculations for the t-test are given in Table V, Appendix A.

**Testing The Adaptive System**

Theoretically, the adaptive variable for a fixed difficulty system should be a constant in relation to the level of skill. When an adaptive system is used, the adaptive variable should be a function of the level of skill. Figure 5 in Chapter II illustrated these two
theoretical concepts. To determine if the experimental data conformed with the theoretical concept, a simple linear regression was run on the data for Group 60, which played the Surgical Scheduler's Game with the adaptive system. The adaptive variable was measured by the Index Level, and the level of skill was measured by the Period Number. Figure 7 shows the experimental data for Group 60 could be represented by the following equation:

\[
\text{Index Level}_{60} = 56.13 + 3.17 \times \text{Period Number}
\]

Table II in Appendix A shows that for Group 60 the correlation coefficient is equal to 0.84. The addition of the Period Number was significant with the F-ratio equalling 359, the critical F-ratio for inclusion being 3.84.

For Group 90, which played the fixed difficulty version of the Surgical Scheduler's Game, the Index Level was held constant, and thus, by definition, is equal to 90. These two equations agree with the first theoretical concept related to adaptive systems.

\[
\text{Index Level}_{90} = 90
\]

Figure 6 in Chapter II illustrates the second theoretical concept related to adaptive systems. This concept states that for a fixed difficulty system, the performance of the subject should theoretically improve. For a Dunlap adaptive system, the performance of the subjects theoretically should be a constant in relation to the level of skill. For the Surgical Scheduler's Game, the measure of performance was the
Figure 7.

ADAPTIVE VARIABLE AS A FUNCTION OF SYSTEM DIFFICULTY IN FIXED AND ADAPTIVE SYSTEMS FOR THE SURGICAL SCHEDULER GAME
CBI, and the measure of the level of skill was the Period Number. To test this concept, a simple linear regression was run on Group 60 and Group 90 data, with the CBI as the dependent variable and the Period Number as the independent variable. The relationship between these two variables for Group 60 was insignificant. The following equation best represented the CBI for Group 60:

\[ \text{CBI}_{60} = 90.2 \]

These results show that the adaptive unit has held the level of difficulty at a constant level, which corresponds with the theoretical concept.

A simple linear regression analysis was run on Group 90 with the CBI as the dependent variable and the Period Number as the independent variable. Figure 8 illustrates these results. The relationship between the CBI and the Period Number can be represented by the following equation:

\[ \text{CBI}_{90} = 96.1 - 6.0 * \text{Period Number} \]

Table III in Appendix A shows that for this equation, the correlation coefficient is equal to 0.46. The addition of the Period Number was significant with the F-ratio equal to 20.47, the critical F-ratio for inclusion being 3.84.

The slope of -6.0 is the opposite of what the theoretical concept indicates should happen. This negative slope means that as the player played the game, his level of performance deteriorated.
PERFORMANCE MEASUREMENT AS A FUNCTION OF SYSTEM DIFFICULTY IN FIXED AND ADAPTIVE SYSTEMS FOR THE SURGICAL SCHEDULER’S GAME
This difference from the expected result might indicate that the 90 percent level of demand is too high. In other words, the game is too hard at the 90 percent level of demand for most players to give a good performance.

Except for the lack of increased performance in the fixed difficulty Surgical Scheduler's Game, the results of the linear regression analysis support the theoretical concepts for a training model.

Group 60 started at Index Level 60 and had the opportunity to reach Index Level 90. The empirical probabilities for reaching the various Index Levels (IL) by the end of the seventh period (PN) were:

\[
\begin{align*}
P(\text{IL} = 70/\text{PN} = 8) &= 0.14 \\
P(\text{IL} = 75/\text{PN} = 8) &= 0.14 \\
P(\text{IL} = 80/\text{PN} = 8) &= 0.38 \\
P(\text{IL} = 85/\text{PN} = 8) &= 0.29 \\
P(\text{IL} = 90/\text{PN} = 8) &= 0.05 \\
\end{align*}
\]

Seventy-two percent of the participants reached Index Level 80 during the seven periods of play. This results in a 0.57 average empirical probability of increasing to the next Index Level.

The probability of increasing to the next Index Level on the first try equals 0.58, by the second try it equals 0.91, by the third try it equals 0.95, by the fourth try it equals 0.98, and by the fifth try it equals 1.00. The Index Level does affect the number of periods needed to increase to the next Index Level. Figure 9 shows the
Figure 9.

