AN ABSTRACT OF THE THESIS OF

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Title: THE DEVELOPMENT OF A MODEL FOR COMPUTER SIMULATION OF A COUNSELING CENTER

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The study resulted from a desire and interest to include computer simulation techniques in the design of educational practices. The purposes of the study were (1) to develop a computer model which would simulate the service functions of a counseling center by tracing students through the center and (2) to experiment with the model in various situations to demonstrate how computer simulation may be utilized in making decisions concerning the center.

The service functions of the counseling center were defined in terms of the types of conferences available to students. The data base for the study was obtained by tracing 2,127 students through a high school counseling center.

The model (COMSIM) was a dynamic, stochastic model. The operating characteristics for the model were:

1. Arrival times are distributed according to a Poisson distribution

2. Conference times are exponentially distributed.

COMSIM was constructed as a general simulation vehicle to permit its utilization in various situations regarding the service functions of a counselor center. The computer program was written in FORTRAN because of the compatability of this language to available computing facilities.

A Chi-square Goodness of Fit test was used to test the validity of operating characteristics of the model and to test for significance between the simulated output and the data base. Results of the test proved that at least 99.5 percent of the time the Poisson and the exponential distributions would be valid operating characteristics for the model. The tests also indicated that at least 97.5 percent of the time the output of COMSIM would be a "good fit" in comparison to the data base. It was concluded that COMSIM presented a reasonable approximation of the real system.

The model was utilized to simulate six educational situations involving the service functions of a counseling center. As various situations were presented, the input to COMSIM was changed and each situation was simulated by the computer model. Imposing new conditions on the model provided an estimate of the magnitude of the changes that would result if such conditions were imposed on the counseling center being studied.

This study illustrated that valid models of educational systems can be developed by stochastic processes and that computer simulation can be used as a technique to aid decision-making in the field of education. Recommendations were made in the study for additional research and for refinement of the model.

The Development of a Model for Computer Simulation of a Counseling Center

by

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CHAPTER I

INTRODUCTION

Background of the Study

This study was undertaken as a result of an interest and desire to apply techniques of computer simulation to educational problems, policy, and management. The study was based on the investigator's belief that it is essential for educators to utilize every new idea and technique available which might improve the quality of education and the efficiency of our educational institutions. Computer simulation was viewed in this study as one method of facilitating the study of present and future educational systems.

Statement of the Problem

This study is to determine if the service functions of a counseling center can be modeled and simulated by computer simulation techniques. The problem was sub-divided into two parts: 1. development of the model; 2. computer simulation experiments with the model. Specifically, the study will seek to determine answers to the following questions:

1. Is it possible to develop the computer simulation model by using the parameters and variables from a data base together with probability distributions and random variables?
2. Is it possible to attach some degree of confidence to the validity of the model?
3. Is it possible to use the model as a basis for decision-making when simulating hypothetical situations?

Delimitations of the Study

The study was limited to the quantifiable aspects of the service functions of the counseling center. Therefore, the elements involved in the study dealt with the types of conferences available to students in terms of time and probability. No attempt was made to simulate the qualitative factors of the counseling center such as the effectiveness of the counseling.

The study was limited to modeling a counseling center where students were arbitrarily assigned to a counselor at the beginning of the school year.

The study was further restricted to the overall counseling services performed by the counselors at the center and did not attempt to model the role or services of an individual counselor.

The data base for the study was formulated by tracing students through the center on randomly selected days from the months of December, 1969, and January and February, 1970.

Need for the Study

Educators have been accused of being remiss in their use of computers; therefore, persons without a primary commitment to education have been performing the pioneering research in the field of education (3). Dr. Andrew Molnar (62), Office of Research of the U.S. Office of Education, concluded that educators need educating, at least when it comes to using computers in education. He expressed the belief that computers are not being put to best use in education and most uses, he claims, are inappropriate. Dr. Molnar also maintained that most educators do not grasp the potential of computers in education and said that many are afraid of the computer. Guertin indicated that "were it not for people with a basic business orientation, there would be no computer processing operations in the schools today" (35, p. 26).

A technical report of System Development Corporation written in 1963 contained a very critical statement about educators and educational design. The statement was:

> At his present level of capability for designing school organizations, the educator formulates a relatively simple plan, tries it in a real school, observes the problems as they arise, and attempts solution on a piecemeal basis. It is in this fashion that schools

> have been designed in the past, and it is the pattern that will be followed in the future unless new solutions can be found. The SDC project, which studies the use of systems analysis and computer simulation, should yield techniques and provide design recommendations that are more carefully conceived, that involve more pervasive and integrated changes throughout the schools, and that employ instructional media more effectively than do current school-design methods (17, pp. 1-2).

In spite of the critics, or because of the critics, the use of the computer has been increasing in the field of education. The interest and concern of educators regarding the use of the computer has generated a focus on administrative and computational uses. However, within the past ten years, there has developed an increase in the non-computational uses of the computer in education. These have generally taken the form of computer-assisted instruction, computer-managed instruction and gaming.

The progress away from the numerical and bookkeeping aspects of the computer certainly parallels the history of the computer in our society. Concomitant with the maturity of the computer, there has developed a sophistication in programing and application which has resulted in a transition from working entirely with numerical calculations to the manipulation of non-numerical symbols. This has permitted the utilization of the computer in functions of a semi-supervisory capacity such as control of refinery operations in the oil industry and control of machine operations in manufacturing processes. In addition, the military placed heavy responsibilities on the computer for control of the air defense system and the movement of troops. Computer programs were then designed which permitted business and war games to train leaders and managers in their respective fields. Gaming led to the need to provide simulated experiences which consequently made it necessary for models of systems to be designed. Computer simulation of systems is the newest non-computational use of the computer.

Although the non-computational uses of the computer are assuming a significant role in computer-oriented research, computer simulation is rarely mentioned in educational circles. There would seem to be a need for educators to become involved in this new brand of research which is emerging, the use of computer simulation for analyzing systems and models of systems. Green (32) agreed with this when he stated that it is time that more people directly connected with education become involved in an attempt to understand how to use computers and to learn how others are using them. He is also of the opinion that this will enable educators to rely more on the use of computers and to use their imagination to invent new applications in their own field of research.

Cooley (21) was very emphatic in his statement regarding the need to train prospective teachers and administrators in data processing techniques. His statement concerning this is as follows:

> We must develop a core of students thoroughly familiar with modern data processing techniques. These people

> are needed to develop the specific applications of these techniques to educational research (no one else will do it for us), and to guide their colleagues in computer application as the need arises (21, p. 262).

Michael R. Lackner, an analyst for System Development Corporation is also a critic of educators for their lack of involvement. Lackner contended:

> Computer simulation has become popular in some departments of business administration, psychology, and engineering. Master's and Doctor's degrees have been earned by studies based on simulation models, but outside the research atmosphere of graduate schools, digital computer simulation is considered to be an esoteric subject. Few teachers have more than a pedestrian acquaintance-ship with information processing, and many view computer-implemented studies with undue awe or disinterested passivity. When information-processing courses are offered in the undergraduate and secondary schools as a part of the regular curriculum, however, more and more teachers will have written a program themselves and will have developed a more sophisticated attitude toward computers (47, p. 55).

There is a definite need for studies which indicate how computer simulation techniques can be applied to educational problems. This study will attempt to make the transition from the general function of computer simulation, as described below, to the development of a specific model of an educational sub-system, a counseling center. The selection of the system to be modeled for this study was due to the investigator's background and experience in the area of counseling and guidance.

Simulation may be defined as the systematic study of a model, an abstraction of the real world, in an attempt to represent reality. Regardless of the model being simulated, it is usually necessary to state initial values for the variables in the system and to state values that will remain fixed. The computer allows the very rapid movement of the model through time while taking into consideration the constants and the variables programmed into the model in conjunction with certain rules which state how the system is to operate. Various events, such as arrival of students, are then generated by the model. These events cause changes to take place within the system. This information is then processed and, according to the relationships contained in the model, another event is generated and processed. The process continues until all events have been processed or until the simulation has run for the desired length of time. The computer can then be used for a statistical analysis of the information to determine the effects of variables in the system.

In an inventory system, an example of this procedure might be the arrival of a sales slip, the changes that are made to current inventory, the updating of a list for ordering replacements and a print-out of items sold, sale price and items to be ordered. In education, perhaps this idea could be applied to the arrival of a student in an office or classroom, the identification of the function he is to perform in that location, the student time necessary for that function, amount of teacher time necessary and the processing and listing of this time. In other words, the flow of student traffic, time of performances involved, type of performance, amount of waiting time to perform a specific operation, could all be traced through the system. This procedure could be analyzed to see if there are more efficient ways to move the students through certain types of performances and also to study the teacher function in the various performances.

After studying other models (see Chapter III), it seemed likely that a variety of educational situations could be simulated, e.g., a proposed curriculum change. Input could be information about the school, the teachers, the students, instructional methods, present curriculum and facilities. This data could then be processed in conjunction with a school system model, and the output could be an evaluation of the program before it was initiated.

Hopefully, educators will profit from the considerable experience that industrial managers have acquired in the utilization of computers. Another way for educators to profit is to have specific examples of computer simulation drawn to their attention, examples which are educationally oriented and presented in terminology which they understand. Dr. Paul Twelker has perhaps summarized the general consensus of writers regarding the need for examples of simulation when he stated:

> There is no serious doubt as to the relevance of simulation to education. While progress is being made in the application of simulation procedures to education, a host of problems still need to be resolved before we can really determine the full impact in the educational arena. We have no clear idea of the nature or range of application. We do not have available models of simulation design that might guide the developers as they specify what form and shape the simulation is to take . . . (79, p. iii).

Significance of the Study

Educators in general are not aware of the potential of computer simulation as a tool for use in the educational field. If computer simulation is a technique which can be adapted to studying educational practices, then its potential should be demonstrated to educators.

Additional knowledge in the area of computer simulation should be of benefit to educational administrators at every level. Various models should be developed to demonstrate how a computer program can use the existing data base, along with estimates of varying probabilities with which important events could happen, to aid in decision-making, policy formation and future planning.

This study develops a specific model which should be helpful in clarifying possible uses of computer simulation in education.

Definition of Terms

Simulation is usually thought of as the act of assuming the appearance of some operation or condition without the real condition being present.

Naylor (64) defines simulation as a technique that involves setting up a model of a real situation and then performing experiments on the model.

Computer simulation in this study will be defined as a numerical technique for conducting experiments on a digital computer which involves models that describe the behavior of a system (or some component thereof) over extended periods of real time.

Naylor (64) also defines a computer simulation experiment as an experiment consisting of a series of computer runs in which the effects of alternative factor levels on the values of the endogenous (dependent or output) variables are tested empirically by using simulation data.

A system is defined by Hall (39) as a set of objects together with relationships between the objects and between their attributes or properties. A similar definition was given by Manetsch (57) in his doctoral dissertation which was a computer simulation model of the plywood industry. According to Manetsch, an engineer considers a system to be composed of sub-systems which individually obey certain laws and which interact according to certain interaction rules.

McMillan and Gomez define a computer model as "a mathematical model expressed or written according to a particular set of rules so that the model may be processed by the computer" (61, p. 9).

Systems analysis is usually defined as the diagnosis, design, and evaluation of organizational systems or of information flow within the system, to achieve a specific purpose.

Additional terms will be defined in Chapter IV. These terms describe the model and therefore, will be defined during the procedural stage of the study.

Overview of the Study

The second chapter is devoted to a review of the literature dealing with the role of computer simulation in studying systems. Chapter III consists of a review of the literature concerning computer simulation studies and research. The procedures of the study, including the development of the model, are discussed in Chapter IV. Chapter V includes the validation of the model and an interpretation of how the model may be used for computer simulation experiments for specific situations. Chapter VI contains the summary, conclusions of the study and recommendations for additional research. Appendices contain forms used, examples of output, summary of data collected, and the computer program.

CHAPTER II

REVIEW OF THE LITERATURE RELATING TO THE ROLE OF COMPUTER SIMULATION

The application of computer simulation techniques to educational practices has been limited in scope. Since this study involves these techniques, this chapter contains a review of the general role of computer simulation, its role in education as viewed by various authorities, and suggested procedures to follow for computer simulation studies.

Selection of Computer Simulation as an Analytical Tool

The decision to use computer simulation is actually no different than to use any other analytical tool such as a set of differential equations, statistical inference, linear programming, or queueing theory. Applicability, cost, and simplicity are three criteria that have been suggested for the selection of any analytical tool (64). If computer simulation is capable of yielding meaningful solutions to a particular problem, if the results are relatively easy to interpret, and if this can be accomplished at a cost which is reasonable in comparison to the cost of other computational procedures, then simulation should be used as the tool for analysis. If these conditions are not met, then computer simulation should be rejected in favor of some other alternative. The selection of the proper tool for analysis is not an easy task, and many times several methods must be experimented with before the experimenter decides on a method.

Computer simulation provides a means for studying systems. At times it may be the only logical path to follow when analyzing a system or proposed changes in a system. In many instances, it would be impossible or extremely costly to observe certain processes or conditions in a real system or to perform experiments on that system.

General Purposes of Computer Simulation

Evans and Wallace (28) stated that simulation studies serve many different purposes, and for this reason state that simulation is a powerful reseach technique. They characterized these purposes as:

1. The establishment of estimates and guidelines, which are particularly useful during the preliminary design phase of the development of a system.
2. Experimental system design--simulation can be used to point the way to modifications intended to improve the system by simulating the system, analyzing the results, modifying the system in a way suggested by the results and then repeating the cycle.
3. Detailed evaluation of performance of a real or hypothetical system under a variety of conditions.

Systems analysts report that computer simulation serves the purposes of problem solving, experimentation, solution of problems dealing with systems design and systems analysis and serves, as well, as a technique which can be resorted to when the systems under consideration cannot be analyzed using direct or formal analytical methods (61).

During the second System Simulation Symposium of the American Institute of Industrial Engineers, D. G. Malcolm stated:

> Simulation is useful in the study of a class of problems wherein the operating rules, policies, procedures, and other elements that control production, inventory, etc. . . . are under question, and in which the number of variables involved, the uncertain nature of inputs, among other things, makes these problems, which are referred to generally as a system, difficult to analyze (56, p. 18).

Manetsch (57) claimed that computer simulation goes beyond the traditional (econometric approach) approach to simulation which required differential equations to describe the operation of the system. He developed a simulation model to study the plywood industry, a model which could not be entirely explained by mathematical equations due to its dynamic characteristics, and concluded that computer simulation is a valuable tool to deduce the behavior of a system. He did not exclude the traditional approach in his study, rather he used it to supplement his computer model.

Other authorities (1, 53) believe that simulation allows the rapid examination of key theoretical and functional questions in existing systems. The general all around flexibility of computers in the preliminary exploration of a new idea was reported by Smith and Smith:

> With computer technology, recorded events can be telescoped in time or expanded for special analysis. The relative time among events can be changed or displaced and correlations

> obtained among such time-displaced variables. The feedback that regulates events can be delayed to study the effects on the events or operations. Such time-freed analysis is of special value in simulating business, industrial and economic operations in order to study events in these fields as short-term problems (73, p. 269-270).

Simulation to Study Innovations

The study presented here was primarily concerned with the use of computer simulation as a forecasting device, that is as a tool to aid in testing new ideas or changes in a system. Don D. Bushnell, formerly of Stanford University and now the Director of Research and Development at the Brook Foundation, supports this viewpoint as one of the main purposes of simulation.

According to Bushnell:

> When the design of new systems or the introduction of innovations into ongoing systems is in question, simulation can be used to manipulate variables to determine in advance the effect of changes. New systems can be tested or evaluated in advance of having to make firm commitments. Information about unpredictable effects that could be costly if they occurred in the real situation are also yielded (11, p. 50).

Other authorities agree with Bushnell's opinion on simulation.

Caffrey and Mosmann were of the opinion:

> . . . the high speeds with which computers can process makes it possible for the administrator to keep trying different solutions until the best one is found. The potential power of the computer to experiment with data prior to decision-making can be of great educational value (12, p. 45).

They continue:

> It (the computer) provides for trial runs and simulation of decisions by automatic projections of the probable effects of present trends and experimental studies of the effects of policies prior to commitment (12, p. 59).

Harry Silberman, Chairman of the Education and Training Staff of System Development Corporation, writes: "It is also possible to try out potentially hazardous procedures or radical innovations in a simulated setting without harmful consequences" (70, p. 347).

The general opinion of the computerized model is that it can give a higher degree of insight into the implications of policy decisions than any other method of analysis, and also, that simulation serves as an accurate predictor of events in the real system and in proposed systems (10, 69).

Computer Simulation in Education

As stated previously, systems analysis and the intelligent use of the computer are vital to the design of education. There has been little agreement, and even less implementation, of these operations in education. However, in a report issued in 1967 concerning policy development for the utilization of computers in education (58), a panel of ten scientists and educators formed a traveling seminar that inspected the state of the art at seven research and development centers throughout the United States. After the inspection, the panel agreed on four principles:

1. A systematic approach to the achievement of educational goals is required.
2. The development of models is useful for the synthesis, presentation and testing of new systems.
3. The computer has vast potential as an administrative aid to education.
4. The introduction of computers into the schools to deal with clerical and administrative problems will lead to their use in an instructional capacity.

In spite of the lack of implementation of the computer on the American educational scene, there has been much written about computer simulation which directly relates to educational practices.

John E. Coulson writes:

> . . . educational facilities and procedures planned for schools of the future can be simulated and their potential contributions evaluated . . . Imaginative new conceptions for school design may be investigated without the need for costly investments in special-purpose equipment. In some situations it may be desirable to simulate types of equipment that do not yet exist but are still in the conceptual or design phase. The effects of proposed changes in the organization or functions of a school system may be analyzed under carefully controlled conditions, without disrupting the ongoing educational activities of that system (23, p. 203).

Goodlad, O'Toole and Tyler state:

> . . . the computer can enter into the simulation of educational maneuvers. One way of viewing the consequences of interrelated decisions before they are made is to simulate a variety of possible answers--in essence, to anticipate and imitate the operation of a school or school system into which certain changes have been or are to be made (31, p. 17).

Molnar and Sherman (62, p. 6) advocated computer models and simulation for the projection and testing of theoretical ideas in educational research and statistics as well as the testing of alternatives for decision-making in real life situations.

Allen and Bushnell (2, p. 235) believe that wide-ranging computer simulation experiences can help educators gain a better grasp of the implications of innovations. In addition, they stated that simulation can greatly reduce the time between the conception and the implementation of change by reducing the amount of experimentation a school must undertake before introducing significant changes. Bushnell also contended that educators should learn from the experience of others. He stated:

> . . . the use of computers portends a broader application in school systems than the computer's more prosaic functions might lead one to expect. One of these applications is computer programs for aiding management and decision-making activities in schools paralleling those in business which supply periodic economic forecasts, balance budgets, and plan financial strategies (10, p. 531).

Baker also draws parallels between industry and education. He writes:

> Although computer simulation of systems such as fiscal needs, personnel utilization, and determination of plant location is commonplace in industry, work pertaining to analogous simulation of educational systems has not been published. There are many aspects of educational administration which appropriately could be studied via computer simulation: for example, the simulation of automobile traffic performed by the National Bureau of Stands (Communications of the ACM, 1962) might provide the basis for the simulation of pupil flow to be used in the design of school buildings. Hopefully, the next few years will produce some results in this interesting area (3, p. 572).

Procedure for Simulation Studies

Jay W. Forrester, Professor of Industrial Management at Massachusetts Institute of Technology, was one of the first to experiment with simulation of complex systems. Under his direction the simulation language known as DYNAMO was developed. Charles C. Holt, in summarizing a speech given by Forrester, submitted the following as a good procedure to follow in simulation studies:

1. Make detailed studies of the decision-making within a company (or other organization) and formulate a model of the decision policy.
2. Use an electronic computer to simulate the resulting model of the over-all decision system in order to determine its characteristics.
3. Validate the model by checking it against the actual performance of the organization.
4. Test proposed improvements in the system by performing experiments on the computer model.
5. Introduce the improved policies into the organization--and ultimately move toward administration of decision policies by the computer itself (33, pp. 68-69).

According to Naylor (64), experience suggests that planning simulation experiments involves a procedure consisting of the following nine elements:

1. Formulation of the problem.
2. Collection and processing of real world data.
3. Formulation of mathematical model.
4. Estimation of parameters of operating characteristics from real world data.

5. Evaluation of the model and parameter estimates.
6. Formulation of a computer program.
7. Validation
8. Design of simulation experiments.
9. Analysis of simulation data.

The investigations made for this chapter revealed that the role of computer simulation is a diversified one and that computer simulation can be applied to a wide variety of systems, including educational systems.

CHAPTER III

REVIEW OF THE LITERATURE RELATING TO COMPUTER SIMULATION STUDIES

Since this study is concerned with the status of computer simulation as applied to education, this chapter is devoted to a review of the literature relating to studies which have involved computer simulation. It was the investigator's purpose to include a variety of studies to indicate the many different areas using computer simulation techniques.

Literature Relating to Non-educational Uses

The widespread use of computer simulation in the military, in business and in industry to model and analyze an entire operation, system or sub-system is well known (6, 9, 18, 37, 38, 42). The use of computer simulation in the behavioral sciences has been increasing (8, 36). Behavioral scientists have been utilizing computer simulation to study a wide range of characteristics such as personality (77); human concept attainment and the operation of memory (43); interaction of social groups (40); human thought, artificial intelligence, verbal learning and concept formation (29); human problem-solving behavior (49).

The medical profession has also discovered uses for computer simulation in such areas as simulation of the dynamic behavior of the human regulatory system (63), laboratory research (71) and as a basis for increasing the efficiency of operations and procedures within the medical laboratory (25).

A wide variety of studies has been undertaken in the areas of public transportation and public health administration (68). Computer simulation studies dealing with the probability of occurrence of different types of injuries as a result of automobile accidents has also been reported (60). The Health and Environmental Systems Department of SDC (System Development Corporation) is making use of computer simulation to study the delivery of quality medical services to residents of rural areas. The computer simulation model is designed to facilitate existing manpower, facilities and services and to aid in forecasting future requirements (13). The same department is also simulating smog production by a computer program designed to aid in a study of air pollution. As a result of this simulation study, it is expected that guidelines will be formed to help officials write laws for the control and elimination of smog (13).

There has also been a trend to simulate laboratory-type experiments, such as chemical analysis, before the actual experiment is conducted in the laboratory (11). R. W. Hemming (75) stated that comparatively few years ago 90 percent of the experiments done at the Bell Telephone Laboratories, Inc., were performed in actual laboratories and only ten percent were done on computers. He also stated that by 1970 this trend will be completely reversed.

Computer simulation has also been used to study the function and operation of computers in areas such as time-sharing (65, 66) and to simulate other computers (50).

Several studies have been reported which deal with the political scene. Lane (48) discusses the relevance of computer simulation to political science. A theoretical model of the voting process in the U. S. House of Representatives was developed. The model was designed to deal with all categories of votes, e.g., foreign affairs, farm bills, welfare legislation, and was found to be approximately 80 percent accurate in prediction. Paine (67) developed a model which dealt with competitive political decision-making rules. The output indicated probable changes in the oligarchical or totalitarian character of the leadership. Paine was of the opinion that the computer model gives very important insights into the political make-up of an organization.

Many studies have been concerned with the simulation of a firm or business. Charles P. Bonini (6) developed a model of a hypothetical business firm. His complex model represented a synthesis of some of the important theory from a number of disciplines, among which are economics, accounting, organization theory and behavioral science. The essential elements of the Bonini hypothetical business organization include: decision centers, information centers, decision rules, information links, information systems and decision systems. The purpose of the model was to study the effects of three types of changes on the behavior of the firm--changes in the external environment, changes in the information system and changes in the decision system. Bonini used a factorially designed experiment to study the main effects and the various interactions of eight specific changes in the model including prices, inventory levels, costs, sales, profits and organizational pressure.

Cohen (18) formulated and experimented with two mathematical models describing the behavior of shoe retailers, shoe manufacturers and cattlehide leather tanners between 1930 and 1940. He found a very close correspondence between the simulated time paths and the actual time paths.

The conclusions expressed by Green (34) after simulating a market organization were that 1) simulation models can help link economic theory and business practice and 2) simulation models are of great assistance to management when it is needed to analyze multivariate problems beyond a relatively low level of complexity.

Gensch (30) developed a computer model to be used in the advertising firm for selection of media to be used in advertising. His conclusion was that the simulation approach was superior to hand-generated schedules for making effective media selections of specified advertising messages for national magazines and network television.

A computerized model of a hypothetical manufacturing firm was formulated by Walker (81). He integrated production, marketing, administration and the economic environment of the firm for the purpose of experimentation with operational decisions. He suggested that simulation models for operational planning can be constructed and that the computer has the capability of successfully evaluating these models while effectively searching for more efficient solutions. Walker also recommended that further experimentation in model simulation of total firms should be continued with the aid of the computer.

Manetsch (57) simulated the softwood plywood industry on a digital computer. Input variables consisted of number of mills, jobbers, firms, retailers, users and also took into consideration the demand and market prices. Major industry variables generated by the program were mill market price, mill production, mill unfilled orders, mill profit, wholesale inventory and wholesale unfilled orders. He concluded that the simulated data bears definite resemblance to data reflecting past industry performance.

A model which provided quantified answers to questions of importance to personnel concerned with the broiler industry was developed by Bender (4). This model takes into consideration the seasonal demand of this industry and results in predictions concerning the hatchery supply, amounts of feed and grain prices and a pattern of monthly output. Bender develops two models--Model I, a basic model of the industry today and Model II which projects a possible future industry.

Several of the studies dealing with managerial decision-making (24, 74) point out the fact that relatively few systems are designed to assist management in the guidance, planning and control of a business enterprise. These studies attempt to show the potential utilization of the computer in the area of field surveys (24) and the aerospace industry (74). Both investigators indicated that simulation results in decisions which produce reasonable, consistent, adequate and stable results as compared with those obtained by human decision-makers operating in a similar environment.

John Donovan (25) was also concerned about designing a specific example to show the effectiveness of digital simulation. For his doctoral dissertation at Yale University, he constructed a model of the Clinical Chemistry Laboratory of the Yale-New Haven Hospital. This model traces the steps necessary for certain chemical analyses of specimens from patients. Donovan concluded that digital simulation is a powerful technique in studying complex systems, systems which cannot be dealt with through the application of differential equations because they are concerned with people, queues, machines or other components which have quite different characteristics and which have complex relationships among these components. He stated that his model may be used to better understand the operation and procedures of the laboratory.

James Husband developed a model for his master's thesis at Oregon State University which can be used for forecasting the peak-load capacity for electric power generation by the use of tidal energy (44).

Literature Relating to Computer Simulation in Education

In addition to the use of the computer for scheduling, business affairs and computer-assisted instruction, there have been a few projects which directly involve computer simulation in counseling (54, 16) and with computer controlled economic games such as the Sumerian Game and the Sierra Leone Development Project (82).

Computer simulation has also been used to aid in decision-making. Cosand and Tirrell (22) used GASP (Generalized Academic Simulation Program) to plan a new junior college of 4, 500 students in the St. Louis area. The simulation technique increased the actual utilization of classrooms to 88 percent and laboratories to 66 percent, figures which were far above the design submitted by an architectural firm. Twenty-seven simulation runs were made before an optimum allocation of classes and instructors was reached. The authors conservatively estimated that through the use of computer simulation in planning the college, they saved the college $3, 000, 000 in building expenses. The cost of the total simulation program was given as $15,000.

Educational Facilities Laboratories and Duke University have collaborated to sponsor a study to develop and demonstrate applications of the computer for use by campus planners and architects (59).

System Development Corporation of Santa Monica, California, has carried out the most extensive research involving computer simulation in education (15, 16, 17, 26, 27, 54). Researchers at SDC have simulated 100 students going through an advanced, individualized, continuous progress high school located at Brigham Young University to compare the number of steps required by slow and fast learners in completing a year of work at their own rate so that implications for changing study schedules on a daily basis may be studied, student advancement requirements may be explored, and the advantages of homogeneous class groups can be investigated. The role of teachers, principals and other school personnel can be clarified and restated in terms of changed pupil progress and system needs as a result of the simulation. Loughary (53), in referring to this study, stated that ". . . the computer simulation vehicle will provide the capability of building detailed and dynamic models of the schools and of hypothetical changes in the schools" (53, p. 46).

Sisson (72) recently claimed to be the first to develop a computer simulation model which looks at the problem of education management. His model shows the financial consequences of various management policies carried out under a variety of assumed conditions. His computer simulation model was run to show the effect of policies on the allocation of finances over a ten-year period (1966-1975) in the Philadelphia School District. A series of four ten-year simulations was run in 1.10 minutes.

Cawley (14) in his doctoral dissertation at the University of Utah in 1968, developed a dynamic, stochastic computer simulation model for sub-systems of a university. This model deals with academic departments, students, research contracts and academic personnel as microcomponents. Simulated activities of these components in the area of instruction, research and other activities were illustrated in detail with flow charts and complete definition of variables. Parameters for the stochastic operating characteristics were estimated for a department in the University of Utah using records kept by the administration. The functioning of the model was illustrated by applying the parameters and flow charts to a set of input data, and complete tables of variables generated by the model were given. The model was judged to function adequately in terms of prediction of the behavior of the system.

Perhaps the most ambitious project concerning computer simulation in long-range planning of complex educational systems is the Asian Educational Model (20). This model was developed by two staff members of UNESCO working with five Asian consultants at the UNESCO Regional Education Office in Bangkok. The function of the model is to forecast and simulate educational systems at any given point in the near or distant future. The model serves as a tool to be used by educational planners to demonstrate instantly the implications of any quantifiable change in the educational system or in any factor directly affecting it. Examples given include the implications of such decisions as: introducing compulsory education, changing the pupil-teacher ratio, altering the level of teachers' qualifications or their salaries, changing a government's manpower needs or revising the amount of gross national product devoted to education.

A total of 280 questions covering the most important elements of Asian educational systems were framed as algebraic equations and fed into the computer. These questions concerned different educational patterns and specific situations at all levels, in each year until 1980. Given the necessary data (which admittedly are projections in many long-term forecasts) it is possible to get a picture reflecting in numbers what the educational system will be like at any level, at any given date and in any type of grade or school. It can be learned what school enrollments are likely to be at different levels in any future date, given certain conditions. If a country's target is, for example, 100, 000 pupils graduating from secondary schools, the model can tell educators what will be needed on a quantitative basis to bring this about--teachers, primary school intake, capital investment in school buildings, equipment, etc. . . . The model predicts various situations on the basis of given educational hypotheses, and it can also show what must be done to alter these hypotheses, if necessary, to achieve a desired result and situation.

The report gives the following example:

> A country may, for example, wish to know now what the size of enrollment in the third year of a university science department will be in 1978. The answer, as worked out in less than a minute, would have to take into account such factors as: the number of children born in 1958 and who survived till the age of six when they presumably entered first grade of primary school; the proportion of all six-year-olds entering first grade in 1964; the proportion continuing through primary school from grade to grade; the proportion entering secondary school and their distribution among various types of specialized education; the proportion continuing on from grade to grade in secondary education; the proportion entering higher education and their distribution among various branches of study; and the proportion continuing through higher education until 1978 (20, p. 122).

However, in considering such a problem, the determining proportions mentioned above are in themselves influenced by such educational factors as the availability of schools, and the efficiency of the educational system itself, as well as by changing demographic situations, social, political and economic requirements and constraints. The UNESCO team believes that the model can be applied to educational systems in all areas of the world at a considerable saving of time, labor and cost.

Literature Relating to Computer-based Information Systems for Student Use in Education

One of the situations to be simulated in Chapter V concerns a system for information retrieval in the counseling center. Therefore, the writer believed it necessary to review some of the literature concerning information systems as they are now viewed in the educational process.

At the present time, one of the functions of most counselors at the secondary level is to disseminate information to students. Much of this information is routine, information which is available or can be made available in printed form. A computerized information system is capable of storing large amounts of such information and can answer most questions faster and more objectively than a counselor (7). More difficult questions and problems of a personal nature can be referred to a counselor. The system would then relieve the counselor of much of the routine work and allow him to spend more time with students who have a real need for human interaction. The counselor would be better able to reschedule the students for additional and sustained counseling sessions since he would be relieved of many of the trivial tasks he now performs. More time would be available for home visitations, meetings with parents and teachers and for working with specialists concerned with the student and his problem.

Bohn and Super (5) described two programs of information systems for counseling which are now being tested. These two systems are:

1. Education and Career Exploration System (ECES) being developed by IBM, counseling psychologists at Columbia University, and the Montclair, N. J. School District.
2. Information System for Vocational Decisions (ISVD), a joint effort by counseling psychologists at Harvard, public school counselors in Newton, Mass., and researchers of the New England Educational Data Systems (NEEDS).

According to Dr. Robert W. Blanchard, Superintendent of Montclair schools:

> The purpose of the study is to determine if a computer can help prepare a student for more productive counseling sessions and free the counselor from clerical tasks so that he can spend more time with each student (52, p. 73).