PROBABILITY OF INCREMENTING
probability of increasing to the next Index Level and shows the changes in the probabilities due on the first try and by the second try. For example, a participant at Index Level 60 has a 24 percent chance of moving to Index Level 65 after the first period of play. After the second period of play, there is an 86 percent chance that he will move to Index Level 65.

In order to give an example of the performance of Group 60 in moving to higher Index Levels, the data for three participants was plotted in Figure 10. These participants were selected to represent the range of performance of the players. Participant One required two tries to move from Index Level 60 to 65, one try to move to Index Level 70, and after four tries was still at Index Level 70. Participant Two moved from Index Level 60 to Index Level 65 after two tries and then proceeded to Index Levels 65, 70, 75, and 80 in one try each. He required two tries to reach Index Level 85. Participant Three moved from Index Level 60 to Index Level 90 in one try at each Index Level, except for Index Level 85, which required two attempts to reach it.

The parameters used in the game for the players in Group 60 and Group 90 allowed patients to be scheduled in three operating rooms. These rooms were regularly available from 8:00 to 14:00. This resulted in Group 90 having to schedule twenty to thirty patients each period. From the comments made by the players and the observations of the author, this was too time consuming for the players. It appears that the 8:00 to 14:00 is a good time span, but the number of operating
Figure 10.
INDEX LEVELS OF THREE PARTICIPANTS
rooms should be reduced to two rooms.

Another problem which was created by the participants was related to careless scheduling. For example, players would attempt to schedule patients that did not exist or schedule patients for operating rooms that did not exist. Errors of this type resulted in a major reprogramming of the input subroutine, so that for almost any error that is made, appropriate action is taken by the game. This eliminates the need for the game administrator to patch, correct, or rerun schedules.

After each period the player receives a Financial Report. This report uses twenty values expressed as dollars to show the results of the player's schedule. From comments by the players in Group 60 and Group 90, twenty values present too much detail in the Financial Report. There are so many values that in the early periods of the game the player cannot relate his action to these values.

CONCLUSIONS

From the results of the experiment it appears that the primary scheduling problems for a surgical scheduler can be captured in a management game. It appears that the addition of an adaptive training unit to a management game offers two advantages. When developing a management game, it is very hard to determine how difficult the game will be for the players. To determine how difficult the game is will be up to the players. To determine the best level of difficulty requires extensive testing and will probably result in major modifications
of the game. By including an adaptive unit, the level of difficulty can be set low enough to make the game very easy. Then the player can raise the level of difficulty through his performance as he plays the game. Thus, the first advantage offered by an adaptive training unit would be to decrease the amount of testing required for the proper development of a management game.

The experimental data indicated that the level of difficulty did remain constant in the Surgical Scheduler's Game. This concept of maintaining a fixed level of difficulty is the second advantage and is desirable in most training devices and in many cases would in itself justify including the adaptive training unit in a management game.

The design of the game appears to allow the player to develop the concepts and problems related to scheduling events in a probabilistic environment within seven periods. The players appear to learn the names of many of the operations and begin to associate the basic length of operating time with the operation.
RECOMMENDATIONS FOR FURTHER STUDY

In the area of adaptive training there are numerous questions to be answered through research. Among these are the following:

1. What type of adaptive variable should be used?
2. Is it better to design an adaptive unit around one variable or around multiple variables?
3. How large should the increment be on the adaptive unit?
4. Is it better to have the adaptive unit both increase and decrease or only increase?
5. What should be the level of sensitivity for the adaptive variable?

Some of the questions related to management games that need to be investigated are:

1. Do management games accomplish their objectives?
2. Is a simple management game better than a complicated one?
3. For how many periods should a management game be played?
4. How many variables should the player be able to influence?
5. How much time should the player be permitted to have to make a decision?
BIBLIOGRAPHY


APPENDIX A

CALCULATIONS
<table>
<thead>
<tr>
<th>CINA-CINB/CINA</th>
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TABLE II
ANALYSIS OF VARIANCE FOR REGRESSION EQUATION
Group 60

<table>
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<th>Source of Variance</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-Ratio</th>
<th>F-Critical</th>
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Correlation Coefficient = 0.84