The system (ECES) consists of computer terminals and experimental image display units. The exploration is a joint effort between the computer, film loaded into the display unit, and the student. Through the use of the ECES the student has quick access to:

A Vocational Orientation Library, which holds information on 1, 600 occupations, 329 of which are in-depth. Work samples, job descriptions, training requirements and starting salaries are included.

An Educational Orientation Library, which allows the student to explore 391 major areas of study available in colleges, technical schools or universities.

A Technical School and College Finder Library, with comprehensive information on 1, 500 colleges, technical schools and universities covering each

> institution's educational emphasis, geographic location, affiliation, tuition, costs and scholarship opportunities (52, p. 73).

A third system, Computer Assisted Career Exploration, is being experimented with in selected public schools of Pennsylvania with the cooperation of Pennsylvania State Univeristy (45).

The only system in full operation at this time is the Computerized Vocational Information System (CVIS) at Willowbrook High School, Villa Park, Illinois. This system was developed by the counselors in this high school. The system provides students with information about 400 career choices and also allows computer access to student personnel records by authorized staff members (41, 51).

System Development Corporation has also designed a system which indicates the potential value of an automated procedure for both research and field application. The system allows a student to have dialogue with a computer concerning student progress, plans and reactions to assist the student in planning a high school schedule. Therefore, the system serves as an aid in the educational planning function of the student. The procedure employed was to simulate, by computer, as much as possible of a counselor's behavior in two phases of educational planning: the appraisal of the cumulative folder and the planning interview with the student (16).

Summary of the Literature

The review of the literature for this chapter revealed that computer simulation has been used for studying many types of systems. Most of the simulation studies reviewed were designed to assist management in the guidance, planning, and control of a system. The review of literature also indicated that computer simulation is a technique which has been used to a very limited degree in studying educational systems.

CHAPTER IV

PROCEDURE OF THE STUDY

This chapter contains the procedures of the study which includes a brief review of a pilot study, factors contributing to the design of the model, data collection methods, and an elaboration of important points of the computer program. Additional terms describing the model are stated and defined.

Pilot Study

This investigation began with a pilot study involving computer simulation of a counseling center. The pilot study was a term project for a class in computer simulation during the winter term of 1969 at Oregon State University. The model developed was a simple model dealing with the services offered by a counseling center involving only two counselors, two types of conferences, personal and informational. The pilot study was concerned with determining the optimum number of computer terminals in a counseling center which hypothetically had a computer-based information system. Parameters and variables for the pilot study were derived from data collected over a period of years at Ellensburg High School, Ellensburg, Washington. The results of four runs of five simulations each were calculated and analyzed. It was concluded that two remote terminals would serve such a center.

Selection of Monitoring Time

When the pilot study was completed, officials of the Corvallis School District, Corvallis, Oregon, were contacted concerning the feasibility of such a study at the local high school. Permission was granted for the study, and several meetings were held during the Spring and Fall of 1969. These meetings were with administrators and counselors at Corvallis High School. The purpose of the study and procedures to implement the study were reviewed and discussed. The decision was made to limit the data collection phase of the study to the months of December, 1969, and January and February, 1970. It was further decided that the monitoring time would consist of three days randomly selected from each of the three months.

Definition of Service Functions at the Center

The service functions of the center were defined during the meetings as "the overall counseling services provided to students who actually enter a counselor's office." Interpretation of this definition eliminated the possibility of simulating the services of each counselor. The counseling services were defined in terms of the types of conferences available to students. These were categorized as:

1. academic
2. attendance
3. employment

4. personal-social
5. post high school planning
6. records
7. schedule
8. vocational
9. other

Data was collected for all students entering the system, but only the purposes of those students desiring a conference were considered in constructing the model.

Data Collection

The counselors assisted in developing the forms used for tracing each student through the center. After a three hour trial run was made, the forms were evaluated and revised.

Arrival times, waiting times, service times (for students not wanting a conference), conference times, types of conferences, and departure times were determined for 2,127 students during the nine day period.

The monitoring time was intended to be 450 minutes per day (8:00 a.m. - 3:30 p.m.); however, on several occasions all counselors were involved in general meetings and therefore not available to students. The monitoring time averaged 421 minutes per day. Each counselor was allowed 60 minutes for breaks during the day, making the average availability time for each counselor equal to 361 minutes.

The counselors were responsible for making decisions concerning (1) the type of conference held with each student and (2) the arrival and departure times of students entering and leaving the counselor's office. Multiple checks on the form indicated that several areas were discussed during a conference. For these cases, the time was equally divided between these areas unless otherwise indicated by the counselor. Appendix I contains examples of the forms used during the data collection phase of the study.

Summary of Data

The data was summarized for each day, each month, and for the three months. The Summary of Data (Appendix II) is self-explanatory with the exception of the categories labeled "Mean contact per counselor", "Percent contact", and "Probability". The "Mean contact per counselor" is the ratio of the average daily conference time to the average number of counselors per day. The "Percent contact" is the ratio of the mean contact time to the average number of minutes each counselor was available during the day. This available time averaged 361 minutes per day for the nine days. The "Percent contact" figure of 58.5 represents the percentage of the counselors' available time which was spent in conferences with students. Accounting for the remainder of the counselor's day, approximately 14 percent was for breaks and 27.5 percent for other affairs such as consulting with teachers, parents, other counselors, telephone calls, writing recommendations, etc. . . . The probability for each type of conference was calculated by taking the number of conferences of each type and dividing by the total number of conferences.

Factors Contributing to the Design of the Model

To develop the model (TRIAL) for the pilot study and to design the model (COMSIM) for this study, it was necessary to answer the following questions:

1. For what purposes do students enter the center?
2. How often do students arrive at the center?
3. How much time do students spend in the center?
4. How much of this time is waiting time and how much is time actually spent in conference with a counselor?
5. Is it possible to service all students who enter the center?

It became evident that these questions could be answered by tracing students through the center. The next consideration was also in the form of a question.

Is it possible to construct a computer model which will trace students through the system?

Additional questions were raised in attempts to answer this question. These were:

1. Is it possible to assign a probability to each type of conference?

2. Do the arrival times and conference times follow any particular pattern, such as a known probability distribution?

After analyzing the data gathered for TRIAL, it was determined that a probability could be assigned to each of the two types of conferences. This probability depended on the percent of students who desired each type of conference. If 60 percent of the students wanted an informational type of conference, the probability would be .60 for that type of conference. Using two-digit random variables, or a random number generator in the case of the computer model, a variable between 00 and 60 would indicate that a student wanted an informational type conference.

The arrival and conference times were determined, mainly by trial and error, to be exponentially distributed. On the basis of these two considerations, TRIAL and COMSIM were constructed as models which involved probability distributions, parameters and variables from the data base, and random variables generated by a subroutine of the program.

The computer model was written in FORTRAN (Formula

Translation) because of the compatability of this computer language with available computing facilities and because of the investigator's familiarity with this language. The program was implemented on the OS-3 system (Oregon State Open Shop Operating System) which has a Control Data Corporation 3300 computer as the central processing unit.

Definition of Terms

For clarity and consistency, the following definitions apply wherever the terms appear:

FORTRAN - a common computer language, the acronym FORTRAN standing for Formula Translation.

Dynamic model - a model that deals with time-varying interactions as an important feature of the model.

Probability density functions - a mathematical equation describing the distribution of a set of random variables.

Cumulative distribution functions - derived from the probability density function by integration and used to obtain the probability that the random variable is "equal to or less than" a specified value.

Poisson probability distribution - a distribution of random variables described by the equation

$$f(x) = \frac{u^x e^{-u}}{x!} \qquad \text{where } x = 0, 1, 2, \ldots n \text{ and } u > 0$$

Exponential probability distribution - a distribution of random variables described by the equation

$$f(x) = \alpha e^{-\alpha x} \qquad \text{where } x > 0$$
$$\text{and } \frac{1}{\alpha} = u$$

Operating characteristics - a hypothesis, usually a mathematical equation relating the variables of the system. Operating processes for stochastic processes take the form of probability density functions.

Stochastic model - a model in which at least one of the operating characteristics is given by a probability density function.

Queue - a waiting line.

Status variable - a variable which describes the state of a system or one of its components either at the beginning of a time period, at the end of a time period or during a time period. These variables interact with both the exogenous and endogenous variables (defined below) according to the operating characteristics of the system.

Exogenous variables - the independent or input variables of the model. Exogenous variables are either controllable or non-controllable. Controllable (or instrumental) variables are those variables or parameters that can be manipulated or controlled by the decision makers or policy makers of the system.

Endogenous variables - the dependent or output variables of the system; they are generated from the interaction of the system's exogenous and status variables according to the system's operating characteristics.

Parameters - a summary number used to describe a population; a constant.

Variable time increment model - time is advanced by the amount necessary to cause the next most imminent event to take place and does not advance in discrete steps.

Random number generator - a subroutine of the main program which generates a uniform distribution of random numbers necessary for the decisions which have to be made and for the times which must be generated.

Differences Between COMSIM and the Real System

The counseling center at Corvallis High School was organized on the basis of each student being assigned to a counselor. A student entering the center for the purpose of having a conference with his counselor would, in essence, be placed in a queue for that counselor. This resulted in having a queue for each counselor. Ordinarily, most queues are thought of as waiting lines where the first individual in line is serviced first. Due to some students entering the center with prior appointments, the first student in each queue was not always the first one to have a conference.

As stated previously, COMSIM was designed to study the overall service functions of the center and not the services of an individual counselor. Therefore, the two factors mentioned above were not considered in the data collection or in the development of the model. Only one queue was developed for the model and it was designed to service students on a FIFO (first-in, first-out) basis.

Statistical Assumptions for COMSIM

The statistical assumptions, or operating characteristics, for the model were:

1. Arrival times are distributed according to a Poisson distribution.

2. Service and conference times are exponentially distributed.

Exponential distributions were utilized for the generation of arrival and conference times for the pilot model. However, experimentation with these distributions revealed that the Poisson distribution yielded a closer approximation to the arrival times of students in the real system; therefore, a Poisson distribution was used in the development of COMSIM. The Poisson and exponential distributions are often used for these purposes in simulation studies because they usually yield close approximations to the actual distributions (61, 64, 68, 76).

Parameters and Exogenous Variables

The input for COMSIM was taken directly from the Summary of Data (Appendix II) and consisted of:

	Variable Name
1. Time in minutes per counseling day	TIME
2. Probability for each type of conference (See discussion on next page concerning COMMON DATA statement.)	
3. Number of counselors	NC
4. Expected time between arrivals	TNXTARR
5. Percent of students wanting a conference	PCTCOUN
6. Mean conference time for each of the nine types of conferences	SVT(N)
7. Mean service time for students who enter system but do not want a conference	SVT(10)

In addition to the above, it was also necessary to set the number of replications (NRUN) and the number of simulations (NSIM). Each run consisted of a desired number of simulations with each simulation representing one day at the counseling center. Each run began with an initial set of five random numbers which are used in the model to assist in making the decisions and generating the times necessary to simulate a student through the system. There were two constraints placed on the initial values of the random numbers. The random numbers must be seven digits or less and they should be odd numbers. Otherwise, any table of random numbers may be used for the selection of these initial values.

The program was written so that the random numbers, number of counselors, number of runs and number of simulations must be entered as integers or counting numbers. The expected time between arrivals, percent of students desiring a conference, conference times and service time must be entered as real numbers, i.e., a decimal point must be present.

Determination of Type of Conference

The COMMON DATA statement (Appendix III, sequence nos. 3, 4) is a vital aspect of the program. It is the part of the program, which, in conjunction with the random number generator, determines the type of conference a student will have after he enters the simulated system. This is accomplished by using the probability of each type of conference in the COMMON DATA statement to form a table described below.

An example of how the COMMON DATA statement functions is given below:

Assume that the following data pertaining to the probability of certain types of conferences is as follows:

Academic	.15	Post H.S.	.17
Attendance	.05	Records	.08
Employment	.03	Schedule	.06
Personal	.30	Vocational	.12
		Other	.04

The numerical part of the COMMON DATA statement would then be inserted as:
15(1), 5(2), 3(3), 30(4), 17(5), 8(6)
6(7),12(8), 4(9)

This information is treated as the cumulative frequency table.

Random Number	Conference Type
97-100	9
85- 96	8
79- 84	7
71- 78	6
54- 70	5
24- 53	4
21- 23	3
16- 20	2
1- 15	1

The random number generator (Appendix III, sequence nos. 378-382) in the program generates a random variable uniformly distributed between 1 and 100. The cumulative table is searched to locate the position of that variable and the corresponding number representing a type of conference is given. This is the type of conference for one student. The process would then be repeated for each student as he arrives and indicates that he would like to have a conference.

COMSIM was developed so that it could be utilized by any school system desiring to study its counseling center. Each school would need to collect its own data for input and make the change necessary in the COMMON DATA statement. The probability for conference types will certainly vary from school to school and from situation to situation; thus the COMMON DATA statement would need to be changed according to the example above.

Time of Next Arrival

The expected time between arrivals in the real system is given in the Summary of Data as 1.8 minutes. This means that, on the average, a student entered the system every 1.8 minutes. COMSIM generates the time for the next arrival by using the mean time between arrivals from the data (1.8 minutes) as the mean of a Poisson distribution (Appendix III, sequences 365-377). In conjunction with the mean time between arrivals, it is necessary to call the random number generator into the main program. Together, these two generate an arrival time in the system for each student. The program keeps a running total of the arrival times. When the total arrival time is equal to or greather than the variable TIME, which was set earlier, one simulation has been completed.

Conference Time and Service Time

The distinction between conference time and service time is that conference time is the actual time spent with a counselor.

Service time is for those students not wanting a conference and merely gives the length of time they stay in the system. Both times are generated by identical methods. A random number is generated and, together with the expected mean time for the type of conference selected, or with the average time in system for students not wanting conferences, is placed in the equation of an exponential distribution and a time is generated (Appendix III, sequence nos. 383-388). A service time or conference time is generated for each student entering the system.

Decisions to be Made

When entering the counseling center, a student had already made a decision whether or not he would want a conference with a counselor. In COMSIM, this decision is made after an arrival time has been generated for the student. A random number is generated and checked against a variable called PCTCOUN which indicates the percent of students entering the system who want to have a conference (Appendix II and Appendix III, sequence nos. 100-104). If the random number generated is less than PCTCOUN, a conference time will be generated for the student. If the random number is greater than PCTCOUN, the student does not want to see a counselor and a service time is generated to indicate the length of time he spends in the system. If a conference is desired, the type of conference is determined prior to the generation of a conference time.

Verbal Description of COMSIM

A general flow of students through the simulated system is illustrated in Figure 1. The program begins by generating an arrival time for the first student, this time being the number of minutes elapsing between the n^{th} arrival and the $(n + 1)^{th}$ arrival. After entering the system, the student makes a decision either to have a conference with a counselor or to stay in the system for other reasons. If a conference is not desired, a service time is generated for the student. He spends that amount of time in the system and then departs. If a conference is desired, a check is made to determine if a counselor is available. When the program indicates that all counselors are busy, waiting time accumulates for the student until a departure from a counselor is indicated. As soon as this occurs, the type of conference for the next student is determined and a conference time is generated. The student confers with the counselor during this time for the purpose decided upon and then departs from the system.

The program is then ready for another arrival. This procedure continues until the CLOCK (total arrival time) is equal to or greater than TIME. TIME, as discussed before, can be set at any desired length. For the validation of COMSIM, TIME was 421.2 minutes as indicated in the Summary of Data. One day has then been simulated.

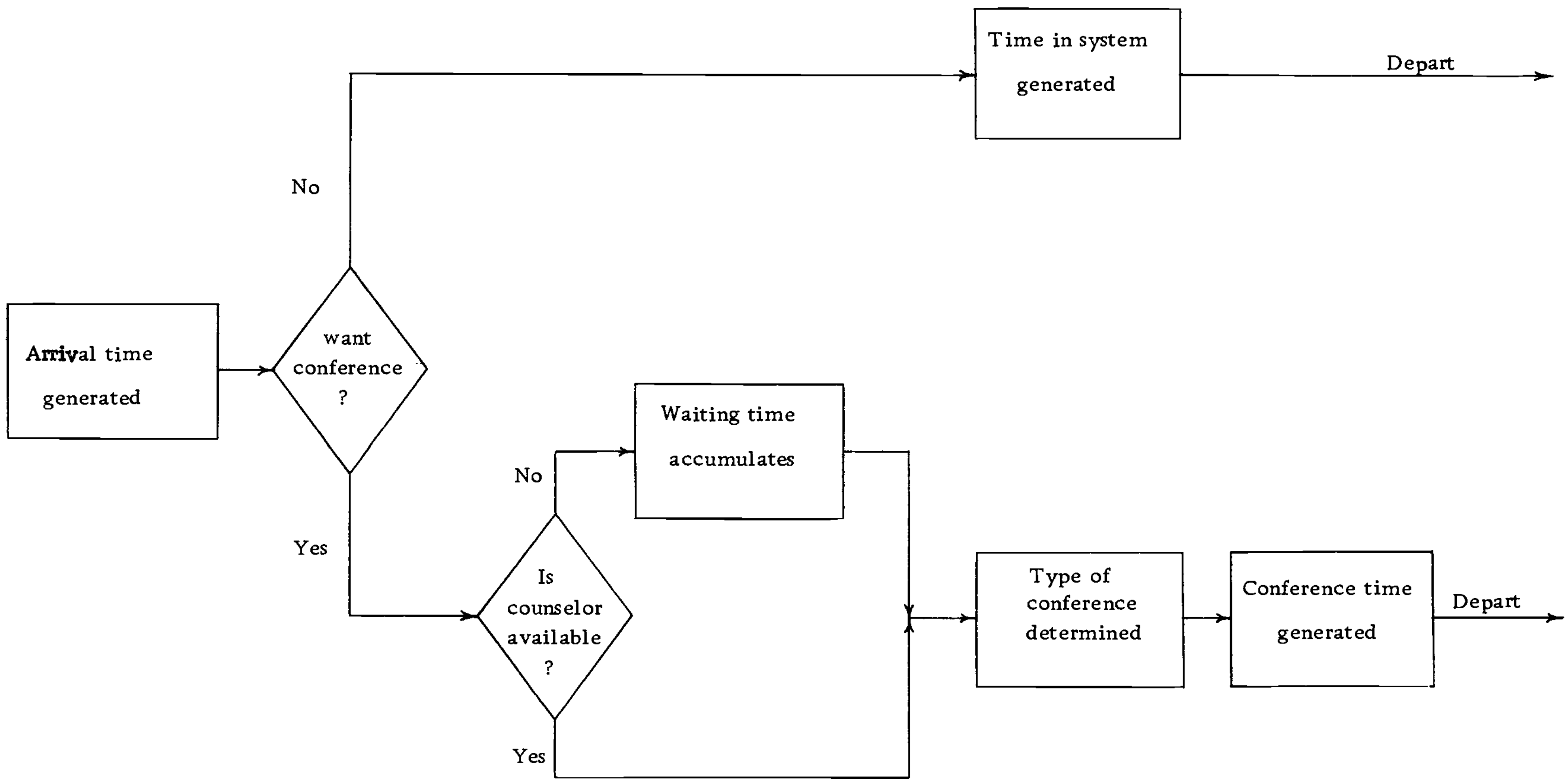

Figure 1. Flow diagram illustrating student through COMSIM.

If the pre-set number of simulations has not yet occurred, the program recycles and another day is simulated.

Number of Simulations for COMSIM

COMSIM is a variable time increment model with each simulation showing the results of one day at the simulated counseling center. Since the data were collected over a period of nine days, it was decided that one computer run would consist of nine simulations. The usual procedure in simulation studies is to make several computer runs with the model, calculate means and variances for the runs and use these results to describe the system. COMSIM was written so that the number of runs and simulations may be changed by the experimenter; however, for validation purposes, three runs of nine simulations each were completed which simulated 6, 345 students entering the system.

Output of COMSIM

COMSIM was written so that the output would be in a form very similar to that of the Summary of Data. This was done to facilitate the matter of validation of the model. Appendix IV contains an example of input in addition to examples of daily output, a summary of the output for one computer run, and a summary table of means for the three runs. Suggested modifications for program output are discussed in Appendix VI.

CHAPTER V

ANALYSIS OF THE MODEL

This chapter contains a statistical evaluation of the model and evidence of the applicability of the model to the simulation of hypothetical situations.

Validation of COMSIM

The test statistic selected to test the output of COMSIM with the data collected from the real system was the Chi-square Goodness of Fit test. This test determines the goodness of fit, or the lack of fit, of observed data (simulated) and expected data (actual).

The test statistic was:

$$\chi^2 = \sum_{i=1}^{n} \left[\frac{(f_i - h_i)^2}{h_i} \right]$$ where f_i is simulated data and h_i is expected data

The test statistic was first applied to the operating characteristics, the basic statistical assumptions of COMSIM, to determine if these characteristics were good approximations for arrival and conference times for the real system. The null and alternate hypotheses to be tested were:

H_o = the Poisson and exponential distributions are realistic distributions for arrival and conference times.

H_a = the Poisson and exponential distributions are not realistic distributions for arrival and conference times.

A Chi-square value of .979 was yielded (see Table 1). The critical Chi-square value for 10 degrees of freedom was 23.2093 at the .01 level of confidence. The calculated value does not fall in the rejection region and therefore the null hypothesis could not be rejected.

Table 1. Chi-square Goodness of Fit Test for the operating characteristics of COMSIM.

	Simulated	Expected
Poisson distribution		
Mean arrival time	1.8	1.8
Exponential distribution		
Mean conference times		
Conference type 1	16.1	15.5
2	22.9	23.2
3	6.6	6.6
4	23.7	25.5
5	17.5	18.4
6	12.0	11.2
7	15.4	14.5
8	29.7	25.7
9	10.1	10.8
No conference	2.8	2.8

d.f. = 10
Level of confidence = .01
Critical Chi-square = 23.2093
Calculated Chi-square = 0.979

Under ordinary circumstances, when a null hypothesis can not be rejected, the only conclusion that can be drawn is that "judgment must be withheld." The null hypothesis cannot be rejected unless the probability of making a Type II error (probability of accepting the null hypothesis when it is false) is known and small. The only conclusion that can be drawn is that the data presents insufficient evidence to reject the null hypothesis. The experimenter must gather more data with the hope that this additional data will be sufficient to reject the null hypothesis.

Computer simulation studies present a different situation. The modeler usually wants to accept the null hypothesis which indicates a good fit for the model. More data can certainly be generated by making more simulations. However, the greater the number of simulations, the closer the data zeroes in on the actual mean because the model is approaching a "steady state". This means that the value of Chi-square will become even smaller and there will be less chance than before of rejecting the null hypothesis.

Usually the experimenter would like to attach some significance (in terms of probability) to the results of his experiment. Suggestions received from members of the Statistics Department at Oregon State University were considered, and a procedure was established so that a probability statement could be made concerning COMSIM. The procedure is to search through the body of a table of Critical Values of Chi-square, under the appropriate degrees of freedom for the test, to determine the probability of a Chi-square value being greater than the calculated one.

Using this procedure, it was determined that a value of Chi-square would exceed .979 (the calculated value) with 10 d.f. only .5 percent of the time. When this .5 percent does occur, there is no way of knowing if it exceeds the critical value of 23.2093 since it is also possible for the value to be in the interval .979-23.2093.

It was concluded that because of the low probability of a Chi-square value exceeding the calculated Chi-square, that the Poisson and exponential distributions generated arrival and conference times which were representative of those times in the real system.

The test was then applied to the probabilities for each type of conference.

H_o = There is no significant difference between the probability for each type of conference as determined by the model and the probabilities derived from the real system.

H_a = There is a significant difference between these probabilities in the simulated and real systems.

The test yielded a Chi-square value of .004 (see Table 2). The magnitude of this value was not high enough to reject the null hypothesis. Using the same procedure as indicated above, it was concluded that a Chi-square value would exceed the calculated value less than .5 percent of the time. Therefore, the probabilities generated by COMSIM were judged to be a good fit to those of the real system.

Table 2. Chi-square Goodness of Fit Test for the probability of each type of conference.

		Simulated	Expected
Conference type	1	.101	.099
	2	.021	.023
	3	.127	.131
	4	.177	.181
	5	.115	.103
	6	.087	.076
	7	.319	.332
	8	.017	.016
	9	.036	.038

d.f. = 8
Level of confidence = .01
Critical Chi-square = 20.0902
Calculated Chi-square = 0.979

As a result of the above two tests, it was also concluded that the random number generator was performing adequately.

The Chi-square test was then applied to 25 critical points of the simulated output with the corresponding points of the data base.

H_o = There is no significant difference between the output of COMSIM and the real system.

H_a = The output of COMSIM is significantly different than that of the real system.

The test resulted in a Chi-square value of 12.766 (see Table 3). Since this was not significant at the .01 level of confidence, the null hypothesis was not rejected. The conclusion was that the value of Chi-square would not exceed 12.766 (the calculated value) more than

Table 3. Chi-square Goodness of Fit Test for comparing COMSIM with the real system.

	Simulated	Expected
Students entering system	235.30	236.33
Students wanting conference	86.41	88.22
Students having conference	77.89	75.11
Average waiting time	6.0	7.8
Average time in system for students not having conference	2.8	2.8
Time between arrivals--students not wanting conference	4.9	4.8
Counselor contact	57.3	58.5
Average conference time per day		
Academic	126.8	115.1
Attendance	37.3	40.2
Employment	66.0	64.7
Personal--Social	326.8	347.9
Post H. S.	156.4	142.8
Records	81.5	64.3
Schedule	381.5	362.1
Vocational	38.5	30.7
Other	28.0	31.0
Average number of conferences per day		
Academic	7.9	7.4
Attendance	1.6	1.7
Employment	9.9	9.8
Personal--Social	13.8	13.6
Post H. S.	8.9	8.9
Records	6.8	5.7
Schedule	24.9	24.9
Vocational	1.3	1.2
Other	2.8	2.9

d.f. = 24
Level of confidence = .01
Critical Chi-square = 42.9798
Calculated Chi-square = 12.766

2.5 percent of the time.

The results of the three tests indicated (1) the model was functioning adequately; and (2) at least 97.5 percent of the time the output of COMSIM would be a "good fit" in comparison to the data representing the real system.

Simulation with COMSIM

The previous section presented evidence that the service functions of a counseling center could be simulated by a computer model. It is the purpose of this section to demonstrate how the model of the real system can be used to simulate various situations. The model is used to simulate these situations to provide a basis for decisions which need to be made.

After the description of each situation, the changes necessary in the input variables and parameters were illustrated. Three computer runs of nine simulations each were run for each situation. In several cases it was necessary to change values of some variables and to make three additional runs to produce sufficient support for the decision. Each run was initialized with a different set of random numbers so that there would be no recursive effect in the generation of the numbers. Each simulated day was considered to be 450 minutes in length. Data pertinent to the decision-maker were displayed in output tables. Appendix V contains print-outs showing all input and output for each situation. The first print-out in Appendix V was used several times for comparison with other output. This was the output from COMSIM with six counselors and a 450 minute day. (Note--some of the print-outs include a horizontal line of zeroes with the exception of the last number which is 2.0. Since it is impossible to divide by zero, the 3300 Computer System assigns the quotient the value of 2.0 when the divisor is zero.)

It was not the purpose of the investigator to advocate a certain type of counseling facility or counseling theory in discussing the situations presented. The decisions made were in terms of the output of the simulated data and not in philosophical considerations.

Situation I

An administrator of a school is continually asking the Director of Guidance to have the counselors substitute in the classroom for teachers who are absent. The Director of Guidance would like to have some objective evidence of the effect of counselors' absences on the activities of the counseling center.

Table 4. Input--Situation I

	Actual	Situation I
No. of counselors	6	5 4 3

Table 5. Simulated output--Situation I.

	Number of Counselors Present			
	Six	Five	Four	Three
Students entering system	250.96	254.04	253.22	248.67
Students wanting conference	91.93	93.04	94.56	90.41
Students having conference	84.44	76.44	67.85	50.70
Percent able to have conference	91.9	82.2	71.8	56.1
Average waiting time	5.2	10.1	14.7	22.7
Counselor contact with students	57.4	63.5	66.4	70.7

Reaction: The remaining counselors could handle the situation in terms of percent of contact time with students. Waiting time increases very rapidly as the number of counselors present decreases. The percent of students able to have a conference decreases quite rapidly. There may be a large number of irate students due to the fact that they were unable to have a conference.

Recommendation: If this practice must continue on a limited scale, use only one counselor at a time as a substitute in the classroom.

Situation II

As a result of some type of group vocational counseling, it is expected that during the next few days there will be an added counseling load. It is expected that the percent of students wanting to have a conference will increase, the time between arrivals will be decreased and the probability of a vocational type conference will be increased (see Table 6). What effect will this have on the system?

Table 6. Input--Situation II.

	Actual	Situation II
Time of next arrival	1.8	1.5
PCTCOUN	37.3	48.0
Probability		
Academic	.10	.08
Attendance	.02	.01
Employment	.13	.05
Personal	.18	.18
Post H. S.	.10	.20
Records	.08	.04
Schedule	.33	.13
Vocational	.02	.27
Other	.04	.04

Table 7. Simulated output--Situation II.

	Actual	Situation II
Students entering system	250.96	298.48
Students wanting conference	91.93	143.70
Students having conference	84.44	86.22
Percent able to have conference	91.9	60.0
Average waiting time	5.2	21.2
Counselor contact with students	57.4	73.6

Reaction: This will be a heavy counseling load but it is possible for a few days. Average waiting time increases 400 percent which will result in a large amount of idle time on the part of the students. The 40 percent who are unable to have conferences also need to be considered.

Recommendations: Definite appointments should be made for students wanting individual counseling as a result of the program. These appointments could be spread out over a period of several weeks to relieve some of the pressure.

Situation III

Several announcements have been made recently concerning scholarships available to local students. It is anticipated that many more seniors than usual will be entering the center. Instead of the usual 13 percent of the student body entering the system per day, 20 percent of the student population will enter. What problems will this create?

Table 8. Input--Situation III.

	Actual	Situation III
Time of next arrival	1.8	1.2
PCTCOUN	37.3	40.0
Probability		
Academic	.10	.07
Attendance	.02	.02
Employment	.13	.12
Personal	.18	.15
Post H.S.	.10	.25
Records	.08	.12
Schedule	.33	.22
Vocational	.02	.02
Other	.04	.03

Table 9. Simulated output--Situation III.

	Actual	Situation III
Students entering system	250.96	367.37
Students wanting conference	91.93	143.52
Students having conference	84.44	103.26
Percent able to have conference	91.9	71.9
Average waiting time	5.2	15.4
Counselor contact with students	57.4	68.1

Reaction: Congestion problems. The average waiting time has tripled and the percent of students able to have a conference has dropped to 70 percent, and the number wanting conferences has increased 50 percent.

Recommendation: Those students who enter the system for academic, attendance, employment, records and schedule problems will not be assisted unless their problems are extremely urgent.

Comment: Use COMSIM to simulate the same circumstances but decrease the conference times for the above mentioned conferences by 70 percent (see Tables 10 and 11). This will allow enough time to find out what the problems are and to schedule an appointment with these students.

Table 10. Input--Situation IIIa.

	Situation III	Situation IIIa
Conference times		
Academic	15.5	4.7
Attendance	23.2	7.0
Employment	6.6	2.0
Personal	25.5	25.5
Post H. S.	18.4	18.4
Records	11.2	3.4
Schedule	14.5	4.4
Vocational	25.7	7.7
Other	10.8	10.8

Table 11. Simulated output--Situation IIIa.

	Actual	Situation III	Situation IIIa
Students entering system	250.96	367.37	371.63
Students wanting conference	91.93	143.52	148.48
Students having conference	84.44	103.26	125.70
Percent able to have a conference	91.9	71.9	84.7
Average waiting time	5.2	15.4	9.3
Counselor contact with students	57.4	68.1	59.2

Reaction: This would make the situation more tolerable. Waiting time is still too high and the percentage of students able to have a conference is lower than desirable.

Recommendation: Make a concerted effort to further decrease the time spent in academic, attendance, employment, records, and schedule conferences.

Situation IV

A new high school is to open in the near future. Since it is in the same community as the present school, it is assumed that the activities of the two counseling centers will parallel each other. The enrollment of the new school will be approximately 925 students which is one-half the size of the present school. Lay personnel will be hired as guidance assistants and will take all responsibility for conferring with students in the areas of attendance, employment, and records. The administrator would like to know how many counselors should be hired for the new school.

Table 12. Input--Situation IV.

	Actual		Situation IV	
Time of next arrival	1.8		3.8	
Probability and conference time				
Academic	.10	15.5	.10	15.5
Attendance	.02	23.2	.00	0.0
Employment	.13	6.6	.00	0.0
Personal	.18	25.5	.26	25.5
Post H. S.	.10	18.4	.17	18.4
Records	.08	11.2	.00	0.0
Schedule	.33	14.5	.33	14.5
Vocational	.02	25.7	.10	25.7
Other	.04	10.8	.04	10.8

Table 13. Simulated output--Situation IV.