Regression Equation: \[ \text{INDEX LEVEL}_{60} = 56.13 + 3.17 \times \text{Period Number} \]
### TABLE III
ANALYSIS OF VARIANCE FOR REGRESSION EQUATION

<table>
<thead>
<tr>
<th>Source of Variance</th>
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<th>Mean Square</th>
<th>F-Ratio</th>
<th>F-Critical</th>
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Correlation Coefficient = 0.40

Regression Equation: $\text{CBI}_{90} = 96.1 - 6.0 \times \text{Period Number}$
TABLE IV
VARIANCE TEST FOR GROUP 60 AND 90

\[ F = \frac{s^2}{s^2_{90}} \]
\[ = \frac{660}{550} \]
\[ = 1.20 \]

\[ F_t = F_{t\left(1-\alpha/2\right)(n_{90}-1)(n_{60}-1)} \]
\[ = F_{t\left(0.975\right)(15)(20)} \]
\[ = 2.57 \]

Accept \( H_0 \) if \( F_c \leq F_t \)

where: \( \sigma^2_{90}, \sigma^2_{60} \) = the variance for Group 90, 60
\( s^2_{90}, s^2_{60} \) = the sample variance for Group 90, 60
\( F_c \) = the calculated F-statistic
\( F_t \) = the table F-statistic
\( n_{90}, n_{60} \) = the number of subjects in Group 90, 60
\( \alpha \) = the alpha error
\( H_0 \) = the null hypothesis
\( H_A \) = the alternative hypothesis
TABLE V
MEAN TEST FOR GROUP 60 AND 90

\( H_0: \mu_{60} = \mu_{90} \)

\( H_A: \mu_{60} \neq \mu_{90} \)

\[
s^2 = \frac{(n_{60}-1)s_{60}^2 + (n_{90}-1)s_{90}^2}{(n_{60} + n_{90} - 2)}
= \frac{(20(23.46)^2 + 15(25.69)^2)}{(21 + 16 - 2)}
= 597
\]

\[
s^2_{\bar{x}_{60} - \bar{x}_{90}} = \frac{s^2}{n_{60}} + \frac{s^2}{n_{90}}
= \frac{597}{21} + \frac{597}{16}
= 65.77
\]

\[
t_c = \frac{\bar{x}_{60} - \bar{x}_{90}}{s_{\bar{x}_{60} - \bar{x}_{90}}}
= \frac{78.60 - 66.94}{8.12}
= 1.476
\]

\[
t = t_{(1-\alpha/2)}(n_{60} + n_{90} - 2)
= t_{0.975, 35}
= 2.030
\]
Accept $H_0$ if $-t < t_c < t$

where: $\mu_{60}, \mu_{90}$ = the true mean of Group 60, 90

$\bar{x}_{60}, \bar{x}_{90}$ = the sample mean of Group 60, 90

$s_{60}^2, s_{90}^2$ = the sample variance of Group 60, 90

$n_{60}, n_{90}$ = the number of participants in Group 60, 90

$s^2$ = the combined variance of Group 60 and 90

$t_c$ = the calculated $t$-statistics

$t_t$ = the table $t$-statistics

$\alpha$ = the alpha error

$H_0$ = the null hypothesis

$H_A$ = the alternative hypothesis
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Abstract

The Surgical Scheduler's Game is a management game structured within the surgical department of a hospital. It is designed to introduce participants to the scheduling function of the surgical service and is based upon surgical data collected on over 4,000 patients. The participant assumes the position of a surgical scheduler in a 400 bed hospital with five operating rooms. For each operation to be scheduled, the participant receives the name of the surgeon placing the scheduling request, the pre-operative procedure name, the patient's age and the date and time requested. The participant must then schedule the patient. He has available an estimate of the duration of different operations based upon historical records. Other actions required of the participant are to schedule modifications generated through cancellation and rescheduling requests.

At the completion of each game period (one day), the participant receives a performance report. This report includes both a measure of scheduling effectiveness and cost of the service that had been performed. In addition, a comparison is made between the best possible schedule for each day and the schedule developed by the participant.
The financial report includes fixed, variable and overtime operating room costs, surgeon and patient delay costs, rescheduling costs, and income from operations. The game is set within a probabilistic environment and includes an adaptive learning feature which makes the scheduling requirements more difficulty as the participant reaches certain levels of proficiency.