	Number of Counselors		
	Four	Three	Two
Students entering system	118.81	119.41	118.81
Students wanting conference	42.41	47.26	44.56
Students having conference	38.89	37.85	26.78
Percent able to have conference	91.7	80.1	60.1
Average waiting time	6.0	11.0	21.6
Counselor contact with students	47.2	62.6	68.0

Reaction: The decision made would have to be in favor of either three or four counselors. In the case of two counselors, the percent of students that are successful in having a conference is too small. The average waiting time is also very high. If three counselors are hired, the average waiting time is still high and only 80 percent of the students are being serviced. However, the percent of contact is favorable. If four counselors were to be hired, the percent of contact is low, but waiting time is favorable and nine out of ten students who want to confer with a counselor are able to do so.

Recommendation: In a few years the school will be growing in size and counselors are difficult to find; therefore, hire four counselors.

Comment: If the guidance assistants were given responsibility in another area, this might make the hiring of three counselors a very realistic possibility.

Situation V

Situation IV may present no clear-cut evidence of the number of counselors to employ. The administrator making the decisions regarding the counseling center has decided that additional lay personnel could be hired to work in the area of scheduling and schedule changes. Every student entering the system for a schedule problem would first consult with one of the guidance assistants. The administrator assumes that by doing this, the average conference time of conference type 7 (schedule) could be decreased by five minutes. He now wants to know if this would assist him in making the decision as to the number of counselors to hire. The only change necessary for this situation in comparison to Situation IV would be a decrease of 5.0 minutes in the scheduling conference time (see Table 12).

Table 14. Input--Situation V.

	Actual		Situation V	
Time of next arrival	1.8		3.8	
Probability and conference time				
Academic	.10	15.5	.10	15.5
Attendance	.02	23.2	.00	0.0
Employment	.13	6.6	.00	0.0
Personal	.18	25.5	.26	25.5
Post H. S.	.10	18.4	.17	18.4
Records	.08	11.2	.00	0.0
Schedule	.33	14.5	.33	9.5
Vocational	.02	25.7	.10	25.7
Other	.04	10.8	.04	10.8

Table 15. Simulated output--Situation V.

	Actual	Situation IV	Situation V
Number of counselors	6	4	3
Students entering system	250.96	118.81	119.15
Students wanting conference	91.93	42.41	43.30
Students having conference	84.44	38.89	37.96
Percent able to have conference	91.9	91.7	87.7
Average waiting time	5.2	6.0	7.3
Counselor contact with students	57.4	47.2	53.9

Reaction: The output from Situation V compares more favorably with the real than does the ouput from Situation IV.

Recommendation: Employ three counselors.

Comment: COMSIM does not generate direct evidence which would assist in determining the number of guidance assistants. However, this is probably not as critical a point as the hiring of certified personnel. Counselors can be hired at only one time during the year. Guidance assistants could be employed and trained practically any time during the year.

However, COMSIM can give an estimate of the number of guidance assistants required. Adding the conference times for academic, attendance and records from the real system gives a total of 186.9 minutes of conference time. Allowing five minutes with a guidance assistant for each student wanting a schedule conference, an additional 134 minutes of conference time is accumulated. The total conference time for the guidance assistants will average 320.9 minutes.

Assuming that the guidance assistants should have the same ratio of number of personnel to conference time as number of counselors to conference time, the following proportion should give an approximation of the number to hire:

(continued)

Table 15 Continued.

$$\frac{x}{321} = \frac{6}{1343} \qquad \therefore\ x = 1.4$$

Three counselors and two guidance assistants will allow the new counseling center to have similar balance with the present one.

Situation VI

The administration is interested in the possibility of a computer-based information system at the new high school (see Chapter III). Teletype terminals on line with a computer would be installed to disseminate information involving records, post high school planning, and vocational planning. Once again it is desired to determine the number of counselors for the new school.

The following situations are expected:

Situation VIa. Due to the novelty of the terminals, the students are expected to make frequent use of them. During the early stages of this information system it is expected that conference times in the three areas covered will actually increase.

Situation VIb. The novelty will wear off after a period of time. When this happens, it is expected that the conference times for the three areas will be decreased by approximately 30 percent.

The approach to this problem is to study Situation VIb first to determine the number of counselors needed to maintain a steady system. The next step is to use the results of VIb in a simulation of VIa to determine what the load might be for the counselors during the time when the teletype terminals are receiving a large amount of traffic.

Table 16. Input--Situation VIb.

	Actual		Situation VIb Counselors Three	
			Three	Two
Time of next arrival			3.8	3.8
PCTCOUN			37.3	37.3
Probability and conference time				
Academic	.10	15.5	.09	15.5
Attendance	.02	23.2	.02	23.2
Employment	.13	6.6	.10	6.6
Personal	.18	25.5	.18	25.5
Post H. S.	.10	18.4	.15	12.0
Records	.08	11.2	.05	7.0
Schedule	.33	14.5	.30	14.5
Vocational	.02	25.7	.08	17.5
Other	.04	10.8	.03	10.8

Table 17. Simulated output--Situation VIb.

	Number of Counselors Three	Two
Students entering system	117.52	118.44
Students wanting conference	43.85	44.85
Students having conference	33.89	31.04
Percent able to have conference	88.7	69.2
Average waiting time	6.7	26.7
Counselor contact with students	52.8	60.3

Reaction: The simulated output for three counselors looks very much like the output for the real system. The simulated output for two counselors indicates a very high average waiting time, and the percentage of students serviced is too low to be satisfactory.

Recommendation: Hire three counselors.

Comment: Simulate VIa using three as the number of counselors.

Table 18. Input--Situation VIa.

	Actual		Situation VIa	
Probability and conferences				
Academic	.10	15.5	.10	15.5
Attendance	.02	23.2	.02	23.2
Employment	.13	6.6	.09	6.6
Personal	.18	25.5	.18	25.5
Post H. S.	.10	18.4	.18	18.4
Records	.08	11.2	.08	11.2
Schedule	.33	14.5	.17	14.5
Vocational	.02	25.7	.15	25.7
Other	.04	10.8	.03	0.8

Table 19. Simulated output--Situation VIa.

	Situation VIa Three Counselors
Students entering system	117.85
Students wanting conference	48.74
Students having conference	38.37
Percent having conference	78.7
Average waiting time	11.5
Counselor contact	62.0

Reaction: The percent of students able to have a conference is low, and the average waiting time per student is greater than in the real system. However, the percent of counselor contact with students is very realistic.

Recommendation: Three counselors should be able to adequately handle the flow of student traffic.

The simulation of the situations presented in this section gave evidence that COMSIM may be used to aid in decision-making processes concerning the service functions of a counseling center. The simulated output gave some basis for making decisions that, in some cases, would be difficult to obtain by other methods.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study resulted from a desire and interest to include computer simulation techniques in the design of educational practices. The study was undertaken to determine if these techniques could be used to model and simulate the service functions of a counseling center.

The review of literature indicated that the role of computer simulation is a diversified one and that it has been and is being used to study many types of systems. The review also revealed that computer simulation has been used only to a limited degree in education. Very few examples exist which illustrate its use in studying educational systems.

The data base for the study was determined by tracing 2,127 students through the counseling center at Corvallis High School, Corvallis, Oregon. The model (COMSIM) developed during the study was a dynamic, stochastic model which traced students through the counseling center. The parameters and variables from the data base were used with the Poisson and exponential distributions to generate arrival times, purposes for being in the system, and service or conference times. The model was constructed as a general simulation vehicle to permit its utilization in various situations regarding the service functions of a counseling center. The computer program was written in FORTRAN because of the compatability of this language with available computing facilities.

A Chi-square Goodness of Fit test was used to test the following null hypotheses:

Test 1. H_o: The Poisson and exponential distributions are realistic distributions for arrival and conference times of students entering the center.

Test 2. H_o: There is no significant difference between the probability for each type of conference as determined by the model and the probabilities derived from the real system.

Test 3. H_o: There is no significant difference between the output of COMSIM and the data from the real system.

As a result of the Chi-square tests, it was not possible to reject any of the null hypotheses.* The model presented a reasonable approximation of the service functions of the real system.

After the validation procedures were completed, six hypothetical

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*The first two test results indicated that 99.5 percent of the time a calculated Chi-square would be less than the value yielded by the tests. The last test indicated that 97.5 percent of the time a calculated Chi-square would be less than the value derived from the test.

situations were presented and simulated. These simulations demonstrated that COMSIM generated output which was helpful in making decisions concerning the service functions of the center.

Conclusions

The high degree of confidence placed on the model by the validation procedures made it possible to conclude that:

1. Computer simulation techniques can be applied to the study of the service functions of a counseling center.
2. Stochastic processes may be used in constructing models to trace students through a counseling center.
3. Valid computer models of a counseling center may be used to simulate hypothetical situations concerning the service functions of the center.
4. Imposing new conditions on such a model, by changing the parameters and input variables, results in estimates of the magnitude of the changes that would occur if such conditions were imposed on the actual center. The degree of confidence placed on these estimates is directly proportional to the validity of the model.

Recommendations

The broadening of the data base to include sampling from each month of the school year would permit simulation studies on a month-to-month basis. The results of such studies might be of value to guidance personnel in the evaluation of patterns of guidance services.

The model should be refined in order to simulate each counselor's activities. It may then be possible to simulate and analyze each counselor's work load in terms of:

1. Types of conferences
2. Student demand for each counselor in terms of probability
3. Lengths of conferences

With this type of information, it would be possible to simulate a system which would assign a student to a particular counselor according to the type of conference the student desires. This type of system would be based on the particular skills that each counselor takes into a counseling situation and not some arbitrary assignment of students to counselors.

The purposes of all students entering the system should be incorporated into the model. This would broaden the definition of service function, as defined in this study, to include services provided by the center other than those directly related to the counselors.

Recommendations for improvement of the model are:

1. Investigate the use of other techniques to replace the COMMON DATA statement's function in determining the type of conference. These techniques should be concerned

with eliminating the necessity of changing a statement in the program each time a different situation is simulated.

2. The program should be written so that the variable name representing the number of counselors (NC) is a real variable. This would provide for situations involving part-time counselors.

The techniques employed for this study should be extended to other educational systems, instructional and managerial, which might benefit from a more scientific approach towards decision-making, policy formation, and future planning.

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APPENDIX

APPENDIX I

FORMS USED FOR COLLECTION OF DATA

Students entering system Date ____________

No.	Time In	Total Time	Purpose	Unusual events - SAT & PSAT
	8:05	8	Course description booklet	
	8:08	1	Made appointment	
	8:11	4	Made appointment	
	8:12	2	Returned college cat.	
	8:12	2	Used telephone	
	8:13	7	SAT scores	
1	8:15	- -	to counselor - -	
	8:16	.5	Schedule	
	8:17	2	Made appointment	
	8:19	.5	Asked for Carlson	
	8:19	1	Course description booklet	
	8:20	1	Made appointment	
2	8:20	- -	to counselor - -	
	8:23	1	Schedule	
	8:24	1	Financial aid form	
	8:25	.5	SAT scores	
	8:26	1	Made appointment	
	8:26	2	Open house into - SOC	
	8:27	.5	PSAT scores	
	8:29	.5	SAT scores	
	8:29	1	Returned college cat.	
	8:31	1	SAT scores	
	8:31	1	SAT scores	
	8:31	1	SAT scores	
	8:32	.5	SAT scores	
	8:32	.5	SAT scores	
	8:34	1	SAT scores	
	8:34	.5	SAT scores	
	8:35	1	SAT scores	
	8:35	.5	SAT scores	
3	8:35	- -	to counselor - -	
	8:35	3	Made appointment	
	8:37	- -	to counselor - -	
	8:38	.5	SAT scores	
	8:39	.5	SAT scores	
	8:40	.5	SAT scores	
	8:40	.5	SAT scores	
4	8:40	- -	to counselor - -	
5	8:42	- -	to counselor - -	
	8:43	1	SAT scores	
	8:43	3	National Parks info.	

(continued)

Date ________________

STUDENT'S NUMBER ____________ COUNSELOR ______________

TIME IN (time student enters your office) ____________________

TIME OUT (time student leaves your office) __________________

_____Referred (counselor has requested that student come in; student is brought in)

_____Self-referred (student has requested an appt. with counselor; student is a walk-in)

Types of Conferences (check primary reason(s) for conference, or primary area covered):

Academic	Attendance	Employment	Personal-Social	Post-High School Plans	Records (Transcript) etc.	Schedule	Vocational Information

Arrival time in office	Waiting time	Time entered counselor	Time departed counselor	Service time	Total time in system	Academic	Attend.	Employ.	Personal Social	Post H. S.	Records	Schedule	Voc. Info	Other	Counselor
8:15	0	8:15	8:35	20	20							x			
8:20	0	8:20	8:34	14	14					x					
8:35	5	8:40	8:50	10	15	x						x			
8:37	8	8:45	9:20	35	43				x						
8:40	20	9:00	9:15	15	35					x		x			
8:42	3	8:45	9:24	39	42				x						
8:44	8	8:52	9:35	43	51	x			x	x		x			
8:45	0	8:45	8:53	13	13							x			
8:46	14	9:00	9:27	27	41				x						
8:47	12	(unable to see counselor)			12										
8:47	71	(unable to see counselor)			71										
8:50	1	(unable to see counselor)			1										
8:52	33	9:25	10:30	65	98				x						
8:54	26	(unable to see counselor)			26										
9:09	11	(unable to see counselor)			11										
9:21	4	9:25	10:10	45	49				x						
9:24	5	9:29	9:39	10	15				x						
9:24	31	(unable to see counselor)			31										
9:24	33	9:57	10:04	7	40					x					
9:25	0	9:25	9:29	4	4							x			
9:25	0	9:25	9:45	20	20							x			
9:27	2	9:29	9:37	8	10							x			
9:31	33	(unable to see counselor)			33										
9:34	14	9:48	9:55	7	21							x			
9:48	0	9:48	9:51	3	3										
10:05	2	10:07	10:12	5	7				x						
10:06	24	10:30	10:43	13	37							x			
10:06	4	10:10	10:27	17	21			1/4				3/4			
10:07	3	10:10	10:53	43	46				3/4			1/4			
10:07	73	11:00	11:15	15	88							x			

APPENDIX II

SUMMARY OF DATA

SUMMARY OF DATA

	December	January	February	Total	Average per day
Students entering system	670	776	681	2127	236.33
Students wanting conference	253	301	240	794	88.22
Student having conference	215	255	206	676	75.11
Time (in minutes)	1350	1260	1185	3795	421.17
Total waiting time	2106.5	2527.0	1581.5	6215	690.55
Average waiting time	8.3	8.4	6.6		7.8
Total conference time	3549	4041	3199	10789	1198.78
Average conference time	16.5	15.8	15.5		16.0

Average time in system students not wanting conference	. 2.8 min.
Percent of students entering system who wanted conference	37.3
Expect student to arrive in center every 1.8 minutes	
Expect student wanting conference every 4.8 minutes	

Average daily conference time	Average no. counselors per day	Mean contact per counselor	Percent contact
1198.78	5.67	211.5	58.5

	Conference Time		Percent of	No. of conferences		Prob-	Mean Conference
	Total	Average	Total Time	Total	Average	ability	Time
Academic	1036	115.1	9.6	66.72	7.4	.099	15.5
Attendance	362	40.2	3.4	15.63	1.7	.023	23.2
Employment	582	64.7	5.4	88.75	9.8	.131	6.6
Personal-Social	3131	347.9	29.0	122.58	13.6	.181	25.5
Post H. S.	1285	142.8	11.9	69.80	8.9	.103	18.4
Records	579	64.3	5.4	51.65	5.7	.076	11.2
Schedule	3259	362.1	30.2	224.22	24.9	.332	14.5
Vocational	276	30.7	2.5	10.75	1.2	.016	25.7
Other	279	31.0	2.6	25.90	2.9	.038	10.8
	10789	1198.8	100.0	676.00	75.1	.999	

APPENDIX III

THE COMPUTER PROGRAM

```
      PROGRAM COMSIM
      COMMON/DATA/KEDLA(100)
      DATA((KEDLA(I),I=1,100)=10(1),2(2),13(3),18(4),10(5),
     18(6),33(7),2(8),4(9))
      DIMENSION NR(20),SVT(20),TCIDLE(20),TOTSERV(20),TSTC(20),
     1TT(20),AKOUNT(20),CIDLE(20),WT(20),SISTC(20),SAKOUNT(20),
     2ASTSTC(20),ASAKOUNT(20),ARRIV(20),
     3A(20),B(20),C(20),AVG(20)
C
C   SET NUMBER OF MINUTES IN DAY
      TIME=TTYIN(4HMINU,4HTES ,4HPER ,4HDAY=)
C
C   SET NUMBER OF COUNSELORS
      NC=TTYIN(4HNUMB,4HER O,4HF CO,4HUNSE,4HLORS,4H   =)
C
C   EXPECTED TIME BETWEEN ARRIVALS
C
      TNXTARR=TTYIN(4HNEXT,4H ARR,4HIVAL,4H   =)
C
C   EXPECTED PERCENT TO SEE COUNSELOR
      PCTCOUN=TTYIN(4HPERC,4HENT ,4HTO C,4HOUNS,3H = )
C
C   EXPECTED TIME FOR CONFERENCES
      WRITE(61,901)
901   FORMAT(1X,'EXPECTED CONFERENCE TIMES',/)
C     ACADEMIC
      SVT(1)=TTYIN(4HACAD,4HEMIC,3H  =)
C     ATTENDANCE
      SVT(2)=TTYIN(4HATTE,4HNDAN,3HCE=)
C     EMPLOYMENT
      SVT(3)=TTYIN(4HEMPL,4HOYME,3HNT=)
C     PERSONAL
      SVT(4)=TTYIN(4HPERS,4HONAL,3H  =)
C     POST H.S.
      SVT(5)=TTYIN(4HPOST,4H H.S,3H. =)
C     RECORDS
      SVT(6)=TTYIN(4HRECO,4HRDS ,3H  =)
C     SCHEDULE
      SVT(7)=TTYIN(4HSCHE,4HDULE,3H  =)
C     VOCATIONAL
      SVT(8)=TTYIN(4HVOCA,4HTION,3HAL=)
C     OTHER
      SVT(9)=TTYIN(4HOTHE,4HR   ,3H  =)
C     NO CONFERENCE
      SVT(10)=TTYIN(4HNO C,4HONF.,3H  =)
C
C   AVERAGES FOR ALL RUNS
      DO 99 J=1,20
      A(J)=0.0
      B(J)=0.0
      C(J)=0.0
99    CONTINUE
C   NUMBER OF RUNS
      NRUN=TTYIN(4HNO. ,4HOF R,4HUNS=)
C   NUMBER OF SIMULATIONS
      NSIM=TTYIN(4HNO. ,4HOF S,4HIMS=)
      DO 717 M=1,NRUN
C
C   INITIAL VALUES RANDOM NUMBERS
      WRITE(61,900)
900   FORMAT(1X,'INITIAL VALUES FOR RANDOM NUMBERS',/)
      NR(1)=TTYIN(4HCONF,4H. TI,4HME =)
      NR(2)=TTYIN(4HARRI,4HVAL ,4H   =)
      NR(3)=TTYIN(4HDECI,4HSION,4H   =)
      NR(4)=TTYIN(4HTYPE,4H CON,4HF. =)
      NR(5)=TTYIN(4HSERV,4H. TI,4HME =)
```

```
C
C  INITIALIZATION FOR SUMMARY STATISTICS
      SCN=SBNCON=SAJ3=SAJ2=SCON=SCLOCK=STWT=STSTALL=STOTIME=0.0
      DO 24 J=1,20
      STSTC(J)=0.0
      SAKOUNT(J)=0.0
24    CONTINUE
      DO 1001 I=1,NSIM
C
C  INITIALIZATION
C
      CLOCK=TOTIME=TAT=TWT=TSTALL=TOTSERV=TSTC=AKOUNT=TCIDLE=0.0

      KDEPART1=KDEPART2=MADDPT=J1=J2=J3=0
      DO 13 J=1,20
      TCIDLE(J)=0.0
      TOTSERV(J)=0.0
      TSTC(J)=0.0
      TT(J)=0.0
      AKOUNT(J)=0.0
      CIDLE(J)=0.0
      WT(J)=0.0
13    CONTINUE
C
C  CHECK CLOCK
10    IF(CLOCK.GE.TIME)GO TO 1000
C
C  FIRST AND SUBSEQUENT ARRIVALS
C   GET COUNT AND GENERATE ARRIVAL TIME
      J3=J3+1
      CALL ARRIVAL(TNXTARR,NR(2),ARRTIME,NR(2))
      TAT=CLOCK+ARRTIME
      CLOCK=CLOCK+ARRTIME
C
C  DECISION - WANT TO SEE COUNSELOR?
C
      CALL RAND(NR(3),DEC,NR(3))
      XDEC=100.0*DEC
      IF(XDEC.LE.PCTCOUN)GO TO 5
C
C  STUDENTS NOT WANTING TO SEE COUNSELOR
C   GET COUNT AND GENERATE SERVICE TIME
      J1=J1+1
      CALL RAND(NR(5),W,NR(5))
      TIMEX=-(SVT(10)*ALOG(W))
      TOTIME=TOTIME+TIMEX
      KDEPART1=KDEPART1+1
      GO TO 10
C
C  STUDENTS WANTING TO SEE COUNSELOR
C   GET COUNT
5     J2=J2+1
      IF(J2-NC)3,18,155
3     ARRIV(J2)=TAT
      GO TO 10
18    ARRIV(J2)=TAT
C
C  NC STUDENTS HAVE ARRIVED AT COUNSELORS
C   DETERMINE TYPE OF CONFERENCE
      DO 500 J=1,NC
      WT(J)=TAT-ARRIV(J)
      TWT=TWT+WT(J)
      TCIDLE(J)=TAT
      CALL RAND(NR(4),D,NR(4))
      K=100.0*D
      K=K+1
```

```
      KN=KEDLA(K)
C
C  GENERATE CONFERENCE TIME
C
      CALL SERVICE(NR(1),SVT(KN),SERVTIME,NR(1))
      TOTSERV(J)=TOTSERV(J)+SERVTIME
      TSTC(KN)=TSTC(KN)+SERVTIME
      AKOUNT(KN)=AKOUNT(KN)+1.0
      TT(J)=TAT+WT(J)+SERVTIME
      TSTALL=TSTALL+SERVTIME
      KDEPART2=KDEPART2+1
500   CONTINUE
C
C  READY FOR NEW ARRIVAL
C
      GO TO 10
C
C  CHECK FOR AVAILABLE COUNSELOR
155   SMIN=TT(1)
      L=1
      DO 150 J=2,NC
      IF(SMIN.LE.TT(J))GO TO 150
      SMIN=TT(J)
      L=J
150   CONTINUE
      DIFF=TAT-TT(L)
      IF(DIFF-0.0)27,28,29
27    WT(L)=-DIFF+35.0
      CIDLE(L)=0.0
      GO TO 30
28    WT(L)=0.0
      CIDLE(L)=0.0
      GO TO 30
29    WT(L)=0.0
      CIDLE(L)=DIFF
30    TCIDLE(L)=TCIDLE(L)+CIDLE(L)
      TWT=TWT+WT(L)
      IF(WT(L).GT.36.5)6,7
6     MADDPT=MADDPT+1
      GO TO 10
C
C  DETERMINE TYPE OF CONFERENCE
7     CALL RAND(NR(4),E,NR(4))
      K=100.0*E
      K=K+1
      KN=KEDLA(K)
C
C  GENERATE CONFERENCE TIME
      CALL SERVICE(NR(1),SVT(KN),SERVTIME,NR(1))
      TOTSERV(L)=TOTSERV(L)+SERVTIME
      TSTC(KN)=TSTC(KN)+SERVTIME
      AKOUNT(KN)=AKOUNT(KN)+1.0
      TT(L)=TAT+WT(L)+SERVTIME
      TSTALL=TSTALL+SERVTIME
      KDEPART2=KDEPART2+1
      GO TO 10
C
C  FOR STATISTICS EACH REPLICATION
1000  AJ3=J3
      AJ2=J2
      COUN=NC
      BNCON=MADDPT
      CON=AJ2-BNCON
      SYS=CLOCK/AJ3
      SYSC=CLOCK/AJ2
      AVWT=TWT/AJ2
```

```
      AVGST=TSTALL/AJ2
      CN=KDEPART1
      CY=KDEPART2
      AVGSTNC=TOTIME/CN
      AMCONT=TSTALL/COUN
      PCT=(100.0*AMCONT)/(TIME-60.0)
C
C  FORMAT FOR OUTPUT
C
      WRITE(61,229)M
229   FORMAT('1RUN NUMBER',I4)
      WRITE(61,230)I
230   FORMAT(1X,'SIMULATION NUMBER',I4/)
      WRITE(61,170)AJ3
      WRITE(61,171)AJ2
      WRITE(61,172)CON
      WRITE(61,173)CLOCK
      WRITE(61,174)SYS
      WRITE(61,175)SYSC
      WRITE(61,176)TWT
      WRITE(61,177)AVWT
      WRITE(61,178)TSTALL
      WRITE(61,179)AVGST
      WRITE(61,180)AVGSTNC
      WRITE(61,181)
      WRITE(61,182)
      WRITE(61,183)
      DO 185 J=1,9
      RATIO=(100.0*TSTC(J))/TSTALL
      ACT=TSTC(J)/AKOUNT(J)
      PROB=AKOUNT(J)/CON
      WRITE(61,184)J,TSTC(J),RATIO,AKOUNT(J),PROB,ACT
185   CONTINUE
      WRITE(61,186)
      WRITE(61,187)TSTALL,AMCONT,PCT
C
C  FOR SUMMARY STATISTICS
      SIM=NSIM+0
      SAJ3=SAJ3+AJ3
      SAJ2=SAJ2+AJ2
      SCON=SCON+CON
      SCLOCK=SCLOCK+CLOCK
      STWT=STWT+TWT
      STSTALL=STSTALL+TSTALL
      STOTIME=STOTIME+TOTIME
      SCN=SCN+CN
      DO 23 J=1,9
      STSTC(J)=STSTC(J)+TSTC(J)
      SAKOUNT(J)=SAKOUNT(J)+AKOUNT(J)
23    CONTINUE
1001  CONTINUE
C  CALCULATIONS FOR SUMMARY STATISTICS
      ASAJ3=SAJ3/SIM
      ASAJ2=SAJ2/SIM
      ASCON=SCON/SIM
      ASTSTALL=STSTALL/SIM
      SSYS=SCLOCK/SAJ3
      SSYSC=SCLOCK/SAJ2
      SAVWT=STWT/SAJ2
      SAVGST=STSTALL/SAJ2
      SAVGSTNC=STOTIME/SCN
      SAMCONT=ASTSTALL/COUN
      SPCT=(100.0*SAMCONT)/(TIME-60.0)
      DO 813 J=1,9
      ASTSTC(J)=STSTC(J)/SIM
      ASAKOUNT(J)=SAKOUNT(J)/SIM
```

```
813   CONTINUE
C
C  OUTPUT - SUMMARY STATISTICS
      WRITE(61,700)M
700   FORMAT('1SUMMARY STATISTICS - RUN NUMBER',1X,I3/)
      WRITE(61,170)ASAJ3
      WRITE(61,171)ASAJ2
      WRITE(61,172)ASCON
      WRITE(61,174)SSYS
      WRITE(61,175)SSYSC
      WRITE(61,177)SAVWT
      WRITE(61,178)ASTSTALL
      WRITE(61,179)SAVGST
      WRITE(61,180)SAVGSTNC
      WRITE(61,181)
      WRITE(61,182)
      WRITE(61,183)
      DO 714 J=1,9
      SRATIO=(100.0*ASTSTC(J))/ASTSTALL
      SACT=ASTSTC(J)/ASAKOUNT(J)
      SPROB=ASAKOUNT(J)/ASCON
      WRITE(61,184)J,ASTSTC(J),SRATIO,ASAKOUNT(J),SPROB,SACT
714   CONTINUE
      WRITE(61,186)
      WRITE(61,187)ASTSTALL,SAMCONT,SPCT
C
C  FOR STATISTICS ALL RUNS
      REP=NRUN+0
      A(1)=A(1)+ASAJ3
      A(2)=A(2)+ASAJ2
      A(3)=A(3)+ASCON
      A(4)=A(4)+SSYS
      A(5)=A(5)+SSYSC
      A(6)=A(6)+SAVWT
      A(7)=A(7)+ASTSTALL
      A(8)=A(8)+SAVGST
      A(9)=A(9)+SAVGSTNC
      DO 33 J=1,9
      B(J)=B(J)+ASTSTC(J)
      C(J)=C(J)+ASAKOUNT(J)
33    CONTINUE
717   CONTINUE
      WRITE(61,718)NRUN,NSIM
718   FORMAT('1SUMMARY OF',I3,1X,'RUNS OF',I3,
     11X,'SIMULATIONS EACH'//)
      DO 34 J=1,9
      AVG(J)=A(J)/REP
34    CONTINUE
      WRITE(61,170)AVG(1)
      WRITE(61,171)AVG(2)
      WRITE(61,172)AVG(3)
      WRITE(61,174)AVG(4)
      WRITE(61,175)AVG(5)
      WRITE(61,177)AVG(6)
      WRITE(61,178)AVG(7)
      WRITE(61,179)AVG(8)
      WRITE(61,180)AVG(9)
      WRITE(61,181)
      WRITE(61,182)
      WRITE(61,183)
      DO 35 J=1,9
      R=B(J)/REP
      S=C(J)/REP
      SR=(100.0*R)/(A(7)/REP)
      CT=R/S
      PR=S/(A(3)/REP)
```

```
      WRITE(61,184)J,R,SR,S,PR,CT
35    CONTINUE
      X=A(7)/REP
      X1=X/NC
      X2=(100.0*X1)/(TIME-60.0)
      WRITE(61,186)
      WRITE(61,187)X,X1,X2
170   FORMAT(1X,'STUDENTS ENTERING SYSTEM',19X,
     1'=',2X,F8.2)
171   FORMAT(1X,'STUDENTS WANTING TO HAVE CONFERENCE',
     18X,'=',2X,F8.2)
172   FORMAT(1X,'STUDENTS ABLE TO HAVE CONFERENCE',
     111X,'=',2X,F8.2/)
173   FORMAT(1X,'TOTAL ARRIVAL TIME',25X,'=',F7.1)
174   FORMAT(1X,'EXPECT ARRIVAL IN CENTER EVERY',F7.1,
     11X,'MINUTES')
175   FORMAT(1X,'EXPECT STUDENT EVERY',F7.1,1X,
     1'MINUTES WANTING TO SEE COUNSELOR'/)
176   FORMAT(1X,'TOTAL WAITING TIME',3X,'=',F8.1)
177   FORMAT(1X,'AVERAGE WAITING TIME',1X,'=',F8.1)
178   FORMAT(1X,'TOTAL CONFERENCE TIME',3X,'=',F8.1)
179   FORMAT(1X,'AVERAGE CONFERENCE TIME',1X,'=',F8.1)
180   FORMAT(1X,'AVERAGE TIME IN SYSTEM STUDENTS NOT',
     11X,'WANTING CONF =',F8.1//)
181   FORMAT(20X,'TOTAL',2X,'PERCENT',2X,'NO.OF',1X,
     1'PROB.',3X,'MEAN')
182   FORMAT(20X,'CONF.',2X,'TOTAL',4X,'CONF',10X,
     1'CONF.')
183   FORMAT(20X,'TIME',3X,'CONF.',18X,'TIME'//)
184   FORMAT(1X,'CONFERENCE TYPE',I3,3F7.1,F7.3,F7.1/)
186   FORMAT(1X,'CONF.TIME',2X,'MEAN CONTACT',2X,
     1'PERCENT CONTACT'/)
187   FORMAT(1X,3F10.1/)
      STOP
      END
      SUBROUTINE ARRIVAL(P,N,XK,N)
      X=0.0
      B=EXP(-P)
      TR=1.0
1     N=AND(2051*N+1221519,37777777B)
      Q=(N/8388608.)
      TR=TR*Q
      IF(TR-B)3,2,2
2     X=X+1.0
      GO TO 1
3     XK=X
      RETURN
      END
      SUBROUTINE RAND(N,Y,N)
      N=AND(2051*N+1221519,37777777B)
      Y=(N/8388608.)
      RETURN
      END
      SUBROUTINE SERVICE(N,B,C,N)
      N=AND(2051*N+1221519,37777777B)
      Y=(N/8388608.)
      C=-B*ALOG(Y)
      RETURN
      END
```

APPENDIX IV

EXAMPLES OF INPUT AND OUTPUT

```
]FILE, COMSIM

]UNEQUIP, 61

]EQUIP, 61=LP

]LABEL, 61/COMPUTER SIMULATION - ED ANDERSON

#FORTRAN, I=COMSIM, R
MINUTES PER DAY=421.2
NUMBER OF COUNSELORS    =6
NEXT ARRIVAL     =1.8
PERCENT TO COUNS =   37.3
ACADEMIC   =  15.5
ATTENDANCE=  23.2
EMPLOYMENT=  6.6
PERSONAL   =  25.5
POST H.S. =  18.4
RECORDS    =  11.2
SCHEDULE   =  14.5
VOCATIONAL=  25.7
OTHER      =  10.8
NO CONF.   =  2.8
NO. OF RUNS=3
NO. OF SIMS=9


CONF. TIME =9243
ARRIVAL     =97957
DECISION    =72621
TYPE CONF. =97839
SERV. TIME =81443


CONF. TIME =54859
ARRIVAL     =55043
DECISION    =74951
TYPE CONF. =69381
SERV. TIME =28859


CONF. TIME =13181
ARRIVAL     =72633
DECISION    =1081
TYPE CONF. =27935
SERV. TIME =84711


#LOGOFF
TIME 37.000 SECONDS  MFBLKS 32  COST $5.22
```

RUN NUMBER 2
SIMULATION NUMBER 3

STUDENTS ENTERING SYSTEM = 258.00
STUDENTS WANTING TO HAVE CONFERENCE = 98.00
STUDENTS ABLE TO HAVE CONFERENCE = 86.00

TOTAL ARRIVAL TIME = 422.0
EXPECT ARRIVAL IN CENTER EVERY 1.6 MINUTES
EXPECT STUDENT EVERY 4.3 MINUTES WANTING TO SEE COUNSELOR

TOTAL WAITING TIME = 668.6
AVERAGE WAITING TIME = 6.8
TOTAL CONFERENCE TIME = 1440.5
AVERAGE CONFERENCE TIME = 14.7
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF = 3.0

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	60.4	4.2	5.0	.058	12.1
CONFERENCE TYPE 2	33.4	2.3	3.0	.035	11.1
CONFERENCE TYPE 3	74.6	5.2	11.0	.128	6.8
CONFERENCE TYPE 4	451.4	31.3	19.0	.221	23.8
CONFERENCE TYPE 5	221.3	15.4	9.0	.105	24.6
CONFERENCE TYPE 6	145.3	10.1	9.0	.105	16.1
CONFERENCE TYPE 7	320.5	22.2	24.0	.279	13.4
CONFERENCE TYPE 8	75.2	5.2	2.0	.023	37.6
CONFERENCE TYPE 9	58.5	4.1	4.0	.047	14.6

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1440.5	240.1	66.5

SUMMARY STATISTICS - RUN NUMBER 3

STUDENTS ENTERING SYSTEM = 236.00
STUDENTS WANTING TO HAVE CONFERENCE = 84.44
STUDENTS ABLE TO HAVE CONFERENCE = 76.89

EXPECT ARRIVAL IN CENTER EVERY 1.8 MINUTES
EXPECT STUDENT EVERY 5.0 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME = 5.4
TOTAL CONFERENCE TIME = 1249.3
AVERAGE CONFERENCE TIME = 14.8
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF = 2.8

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	116.0	9.3	7.1	.092	16.3
CONFERENCE TYPE 2	21.0	1.7	1.3	.017	15.7
CONFERENCE TYPE 3	56.4	4.5	9.6	.124	5.9
CONFERENCE TYPE 4	354.0	28.3	12.8	.166	27.7
CONFERENCE TYPE 5	151.3	12.1	8.1	.105	18.7
CONFERENCE TYPE 6	96.4	7.7	7.8	.101	12.4
CONFERENCE TYPE 7	390.8	31.3	26.3	.342	14.8
CONFERENCE TYPE 8	45.5	3.6	1.4	.019	31.5
CONFERENCE TYPE 9	17.9	1.4	2.4	.032	7.3

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1249.3	208.2	57.6

SUMMARY OF 3 RUNS OF 9 SIMULATIONS EACH

STUDENTS ENTERING SYSTEM = 235.30
STUDENTS WANTING TO HAVE CONFERENCE = 86.41
STUDENTS ABLE TO HAVE CONFERENCE = 77.89

EXPECT ARRIVAL IN CENTER EVERY 1.8 MINUTES
EXPECT STUDENT EVERY 4.9 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME = 6.0
TOTAL CONFERENCE TIME = 1242.8
AVERAGE CONFERENCE TIME = 14.4
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF = 2.8

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	126.8	10.2	7.9	.101	16.1
CONFERENCE TYPE 2	37.3	3.0	1.6	.021	22.9
CONFERENCE TYPE 3	66.0	5.3	9.9	.127	6.6
CONFERENCE TYPE 4	326.8	26.3	13.8	.177	23.7
CONFERENCE TYPE 5	156.4	12.6	8.9	.115	17.5
CONFERENCE TYPE 6	81.5	6.6	6.8	.087	12.0
CONFERENCE TYPE 7	381.5	30.7	24.9	.319	15.4
CONFERENCE TYPE 8	38.5	3.1	1.3	.017	29.7
CONFERENCE TYPE 9	28.0	2.3	2.8	.036	10.1

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1242.8	207.1	57.3

APPENDIX V

INPUT AND OUTPUT FOR EACH SIMULATED SITUATION

Situation I
Six counselors

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =6
NEXT ARRIVAL    =1.8
PERCENT TO COUNS =   37.3
EXPECTED CONFERENCE TIMES

ACADEMIC  = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL  = 25.5
POST H.S. = 18.4
RECORDS   = 11.2
SCHEDULE  = 14.5
VOCATIONAL= 25.7
OTHER     = 10.8
NO CONF.  = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =15647
ARRIVAL    =11679
DECISION   =1385
TYPE CONF. =39613
SERV. TIME =92657
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =45443
ARRIVAL    =64257
DECISION   =997
TYPE CONF. =87565
SERV. TIME =92149
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =78583
ARRIVAL    =80035
DECISION   =1023
TYPE CONF. =60509
SERV. TIME =43061
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                    =    250.96
STUDENTS WANTING TO HAVE CONFERENCE         =     91.93
STUDENTS ABLE TO HAVE CONFERENCE            =     84.44

EXPECT ARRIVAL IN CENTER EVERY    1.8 MINUTES
EXPECT STUDENT EVERY    4.9 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =      5.2
TOTAL CONFERENCE TIME   =  1342.8
AVERAGE CONFERENCE TIME =    14.6
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.8
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	143.7	10.7	9.0	.107	15.9
CONFERENCE TYPE 2	40.6	3.0	1.6	.018	26.1
CONFERENCE TYPE 3	72.7	5.4	11.1	.132	6.5
CONFERENCE TYPE 4	392.7	29.2	14.9	.176	26.4
CONFERENCE TYPE 5	177.6	13.2	9.4	.111	19.0
CONFERENCE TYPE 6	73.6	5.5	6.5	.077	11.4
CONFERENCE TYPE 7	359.1	26.7	26.8	.318	13.4
CONFERENCE TYPE 8	51.5	3.8	1.9	.023	26.8
CONFERENCE TYPE 9	31.3	2.3	3.3	.039	9.5

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1342.8	223.8	57.4

Situation I
Five counselors

```
MINUTES PER DAY=450.00
NUMBER OF COUNSELORS    =5
NEXT ARRIVAL    =1.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 11.2
SCHEDULE   = 14.5
VOCATIONAL= 25.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =51073
ARRIVAL     =2641
DECISION    =41054
TYPE CONF. =10375
SERV. TIME =15655


INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =49067
ARRIVAL     =2887
DECISION    =90169
TYPE CONF. =54755
SERV. TIME =30295

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =33319
ARRIVAL     =92975
DECISION    =24015
TYPE CONF. =50193
SERV. TIME =80237
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                          =    254.04
STUDENTS WANTING TO HAVE CONFERENCE               =     93.04
STUDENTS ABLE TO HAVE CONFERENCE                  =     76.44

EXPECT ARRIVAL IN CENTER EVERY    1.8 MINUTES
EXPECT STUDENT EVERY    4.9 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =     10.1
TOTAL CONFERENCE TIME   =  1238.0
AVERAGE CONFERENCE TIME =    13.3
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =     2.3
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	117.7	9.5	7.7	.101	15.2
CONFERENCE TYPE 2	41.1	3.3	1.7	.022	24.1
CONFERENCE TYPE 3	66.7	5.4	9.9	.129	6.8
CONFERENCE TYPE 4	368.5	29.8	13.8	.180	26.7
CONFERENCE TYPE 5	133.2	10.8	8.3	.108	16.1
CONFERENCE TYPE 6	73.4	5.9	6.1	.080	12.0
CONFERENCE TYPE 7	376.3	30.4	25.0	.327	15.1
CONFERENCE TYPE 8	28.9	2.3	1.4	.018	21.1
CONFERENCE TYPE 9	32.2	2.6	2.7	.035	12.1

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1238.0	247.6	63.5

Situation I
Four counselors

MINUTES PER DAY=450.0
NUMBER OF COUNSELORS =4
NEXT ARRIVAL =1.8
PERCENT TO COUNS = 37.3
EXPECTED CONFERENCE TIMES

ACADEMIC = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL = 25.5
POST H.S. = 18.4
RECORDS = 11.2
SCHEDULE = 14.5
VOCATIONAL= 25.7
OTHER = 10.8
NO CONF. = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =12463
ARRIVAL =10531
DECISION =35167
TYPE CONF. =76515
SERV. TIME =79107
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =95045
ARRIVAL =53765
DECISION =44553
TYPE CONF. =34691
SERV. TIME =96749
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =92923
ARRIVAL =99501
DECISION =37431
TYPE CONF. =13463
SERV. TIME =95947
SUMMARY OF 3 RUNS OF 9 SIMULATIONS EACH

STUDENTS ENTERING SYSTEM = 253.22
STUDENTS WANTING TO HAVE CONFERENCE = 94.56
STUDENTS ABLE TO HAVE CONFERENCE = 67.35

EXPECT ARRIVAL IN CENTER EVERY 1.8 MINUTES
EXPECT STUDENT EVERY 4.8 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME = 14.7
TOTAL CONFERENCE TIME = 1036.4
AVERAGE CONFERENCE TIME = 11.0
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF = 2.7

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	104.1	10.0	6.7	.093	15.6
CONFERENCE TYPE 2	32.4	3.1	1.7	.025	19.5
CONFERENCE TYPE 3	63.1	6.1	9.7	.144	6.5
CONFERENCE TYPE 4	292.0	28.2	11.6	.171	25.2
CONFERENCE TYPE 5	122.6	11.8	7.0	.103	17.5
CONFERENCE TYPE 6	66.4	6.4	5.6	.082	11.9
CONFERENCE TYPE 7	296.5	28.6	21.6	.318	13.7
CONFERENCE TYPE 8	34.1	3.3	1.3	.019	27.1
CONFERENCE TYPE 9	25.0	2.4	2.7	.040	9.1

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1036.4	259.1	66.4

Situation I
Three counselors

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =3
NEXT ARRIVAL    =1.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 11.2
SCHEDULE   = 14.5
VOCATIONAL= 25.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =69149
ARRIVAL     =7539
DECISION    =62377
TYPE CONF. =87229
SERV. TIME =96367
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =61961
ARRIVAL     =22013
DECISION    =89221
TYPE CONF. =4005
SERV. TIME =41719
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =28733
ARRIVAL     =65213
DECISION    =65553
TYPE CONF. =7513
SERV. TIME =86593
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                         =    248.67
STUDENTS WANTING TO HAVE CONFERENCE              =     90.41
STUDENTS ABLE TO HAVE CONFERENCE                 =     50.70

EXPECT ARRIVAL IN CENTER EVERY    1.8 MINUTES
EXPECT STUDENT EVERY     5.0 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =     22.7
TOTAL CONFERENCE TIME    =   827.4
AVERAGE CONFERENCE TIME =      9.2
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.3
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	74.1	9.0	4.8	.095	15.4
CONFERENCE TYPE 2	22.2	2.7	.8	.016	27.2
CONFERENCE TYPE 3	46.4	5.6	6.8	.134	6.8
CONFERENCE TYPE 4	237.0	28.6	8.7	.172	27.2
CONFERENCE TYPE 5	96.9	11.7	5.5	.108	17.7
CONFERENCE TYPE 6	44.6	5.4	3.7	.073	12.1
CONFERENCE TYPE 7	268.7	32.5	17.4	.344	15.4
CONFERENCE TYPE 8	15.9	1.9	.9	.017	18.6
CONFERENCE TYPE 9	21.7	2.6	2.1	.041	10.5

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
827.4	275.3	70.7

Situation II

MINUTES PER DAY=450.0
NUMBER OF COUNSELORS =6
NEXT ARRIVAL =1.5
PERCENT TO COUNS = 48.0
EXPECTED CONFERENCE TIMES

ACADEMIC = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL = 25.5
POST H.S. = 18.4
RECORDS = 11.2
SCHEDULE = 14.5
VOCATIONAL= 25.7
OTHER = 10.8
NO CONF. = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =83735
ARRIVAL =8595
DECISION =41273
TYPE CONF. =473
SERV. TIME =86131
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =33849
ARRIVAL =29939
DECISION =38505
TYPE CONF. =38635
SERV. TIME =84401
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =72489
ARRIVAL =83927
DECISION =68501
TYPE CONF. =22599
SERV. TIME =27149
SUMMARY OF 3 RUNS OF 9 SIMULATIONS EACH

STUDENTS ENTERING SYSTEM = 298.48
STUDENTS WANTING TO HAVE CONFERENCE = 143.76
STUDENTS ABLE TO HAVE CONFERENCE = 86.22

EXPECT ARRIVAL IN CENTER EVERY 1.5 MINUTES
EXPECT STUDENT EVERY 3.1 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME = 21.2
TOTAL CONFERENCE TIME = 1721.6
AVERAGE CONFERENCE TIME = 12.0
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF = 2.8

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	99.3	5.8	6.7	.073	14.8
CONFERENCE TYPE 2	19.5	1.1	1.1	.012	18.1
CONFERENCE TYPE 3	21.3	1.2	3.4	.039	6.3
CONFERENCE TYPE 4	383.9	22.3	15.1	.175	25.4
CONFERENCE TYPE 5	344.2	20.0	17.7	.206	19.4
CONFERENCE TYPE 6	42.2	2.5	3.7	.043	11.3
CONFERENCE TYPE 7	144.9	8.4	10.9	.127	13.3
CONFERENCE TYPE 8	626.1	36.4	24.3	.279	26.0
CONFERENCE TYPE 9	40.3	2.3	3.5	.041	11.5

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1721.6	286.9	73.6

Situation III

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =6
NEXT ARRIVAL    =1.2
PERCENT TO COUNS =  40.0
EXPECTED CONFERENCE TIMES

ACADEMIC    = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 11.2
SCHEDULE   = 14.5
VOCATIONAL= 25.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =53789
ARRIVAL     =78459
DECISION    =41657
TYPE CONF. =65923
SERV. TIME =39123
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =65555
ARRIVAL     =38431
DECISION    =3767
TYPE CONF. =65787
SERV. TIME =785
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =73029
ARRIVAL     =49757
DECISION    =45879
TYPE CONF. =97977
SERV. TIME =54655
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                        =    367.37
STUDENTS WANTING TO HAVE CONFERENCE             =    143.52
STUDENTS ABLE TO HAVE CONFERENCE                =    103.26

EXPECT ARRIVAL IN CENTER EVERY    1.2 MINUTES
EXPECT STUDENT EVERY      3.1 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =     15.4
TOTAL CONFERENCE TIME    =  1592.8
AVERAGE CONFERENCE TIME =     11.1
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =     2.8
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	125.0	7.8	8.0	.077	15.7
CONFERENCE TYPE 2	41.3	2.6	2.1	.020	19.9
CONFERENCE TYPE 3	87.8	5.5	12.9	.125	6.8
CONFERENCE TYPE 4	357.4	22.4	14.9	.145	23.9
CONFERENCE TYPE 5	454.5	28.5	24.9	.241	18.2
CONFERENCE TYPE 6	138.5	8.7	13.0	.126	10.7
CONFERENCE TYPE 7	302.6	19.0	22.5	.218	13.5
CONFERENCE TYPE 8	55.3	3.5	2.2	.022	24.9
CONFERENCE TYPE 9	30.4	1.9	2.8	.027	11.0

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1592.8	265.5	68.1

Situation IIIa

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS   =6
NEXT ARRIVAL   =1.2
PERCENT TO COUNS =  40.0
EXPECTED CONFERENCE TIMES

ACADEMIC   = 4.7
ATTENDANCE= 7.0
EMPLOYMENT= 2.0
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 3.4
SCHEDULE   = 4.4
VOCATIONAL= 7.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =23157
ARRIVAL     =5545
DECISION    =14871
TYPE CONF. =43361
SERV. TIME =9243

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =97957
ARRIVAL     =72621
DECISION    =97839
TYPE CONF. =81443
SERV. TIME =54859

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =55043
ARRIVAL     =74951
DECISION    =69381
TYPE CONF. =28859
SERV. TIME =13181
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                        =    371.63
STUDENTS WANTING TO HAVE CONFERENCE             =    148.48
STUDENTS ABLE TO HAVE CONFERENCE                =    125.70

EXPECT ARRIVAL IN CENTER EVERY    1.2 MINUTES
EXPECT STUDENT EVERY    3.0 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =       9.3
TOTAL CONFERENCE TIME    =  1384.8
AVERAGE CONFERENCE TIME =      9.3
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.8
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	40.4	2.9	9.4	.075	4.3
CONFERENCE TYPE 2	17.1	1.2	2.3	.018	7.4
CONFERENCE TYPE 3	26.8	1.9	14.7	.117	1.8
CONFERENCE TYPE 4	512.6	37.0	19.2	.153	26.7
CONFERENCE TYPE 5	550.0	39.7	30.4	.242	18.1
CONFERENCE TYPE 6	54.8	4.0	15.2	.121	3.6
CONFERENCE TYPE 7	119.9	8.7	28.1	.224	4.3
CONFERENCE TYPE 8	19.0	1.4	2.8	.022	6.8
CONFERENCE TYPE 9	44.2	3.2	3.5	.028	12.7

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
1384.8	230.8	59.2

Situation IV
Four counselors

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =4
NEXT ARRIVAL    =3.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 0.0
EMPLOYMENT= 0.0
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 0.0
SCHEDULE   = 14.5
VOCATIONAL= 25.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =94239
ARRIVAL    =9253
DECISION   =5403
TYPE CONF. =4881
SERV. TIME =86529

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =93137
ARRIVAL    =30105
DECISION   =42757
TYPE CONF. =44437
SERV. TIME =38337

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =46329
ARRIVAL    =79867
DECISION   =25365
TYPE CONF. =71017
SERV. TIME =89977
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                         =    118.81
STUDENTS WANTING TO HAVE CONFERENCE              =     42.41
STUDENTS ABLE TO HAVE CONFERENCE                 =     38.89

EXPECT ARRIVAL IN CENTER EVERY     3.8 MINUTES
EXPECT STUDENT EVERY    10.7 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =       6.0
TOTAL CONFERENCE TIME    =    736.8
AVERAGE CONFERENCE TIME =     17.4
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.7
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	73.6	10.0	4.7	.122	15.5
CONFERENCE TYPE 2	0	0	0	0	2.0
CONFERENCE TYPE 3	0	0	0	0	2.0
CONFERENCE TYPE 4	282.7	38.4	10.7	.274	26.5
CONFERENCE TYPE 5	117.3	15.9	7.1	.183	16.5
CONFERENCE TYPE 6	0	0	0	0	2.0
CONFERENCE TYPE 7	155.8	21.2	11.1	.287	14.0
CONFERENCE TYPE 8	88.5	12.0	3.3	.086	26.5
CONFERENCE TYPE 9	18.8	2.6	1.9	.049	10.0

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
736.8	184.2	47.2

Situation IV

Three counselors

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =3
NEXT ARRIVAL    =3.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 0.0
EMPLOYMENT= 0.0
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 0.0
SCHEDULE   = 14.5
VOCATIONAL= 25.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =44293
ARRIVAL     =81383
DECISION    =67125
TYPE CONF. =13561
SERV. TIME =74733
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =75045
ARRIVAL     =25843
DECISION    =79519
TYPE CONF. =29431
SERV. TIME =45985
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =87229
ARRIVAL     =4085
DECISION    =65213
TYPE CONF. =86593
SERV. TIME =34691
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                    =    119.41
STUDENTS WANTING TO HAVE CONFERENCE         =     47.26
STUDENTS ABLE TO HAVE CONFERENCE            =     37.85

EXPECT ARRIVAL IN CENTER EVERY    3.8 MINUTES
EXPECT STUDENT EVERY      9.6 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =      11.0
TOTAL CONFERENCE TIME    =    732.1
AVERAGE CONFERENCE TIME =      15.6
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.8
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	60.1	8.2	3.7	.097	16.4
CONFERENCE TYPE 2	0	0	0	0	2.0
CONFERENCE TYPE 3	0	0	0	0	2.0
CONFERENCE TYPE 4	244.3	33.4	9.7	.257	25.1
CONFERENCE TYPE 5	136.6	18.7	6.7	.177	20.4
CONFERENCE TYPE 6	0	0	0	0	2.0
CONFERENCE TYPE 7	162.8	22.2	11.6	.306	14.0
CONFERENCE TYPE 8	116.4	15.9	4.9	.130	23.6
CONFERENCE TYPE 9	11.9	1.6	1.2	.032	9.8

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
732.1	244.0	62.6

Situation IV
Two counselors

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =2
NEXT ARRIVAL    =3.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC  = 15.5
ATTENDANCE= 0.0
EMPLOYMENT= 0.0
PERSONAL  = 25.5
POST H.S. = 18.4
RECORDS   = 0.0
SCHEDULE  = 14.5
VOCATIONAL= 25.7
OTHER     = 10.8
NO CONF.  = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =18457
ARRIVAL    =55825
DECISION   =26999
TYPE CONF. =8133
SERV. TIME =8133
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =62223
ARRIVAL    =7217
DECISION   =26695
TYPE CONF. =2941
SERV. TIME =44681
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =80569
ARRIVAL    =31083
DECISION   =30647
TYPE CONF. =81265
SERV. TIME =15177
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                  =    118.81
STUDENTS WANTING TO HAVE CONFERENCE       =     44.56
STUDENTS ABLE TO HAVE CONFERENCE          =     26.78

EXPECT ARRIVAL IN CENTER EVERY    3.8 MINUTES
EXPECT STUDENT EVERY   10.1 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =    21.6
TOTAL CONFERENCE TIME   =   530.7
AVERAGE CONFERENCE TIME =    11.9
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =     2.9
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	39.8	7.5	2.7	.100	14.9
CONFERENCE TYPE 2	0	0	0	0	2.0
CONFERENCE TYPE 3	0	0	0	0	2.0
CONFERENCE TYPE 4	192.0	36.2	7.3	.271	26.4
CONFERENCE TYPE 5	85.4	16.1	4.6	.172	18.6
CONFERENCE TYPE 6	0	0	0	0	2.0
CONFERENCE TYPE 7	126.9	23.9	8.6	.320	14.8
CONFERENCE TYPE 8	74.7	14.1	2.6	.098	28.4
CONFERENCE TYPE 9	11.8	2.2	1.1	.040	11.0

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
530.7	265.3	68.0

Situation V
Three counselors

```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS    =3
NEXT ARRIVAL    =3.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 0.0
EMPLOYMENT= 0.0
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 0.0
SCHEDULE   = 9.5
VOCATIONAL= 25.7
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =6971
ARRIVAL     =43225
DECISION    =6915
TYPE CONF. =99861
SERV. TIME =85493
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =8997
ARRIVAL     =76787
DECISION    =36469
TYPE CONF. =87515
SERV. TIME =37789
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =53587
ARRIVAL     =45539
DECISION    =53263
TYPE CONF. =63175
SERV. TIME =10589
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                     =    119.15
STUDENTS WANTING TO HAVE CONFERENCE          =     43.30
STUDENTS ABLE TO HAVE CONFERENCE             =     37.96

EXPECT ARRIVAL IN CENTER EVERY    3.8 MINUTES
EXPECT STUDENT EVERY   10.4 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =      7.3
TOTAL CONFERENCE TIME   =    630.4
AVERAGE CONFERENCE TIME =    14.5
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =     2.9
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	47.3	7.5	3.4	.091	13.7
CONFERENCE TYPE 2	0	0	0	0	2.0
CONFERENCE TYPE 3	0	0	0	0	2.0
CONFERENCE TYPE 4	213.1	33.8	9.1	.239	23.5
CONFERENCE TYPE 5	113.4	18.0	6.1	.162	18.4
CONFERENCE TYPE 6	0	0	0	0	2.0
CONFERENCE TYPE 7	130.4	20.7	13.0	.343	10.0
CONFERENCE TYPE 8	106.4	16.9	4.7	.124	22.6
CONFERENCE TYPE 9	19.8	3.1	1.6	.041	12.7

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
630.4	210.1	53.9

Situation VIa
Three counselors


```
MINUTES PER DAY=450.Ø
NUMBER OF COUNSELORS   =3
NEXT ARRIVAL    =3.8
PERCENT TO COUNS =  42.Ø
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL   = 25.5
POST H.S. = 18.4
RECORDS    = 11.2
SCHEDULE   = 14.5
VOCATIONAL= 25.7
OTHER  .   = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =40549
ARRIVAL     =10229
DECISION    =13483
TYPE CONF. =66523
SERV. TIME =91665

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =67415
ARRIVAL     =76527
DECISION    =19615
TYPE CONF. =89673
SERV. TIME =6971

INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =43225
ARRIVAL     =6915
DECISION    =99861
TYPE CONF. =85493
SERV. TIME =8997
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                     =    117.85
STUDENTS WANTING TO HAVE CONFERENCE          =     46.74
STUDENTS ABLE TO HAVE CONFERENCE             =     38.37

EXPECT ARRIVAL IN CENTER EVERY    3.8 MINUTES
EXPECT STUDENT EVERY     9.3 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =     11.5
TOTAL CONFERENCE TIME    =    725.7
AVERAGE CONFERENCE TIME =     14.9
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.8
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	56.6	7.8	3.8	.Ø98	15.Ø
CONFERENCE TYPE 2	22.7	3.1	.9	.Ø22	26.7
CONFERENCE TYPE 3	21.3	2.9	3.4	.Ø89	6.3
CONFERENCE TYPE 4	188.2	25.9	7.Ø	.183	26.7
CONFERENCE TYPE 5	124.7	17.2	6.3	.165	19.7
CONFERENCE TYPE 6	47.6	6.6	3.2	.Ø84	14.8
CONFERENCE TYPE 7	113.4	15.6	7.5	.195	15.2
CONFERENCE TYPE 8	139.9	19.3	5.Ø	.131	27.8
CONFERENCE TYPE 9	11.3	1.6	1.2	.Ø32	9.3

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
725.7	241.9	62.Ø

Situation VIb
Three counselors


```
MINUTES PER DAY=450.0
NUMBER OF COUNSELORS   =3
NEXT ARRIVAL    =3.8
PERCENT TO COUNS =  37.3
EXPECTED CONFERENCE TIMES

ACADEMIC   = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL   = 25.5
POST H.S. = 12.0
RECORDS    = 7.0
SCHEDULE   = 14.5
VOCATIONAL= 17.5
OTHER      = 10.8
NO CONF.   = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =13103
ARRIVAL     =43569
DECISION    =92053
TYPE CONF. =78005
SERV. TIME =57593
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =34355
ARRIVAL     =82887
DECISION    =14565
TYPE CONF. =38127
SERV. TIME =48721
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =38137
ARRIVAL     =21539
DECISION    =41021
TYPE CONF. =51587
SERV. TIME =31137
SUMMARY OF  3 RUNS OF  9 SIMULATIONS EACH


STUDENTS ENTERING SYSTEM                        =    117.52
STUDENTS WANTING TO HAVE CONFERENCE             =     43.85
STUDENTS ABLE TO HAVE CONFERENCE                =     38.89

EXPECT ARRIVAL IN CENTER EVERY     3.8 MINUTES
EXPECT STUDENT EVERY   10.3 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME =      6.7
TOTAL CONFERENCE TIME    =    617.4
AVERAGE CONFERENCE TIME =      14.1
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF =      2.9
```

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	50.0	8.1	3.0	.076	16.9
CONFERENCE TYPE 2	14.4	2.3	.6	.016	22.9
CONFERENCE TYPE 3	21.1	3.4	3.5	.090	6.1
CONFERENCE TYPE 4	211.6	34.3	7.5	.193	28.1
CONFERENCE TYPE 5	55.4	9.0	5.8	.150	9.5
CONFERENCE TYPE 6	13.4	2.2	2.0	.051	6.7
CONFERENCE TYPE 7	178.7	28.9	12.1	.311	14.8
CONFERENCE TYPE 8	61.1	9.9	3.3	.084	18.7
CONFERENCE TYPE 9	11.8	1.9	1.1	.029	10.6

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
617.4	205.8	52.8

Situation VIb
Two counselors

MINUTES PER DAY=450.0
NUMBER OF COUNSELORS =2
NEXT ARRIVAL =3.8
PERCENT TO COUNS = 37.3
EXPECTED CONFERENCE TIMES

ACADEMIC = 15.5
ATTENDANCE= 23.2
EMPLOYMENT= 6.6
PERSONAL = 25.5
POST H.S. = 12.0
RECORDS = 7.0
SCHEDULE = 14.5
VOCATIONAL= 17.5
OTHER = 10.8
NO CONF. = 2.8
NO. OF RUNS=3
NO. OF SIMS=9
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =18155
ARRIVAL =96917
DECISION =60887
TYPE CONF. =5739
SERV. TIME =47491
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =21363
ARRIVAL =48111
DECISION =24373
TYPE CONF. =98335
SERV. TIME =68909
INITIAL VALUES FOR RANDOM NUMBERS

CONF. TIME =69699
ARRIVAL =90617
DECISION =54407
TYPE CONF. =87659
SERV. TIME =33333
SUMMARY OF 3 RUNS OF 9 SIMULATIONS EACH

STUDENTS ENTERING SYSTEM = 118.44
STUDENTS WANTING TO HAVE CONFERENCE = 44.85
STUDENTS ABLE TO HAVE CONFERENCE = 31.04

EXPECT ARRIVAL IN CENTER EVERY 3.8 MINUTES
EXPECT STUDENT EVERY 10.1 MINUTES WANTING TO SEE COUNSELOR

AVERAGE WAITING TIME = 16.7
TOTAL CONFERENCE TIME = 470.6
AVERAGE CONFERENCE TIME = 10.5
AVERAGE TIME IN SYSTEM STUDENTS NOT WANTING CONF = 2.8

	TOTAL CONF. TIME	PERCENT TOTAL CONF.	NO.OF CONF	PROB.	MEAN CONF. TIME
CONFERENCE TYPE 1	36.4	7.7	2.6	.082	14.2
CONFERENCE TYPE 2	21.1	4.5	.7	.023	30.0
CONFERENCE TYPE 3	18.9	4.0	3.1	.099	6.1
CONFERENCE TYPE 4	137.4	29.2	5.5	.178	24.9
CONFERENCE TYPE 5	51.0	10.8	4.1	.134	12.3
CONFERENCE TYPE 6	12.5	2.7	1.7	.055	7.4
CONFERENCE TYPE 7	134.3	28.5	9.3	.298	14.5
CONFERENCE TYPE 8	47.2	10.0	2.8	.091	16.8
CONFERENCE TYPE 9	11.8	2.5	1.3	.041	9.4

CONF.TIME	MEAN CONTACT	PERCENT CONTACT
470.6	235.3	60.3

APPENDIX VI

PROGRAM MODIFICATIONS

In this Appendix, two possible modifications of the simulation model will be discussed.

The program was written for teletype input. If this type of input device is available, the COMMON DATA statement is the only statement in the program that needs to be changed for different simulation experiments. The parameters, variables, and random numbers are entered in the program through teletype input when called for by a teletype statement. If teletype input is not available, the program can be entered by card input. It would be necessary to keypunch the program on cards and to change the TTYIN statements. It would be necessary to change these to READ statements and appropriate FORMAT statements. For example, the statements in the program sequenced by numbers 10-21 could be replaced by two cards as follows:

1st card READ(60, 901)NC, TIME, TNXTARR, PCTCOUN

2nd card 901 FORMAT (1X, I4, 3F10.2)

The desired values would then be placed on another card, according to the above format, placed in the card deck in the appropriate place for the data, and read into the program. The cards containing the COMMON DATA statement would still need to be changed for each experiment whenever the probabilities vary from the previous situation.

The output phase of the program should adhere to the purpose and needs of the study. Additional output could be obtained from COMSIM by adding more WRITE statements to the program. For example, the model could give information about each student who enters the system. This information could be in the form of a printout indicating arrival time, purpose for being in the system, amount of time spent waiting, amount of time spent with a counselor, and total time in the system. It might also be practical to have data printed for certain time periods, e.g., every hour. The model is also capable of giving data which would be helpful in studying each counselor's day in terms of total counseling time, type of counseling services provided, amount of time spent in each type of conference, and an average conference time for students conferring with him.